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# Is prenatal sex selection associated with lower female child mortality?

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*I examine whether prenatal sex selection has substituted postnatal excess female mortality by analysing the dynamics of child sex ratios between 1980 and 2015 using country-level life table data. I decompose changes in child sex ratios into a ‘fertility’ component attributable to prenatal sex selection and a ‘mortality’ component attributable to sex differentials in postnatal survival. Although reductions in numbers of excess female deaths have accompanied increases in missing female births in all countries experiencing the emergence of prenatal sex selection, relative excess female mortality has persisted in some countries but not others. In South Korea, Armenia, and Azerbaijan, mortality reductions favouring girls accompanied increases in prenatal sex selection. In India, excess female mortality was much higher and largely stable as prenatal sex selection emerged, but slight reductions were seen in the 2000s. In China, although absolute measures showed reductions, relative excess female mortality persisted as prenatal sex selection increased.*

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**Keywords:** gender; sex ratio at birth; missing women; excess female mortality; son preference; sex selection; decomposition

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## Introduction

An extensive literature has documented the rise and spread of prenatal sex selection, as indicated by male-to-female sex ratios at birth (SRBs) becoming more masculine across Asia, the Caucasus, and parts of the Balkans (Guilmoto 2015). Described as one of the ‘most notable anomalies in contemporary demography’ (Guilmoto 2009, p. 519), the growing population sex imbalance at birth is a modern manifestation of a long-standing norm guiding fertility behaviour—that of a preference for male offspring, otherwise known as son preference. Parental son preference can manifest itself in both prenatal and postnatal forms. The adoption of prenatal strategies for sex selection requires three preconditions: (1) parents must find it necessary to bear a son; (2) parents must have access to both prenatal sex testing technology, such as ultrasound, and to abortion; and (3) parents must find it necessary to keep their family size small (Guilmoto 2009).

Before the availability of sex detection technology, postnatal manifestations of son preference in the

form of excess female mortality in infancy and childhood had been widely documented in the demographic literature. More recent global analyses have found that excess female mortality in both infancy and childhood remains prevalent, most prominently in South Asia, the Middle East, and parts of Africa (Sawyer 2012; Alkema et al. 2014). The notion of excess implies that girls experience mortality that is higher than biologically expected, on account of both direct and indirect forms of gender discrimination, which, as prominently described by Sen (1990), results in girls being ‘missing’ from population structures. Excess mortality may result directly from infanticide or from the unequal allocation of healthcare and nutrition to girls within families (Das Gupta 1987; Miller 1987; Arnold et al. 1998; Li et al. 2004; Borooah 2004; Jayachandran and Kuziemko 2011). Excess mortality may also emerge indirectly from the fertility effects of son preference. Differential stopping behaviour (DSB) by sex, practised by parents desiring a boy, causes girls to be born into larger families compared with boys (Clark 2000; Basu and De Jong 2010). Through this

indirect mechanism, within-family differences between girls and boys may not be apparent but, instead, aggregate-level gender gaps are likely to emerge if net resources per child are fewer in larger families than smaller ones (Choe and Kim 1998; Rosenblum 2013; Carvalho et al. 2014; Jain 2014).

As the preceding discussion illustrates, the preconditions underlying prenatal and postnatal manifestations of son preference are different. On the one hand, postnatal excess female mortality is more likely to occur in populations where norms for larger family sizes prevail and families practise DSB to achieve their son preference. In such populations, mortality differentials resulting from 'high fertility' behaviour are likely to emerge. On the other hand, prenatal sex selection is likely to be practised in societies where families prefer to keep their families small by practising abortion instead of proceeding to additional births and where ultrasound is more widely available. Consequently, the relative demographic contributions of prenatal and postnatal manifestations of son preference to missing girls in the population are likely to vary by the stage of the demographic transition that a population is at.

Changes in prenatal sex selection may also influence changes in postnatal excess female mortality. If an important factor underlying postnatal excess mortality is child unwantedness, the increasing adoption of sex-selective abortion may plausibly imply better survival chances for those girls who *are* born, as they are more likely to be wanted (Goodkind 1996). An emerging literature has empirically tested what Goodkind called the substitution hypothesis, or in other words, an increase in prenatal sex selection being associated with a decrease in postnatal excess female mortality. This literature has adopted different approaches and shown mixed results. Drawing on birth registration data in Taiwan, Lin et al. (2014) found evidence in favour of substitution; in a country where ultrasound was already available, the legalization of abortion in 1985 led to faster improvements in neonatal survival for females than males for higher parity births. For India, evidence has been mixed. Hu and Schlosser (2015) found that birth cohorts experiencing prenatal sex selection, as indicated by distorted SRBs, exhibited faster reductions in malnutrition rates for girls relative to boys; however, they found no statistically significant evidence for correspondingly faster reductions in mortality for girls. In contrast, Anukriti et al. (2016) found evidence for faster reductions in mortality for a subset of girls in India. In the period when ultrasound became widely available, the

authors found the mortality gap between second- and higher-order girls with firstborn brothers compared with those with firstborn sisters was eliminated.

In contrast to these country-specific analyses, studies such as Bongaarts and Guilimoto (2015) and Goodkind (2015) have adopted descriptive approaches over a wider geographical area. Goodkind examined macro-level correlations between male-to-female SRBs and male-to-female infant and child mortality ratios, during the period from the 1970s to early 1990s, across several East Asian countries. He found evidence suggesting that prenatal sex selection was substituting postnatal excess female mortality in South Korea, but no such pattern in China. Using measures from the same period might not have captured the interrelated dynamics of the two processes, however. If substitution were occurring, improvements in relative survival for the birth cohorts affected by prenatal sex selection as they move past infancy and childhood would only be visible one to five years later and not in the same period. Furthermore, examining changes in the sex ratios of mortality is not sufficient to detect whether prevailing mortality levels indicate excess female mortality, and whether changes in mortality ratios are aligned with expected patterns of mortality change. This is an important consideration because sex ratios of infant and child mortality have been shown to change with mortality decline (Sawyer 2012; Alkema et al. 2014).

More recently, Bongaarts and Guilimoto (2015) have presented global estimates of the contributions of prenatal vs. postnatal discrimination to the numbers of missing women since the 1970s using United Nations (UN) World Population Prospects (WPP) 2012 data. In contrast to Goodkind's analysis, they explicitly adopted a reference standard to generate expected sex ratios of mortality at different levels of overall mortality and, from these, derived estimates of absolute numbers of excess female deaths. They found that the contribution of prenatal discrimination to missing women in the world had increased since the 1980s, while the contribution of postnatal discrimination had shown small declines since the 1990s. While Goodkind measured mortality change in terms of sex ratios of child mortality, Bongaarts and Guilimoto focused on excess deaths at all ages and computed the absolute contributions of prenatal and postnatal discrimination to the total numbers of missing women in each five-year period. The contributions of absolute numbers of excess female deaths to total missing women, however, might plausibly decline as a consequence

of improving overall mortality conditions and declining numbers of deaths. Both relative and absolute measurements of excess mortality are helpful in assessing improvements in female relative to male survival.

This study contributes to the literature tackling the relationship between prenatal sex selection and postnatal excess mortality by adopting a cross-national, comparative perspective. Has the rise and spread of prenatal sex selection substituted the postnatal excess mortality of girls in countries where excess female mortality has been prevalent? The term ‘substitution’ can be interpreted in two ways. First, substitution implies a greater demographic contribution of prenatal sex selection to the number of missing women, or distorted sex ratios accompanied by reductions in postnatal excess female mortality over time, as countries proceed along the path of demographic modernization. Second, increases in prenatal sex selection, via either availability of abortion or increasing access to ultrasound, may themselves also *cause* reductions in excess female mortality, as distinct from the weakening of son preference norms that trigger reductions in excess female mortality.

I develop and apply life table decomposition methods to UN WPP 2015 data, to assess the relative contributions of prenatal sex selection and postnatal excess mortality to changes in sex ratios at the childhood ages of five to ten since the 1980s (United Nations 2015a). This approach highlights how the contribution of each component has varied over time and across countries, as well as how changes in prenatal sex selection are associated with changes in excess female mortality within countries. Examining associations between the prenatal and postnatal does not, however, clarify whether increases in prenatal sex selection are driving changes in girls’ mortality relative to boys’. The results from this approach are limited in their ability to address substitution of postnatal excess mortality by prenatal sex selection as a *causal* response.

The paper is organized as follows: first, I discuss how prenatal and postnatal manifestations of son preference are likely to shift with demographic modernization, and suggest how the pace at which prenatal manifestations substitute postnatal ones might vary at different stages of the transition. I then develop a method to measure the dynamics of substitution by decomposing child sex ratio change into its mortality and fertility components. I present results of the analysis by focusing on countries that have experienced outlying levels of change in both the mortality (postnatal) and fertility (prenatal)

components of their child sex ratio trajectories. I conclude with a discussion of the patterns observed.

## Theoretical framework

### *Prenatal and postnatal mechanisms*

Prenatal sex selection provides parents with strong son preference a more effective means of implementing their preference than relying on DSB alone. In the absence of prenatal sex selection, parents must rely on contraceptive use to stop childbearing when they bear a son. However, DSB cannot guarantee the parity at which parents bear a son, and parents who rely on DSB may consequently have several unwanted daughters before realizing their desire for a son. Studies from South Asia have shown how son preference results in daughters being born into larger families (Clark 2000; Basu and De Jong 2010). Within these families, not all daughters are unwanted. It is daughters born at parities three or higher without surviving brothers who show the worst outcomes in mortality (Das Gupta 1987; Muhuri and Preston 1991; Choe et al. 1995; Arnold et al. 1998; Pande 2003).

The mechanisms for and levels of excess female mortality are likely to vary at different stages of the demographic transition. In societies at an early stage of the demographic transition—with high mortality and fertility, low incomes, and resource constraints—parents are likely to implement their son preference through postnatal discrimination in the form of sex-selective allocation of resources (Bongaarts 2013). However, as the transition proceeds and parents benefit from greater access to contraception, postnatal excess mortality for girls may emerge indirectly from the fertility effects of son preference. In this mechanism, while within-family differences for girls and boys may be small, the indirect effects of the fewer resources per capita available in larger families (into which girls are more likely to be born) compared with smaller ones result in higher aggregate-level mortality risks for girls (Rosenblum 2013; Carvalho et al. 2014; Jain 2014).

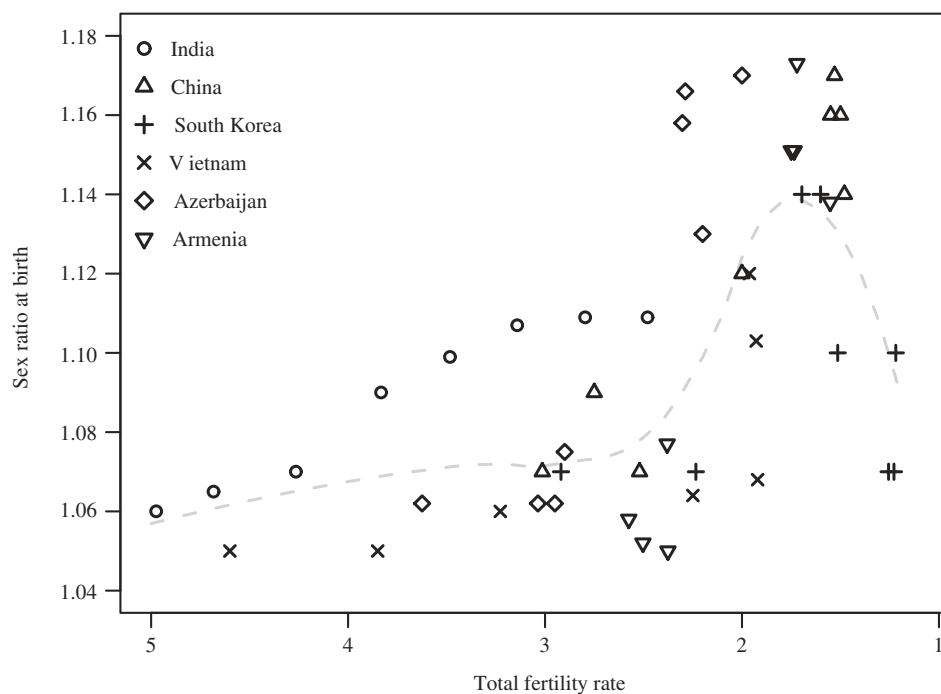
It is plausible that better control of fertility implies lower levels of excess mortality for girls and, thus, the contribution of excess mortality to the number of missing women is likely to be higher in early transition societies with higher mortality and fertility than in mid- to late-transition ones. A better control of fertility in societies with son preference may come about through different channels, involving either the weakening of son preference or the

uptake of sex-selective abortion to reduce fertility while realizing son preference.

Existing literature has suggested that demographic modernization entails a weakening of son preference (Bhat and Zavier 2003; Chung and Das Gupta 2007). At early transition stages, son preference is likely to be high and stable, whereas in mid- to late-transition stages, son preference is likely to be moderate to low, and declining (Bongaarts 2013). Despite weaker and declining son preference in mid- to late-transition populations, for example, in South Korea in the 1980s and early 1990s, the swift diffusion of ultrasound in more modernized, richer contexts, alongside the spread of small family norms, is likely to result in increasing prenatal sex selection as indicated by steep rises in macro-level SRB trajectories (Kashyap and Villavicencio 2016). In contrast, despite more widespread son preference norms, countries like India that are at an earlier stage of demographic modernization are likely to exhibit flatter SRB trajectories and less peaked SRB levels, suggestive of more heterogeneous access to prenatal sex testing technology and higher overall fertility levels, respectively (Kashyap and Villavicencio 2017). Figure 1 shows how SRB levels vary with the total fertility rate (TFR) across some of the countries where SRBs have become distorted. The TFR scale

goes from higher values on the left to lower values on the right, indicating demographic modernization. The figure highlights how SRB levels are generally lower and SRB trajectories flatter at the higher fertility levels that would be expected in early to mid-transition societies (e.g., India or Vietnam), and SRBs begin to rise steeply as fertility falls from the mid- to late-transition stages.

The discussion so far suggests that we should expect the contribution of prenatal sex selection relative to postnatal excess mortality to the distorted sex ratios seen in populations with son preference to increase as societies experience demographic modernization. Across different countries where SRB distortions have been noted, SRB trajectories show a common pattern that resembles a diffusion process, involving an initial rise followed by a process of levelling-off (Guilmoto 2009). Simulation studies have indicated that this levelling-off phase is likely to occur when ultrasound diffusion is complete and low fertility norms become widespread (Kashyap and Villavicencio 2016, 2017). As son preference continues to weaken and populations move further into an advanced (or post-transition) stage with very low fertility levels, SRBs are likely to show reductions and an eventual return to normal values (Chung and Das Gupta 2007). As indicated in



**Figure 1** Total fertility rate (TFR) and sex ratio (male/female) at birth (SRB), select countries, 1975–80 to 2010–15

Notes: Grey dashed line shows a locally weighted least squares smoother applied to the data. Data for eight five-year periods covering 1975–80 to 2010–15 are shown for each country.

Source: Data from United Nations (2015a).

Figure 1, this turnaround has already been witnessed in South Korea (Chung and Das Gupta 2007) and there is evidence for incipient turnarounds in SRBs in China and India (Das Gupta et al. 2009).

### *Expected findings*

At the macro level, the substitution hypothesis pertains to relative changes in prenatal sex selection and postnatal excess female mortality over time. In contexts with prevailing postnatal excess female mortality, substitution would be suggested if increases in masculinity in SRBs were associated with faster declines in mortality for girls relative to boys. As noted previously, observing such a macro-level pattern would not, however, indicate conclusively that sex-selective abortion was *causing* changes in sex differentials in mortality. Wider modernization processes, such as the weakening of son preference norms, could independently cause faster improvements in mortality for girls relative to boys. Changes in excess female mortality may even plausibly precede changes in SRBs.

When discussing substitution, I will adopt two slightly different interpretations of the term. First, following from discussions in the previous section, I will refer to how prenatal sex selection might come to substitute postnatal excess mortality in terms of its demographic contribution to distorted sex ratios in countries at different stages of the demographic transition. Second, I will discuss when and where we might expect changes in prenatal sex selection to *cause* changes in postnatal excess mortality.

In terms of its demographic contribution to distorted sex ratios, I would expect prenatal sex selection to substitute postnatal excess mortality swiftly in populations at mid to late stages of the demographic transition. In these contexts, son preference is less widespread and likely to be weakening rapidly, while levels of excess female mortality are also likely to be low. Swift technology diffusion amid already low and declining total fertility is likely to enable increases in prenatal sex selection. South Korea, Armenia, Azerbaijan, and Taiwan exemplify such populations.

The substitution of postnatal excess mortality by prenatal sex selection in underpinning distorted sex ratios is likely to be slower in early to mid-transition populations with stronger and widespread son preference norms that are weakening slowly, as suggested by high prevailing levels of excess female mortality. In these less developed contexts, I would expect that more gradual or heterogeneous diffusion of

prenatal sex testing technology combined with higher fertility norms may plausibly result in a slower population-wide uptake of prenatal sex selection. The South Asian countries of India, Pakistan, and Nepal, and East Asian contexts, such as China, are examples where excess female mortality levels are high and would be expected to change slowly, even as SRBs begin to rise. Son preference may also be more widespread across different social groups in these settings. For example, in north-west India, son preference has been reported in both Hindu and Muslim populations (Guilmoto 2015). Sex-selective abortion, however, may not be practised equally by both groups, despite availability of ultrasound, due to differential religious taboos against abortion. More widespread son preference, combined with social variations in methods of implementing it, would suggest the persistence of excess female mortality accompanying gradual population-level increases in prenatal sex selection.

Prenatal sex selection may have greater impact on reducing excess female mortality in societies where son preference is strong and widespread, which is plausible in mid-transition stages, but less so when the transition is nearly complete and son preference is likely to be weaker. For postnatal excess mortality levels to change directly in response to prenatal sex selection, populations adopting prenatal sex selection must overlap with those where postnatal manifestations are otherwise present. Existing literature has highlighted how SRB distortions have been concentrated among tertiary-educated mothers with better access to ultrasound and low fertility norms; at least when SRBs first became distorted in South Korea and India (Jha et al. 2011; Guilmoto 2015). Monden and Smits (2013) found that patterns of disadvantage for girls in under-five mortality were concentrated among less educated social groups in South Asia. If prenatal and postnatal manifestations of son preference remain socially stratified, prenatal sex selection will not cause changes in mortality. In this case increases in SRBs at the aggregate level may accompany stability in excess female mortality, or potentially even increases in excess female mortality due to the negative selection of female births into disadvantaged households. However, as ultrasound and low fertility norms gradually diffuse across the population to less privileged social groups, where disadvantage in female mortality prevails and son preference is strong, prenatal sex selection may drive changes in mortality by enabling parents to better target the desired sex composition of children.

The discussion in this section assumes that postnatal excess mortality exists before the onset of



prenatal sex selection in a population. However, postnatal excess mortality and prenatal sex selection may appear simultaneously and reinforce each other if conditions result in the emergence or intensification of son preference. For example, in the Caucasus, some scholars have suggested that the protracted civil conflict in Azerbaijan and Armenia led to the resurgence of patriarchy and reinforced the preference for sons (Michael et al. 2013). Others have pointed to the role of widening gender inequalities after independence from the Soviet Union as intensifying the preference for sons (Duthé et al. 2012).

## Data and methods

### Child sex ratios

A key requirement for analysing substitution is to be able to follow male and female cohorts separately, to distinguish the effects of prenatal sex selection and postnatal child survival on the composition of the cohort at a specific age. Once this population is approximated separately for each sex, the ratio of male to female survivors (the sex ratio) can be estimated. All sex ratio quantities reported in this paper will follow the convention used in the demographic literature, with the estimate of males as the numerator and the estimate of females as the denominator. The UN WPP is a global, harmonized database that provides the relevant demographic estimates in the form of period life tables, birth counts, and SRBs for five-year periods (e.g., 1980–85, 1990–95, etc.) so users can approximate age and sex population composition (United Nations 2015a). Limitations of the UN WPP data are noted in the Appendix. The UN data are available for five-year periods and five-year age intervals. With these data, the population sex ratio after infancy and early childhood that is most readily estimated is the sex ratio of five- to ten-year-olds, that is, children who have had their fifth birthday but have yet to have their tenth, denoted as  $[5, 10)$ . Throughout the paper, I term this the child sex ratio (CSR).

As shown in Figure 2, the population of survivors at ages  $[5, 10)$  for the period  $[t, t + 5)$  can be visualized as the  ${}_5L_5$  parallelogram in the age-cohort lexis surface, which indicates the cohort of survivors from the birth cohort born five years before, in the period  $[t - 5, t)$ . The cohort life table data needed to track actual cohort survivorship are not readily available for all countries. With available period data, the survivors between the ages of five and ten in the population

can be approximated from the synthetic cohort of survivors in the period life table, as indicated in the  ${}_5L_5$  square in the age-period surface in Figure 2.

The CSR of  $[5, 10)$  year-olds at time  $[t, t + 5)$ ,  $CSR_{t,t+5}^{5-10}$ , can be written as:

$$\begin{aligned} CSR_{t,t+5}^{5-10} &\equiv \frac{P_{m,t,t+5}^{5-10}}{P_{f,t,t+5}^{5-10}} \\ &\equiv \frac{B_{m,t-5,t}}{B_{f,t-5,t}} \times \frac{((l_5^{m,t,t+5})/(l_0^{m,t,t+5}))}{((l_5^{f,t,t+5})/(l_0^{f,t,t+5}))} \\ &\quad \times \frac{(({}_5L_5^{m,t,t+5})/({}_5L_5^{f,t,t+5}))}{(({}_5L_5^{f,t,t+5})/({}_5L_5^{f,t,t+5}))} \end{aligned} \quad (1)$$

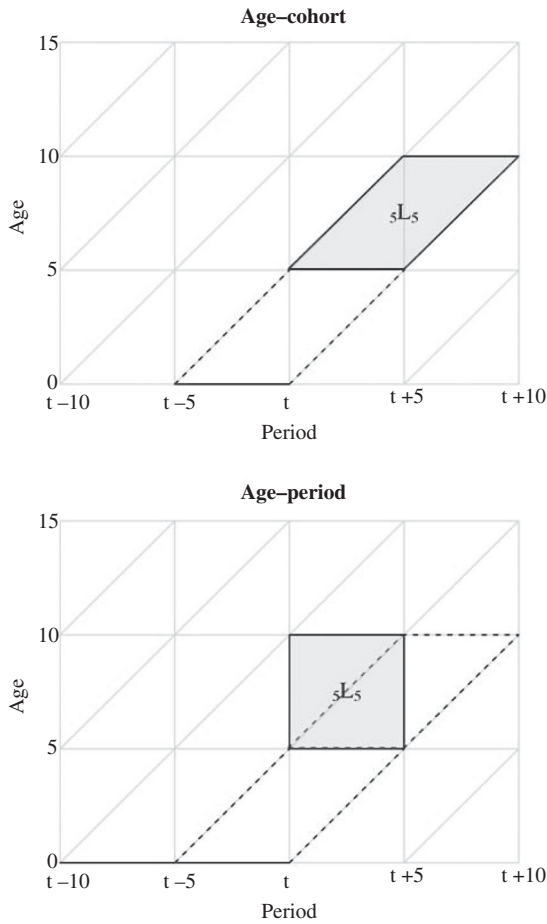
where  $P_{m,t,t+5}^{5-10}$  refers to the male population of five- to ten-year-olds for time  $[t, t + 5)$  and  $P_{f,t,t+5}^{5-10}$  the female population of five- to ten-year-olds for the same time period.  $B_{m,t-5,t}$  indicates the male births and  $B_{f,t-5,t}$  female births for  $[t - 5, t)$ . The following quantities are derived from the life tables for males and females, as indicated by the superscript  $m$  or  $f$ , respectively:  $l_5^{t,t+5}$  refers to the life table survivors up to age five,  $l_0^{t,t+5}$  the life table radix, and  ${}_5L_5^{t,t+5}$  the person-years lived between the ages of five and ten.

As  $l_0^{m,t,t+5} = l_0^{f,t,t+5}$  and the ratio of male to female births  $((B_{m,t-5,t})/(B_{f,t-5,t}))$  is the sex ratio at birth (SRB), the CSR in equation (1) can be simplified to:

$$CSR_{t,t+5}^{5-10} \equiv \underbrace{SRB_{t-5,t}}_{\text{fertility component}} \times \underbrace{\frac{{}_5L_5^{m,t,t+5}}{{}_5L_5^{f,t,t+5}}}_{\text{mortality component}} \quad (2)$$

As shown in equation (2), the CSR can be expressed as the product of two components: the *fertility* component that refers to the sex ratio at birth,  $SRB_{t-5,t}$ , and the *mortality* component that captures the ratio of male to female person-years lived in the life table population between the ages of five and ten, for those who survived up to age five,  $(({}_5L_5^{m,t,t+5})/({}_5L_5^{f,t,t+5}))$ .

The two quantities required to calculate the CSR in equation (2) can be derived from the SRB time series and the period life tables (person-years) available in the UN WPP database. I calculate  $CSR_{t,t+5}^{5-10}$  for 171 countries for four time periods: 1980–85, 1990–95, 2000–05, and 2010–15. I also calculate changes in the CSR and its two components across countries to assess countries with distinctive, outlying trajectories. The original data set contains 201 countries after dropping regional geographical units; 30 countries with populations under 1 million are also dropped due to small numbers and erratic



**Figure 2** Population aged five to ten in age-cohort and age-period perspectives

fluctuations in their sex ratio values, leaving 171 countries. I also calculate changes in the CSR and its two components across countries to assess countries with distinctive, outlying trajectories. By analysing patterns of change in the prenatal (fertility) and postnatal (mortality) components across consecutive decades for the synthetic cohort, it is possible to assess if, as predicted by the substitution hypothesis, increasing masculinity of birth cohorts is being offset by faster improvements in relative survivorship for females.

### Quantifying anomalous change

Having calculated CSRs, their relative components, and changes in their relative components, I analyse whether the levels of the fertility or mortality components in each period are anomalous. I quantify missing female births and excess female deaths that underlie the distorted ratios for each period (1980–85, 1990–95, 2000–05, and 2010–15).

*Prenatal: missing births.* Natural variations in the SRB are well known, with low SRBs reported in sub-Saharan Africa and higher SRBs in Asian populations (Garenne 2002; Klasen and Wink 2003). Despite these natural variations, a steady increase in the SRB in several countries within a time span of a decade since the 1980s or 1990s has been widely documented in the demographic literature and attributed to the practice of sex-selective abortion (Arnold et al. 2002; Chung and Das Gupta 2007; Guilmoto 2009, 2015; Duthé et al. 2012; Frost et al. 2013; Michael et al. 2013). Before the 1980s, before diffusion of the accurate and early ultrasonography that allows for the determination of foetal sex, the impact of prenatal sex selection was limited (Guilmoto 2009). To estimate missing female births resulting from prenatal sex selection, I compare female birth estimates for the period of interest with the number of female births that would have resulted, holding the SRB at the country's 1970–75 level, before ultrasound technology became widely available.

The missing female births in the CSR ( $CSR_{t,t+5}^{5-10}$ ) can be expressed as:

$$\text{MissingBirths}_{t,t+5}^{\text{females}} \equiv B_{t-5,t} \times \left[ \frac{1}{1 + \text{SRB}_{t-5,t}} - \frac{1}{1 + \text{SRB}_{1970,1975}} \right] \quad (3)$$

where  $B_{t-5,t}$  refers to the observed births.

*Postnatal: excess female child mortality.* For changes in the mortality component, quantifying 'excess' female mortality requires a counterfactual (model-generated) estimate of what mortality would have been in the absence of gender discrimination. This standard, moreover, needs to account for the fact that the sex ratio of mortality changes as mortality declines. Assuming no sex differential in allocation of food and medical care, boys and girls experience different probabilities of death due to a number of biological factors (Sawyer 2012). Therefore, equity in survival chances during infancy and childhood does not entail a sex ratio of mortality of one.

In the first year of life, newborn girls have a biological advantage over boys due to their lower vulnerability to perinatal conditions, congenital abnormalities, and certain infectious diseases such as intestinal and lower respiratory infections (Drevenstedt et al. 2008). The same biological advantages for girls with respect to infectious diseases do not transfer to later infancy or the early childhood



years. Consequently, the sex ratio of mortality in the first year of life is expected to be higher (indicative of higher male mortality compared with female mortality) than in early childhood. Infections, in general, are more sex neutral in their mortality risks than congenital conditions. Since infections are more common in high-mortality settings, the sex ratio of mortality in infancy and childhood tends to rise with declining mortality, as congenital conditions acquire greater importance as causes of death. In recent years, the sex ratio of infant mortality has started to fall again in high-income, low-mortality settings, indicating improvements in the relative survival of male infants (Sawyer 2012).

Previous attempts to quantify excess female infant and child mortality, most notably by Hill and Upchurch (1995), have used life tables based on historical data from European populations to generate an expected sex ratio of mortality at any given level of mortality. Hill and Upchurch (1995) modelled the sex ratios of infant and child mortality separately as functions of male under-five mortality using a flexible, locally weighted least squares regression model. This approach assumed that historical populations did not show significant sex discrimination in the allocation of food and resources. Sawyer (2012) found that while the direction of change observed in historical populations—with increasing sex ratios of infant and child mortality accompanying declines in overall mortality—is also observed in the contemporary less developed world, the extent of advantage for girls at a given level of mortality is lower in the less developed world than in historical data.

The appropriateness of historical European populations for constructing a standard of expected sex ratios of mortality for the contemporary less developed world, given the vastly different environmental and cause-of-death environments between the two, has been questioned further in recent studies (Alkema et al. 2014; Bongaarts and Guilmoto 2015). These studies pooled data from a wider set of contemporary populations reflecting different mortality environments to derive estimates of excess mortality. Like Hill and Upchurch, Alkema et al. (2014) modelled the sex ratios of infant and child mortality as functions of male under-five mortality, and separately estimated country-specific deviations from this global relationship with a Bayesian hierarchical time series model. They used mortality estimates from the UN Inter-agency Group on Mortality Estimation (IGME) (Hill et al. 2012). The UN WPP 2015 revision used the same analytical approach as the UN IGME to estimate under-five mortality (United Nations 2015b). Pooling UN WPP 2012 data to form a reference group of 93 countries, Bongaarts and Guilmoto (2015) predicted logged sex ratios of mortality as a linear function of

life expectancy. Their reference group comprised 93 countries, and excluded countries with populations of less than 5 million, select eastern European countries, and those where prenatal sex selection or excess female mortality have previously been documented.

In what follows, I draw on these different approaches. Following Alkema et al. (2014) and Hill and Upchurch (1995), I estimate a flexible locally weighted least squares regression model with the sex ratio of mortality as the outcome variable and the probability of dying before age five for males ( ${}_5q_0^m$ ) as the predictor. This model is separately estimated for sex ratios of: (1) the probability of an infant dying before age one ( $({}_1q_0^m)/({}_1q_0^f)$ ); (2) the probability of dying between ages one and five ( $({}_4q_1^m)/({}_4q_1^f)$ ); and (3) the probability of dying between ages five and ten ( $({}_5q_5^m)/({}_5q_5^f)$ ), using UN WPP 2015 mortality data pooled for the period from 1970–75 to 2010–15, for the same 93 countries used by Bongaarts and Guilmoto. The model generates predicted sex ratios of mortality at a given level of male under-five mortality. From these estimates of the sex ratio of mortality, estimates of expected female  $\widehat{{}_1q_0^f}$ ,  $\widehat{{}_4q_1^f}$ , and  $\widehat{{}_5q_5^f}$  are derived, and corresponding person-years lived by the cohort between ages  $x$  and  $x+n$  can be computed (Preston et al. 2000). The person-years derived from the model-predicted  $\widehat{{}_1q_0^f}$ ,  $\widehat{{}_4q_1^f}$ , and  $\widehat{{}_5q_5^f}$  give the expected mortality component,  ${}_5\hat{L}_5^{f,t,t+5}$ .

Reapplying equation (2), excess female deaths underlying the ratio  $CSR_{t,t+5}^{5-10}$  for period  $[t, t+5]$  can be expressed as:

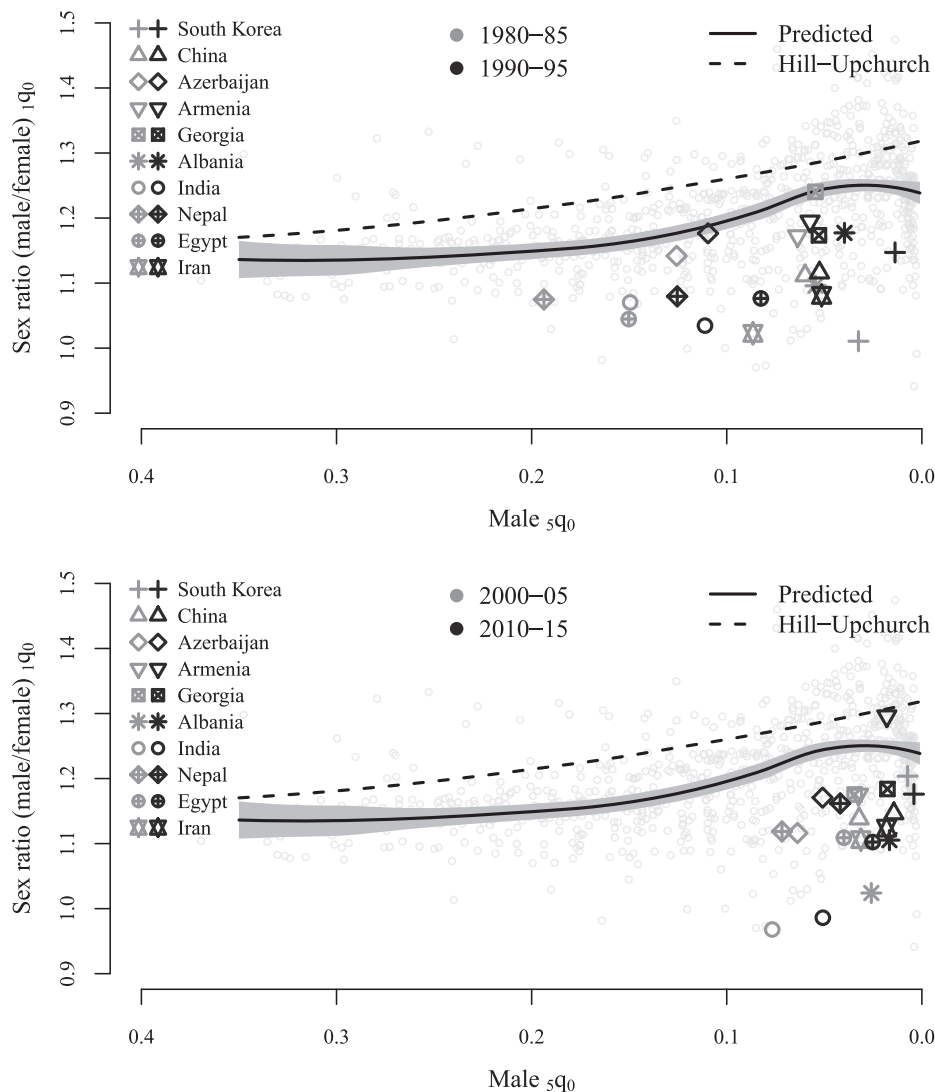
$$ExcessDeaths_{t,t+5}^f = B_{t-5,t}^f \times [{}_5\hat{L}_5^{f,t,t+5} - {}_5L_5^{f,t,t+5}]. \quad (4)$$

As existing literature on excess female mortality has reported measures of mortality in terms of risk or probability of dying ( $qx$ ) rather than person-years lived ( $Lx$ ), I also follow the convention of reporting  $qx$  in addition to the measure of excess female deaths from equation (4). Moreover, as most excess female mortality is concentrated at ages under five, I report on under-five mortality in terms of the probability of dying at under age five for females,  ${}_5q_0^f$ , which is composed of two components—the probability of dying between birth and age one (infant mortality,  $\widehat{{}_1q_0^f}$ ) and the probability of dying between ages one and five ( $\widehat{{}_4q_1^f}$ )—and can be expressed as  $\widehat{{}_5q_0^f} = \widehat{{}_1q_0^f} + \widehat{{}_4q_1^f}(1 - \widehat{{}_1q_0^f})$  (Preston et al. 2000).

Predicted estimates of  $\widehat{{}_5q_0^f}$  can be compared with life table estimates of the same for a given period to assess the extent of excess mortality using two measures: (1) *relative* excess female mortality: the ratio of life table mortality estimates to model-predicted, expected values of mortality (i.e.,  $\widehat{{}_5q_0^f}/({}_5q_0^f)$ ); and (2) *absolute* excess female mortality: the difference between life table estimates of mortality and expected mortality (i.e.,  $\widehat{{}_5q_0^f} - {}_5q_0^f$ ). Both measures of excess female mortality are helpful in determining excess mortality at different levels of overall mortality, especially as at low levels of overall

mortality, sex ratios of infant and child mortality can fluctuate significantly over time due to small death counts. Moreover, with declining mortality, absolute excess female mortality could decline even if relative excess mortality remained stable or increased. I rely on both measures to determine whether a country in a particular period shows excess female under-five mortality: it must indicate a relative excess mortality level greater than one and absolute excess mortality of at least 0.001 (one excess death per 1,000).

Figure 3 shows the model-predicted levels (black solid line) for the sex ratio of infant mortality, and



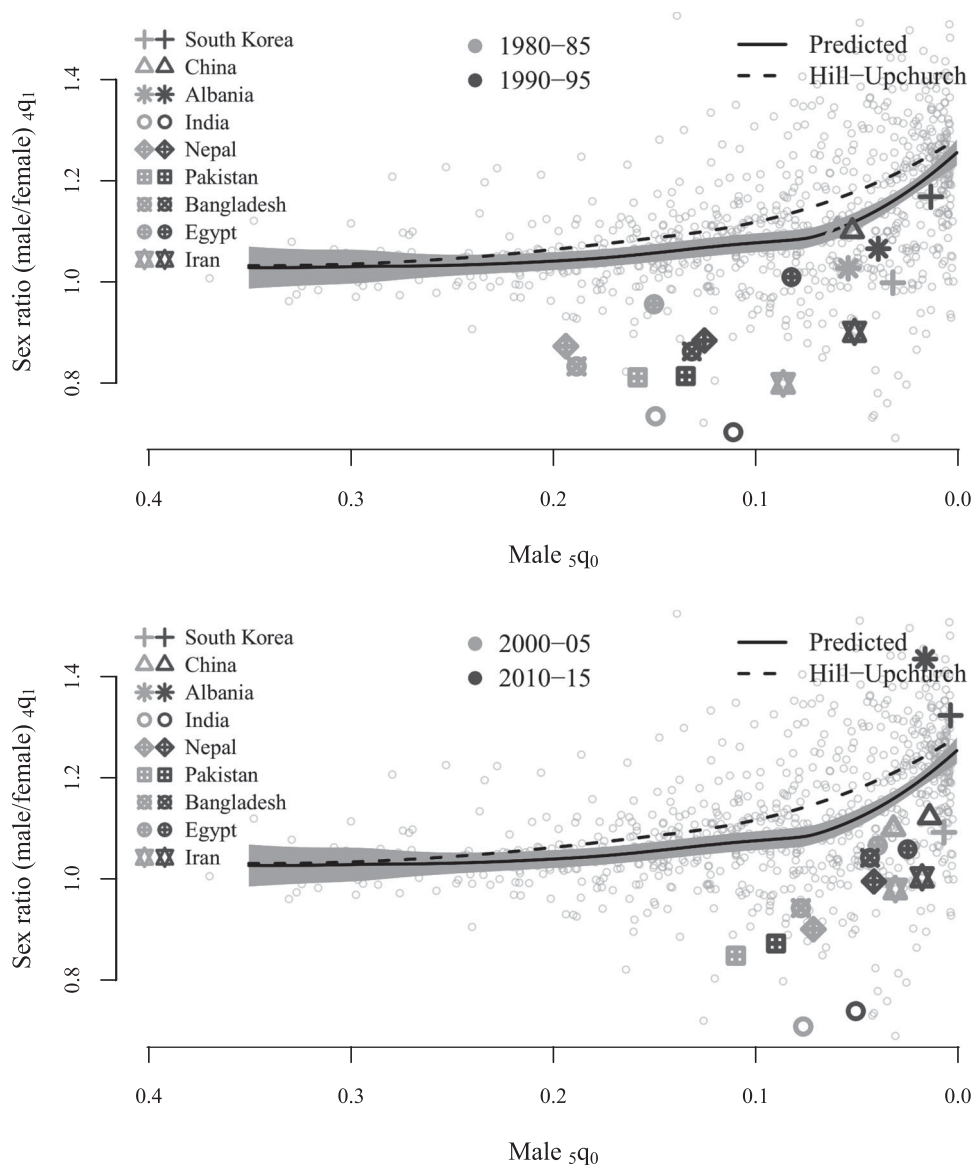
**Figure 3** Model-predicted values of the sex ratio of infant mortality ( ${}_1q_0^m/{}_1q_0^f$ ) as a function of male under-five ( ${}_5q_0^m$ ) mortality, highlighting outlier countries for 1980–85, 1990–95, 2000–05, and 2010–15

Notes: 99 per cent confidence interval bands are shown in grey. Dashed line shows model-predicted values of sex ratios of  ${}_1q_0$  applying the Hill–Upchurch standard. Selected outliers ( $p < 0.01$ ) indicating excess female infant mortality levels for 1980–85 and 1990–95 are highlighted in the upper panel and for 2000–05 and 2010–15 in the lower panel. The level of  ${}_5q_0^m$  on the x-axis moves from high to low to highlight how sex ratios of mortality increase with mortality decline.

Source: Author's calculations based on life table mortality estimates from United Nations (2015a) for the period from 1970–75 to 2010–15 for 93 countries.

Figure 4 shows the sex ratio of child mortality. The corresponding predicted sex ratios of infant and child mortality from the Hill–Upchurch standard are also depicted, with a black dashed line. The figures highlight several countries where excess female mortality at infant and child ages was observed in 1980–85 and 1990–95 (top panel) and in 2000–05 and 2010–15 (bottom panel). These outliers include some countries whose SRBs indicate prenatal sex selection (e.g., South Korea, China, India) and others whose do not (e.g., Iran, Egypt). Statistically significant outlier countries ( $p < 0.01$ ),

where excess female mortality was present throughout the study period, are detailed in the supplementary material (Tables A1 and A2). In Figure 3 (top panel), the country point for South Korea exemplifies a context where excess infant mortality was observed for girls in 1980–85, but had largely disappeared by 1990–95, shown by the country point moving from well below the predicted line (in the direction of higher life table estimates of female  ${}_1q_0^f$  than expected  ${}_1q_0^f$ ) to much closer to the predicted line by 1990–95. India, on the other hand, exemplifies a country that remains well below the line of



**Figure 4** Model-predicted values of the sex ratio of child mortality ( ${}_4q_1^m/{}_4q_1^f$ ) as a function of male under-five ( ${}_5q_0^m$ ) mortality, highlighting outlier countries for 1980–85, 1990–95, 2000–05, and 2010–15

Notes: 99 per cent confidence interval bands are shown in grey. Dashed line shows model-predicted values of sex ratios of ( ${}_4q_1$ ) applying the Hill–Upchurch standard. Selected outliers ( $p < 0.01$ ) indicating excess female child mortality levels for 1980–85 and 1990–95 are highlighted in the upper panel and for 2000–05 and 2010–15 in the lower panel. The level of  ${}_5q_0^m$  on the x-axis moves from high to low to highlight how sex ratios of mortality increase with mortality decline.

Source: As for Figure 3.

expected levels of female mortality at both infant and child ages, despite mortality levels falling.

## Results

### *Changes in child sex ratios*

CSRs were largely stable for the vast majority of countries across consecutive decades between 1980–85 and 2010–15. [Figure 5](#) plots the *ratio* of change in CSRs across consecutive decades from 1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15. The grey dotted lines in the figure identify the 90 per cent range for the empirical distribution of changes observed between two consecutive periods across all countries. Outliers on the right tail are indicated above the upper grey line in the figure and refer to countries that witnessed CSR change in the direction of increases in masculinity, and outliers on the left tail are indicated below the lower grey line of the figure and refer to countries that witnessed CSR change in terms of increases in femininity. Proximity between two points along the horizontal axis indicates geographical proximity between those countries.

The largest outliers were concentrated in the 1990–95 to 2000–05 period, shown in the middle panel, and changes in the CSR over this period were concentrated in the direction of increases in masculinity. With the exception of Rwanda, countries experiencing the greatest magnitudes of change in their CSR witnessed change in both the mortality and fertility components of their CSR (denoted by a square in [Figure 5](#)). Since the focus of this paper is to study the dynamics of both the fertility and mortality components of CSRs, in what follows I restrict my analysis to outliers where both components changed. There is a strong correspondence between countries that experienced the largest sex ratio changes and those with outlying sex ratio levels in each period. Further details about outlier countries in terms of CSR levels are available in the supplementary material (Figures A1 and A2).

[Figure 6](#) highlights CSR trajectories for the eight countries experiencing the largest increases in masculinity, where change occurred in both their fertility and mortality components. The countries experiencing these outlying trajectories were in East Asia (China, South Korea, Vietnam), South Asia (India, Nepal), and the South Caucasus (Georgia, Armenia, Azerbaijan).

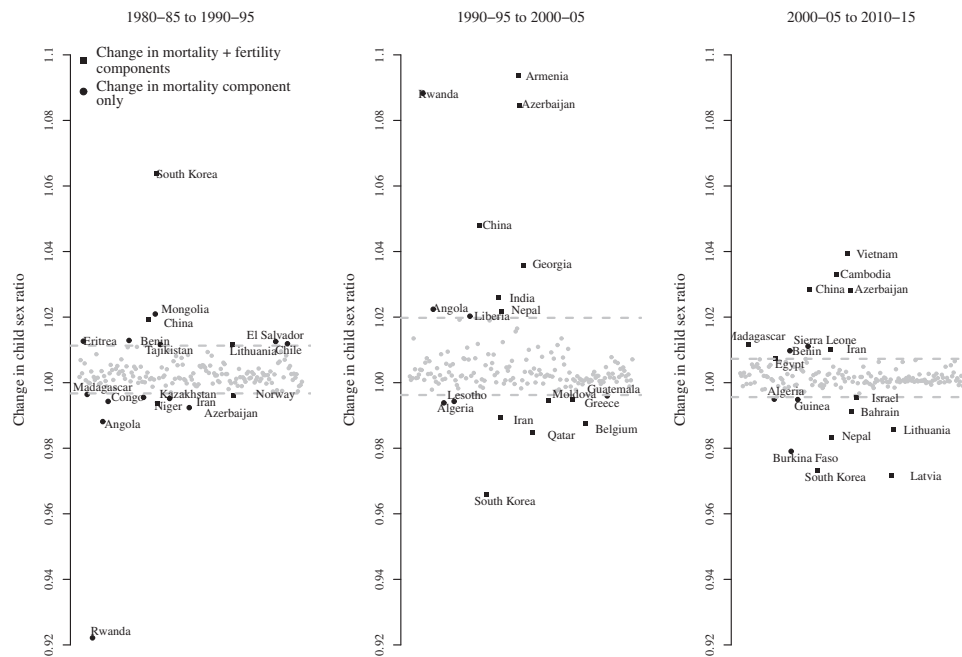
### *East Asia*

How much of the change in CSR trajectories in East Asia was attributable to fertility vs. mortality

dynamics? [Figure 7](#) highlights the ratio of change in the fertility component (indicated on the *x*-axis) and the mortality component (indicated on the *y*-axis) across consecutive decades from 1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15, for China, South Korea, and Vietnam. The *ratio* of change is depicted here, thus, for the fertility component underlying CSRs between 1980–85 and 1990–95, this is  $(SRB_{1985,1990})/(SRB_{1975,1980})$ . Values greater than one indicate that the ratio changed in the direction of increases in the proportion of male births across the two periods. Similarly, the ratio of change in the mortality component can be expressed as  $(({}_5L_5^{m,1990,1995})/({}_5L_5^{f,1990,1995})) / (({}_5L_5^{m,1980,1985})/({}_5L_5^{f,1980,1985}))$ . A ratio greater than one indicates that boys made faster improvements than girls in survivorship across the two periods and a ratio less than one indicates that girls made faster improvements. The substitution hypothesis implies that increases in the fertility component in the direction of increased masculinity of the birth cohorts (greater than one) would be offset by faster improvements in girls' survivorship relative to boys' (mortality component less than one) if the country had excess levels of female under-five mortality in the preceding period. In [Figure 7](#), black points that lie in the lower right rectangle meet these criteria. For each country, [Table 1](#) shows measures of relative excess,  ${}_5q_0^f$ , absolute excess,  ${}_5q_0^f$ , absolute number of missing female births (see equation (3)), and excess female deaths (see equation (4)) underlying the CSR.

When comparing the explanatory factors for the dynamics of the CSRs across the three panels in [Figure 7](#), it is clear that the mortality component changed much less than the fertility component in all three countries. The greater contribution of the fertility component in absolute terms (the number of missing births) as compared with the mortality component (number of excess female deaths) is highlighted in [Table 1](#).

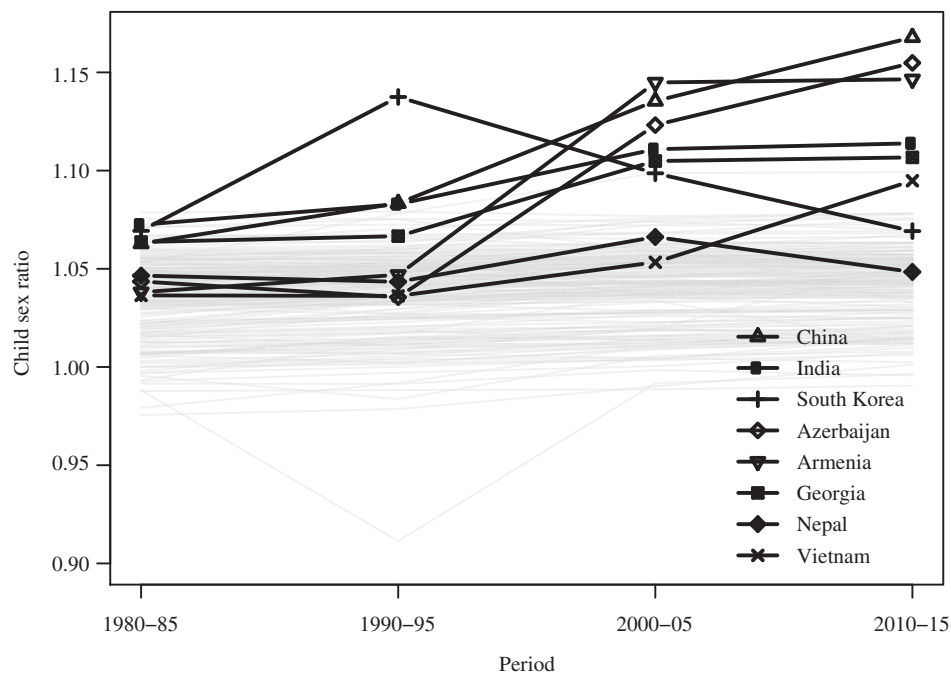
Of the three East Asian contexts, South Korea shows the clearest evidence suggesting substitution between 1980–85 and 1990–95 ([Figure 7](#)). Although the numbers of excess female deaths in South Korea were already relatively low in 1980–85 (12,500) compared with China (see [Table 1](#)) or India (see [Table 2](#)), the indicators for both relative and absolute excess female mortality were anomalous in the 1980s. Changes in the mortality component between 1980–85 and 1990–95 showed reductions in excess female child mortality, as evident in both relative and absolute measures,



**Figure 5** Changes in life table child sex ratios across consecutive decades (1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15), highlighting outlier countries experiencing the largest changes and showing whether changes are due to mortality and fertility components or the mortality component only

*Notes:* The grey dashed lines identify the 90 per cent range for the empirical distribution of the within-country changes observed between two consecutive periods. Proximity between two points along the horizontal axis indicates geographical proximity between those countries.

*Source:* Author's calculations based on data from United Nations (2015a).

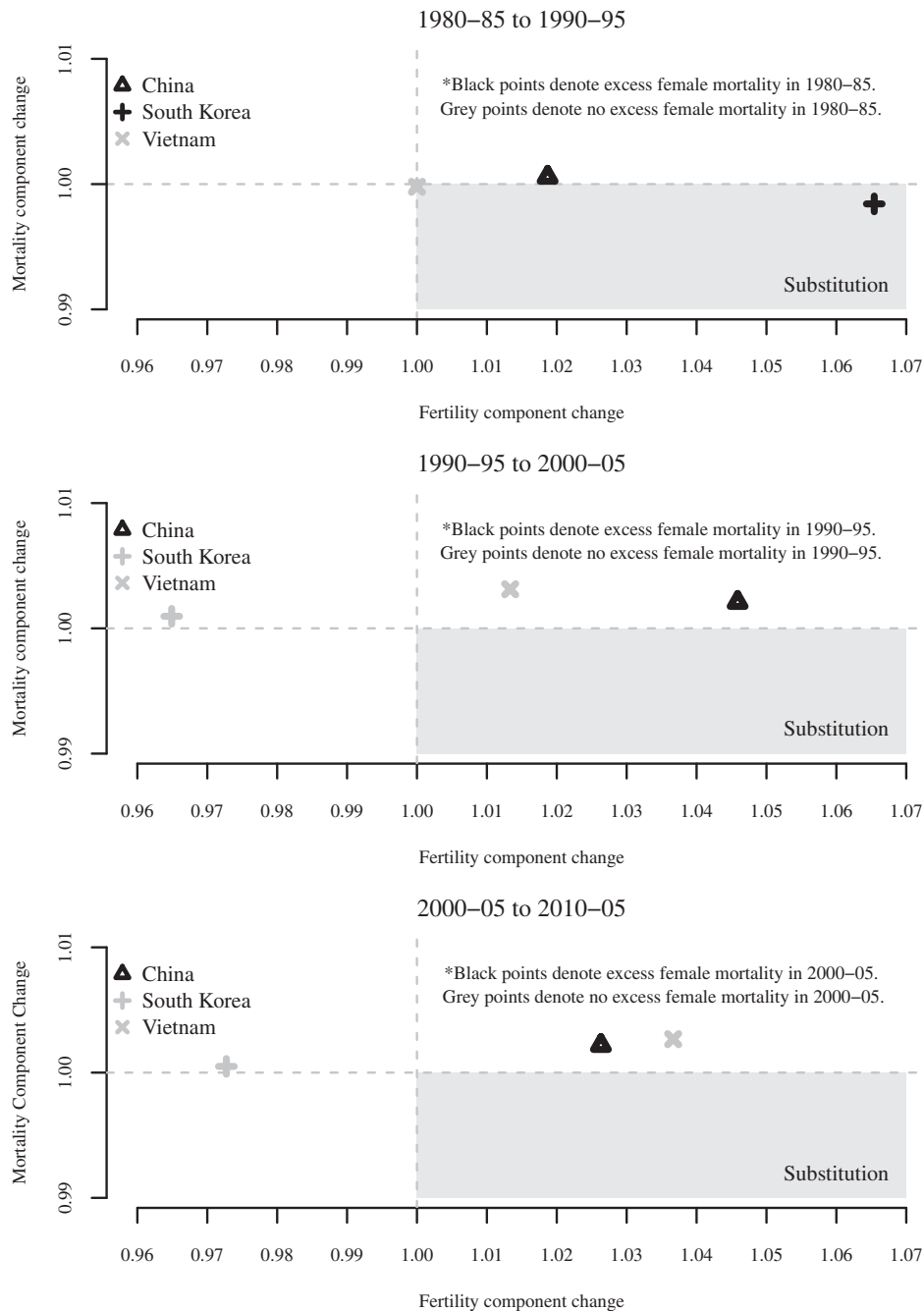


**Figure 6** Life table child sex ratios, 1980–85 to 2010–15, highlighting countries with outlying trajectories (those that witnessed significant increases in masculinity in their child sex ratios)

*Note:* Child sex ratio trajectories for all 171 countries between 1980–85 and 2010–15 are shown in grey in the background.

*Source:* As for Figure 5.





**Figure 7** Changes in fertility and mortality components underlying child sex ratios in China, South Korea, and Vietnam, across consecutive decades: 1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15

*Notes:* Change in the fertility component indicates change in the sex ratio at birth. Change in the mortality component indicates change in sex ratios of survivorship. Black points lying in the shaded bottom right rectangle indicate countries where substitution occurred over the period, that is, increases in the fertility component in the direction of increased masculinity of the birth cohorts (value greater than one) were offset by faster improvements in girls' survivorship relative to boys' (mortality component less than one).

*Source:* As for Figure 5.

with excess mortality disappearing by the early 2000s. As Table 1 highlights, relative excess female mortality levels fell from around 20 to 5 per cent excess mortality.

Between 1990–95 and 2000–05, the fertility component in South Korea shows significant reductions

in masculinity (Figure 7), indicating the decline of prenatal sex selection. China saw increases in its fertility component later than in South Korea, with the most noticeable change in the period after the 1990s. Unlike in South Korea, changes in the mortality component over the period when prenatal sex

**Table 1** Missing female births (in 1,000s), excess female deaths (in 1,000s), relative excess under-five mortality, and absolute excess under-five mortality (per 1,000 births) underlying child sex ratios for China, South Korea, and Vietnam: 1980–85, 1990–95, 2000–05, and 2010–15

Country	Indicator	1980–85	1990–95	2000–05	2010–15
China	Missing female births	0.0	642.8	1,311.2	1,790.2
	Excess female deaths	240.7	271.7	98.9	44.7
	Relative excess ${}_5q_0^f$	1.09	1.09	1.09	1.09
	Absolute excess ${}_5q_0^f$	4	4	2	1
South Korea	Missing female births	0.0	51.1	21.3	0.0
	Excess female deaths	12.5	1.2	0.5	0.1
	Relative excess ${}_5q_0^f$	1.22	1.07	1.05	1.03
	Absolute excess ${}_5q_0^f$	6	1	0	0
Vietnam	Missing female births	0.0	0.0	24.8	91.7
	Excess female deaths	–4.2	–14.9	–9.5	–6.3
	Relative excess ${}_5q_0^f$	1.00	0.95	0.94	0.94
	Absolute excess ${}_5q_0^f$	0	–2	–2	–1

*Note:* Relative excess mortality refers to the ratio of life table estimates to model-predicted female  ${}_5q_0^f$ , while absolute excess mortality refers to the difference between these two quantities.

*Source:* Author's calculations based on United Nations (2015a).

selection increased showed not a decline but a stabilization in the levels of relative excess female mortality. Despite stabilization in relative excess mortality, however, absolute numbers of excess female deaths declined in China between 2000–05 and 2010–15, after showing a slight increase between 1980–85 and 1990–95 (see Table 1).

For China, fertility restrictions, in the form of the one-child policy put in place in 1979 have been linked with an intensification of prenatal sex selection (Guilmoto 2009). However, the policy was implemented well before the widespread availability of prenatal sex determination technologies, which were likely not a significant factor underlying China's SRB increases before the 1990s (Goodkind 2015). For those constrained by the fertility restrictions in the 1980s, son preference likely manifested itself either in the systematic under-reporting of daughters (Merli and Raftery 2000; Goodkind 2011) or the potential intensification of postnatal excess female mortality at low birth parities. The mortality effects of the fertility restrictions are suggested by the fact that in the period between 1980–85 and 1990–95, when the diffusion of prenatal sex determination technologies was likely low, both relative and absolute excess female mortality remained high (see Table 1). In a context of strong son preference, fertility restrictions, and variations in regional development that would likely trigger a more gradual and stratified diffusion of prenatal sex determination technology, these trends suggest that the uptake of prenatal sex selection, especially among groups with excess female mortality, may have been limited.

Vietnam saw significant increases in prenatal sex selection, particularly in the period between 2000–05 and 2010–15 when change in the fertility component was around 1.04 (or an increase of 4 per cent), as indicated in the third panel of Figure 7. Unlike South Korea and China, Vietnam did not exhibit excess female child mortality either before or during the period when the uptake of prenatal sex selection was visible. Interestingly, Table 1 shows that Vietnam experienced slight levels of excess male mortality and had fewer female deaths than predicted for all four periods. Vietnam's neighbour, Cambodia, was also identified as an outlier in terms of sex ratio change in 2000–05 to 2010–15 (Figure 5), showing a sex ratio change of 1.03 or 3 per cent. Most of this change was driven by an elevation in Cambodia's fertility component or SRB levels, which increased by about 2 per cent over this period, going from a level of 1.04 to 1.06. Like in Vietnam, this occurred in the absence of any excess female mortality either preceding or during the period that witnessed the change in the fertility component. In the 1980s and 1990s, the SRB in Cambodia was in the range of 1.03–1.04, lower than SRB values for Vietnam (1.05) (United Nations 2015a). It is unclear whether prenatal sex selection was underlying these changes in the SRB in Cambodia.

### *South Asia*

India, Pakistan, and Nepal all showed some evidence for substitution in the 2000s. Girls experienced faster

**Table 2** Missing female births (in 1,000s), excess female deaths (in 1,000s), relative excess under-five mortality, and absolute excess under-five mortality (per 1,000 births) underlying child sex ratios for India, Pakistan, and Nepal: 1980–85, 1990–95, 2000–05, and 2010–15

Country	Indicator	1980–85	1990–95	2000–05	2010–15
India	Missing female births	0.0	319.5	1,253.8	1,536.3
	Excess female deaths	1,835.2	1,882.7	1,573.1	920.8
	Relative excess ${}_5q_0^f$	1.19	1.25	1.32	1.31
	Absolute excess ${}_5q_0^f$	25	24	21	13
Nepal	Missing female births	0.0	0.0	23.8	7.1
	Excess female deaths	35.8	28.2	15.5	5.1
	Relative excess ${}_5q_0^f$	1.11	1.12	1.12	1.09
	Absolute excess ${}_5q_0^f$	19	13	7	3
Pakistan	Missing female births	0.0	0.0	78.2	119.3
	Excess female deaths	123.1	145.3	111.8	89.4
	Relative excess ${}_5q_0^f$	1.10	1.10	1.09	1.08
	Absolute excess ${}_5q_0^f$	14	12	9	6

Note: Relative excess mortality refers to the *ratio* of life table estimates to model-predicted female  ${}_5q_0^f$ , while absolute excess mortality refers to the *difference* between these two quantities.

Source: As for Table 1.

improvements in mortality reduction than boys, as indicated by a change in mortality components of under one in all three countries after 1990–95, which accompanied increases in masculinity in their fertility components in the 1990–95 to 2000–05 period (Figure 8). Given the high levels of excess female mortality present in South Asia, as shown in Table 2, these faster improvements only gradually reduced the prevailing high levels of excess female mortality.

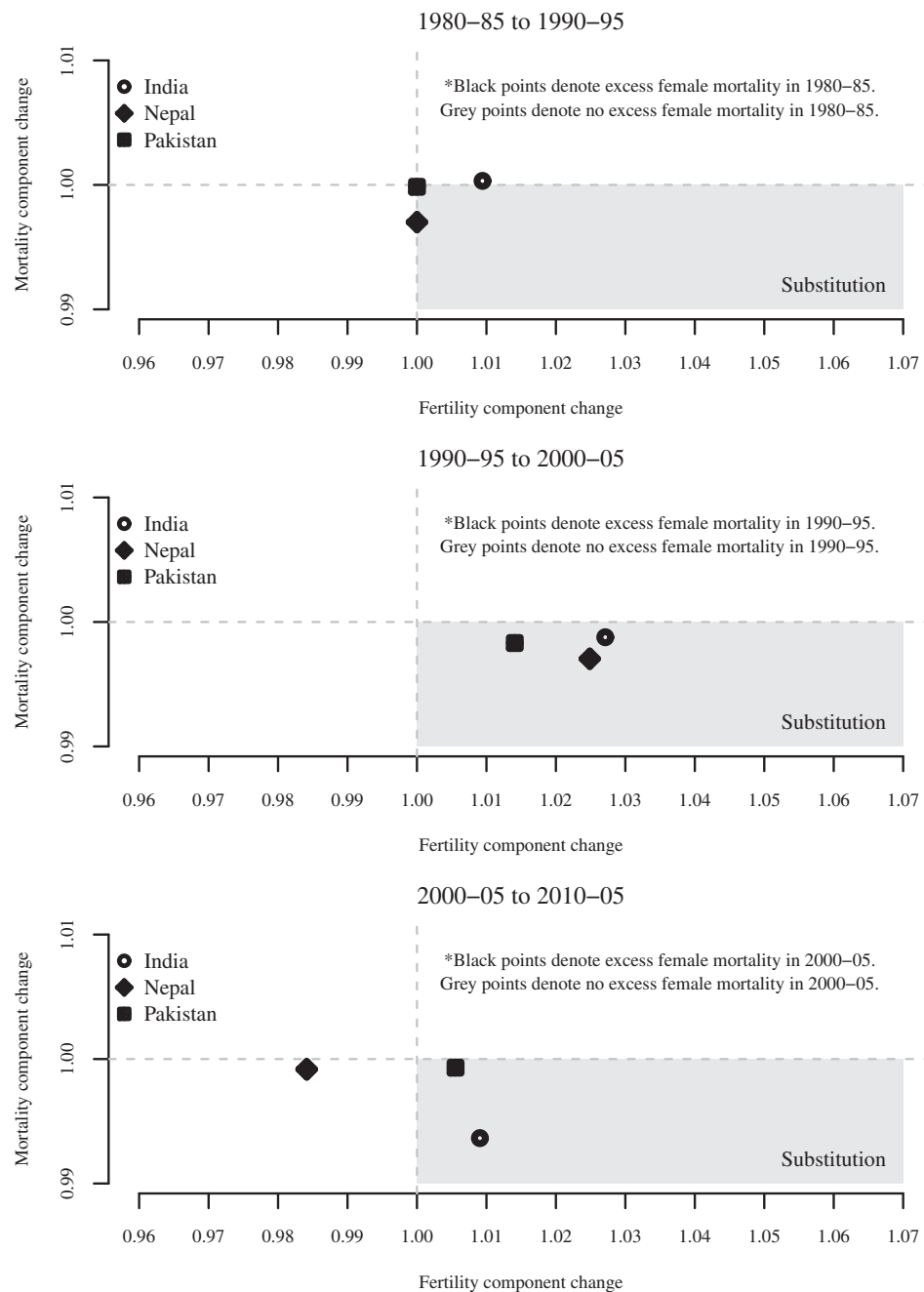
Changes in the mortality components between 1980–85 and 1990–95 (Figure 8) are indicative of either stability (Pakistan, India) or slight reductions (Nepal) in the levels of both relative and absolute excess female mortality. In both Pakistan and Nepal, little change in the fertility component is evident between 1980–85 and 1990–95. India shows the highest levels of under-five excess female mortality in the world. In 2010–15, the population of five- to ten-year-olds was affected by 1.5 million missing female births compared with 921,000 excess female deaths. Numbers of excess female deaths accounted for a greater number of missing girls than missing female births in India until 2000–05, after which missing female births contributed more. The faster pace of mortality reduction for girls that accompanied the masculinity of its fertility component, as shown in Figure 8, was not sufficient to make India less of an outlier in terms of its levels of relative excess mortality. As highlighted in Table 2, although between 1990–95 and 2000–05, and more significantly between 2000–05 and 2010–15, absolute excess mortality levels and absolute numbers of excess female deaths declined in India, relative

excess female mortality levels were remarkably persistent.

As anticipated in early and mid-transition contexts, with strong son preference, higher fertility, and high prevailing levels of excess mortality (such as South Asia), the contribution of excess female mortality to sex ratio distortions remained significant even as the fertility component became distorted. Reductions in excess mortality only appeared in the 2000s, coinciding with a slowdown in increases in the fertility component. This pattern suggests that prenatal sex selection became more widely practised in the 2000s than in the initial stages of the rise in SRBs when it was likely concentrated among pioneer groups, such as the richer and better educated. India witnessed the most gradual reductions in excess female mortality in the region; it also witnessed the largest increases in its fertility component of the three South Asian countries, with Nepal seeing the second largest. In Nepal, changes in the fertility component appeared later than in India (between 1990–95 and 2000–05), and SRB trajectories had already begun to level off between 2000–05 and 2010–15. Abortion legalization in 2002 in Nepal may have played an important role in its onset of prenatal sex selection in the early 2000s, unlike in the Indian context, where abortion has been legal since the 1970s (Frost et al. 2013).

### *The South Caucasus and Albania*

Azerbaijan, Armenia, and Georgia saw sharp rises in their SRBs in the 1990s, indicative of the onset of



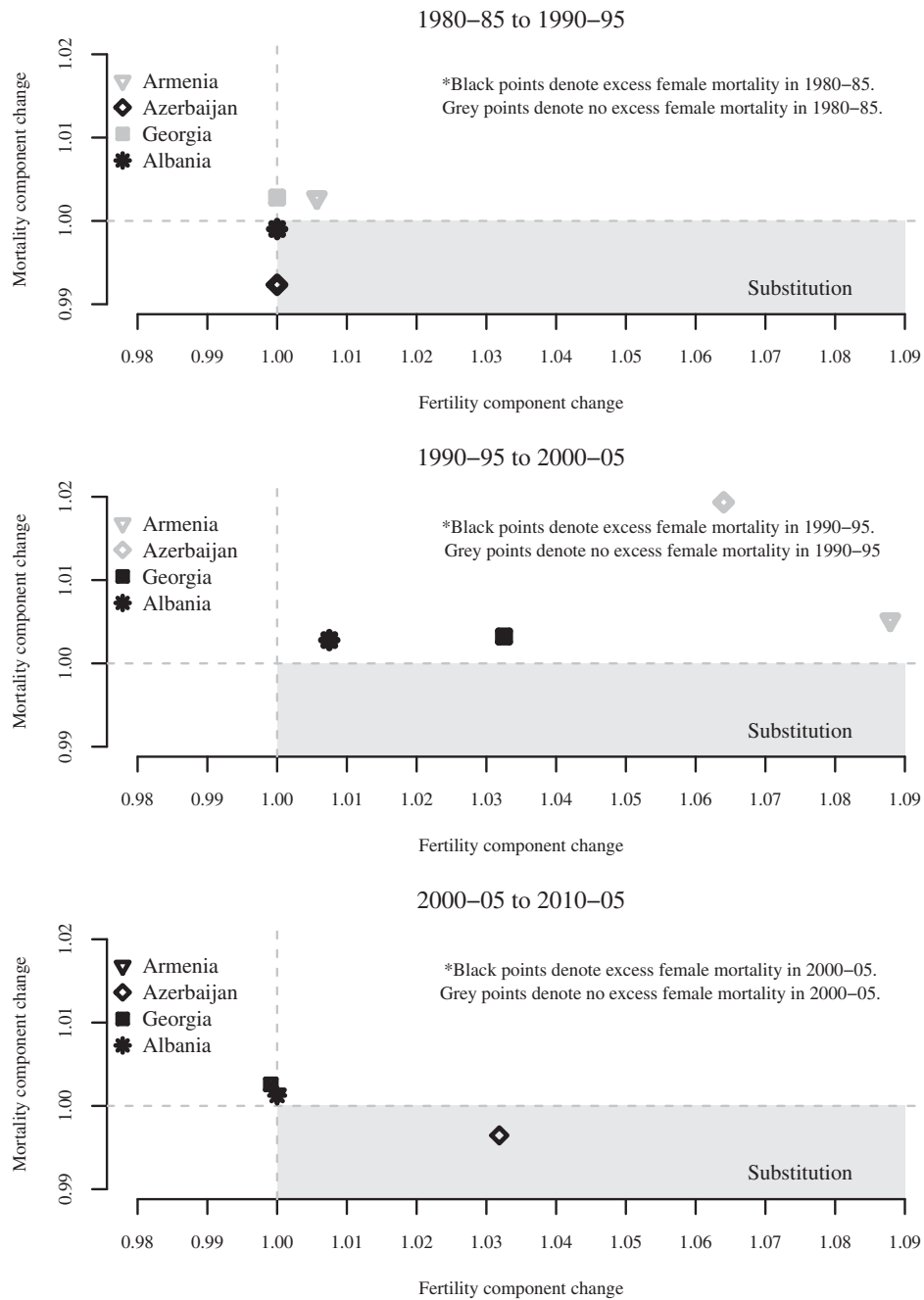
**Figure 8** Changes in fertility and mortality components underlying child sex ratios in India, Pakistan, and Nepal across consecutive decades: 1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15

*Note:* Change in the fertility component indicates change in the sex ratio at birth. Change in the mortality component indicates change in sex ratios of survivorship. Black points lying in the shaded bottom right rectangle indicate countries where substitution occurred over the period, that is, increases in the fertility component in the direction of increased masculinity of the birth cohorts (value greater than one) were offset by faster improvements in girls' survivorship relative to boys' (mortality component less than one).

*Source:* As for Figure 5.

prenatal sex selection. No other parts of the former Soviet Republics spanning southern Europe to Central Asia witnessed similar rises in their SRBs following independence from the Soviet Union, with the exception of Albania. In contrast to the East and South Asian populations, where excess

female mortality preceded increases in their SRBs (as indicated by the black points in the top panels of Figures 7 and 8), the onset of excess female mortality in the South Caucasus countries broadly coincided with the period that saw increases in these populations' SRBs. Georgia saw an emergence



**Figure 9** Changes in fertility and mortality components underlying child sex ratios in Armenia, Azerbaijan, Georgia, and Albania across consecutive decades: 1980–85 to 1990–95, 1990–95 to 2000–05, and 2000–05 to 2010–15

*Notes:* Change in the fertility component indicates change in the sex ratio at birth. Change in the mortality component indicates change in sex ratios of survivorship. Black points lying in the shaded bottom right rectangle indicate countries where substitution occurred over the period, that is, increases in the fertility component in the direction of increased masculinity of the birth cohorts (value greater than one) were offset by faster improvements in girls' survivorship relative to boys' (mortality component less than one).

*Source:* As for Figure 5.

of excess female mortality in the 1990s, as shown in the 1990–95 to 2000–05 panel in Figure 9, whereas Azerbaijan and Armenia saw its emergence in the early 2000s, as seen in the 2000–05 to 2010–15 panel in Figure 9. Azerbaijan initially exhibited

higher than expected levels of female  ${}_5q_0^f$  in the 1980–85 period, but these had normalized by 1990–95. Between 1990–95 and 2000–05, the mortality component saw a nearly 2 per cent increase in masculinity, resulting in the re-emergence of



**Table 3** Missing female births (in 1,000s), excess female deaths (in 1,000s), relative excess under-five mortality, and absolute excess under-five mortality (per 1,000 births) underlying child sex ratios for Armenia, Azerbaijan, Georgia, and Albania: 1980–85, 1990–95, 2000–05, and 2010–15

Country	Indicator	1980–85	1990–95	2000–05	2010–15
Armenia	Missing female births	–0.4	0.1	4.5	4.5
	Excess female deaths	–0.2	0.1	0.1	0.0
	Relative excess ${}_5q_0^f$	0.99	1.01	1.05	0.98
	Absolute excess ${}_5q_0^f$	–1	0	1	0
Azerbaijan	Missing female births	0.0	0.0	11.6	21.7
	Excess female deaths	0.3	–3.6	2.1	0.2
	Relative excess ${}_5q_0^f$	1.03	0.95	1.10	1.02
	Absolute excess ${}_5q_0^f$	3	–5	6	1
Georgia	Missing female births	0.0	0.0	2.5	2.4
	Excess female deaths	–0.1	0.4	0.2	0.1
	Relative excess ${}_5q_0^f$	1.00	1.05	1.05	1.05
	Absolute excess ${}_5q_0^f$	0	2	2	1
Albania	Missing female births	0.0	0.0	0.5	0.3
	Excess female deaths	0.9	0.4	0.3	0.1
	Relative excess ${}_5q_0^f$	1.12	1.06	1.09	1.10
	Absolute excess ${}_5q_0^f$	5	2	2	1

Notes: Relative excess mortality refers to the ratio of life table estimates to model-predicted female  ${}_5q_0^f$ , while absolute excess mortality refers to the difference between these two quantities.

Source: As for Table 1.

excess female mortality that coincided with the period when its SRBs witnessed distortions. Period conditions that likely resulted in the strengthening of the incentives to bear a son following the collapse of the Soviet Union in the 1990s also appear to have triggered postnatal excess female mortality in the region.

Notably, the marker for Albania in Figure 9 remains black in all three panels, indicating that the country showed excess female mortality before the 1990s and throughout the period under consideration. As shown in Table 3, the levels of excess female mortality in terms of excess female deaths and absolute excess female  ${}_5q_0^f$  in the South Caucasus and Albania were generally low and similar to estimates from South Korea after the 1990–95 period. Missing female births accounted for a greater fraction of the distortion in CSRs than excess female deaths for these four countries. Figure 9 highlights that between 1990–95 and 2000–05 the fertility component increased in all four countries, with the steepest increase in Armenia, followed by Azerbaijan, Georgia, and Albania. Although UN SRB figures for Azerbaijan, Armenia, and Georgia correspond with the SRB data from their statistical offices, the UN figures for SRBs are likely to be underestimating SRB increases for Albania. According to UN figures, Albania's SRB increased from 1.07 to 1.08 between 1990–95 and 2000–05. In contrast, birth registration data for 2006 showed an SRB of 1.16 (Guilmoto 2009), whereas for the

period between 2008 and 2011 it was estimated to be 1.12 (UNFPA 2012).

Changes in the mortality component remained stable above one for Georgia and Albania between 1990–95 and 2000–05 (Figure 9). This indicates that slight excess levels of female mortality persisted as their fertility component increased and subsequently levelled off between 2000–05 and 2010–15. Azerbaijan and Armenia witnessed faster reductions in mortality for girls between 2000–05 and 2010–15 as changes in the fertility component levelled off over this period. Azerbaijan, with higher fertility and mortality levels, is at an earlier stage of the demographic transition than the other South Caucasus countries and saw a greater contribution of excess female mortality to its sex ratio distortions, as noted by the higher values of relative and absolute excess  ${}_5q_0^f$  in 1990–95 in Table 3 compared with the other countries. In contrast, as also shown in Table 3, Armenia saw only slight excess female mortality levels in 2000–05 that disappeared by 2010–15.

## Conclusions

By 2010–15, in all countries where SRB distortions were noted, missing female births resulting from prenatal sex selection contributed significantly more than excess female deaths to increases in the masculinity of CSRs. This finding at the country level concurs with the aggregate, global trends in prenatal

and postnatal contributions to missing women reported in Bongaarts and Guilmoto (2015). From the 1990s onwards, these steady increases in the contribution of missing female births were accompanied by reductions in absolute numbers of excess female deaths at infant and childhood ages. Nevertheless, changes in relative excess female mortality for cohorts experiencing rises in prenatal sex selection were more ambiguous.

In South Korea, swift substitution was found, as implied by the reductions in both relative and absolute excess female mortality for (synthetic) cohorts experiencing increases in SRBs. In South Asia, a less steep rise in SRBs was accompanied by initial stability in prevailing high levels of relative and absolute excess female mortality, followed by gradual reductions in the 2000s. High levels of relative excess female mortality (30 per cent) in India persisted until 2010–15. Indeed, although levels of both absolute and relative excess female mortality were much lower in China, like India, little reduction in relative excess mortality accompanied the SRB rise in China. It is plausible that widespread son preference, combined with limited overlap between populations that practise prenatal and postnatal forms of sex selection, might explain the persistence of relative excess female mortality in both settings. The mortality components of the Caucasus countries of Armenia, Azerbaijan, and Georgia showed the onset of excess female mortality in the 1990s and early 2000s, coinciding with the emergence of prenatal sex selection in these populations. In contrast, in Albania slight excess female mortality was noted throughout the period from 1980–85 to 2010–15. In these populations at a later stage of the demographic transition, with presumably weaker son preference than in South Asia, a swift uptake of prenatal sex selection accompanied by reductions in excess female mortality would be expected to underpin changes in CSRs. This pattern was seen in Azerbaijan and Armenia in the 2000s. Albania and Georgia saw a persistence of slight relative excess mortality levels, even as the SRBs became distorted, although reductions in absolute excess mortality were noted in these countries as well.

With the exception of Vietnam, this study has shown that postnatal excess female mortality has been a precursor to, or coincided with, the emergence of prenatal sex selection. It is important to note though that a number of countries had outlying sex ratios of mortality indicative of postnatal excess mortality without clear evidence for prenatal sex selection. This study has focused largely on examining mortality dynamics in countries that did experience prenatal sex selection.

A few countries showing excess  ${}_1q_0^f$  and  ${}_4q_1^f$  are highlighted in Figures 3 and 4, respectively, and all outliers for the period 1980–2015 are listed in the supplementary material (Tables A2 and A3). These countries are geographically clustered, with significant concentrations of excess female child mortality in the Middle East and North Africa (Iran, Egypt, Jordan, Bahrain), as well as in sub-Saharan Africa (e.g., Mali, Niger, Nigeria). Bangladesh, too, showed high levels of excess female child mortality. Moreover, in Iran, Egypt, and Bangladesh, among others, reductions in excess female mortality have been observed since the 1990s without any corresponding increase in SRBs.

Why have SRB distortions emerged in some but not all contexts where postnatal excess female mortality was present? Bongaarts has speculated on whether there may be pent-up demand for sex-selective abortion in parts of Africa with son preference and excess female mortality; demand that is currently constrained due to limited access to ultrasound and abortion (Bongaarts 2013). Limited access to abortion, or its limited uptake due to religious grounds, may also be responsible for SRB distortions not being observed in Iran or Egypt (Hessini 2007). For the Bangladeshi context though, Kabeer et al. (2014) have claimed that limited access to technology, restricted abortion access, and the presence of Islamic norms with weaker son preference (unlike for its Hindu neighbours, India and Nepal) do not provide sufficient explanations as to why prenatal sex selection did not spread. They attributed the divergent trajectories observed in Bangladesh compared with its South Asian neighbours to the significant role played by civil society in shifting norms surrounding sex preferences.

As the previous discussion clarifies, significant postnatal excess female mortality can exist and decline without the uptake of prenatal sex selection. This highlights the challenges of clarifying the causal contribution of the uptake of prenatal sex selection, as distinct from the weakening of son preference norms, to the decline of excess female mortality using the empirical approach undertaken in this study. In contrast to micro-level studies that have attempted to estimate causal impacts but often relied on assumptions that are country-specific, the aggregate-level framework developed in this paper can be applied across countries to measure the contributions and dynamics of prenatal and postnatal strategies of sex selection on sex ratios. This work has drawn on approaches to measuring excess mortality presented in Alkema et al. (2014), while extending their work by jointly examining mortality and fertility dynamics. In contrast to the more

global trends in missing women at all ages reported by Bongaarts and Guilмото (2015), this work has focused on country-level trends, and presented measures of both relative and absolute excess under-five female mortality to better understand country-level magnitudes of and trends in the prenatal and postnatal manifestations of son preference.

The findings presented here highlight a number of open questions and issues of policy relevance. In the light of the finding that missing female births now contribute more than excess female deaths to increasing SRBs in all countries that have experienced the emergence of prenatal sex selection, an investigation of the factors that can lead to a slow-down in prenatal sex selection and its eventual turn-around, such as that witnessed in South Korean SRB trajectories, would be especially pertinent. Furthermore, research is needed to examine the processes that lead to the uptake of prenatal sex selection in some contexts but not others. Although absolute numbers of excess female deaths across different countries with son preference have declined in recent decades, relative excess female mortality at infant and childhood ages persists, most notably in India and China. Understanding the contributing factors and pathways for reducing gender gaps in mortality remains an important area of research with significant policy implications. In addition to its empirical contributions, this study has attempted to theorize the relationship between prenatal and postnatal strategies of sex selection and to present a framework for thinking about this relationship at different stages of demographic modernization. This remains an area for further theoretical development and empirical research.

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## References

- Alkema, L., F. Chao, D. You, J. Pedersen, and C. C. Sawyer. 2014. National, regional, and global sex ratios of infant, child, and under-5 mortality and identification of countries with outlying ratios: a systematic assessment, *The Lancet Global Health* 2(9): e521–e530.
- Anukriti, S., S. R. Bhalotra, and H. Tam. 2016. On the quantity and quality of girls: new evidence on abortion, fertility, and parental investments, *Institute for the Study of Labor (IZA) Discussion Paper No. 10271*.
- Arnold, F., M. K. Choe, and T. K. Roy. 1998. Son preference, the family-building process and child mortality in India, *Population Studies* 52(3): 301–315.
- Arnold, F., S. Kishor, and T. K. Roy. 2002. Sex-selective abortions in India, *Population and Development Review* 28(4): 759–785.
- Attané, I. and C. Z. Guilмото (eds). 2007. *Watering the Neighbour's Garden: The Growing Demographic Female Deficit in Asia*. Paris: CICRED; CEPED.
- Basu, D. and R. De Jong. 2010. Son targeting fertility behavior: some consequences and determinants, *Demography* 47(2): 521–536.
- Bhat, P. N. M. and A. J. F. Xavier. 2003. Fertility decline and gender bias in northern India, *Demography* 40(4): 637–657.
- Bongaarts, J. 2013. The implementation of preferences for male offspring, *Population and Development Review* 39(2): 185–208.
- Bongaarts, J. and C. Z. Guilмото. 2015. How many more missing women? Excess female mortality and prenatal sex selection, 1970–2050, *Population and Development Review* 41(2): 241–269.
- Borooah, V. K. 2004. Gender bias among children in India in their diet and immunisation against disease, *Social Science & Medicine* 58(9): 1719–1731.
- Carvalho, L. S., S. H. Barcellos, and A. Lleras-Muney. 2014. Child gender and parental investments in India: are boys and girls treated differently? *American Economic Journal: Applied Economics* 6(1): 157–189.
- Choe, M. K. and S.-K. Kim. 1998. Son preference and family building during fertility transition: implications on child survival, *Korean Journal of Population Studies* 21(1): 184–228.

- Choe, M. K., H. Hongsheng, and W. Feng. 1995. Effects of gender, birth order, and other correlates on childhood mortality in China, *Social Biology* 42(1–2): 50–64.
- Chung, W. and M. Das Gupta. 2007. The decline of son preference in South Korea: the roles of development and public policy, *Population and Development Review* 33 (4): 757–783.
- Clark, S. 2000. Son preference and sex composition of children: evidence from India, *Demography* 37(1): 95–108.
- Das Gupta, M. 1987. Selective discrimination against female children in rural Punjab, India, *Population and Development Review* 13(1): 77–100.
- Das Gupta, M., W. Chung, and L. Shuzhuo. 2009. Evidence for an incipient decline in numbers of missing girls in China and India, *Population and Development Review* 35(2): 401–416.
- Drenstedt, G. L., E. M. Crimmins, S. Vasunilashorn, and C. E. Finch. 2008. The rise and fall of excess male infant mortality, *Proceedings of the National Academy of Sciences* 105(13): 5016–5021.
- Duthé, G., F. Meslé, J. Vallin, I. Badurashvili, and K. Kuyumjian. 2012. High sex ratios at birth in the Caucasus: modern technology to satisfy old desires, *Population and Development Review* 38(3): 487–501.
- Frost, M. D., M. Puri, and P. R. A. Hinde. 2013. Falling sex ratios and emerging evidence of sex-selective abortion in Nepal: evidence from nationally representative survey data, *BMJ Open* 3(5): e002612.
- Garenne, M. 2002. Sex ratios at birth in African populations: a review of survey data, *Human Biology* 74(6): 889–900.
- Goodkind, D. 1996. On substituting sex preference strategies in East Asia: does prenatal sex selection reduce postnatal discrimination? *Population and Development Review* 22(1): 111–125.
- Goodkind, D. 2011. Child underreporting, fertility, and sex ratio imbalance in China, *Demography* 48(1): 291–316.
- Goodkind, D. 2015. The claim that China's fertility restrictions contributed to the use of prenatal sex selection: a sceptical reappraisal, *Population Studies* 69(3): 263–279.
- Guilmoto, C. Z. 2009. The sex ratio transition in Asia, *Population and Development Review* 35(3): 519–549.
- Guilmoto, C. Z. 2015. The masculinization of births: overview and current knowledge, *Population* 70(2): 201–264.
- Hessini, L. 2007. Abortion and Islam: policies and practice in the Middle East and North Africa, *Reproductive Health Matters* 15(29): 75–84.
- Hill, K. and D. M. Upchurch. 1995. Gender differences in child health: evidence from the demographic and health surveys, *Population and Development Review* 21(1): 127–151.
- Hill, K., D. You, M. Inoue, and M. Oestergaard. 2012. Technical advisory group of United Nations inter-agency group for child mortality estimation. child mortality estimation: accelerated progress in reducing global child mortality, 1990–2010, *PLoS Medicine* 9(8): e1001303.
- Hu, L. and A. Schlosser. 2015. Prenatal sex selection and girls' well-being: evidence from India, *The Economic Journal* 125(587): 1227–1261.
- Jain, T. 2014. Where there is a will: fertility behavior and sex bias in large families, *Journal of Human Resources* 49(2): 393–423.
- Jayachandran, S. and I. Kuziemko. 2011. Why do mothers breastfeed girls less than boys? Evidence and implications for child health in India, *The Quarterly Journal of Economics* 126(3): 1485–1538.
- Jha, P., M. A. Kesler, R. Kumar, F. Ram, U. Ram, L. Aleksandrowicz, D. G. Bassani, S. Chandra, and J. K. Banthia. 2011. Trends in selective abortions of girls in India: analysis of nationally representative birth histories from 1990 to 2005 and census data from 1991 to 2011, *The Lancet* 377(9781): 1921–1928.
- Kabeer, N., L. Huq, and S. Mahmud. 2014. Diverging stories of 'missing women' in South Asia: is son preference weakening in Bangladesh? *Feminist Economics* 20 (4): 138–163.
- Kashyap, R. and F. Villavicencio. 2016. The dynamics of son preference, technology diffusion, and fertility decline underlying distorted sex ratios at birth: a simulation approach, *Demography* 53(5): 1261–1281.
- Kashyap, R. and F. Villavicencio. 2017. An agent-based model of sex ratio at birth distortions, in A. Grow and J. Van Bavel (eds), *Agent-Based Modelling in Population Studies*. Cham: Springer, pp. 343–367.
- Klasen, S. and C. Wink. 2003. 'Missing women': revisiting the debate, *Feminist Economics* 9(2–3): 263–299.
- Li, S., C. Zhu, and M. W. Feldman. 2004. Gender differences in child survival in contemporary rural China: a county study, *Journal of Biosocial Science* 36(01): 83–109.
- Lin, M.-J., J.-T. Liu, and N. Qian. 2014. More missing women, fewer dying girls: the impact of sex-selective abortion on sex at birth and relative female mortality in Taiwan, *Journal of the European Economic Association* 12(4): 899–926.
- Merli, M. G. and A. E. Raftery. 2000. Are births underreported in rural China? Manipulation of statistical records in response to China's population policies, *Demography* 37(1): 109–126.
- Michael, M., L. King, L. Guo, M. McKee, E. Richardson, and D. Stuckler. 2013. The mystery of missing female children in the Caucasus: an analysis of sex ratios by birth order, *International Perspectives on Sexual and Reproductive Health* 39(02): 097–102.



- Miller B. D. 1987. Female infanticide and child neglect in rural North India, in N. Scheper-Hughes (ed), *Child Survival. Culture, Illness and Healing*, vol. 11. Dordrecht: Springer, pp. 95–112.
- Monden, C. W. and J. Smits. 2013. Maternal education is associated with reduced female disadvantages in under-five mortality in sub-Saharan Africa and southern Asia, *International Journal of Epidemiology* 42(1): 211–218.
- Muhuri, P. K. and S. H. Preston. 1991. Effects of family composition on mortality differentials by sex among children in Matlab, Bangladesh, *Population and Development Review* 17(3): 415–434.
- Pande, R. P. 2003. Selective gender differences in childhood nutrition and immunization in rural India: the role of siblings, *Demography* 40(3): 395–418.
- Preston, S., P. Heuveline, and M. Guillot. 2000. *Demography: Measuring and Modeling Population Processes*. Oxford: Blackwell.
- Rosenblum, D. 2013. The effect of fertility decisions on excess female mortality in India, *Journal of Population Economics* 26(1): 147–180.
- Sawyer, C. C. 2012. Child mortality estimation: estimating sex differences in childhood mortality since the 1970s, *PLoS Medicine* 9(8): e1001287.
- Sen, A. 1990. More than 100 million women are missing, *The New York Review of Books*.
- UNFPA. 2012. *Sex Imbalances at Birth in Albania*. Tirane: UNFPA. Available: [http://www.unfpa.org/sites/default/files/resource-pdf/UNFPA\\_report\\_Albania2012.pdf](http://www.unfpa.org/sites/default/files/resource-pdf/UNFPA_report_Albania2012.pdf)
- United Nations. 2002. *Measuring International Migration: Many Questions, Few Answers*. Technical report, United Nations, New York: Population Division. Department of Economic and Social Affairs.
- United Nations. 2015a. *World Population Prospects: The 2015 Revision*. New York: United Nations, Department of Economic and Social Affairs, Population Division. DVD Edition.
- United Nations. 2015b. *World Population Prospects: The 2015 Revision, Methodology of the United Nations Population Estimates and Projections* (Working Paper No. ESA/P/WP.242. ed.). Department of Economic and Social Affairs, Population Division.

## Appendix: Data quality

The set-up presented in this study examines the fertility and mortality changes underpinning changes in CSRs. The set-up does not account for sex differentials in migration dynamics. This assumes that sex differentials in migration at childhood ages are not a significant factor in determining the dynamics of CSRs, which is an assumption also made in previous research (Bongaarts and Guilmoto 2015). Although migration dynamics can be included in equation (2), data on international migration are not as widely available nor as easily harmonized as mortality and fertility data (United Nations 2002).

A number of limitations related to data quality pertaining to the UN WPP estimates should be noted. Like other work using UN data (Bongaarts and Guilmoto 2015), this study does not make any corrections to the data to account for sources of bias such as underenumeration of females for correcting sex ratios at birth or sex-specific mortality measures. Each new edition of the UN WPP estimates is revised to account for newly available data sources (United Nations 2015b). SRB time series have often been revised accordingly across different editions to account for factors such as underenumeration (Attané and Guilmoto 2007). For a number of African countries for which data sources such as censuses or death registration systems are very limited, life table estimates rely heavily on model life tables (United Nations 2015b). The estimates of excess female mortality, such as those reported in the supplementary material (Tables A1 and A2) may be an artefact of these models as a result. Data sources used to generate UN estimates vary by country and range from vital registration, such as those in high-income countries, to census or birth history data from sources such as the Demographic and Health Surveys or Multiple Indicator Cluster Surveys. The quality of the estimates may consequently vary considerably across countries depending on sources used.