Does Prenatal Sex Selection Substitute Postnatal Bias in Mortality? Decomposing the Fertility and Mortality Components of Changes in Child Sex Ratios

Ridhi Kashyap

University of Oxford &
Max Planck Institute for Demographic Research

Abstract

Is postnatal excess mortality for girls a necessary precursor to prenatal sex selection? Has the rise and spread of prenatal sex selection substituted postnatal bias in mortality against girls? This paper attempts to answer these questions by analysing the dynamics of child sex ratios between 1980 and 2015 using United Nations country-level lifetable data in a comparative perspective. The analysis proceeds in two steps: 1) I develop and apply a lifetable decomposition approach to distinguish between a 'fertility' component attributable to prenatal sex selection and 'mortality' components attributable to sex-differentials in postnatal survival to assess where the two components overlap and where they have substituted one another as child sex ratios have changed. 2) I assess to what extent changes in each component are anomalous. To assess to what extent sex differentials in survivorship indicate excess female infant and child mortality, I compare female mortality estimates to expected female mortality estimates at a given level of male mortality generated using a segmented regression approach. The analysis indicates that in several countries, such as Vietnam, Georgia and Armenia, prenatal sex selection emerged without significant traces of excess female infant or child mortality. Conversely, postnatal excess mortality for girls was evident in a number of Middle Eastern (Iran, Egypt) and sub-Saharan African (Nigeria, Niger, Malawi) contexts without clear evidence for prenatal sex selection. Substitution was evident in South Korea and Nepal where the onset of prenatal sex selection saw a corresponding disappearance (South Korea) or reduction (Nepal) in excess female mortality levels. Most notably, China and India, did not show clear evidence of substitution between prenatal and postnatal sex bias.

1. Introduction

An extensive literature has documented the rise and spread of prenatal sex selection, as indicated by sex ratio at birth (SRB) distortions, across Asia, the Caucasus and parts of the Balkans (Guilmoto 2015). Global, comparative studies on sex differentials in infant and child mortality point to regions in the world, most prominently in South Asia, the Middle East and parts of Africa, where excess female infant and child mortality remain prevalent (Alkema et al. 2014; Sawyer 2012). Is postnatal excess mortality for girls a necessary precursor to prenatal sex selection? Has the rise and spread of prenatal sex selection substituted postnatal bias in mortality against girls where excess female mortality has been prevalent?

This paper examines these questions by developing and applying lifetable decomposition methods to United Nations World Population Prospects (2015) data to assess changes in child sex ratios across countries since the 1980s. In contrast to recent, comprehensive global analysis of stocks of 'missing women' across all ages by Bongaarts and Guilmoto (2015), this analysis focuses on country-level changes across consecutive decades at childhood ages – the age groups where most 'missing women' tend to be concentrated – to examine the fertility and mortality dynamics that underpin child sex ratios in different national contexts. Moreover, the paper contributes a new straightforward methodological approach to analysing sex ratio dynamics using widely available lifetable data that overcome limitations of existing approaches.

From a methodological standpoint, by focusing on childhood ages of 5 – 9 years within a lifetable perspective, the sex-differentials in the likelihood of being born and dying can be disentangled when looking at the age and sex composition of survivors. I decompose changes in child sex ratios into two components: a 'fertility' component, attributable to prenatal sex selection and a 'mortality' component attributable to changes in sex-differential survivorship over time. I then assess to what extent the changes in each component are anomalous and deviate from expected patterns of demographic change to quantify the missing female births and excess female deaths that underpinned the child sex ratio change. An analysis of the two components across consecutive decades from 1980-1985 to 2010-2015 highlights four sets of countries: 1) where prenatal sex bias has substituted postnatal excess mortality (e.g South Korea, Nepal); 2) where prenatal sex bias continues to overlap with postnatal excess mortality (e.g China and India); 3) where prenatal sex bias emerged without significant evidence for postnatal excess mortality (e.g Vietnam, Armenia and Georgia); 4) where postnatal excess mortality has existed or currently exists without strong evidence for prenatal sex selection (e.g Iran, Egypt, Nigeria and Malawi). The paper seeks to use this systematic analysis of changes in prenatal and postnatal manifestations of sex bias in a comparative perspective to contribute to a growing literature, as exemplified by Bongaarts (2013) and Guilmoto (2010), that develops a theoretical understanding of the dynamics of demographic manifestations of sex bias at different stages of the fertility transition.

2. Data and Methodology

I. Decomposing Child Sex Ratio Changes

I calculate child sex ratios using the United Nations World Population Prospects database that provides period lifetables for 196 countries in the world for five-year periods (e.g 1980-1985, 1990-1995, etc.) for 1980-1985, 1990-1995, 2000-2005 and 2010-2015. I then assess changes in the child sex ratios across consecutive decades, that is, child sex ratio changes from 1980-85 to 1990-95, 1990-95 to 2000-05, 2000-05 to 2010-15.

In a stationary population, the sex ratio of 5-9 year olds at time *t, t+5* is the population of males aged 5-9 divided by females of the same age group*:* $P_{5-9}^{m,t,t+5}\ /P_{5-9}^{f,t,t+5}$.[1] This can be expressed as:

$$SR_{5-9}^{t,t+5}\,\frac{P_{5-9}^{m,t,t+5}}{P_{5-9}^{f,t,t+5}}=\frac{B_{t,t-5}^{m}}{B_{t,t-5}^{f}}\,\frac{\frac{l_{5,t,t+5}^{m}}{l_{0,t,t+5}^{m}}}{\frac{l_{5,t,t+5}^{f}}{l_{0,t,t+5}^{f}}}\,\frac{\frac{{}_5L_{5,t,t+5}^{m}}{l_{5,t,t+5}^{m}}}{\frac{{}_5L_{5,t}^{f}}{l_{5,t,t+5}^{f}}}$$

As $l_{0,t,t+5}^{fm}=l_{0,t,t+5}^{f}$ in a lifetable, the sex ratio can be simplified to:

[1] The United Nations lifetable data are available for five-year periods. The notation for the lifetable sex ratios is adapted to reflect this.

$$SR_{5-9}^{t,t+5} = \frac{P_{5-9}^{m,t,t+5}}{P_{5-9}^{f,t,t+5}} = SRB_{t,t-5}\frac{{}_5L_{5,t,t+5}^{m}}{{}_5L_{5,t,t+5}^{f}}$$

The ratio of change in the child sex ratio $SR_{5-9}^{t,t+5}$ between two periods t_1 and t_2 can be written as:

$$SR_{5-9}^{t_1\to t_2} = \frac{SR_{5-9}^{t_2,t_2+5}}{SR_{5-9}^{t_1,t_1+5}} = \frac{SRB_{t_2,t_2-5}\frac{{}_5L_{5,t_2,t_2+5}^{m}}{{}_5L_{5,t_2,t_2+5}^{f}}}{SRB_{t_1,t_1-5}\frac{{}_5L_{5,t_1,t_1+5}^{m}}{{}_5L_{5,t_1,t_1+5}^{f}}}$$

The ratio of change in child sex ratios SR_{5-9}^{t} between two periods t_1 and t_2 is the product of a change in the 'fertility' component $\frac{SRB_{t_2,t_2-5}}{SRB_{t_1,t_1-5}}$ that captures the ratio of the changes in the sex ratio at birth across the two periods, and a 'mortality' component, $\frac{\frac{{}_5L_{5,\,t_2,t_2+5}^{m}}{{}_5L_{5,\,t_2,t_2+5}^{f}}}{\frac{{}_5L_{5,\,t_1,t_1+5}^{m}}{{}_5L_{5,\,t_1,t_1+5}^{f}}}$ that captures the effects of differential survivorship by sex over the period for the stationary population.

II. Assessing anomalous change

Once changes in child sex ratios and their relative components are calculated, I analyse whether the changes observed in the fertility or mortality components are suggestive of sex bias and quantify missing female births and excess female deaths that underlie the distorted ratios. For sex ratio at birth deviations a number of extensive country-level studies highlight anomalous deviations in sex ratios at birth that point to the use of prenatal sex selection. To estimate missing female births resulting from prenatal sex selection I compare female births estimates for the period with female births that would have resulted holding the SRB at the country's 1970 levels before ultrasound technology became widely available.

a) Prenatal: Missing Births

Disentangling anomalous changes in patterns of survivorship by sex as distinct from patterns expected as a part of the mortality transition is trickier. For changes in the mortality component, the question of quantifying 'excess' female mortality – that is at best suggestive of sex bias – requires a counterfactual, or a model-generated estimate of what mortality would have been in the absence of sex bias. Previous attempts have relied on using data from historical Europe when using a standard (e.g Hill and Upchurch 1999), although recent studies of sex ratios of mortality challenge the appropriateness of using this standard given the vastly different environmental and cause of death environment observed in the contemporary developing world (Alkema et al. 2014).

b) Postnatal: excess female child mortality

In order to identify countries where the mortality component is suggestive of excess female mortality I use a model to predict what female infant, child (1-4, 5-9 years) mortality levels would be given the male infant and child mortality levels in that country in a particular period. The estimates of expected female infant and child mortality are generated using all country-year combinations for the infant mortality rate and separately for the child mortality rate from the UN WPP dataset. A segmented regression is applied with the female infant mortality rate as the outcome variable, and the male infant mortality rate as the predictor (Muggeo 2003). A separate regression is applied with the female child mortality rate as the outcome and male child mortality rate as the predictor. Models are estimated separately for childhood mortality for both 1-4 and 5-9 year olds. As the literature reports that sex ratios of infant and child mortality vary at different levels of mortality (Alkema 2014; Sawyer 2012), the segmented regression approach that allows the slope (sex ratio of mortality) to vary at different levels of mortality by finding the most appropriate cut-points when the relationship between male and female mortality levels change. These predicted mortality levels when multiplied by cohort sizes are then used to generate estimates of predicted deaths, which when are compared with actual deaths from mortality rate estimated in the UN data, can be used to generate estimates of both absolute excess mortality (absolute number of excess female deaths) and relative (observed deaths/predicted deaths) excess mortality.

Figure 1 shows the estimated levels of female infant mortality at given levels of male infant mortality, and Figure 2 shows the same for child (1-4 years) mortality levels. The figures highlight several countries where excess female mortality at infant and child ages was observed in 1980 and 1990. In Figure 1, the country point for South Korea exemplifies a context where excess infant mortality was observed for girls in 1980, which largely disappeared by 1990, as the country point moves from above the line to being on the line. India, on the other hand, exemplifies a country that remains above the line of expected levels of female mortality at both infant and child ages, even as mortality levels fall.

3. Preliminary Results

I. Changes in Child Sex Ratios

The vast majority of countries (135) saw little or no change (< 0.5%) in their child sex ratios over the period between 1980-1985 to 2010-2015. As Figure 3 highlights, a number of countries had outlying trajectories where child sex ratios saw significant rises in masculinity.

a) 1980-1990

Across consecutive decades (1980-85 to 1990-95, 1990-95 to 2000-05 and 2000-05 to 2010-15), changes in the fertility component (sex ratios at birth) outweighed changes in the mortality component in their contribution to changes in child sex ratios. In the period between 1980 and 1990, the most significant changes were observed in South Korea and China that both saw a rapid masculinization of their child sex ratios, which were largely attributable to the fertility component. Figure 4 highlights these changes. In South Korea the child sex ratio became about 7% more masculine between 1980 and 1990, a change that was predominantly due to the rise in the fertility component and small countervailing changes in the mortality component that feminized the ratio. In both China and South Korea, the change in the mortality component was quite small (less than 0.05%).

a) 1990-2000

China, India, Nepal, Vietnam, Azerbaijan, Armenia, Georgia and Kyrgyzstan all witnessed a rise in their child sex ratios in the 1990s, which were largely attributable to distortions in their sex ratios at birth (Figure 5). The mortality components appeared to add to, rather than substitute, these changes in the fertility component of the child sex ratios in a number of countries: China, Kyrgyzstan, Vietnam, Armenia, Azerbaijan, and Georgia. The blue bars in Figure 5 are in the positive direction indicating that mortality change contributed to increasing masculinity of these countries' child sex ratios, adding to the masculinity attributable to changes in the fertility component.

a) 2000-2010

Child sex ratios in India, Nepal, Georgia and Armenia levelled off in the mid-2000s, while China, Vietnam and Azerbaijan continued to witness rising masculinity of their child sex ratios (Figure 6). The levelling off in India was due to the offsetting influence of the mortality and fertility components, and similarly in Azerbaijan where the mortality component offset the masculinity of the fertility component.

4. Anomalous Levels in Child Sex Ratios

Are the changes in the fertility and mortality component anomalous, or in line with what would be expected given previous SRB levels in the country in the 1970s and the changes in total mortality levels across the decade? I quantify absolute and relative levels of missing female births and excess female deaths to assess the extent to which levels are indicative of sex bias. I jointly use the *change* in *relative* excess mortality (estimated female deaths / expected female deaths) and *change* in *absolute* female deaths, as well as similar measures of change in *relative* missing female births (estimated female births / expected female births) and *absolute* missing female births across decades to identify countries as belonging to four groups: 1) where prenatal sex selection emerged without significant evidence for excess female mortality; 2) where postnatal excess female mortality prevails without significant evidence for prenatal sex selection; 3) where prenatal sex selection has come to substitute postnatal bias in excess mortality; 4) where prenatal sex selection has added to postnatal sex bias in mortality.

I. Group 1: Prenatal, limited Postnatal

Although when examining changes in child sex ratios, Armenia, Georgia, Cambodia and Vietnam showed improvements in male survivorship (a positive mortality component) that contributed to the rising masculinity of their child sex ratios, these mortality improvements were not suggestive of excess female mortality. They were in line with the expected improvements in male mortality given changes in mortality levels over the period – or in fact suggestive of slight excess male mortality (e.g Vietnam and Cambodia). Table 1 highlights trends in the child sex ratios, the absolute and relative levels of missing female births and excess female deaths underlying changes in child sex ratios across 1980-85 to 2010-15 in these countries.

II. Group 2: Postnatal, limited Prenatal

Even as overall levels of mortality declined between 1980 and 2010, excess mortality measured in relative terms (estimated female deaths / expected female deaths) remained in middle eastern contexts of Iran and Egypt, as well as sub-Saharan contexts of Nigeria, Niger and Malawi. These are documented in Table 2. Iran and Egypt saw reductions in the levels of excess female infant and child mortality, as shown in Table 2 where their deviations from predicted mortality levels for both infant and child mortality levels narrowed between 2000 and 2010.

III. Group 3: Substitution

In South Korea, Nepal, Azerbaijan and Pakistan, a rise in prenatal sex selection as evidenced by both increases in absolute and relative number of male births between 1980 and 2010 was accompanied by a reduction in absolute, and more crucially, relative levels of excess female mortality (Table 3).

IV. Group 4: Addition

In China and India most notably, prenatal sex selection emerged even as postnatal excess mortality remained, or in the case of China appears to have intensified. In India, changes between 2000-05 and 2010-15 suggest a slight reduction in excess female mortality even though levels remain high, whereas relative excess mortality across 2000 and 2010 increased for China.

References

Alkema, Leontine, et al. "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 (2014): e521-e530.

Bongaarts, John. "The implementation of preferences for male offspring." *Population and Development Review* 39.2 (2013): 185-208.

Bongaarts, John, and Christophe Z. Guilmoto. "How many more missing women? Excess female mortality and prenatal sex selection, 1970–2050." *Population and Development Review* 41.2 (2015): 241-269.

Guilmoto, Christophe Z. "The sex ratio transition in Asia." *Population and Development Review* 35.3 (2009): 519-549.

Guilmoto, Christophe Z., and James Tovey. "The Masculinization of Births: Overview and Current Knowledge." *Population, English edition* 70.2 (2015): 185-242.

Hill, Kenneth, and Dawn M. Upchurch. "Gender differences in child health: evidence from the demographic and health surveys." *Population and Development Review* (1995): 127-151.

Muggeo, Vito MR. "Estimating regression models with unknown break-points." *Statistics in medicine* 22.19 (2003): 3055-3071.

Sawyer, Cheryl Chriss. "Child mortality estimation: estimating sex differences in childhood mortality since the 1970s." (2012): e1001287.

Figures

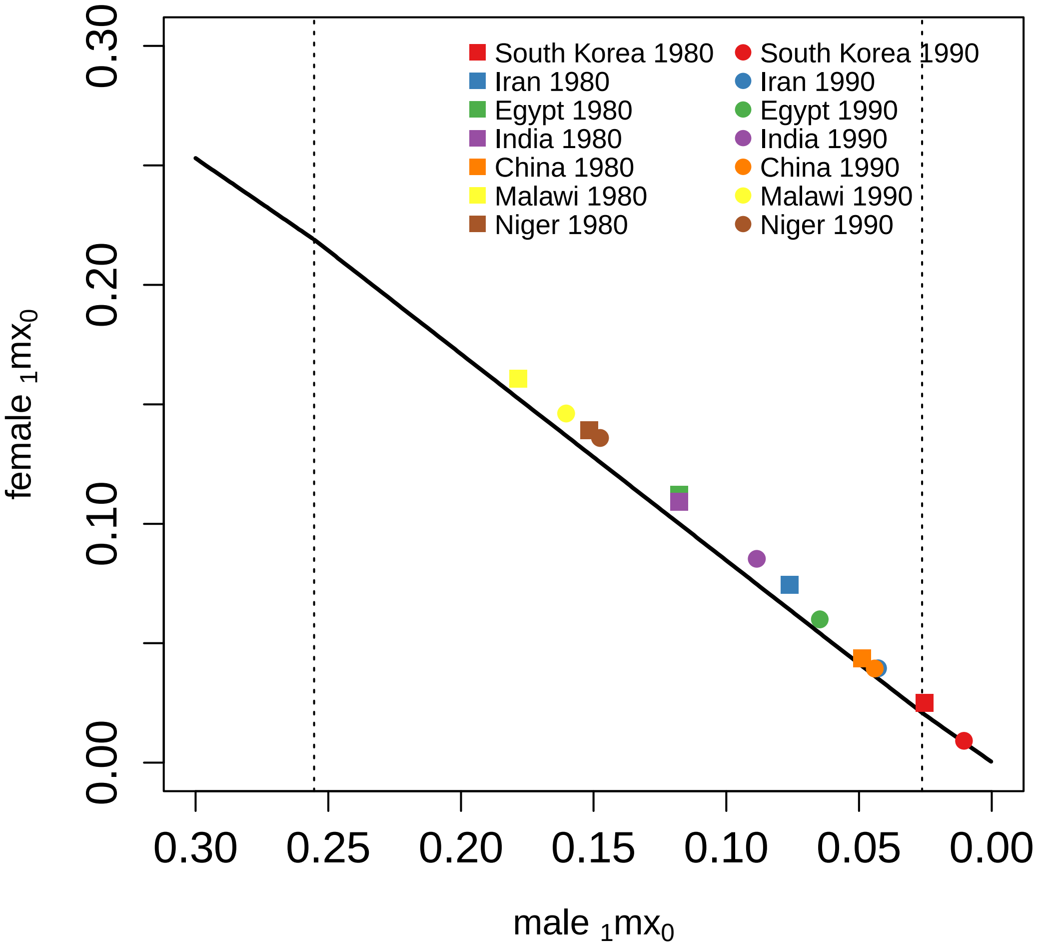

Figure 1: Relation between male and female infant mortality rates in 1980 and 1990. Black line refers to model-generated estimates of expected female infant mortality at a given level of male infant mortality and points refer to country estimates.

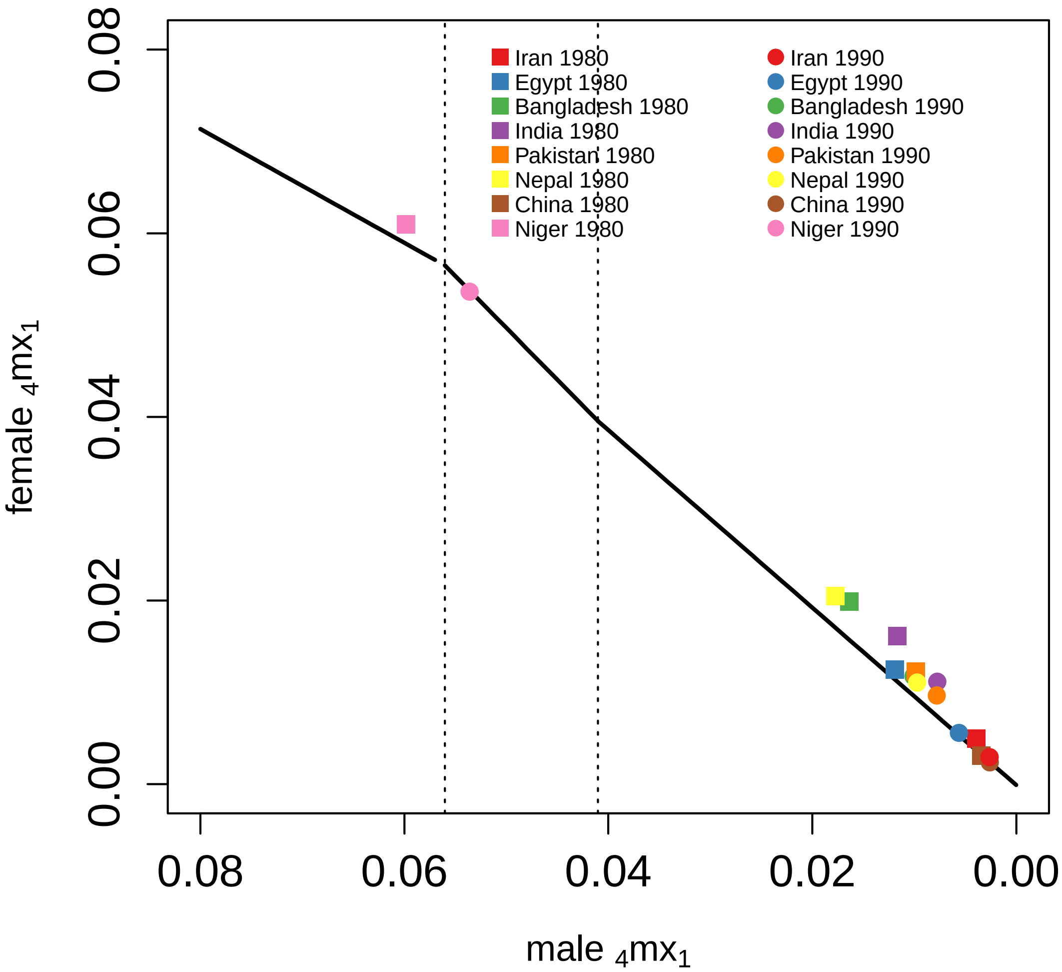

Figure 2: Relation between male and female child mortality rates in 1980 and 1990. Black line refers to model-generated estimates of expected female infant mortality at a given level of male infant mortality and points refer to country estimates.

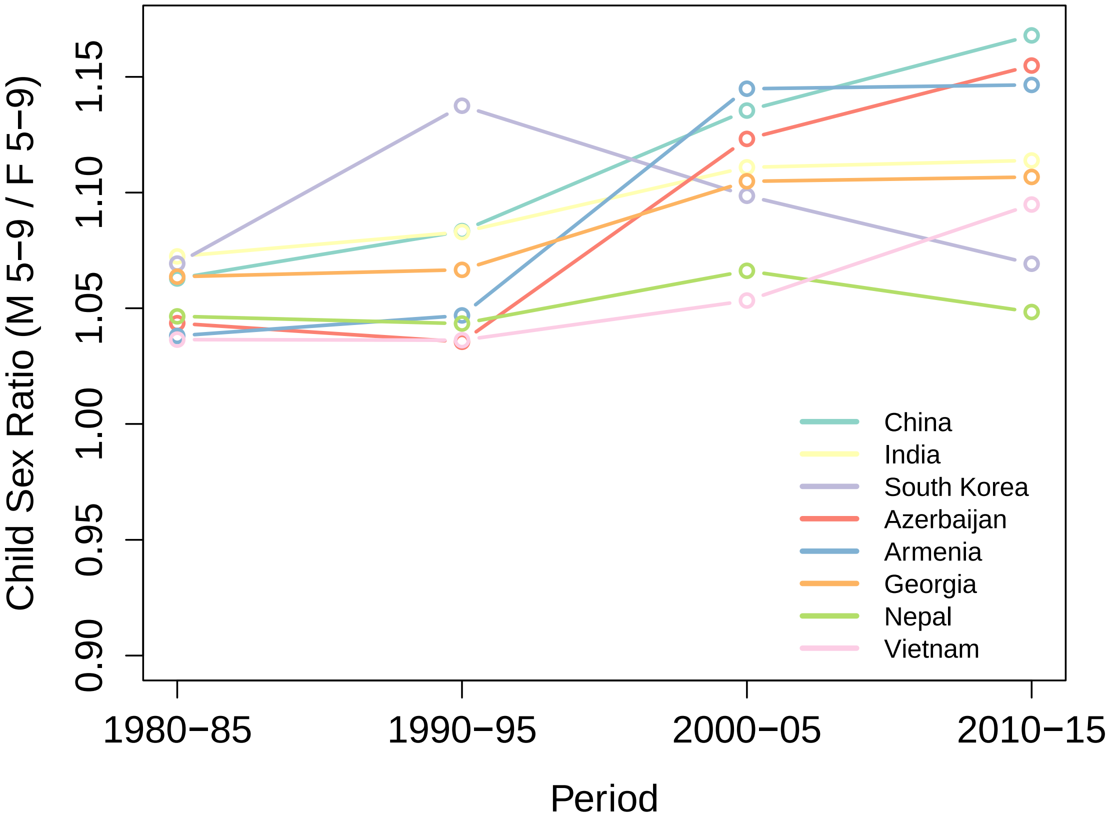

Figure 1: Child Sex Ratios, 1980-85 to 2010-15, with countries witnessing significant increases in child sex ratios

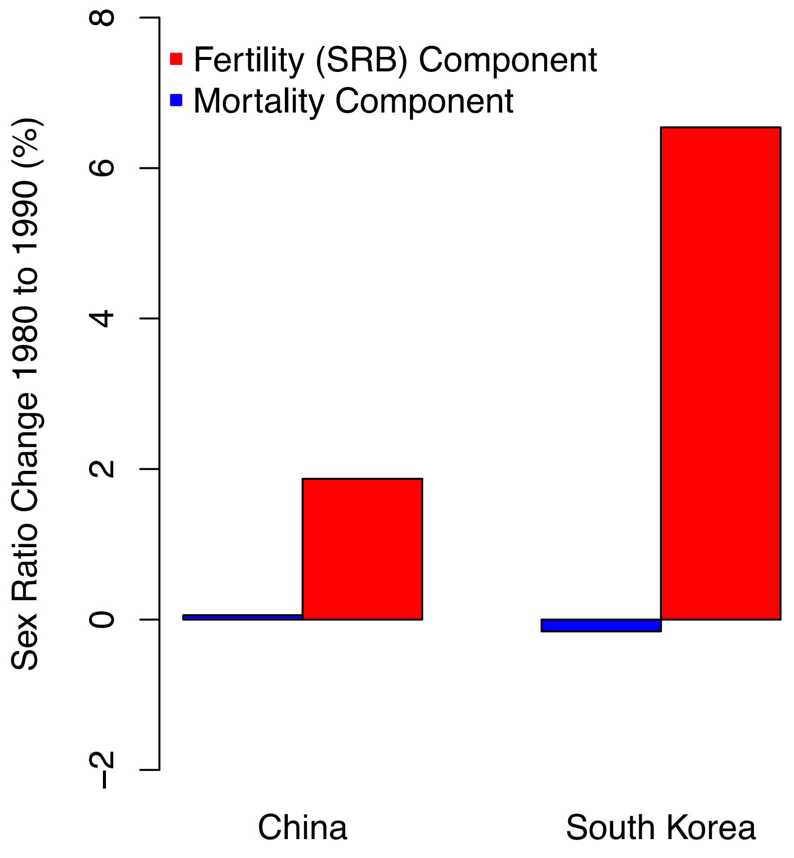

Figure 2 Countries experiencing a significant change in child sex ratios between 1980 and 1990, and the components of the change.

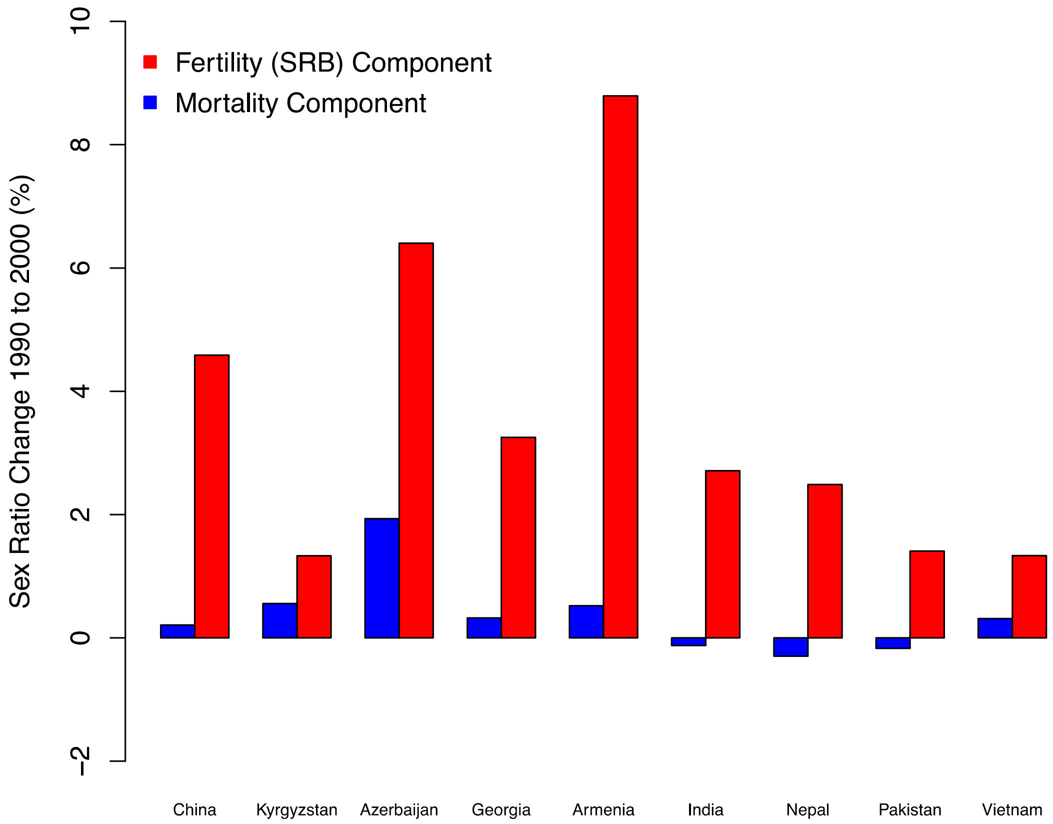

Figure 3: Countries experiencing a significant change in child sex ratios between 1990 and 2000, and the components of the change.

Country	Measure	1980-1985	1990-1995	2000-2005	2010-2015

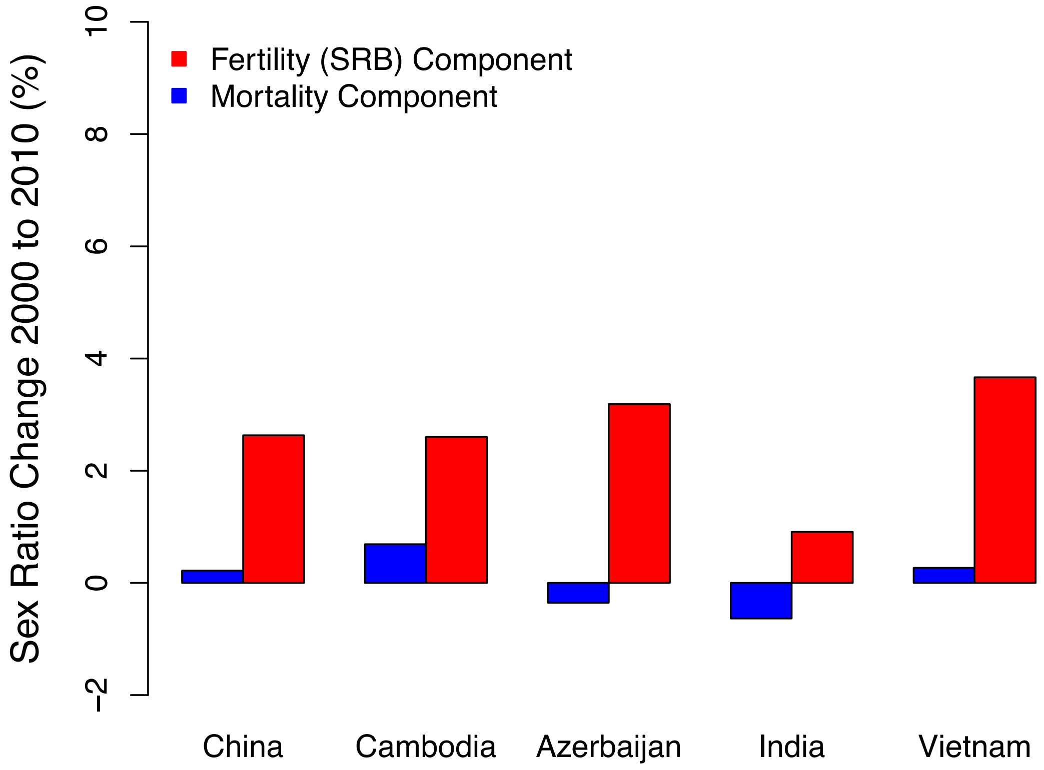

Figure 4 Countries experiencing a significant change in child sex ratios between 2000 and 2010, and the components of the change.

Country	Measure	1980-1985	1990-1995	2000-2005	2010-2015
Vietnam	Child Sex Ratio	1.036	1.053	1.053	1.095
	Missing female births	0	0	24802	91773
	Estimated / Expected female births	1	1	0.993	0.974
	Excess female deaths	-19473	-25240	-12520	-7971
	Estimated / Expected female deaths	0.929	0.893	0.898	0.909
Cambodia	Child Sex Ratio	1.006	1.014	1.019	1.053
	Missing female births	-348	-2795	-1693	9920
	Estimated / Expected female births	1	1.002	1.002	0.99
	Excess female deaths	-4490	-4007	-4223	-3650
	Estimated / Expected female deaths	0.972	0.969	0.949	0.904
Kyrgyzstan	Child Sex Ratio	1.034	1.035	1.055	1.054
	Missing female births	0	-809	1236	599
	Estimated / Expected female births	1	1.002	0.996	0.998
	Excess female deaths	-1145	-898	-187	-250
	Estimated / Expected female deaths	0.947	0.961	0.986	0.964
Armenia	Child Sex Ratio	1.038	1.047	1.145	1.146
	Missing female births	-387	95	4504	4525
	Estimated / Expected female births	1.002	0.99	0.956	0.956
	Excess female deaths	-439	-189	125	-9
	Estimated / Expected female deaths	0.95	0.981	1.046	0.994
Georgia	Child Sex Ratio	1.064	1.066	1.105	1.107
	Missing female births	0	0	2492	2352
	Estimated / Expected female births	1	1	0.983	0.984
	Excess female deaths	-448	80	194	110
	Estimated / Expected female deaths	0.958	1.008	1.045	1.051

Table 1: Levels of absolute and relative levels of missing female births and excess female deaths for group 1 countries showing evidence for prenatal sex selection without postnatal excess mortality for girls.

Country	Measure	1980-1985	1990-1995	2000-2005	2010-2015
Iran	Child Sex Ratio	1.053	1.048	1.037	1.048
	Missing female births	0	0	-15739	0
	Estimated / Expected female births	1	1	1.005	1
	Excess female deaths	61907	39450	13732	6199
	Estimated / Expected female deaths	1.201	1.174	1.154	1.125
Egypt	Child Sex Ratio	1.056	1.054	1.055	1.063
	Missing female births	0	0	0	13957
	Estimated / Expected female births	1	1	1	0.997
	Excess female deaths	52710	28597	11299	10890
	Estimated / Expected female deaths	1.098	1.08	1.077	1.1
Nigeria	Child Sex Ratio	1.038	1.038	1.046	1.053
	Missing female births	0	0	0	0
	Estimated / Expected female births	1	1	1	1
	Excess female deaths	37289	47997	119940	190700
	Estimated / Expected female deaths	1.021	1.022	1.052	1.094
Malawi	Child Sex Ratio	1.007	1.007	1.009	1.012
	Missing female births	0	0	0	0
	Estimated / Expected female births	1	1	1	1
	Excess female deaths	9286	10984	9502	6174
	Estimated / Expected female deaths	1.048	1.048	1.054	1.055
Niger	Child Sex Ratio	1.046	1.041	1.044	1.041
	Missing female births	0	0	0	0
	Estimated / Expected female births	1	1	1	1
	Excess female deaths	12157	9854	18562	11959
	Estimated / Expected female deaths	1.051	1.034	1.072	1.062

Table 2: Levels of absolute and relative levels of missing female births and excess female deaths for group 2 countries showing evidence for postnatal excess mortality for girls without prenatal sex selection.

Country	Measure	1980-1985	1990-1995	2000-2005	2010-2015
South Korea	Child Sex Ratio	1.069	1.137	1.099	1.069
	Missing female births	0	51088	21277	0
	Estimated / Expected female births	1	0.967	0.986	1
	Excess female deaths	12116	1126	855	475
	Estimated / Expected female deaths	1.192	1.057	1.089	1.122
Pakistan	Child Sex Ratio	1.059	1.059	1.073	1.078
	Missing female births	0	0	78161	119309
	Estimated / Expected female births	1	1	0.992	0.99
	Excess female deaths	104990	129332	99404	59121
	Estimated / Expected female deaths	1.095	1.102	1.091	1.081
Nepal	Child Sex Ratio	1.046	1.043	1.067	1.048
	Missing female births	0	0	23789	7092
	Estimated / Expected female births	1	1	0.987	0.996
	Excess female deaths	31265	24305	12657	4046
	Estimated / Expected female deaths	1.113	1.117	1.1	1.067
Azerbaijan	Child Sex Ratio	1.044	1.035	1.123	1.155
	Missing female births	0	0	11627	21656
	Estimated / Expected female births	1	1	0.968	0.952
	Excess female deaths	-814	-4702	1524	-539
	Estimated / Expected female deaths	0.981	0.9	1.077	0.972

Table 3: Levels of absolute and relative levels of missing female births and excess female deaths for group 3 countries showing substitution between prenatal sex selection and postnatal excess mortality for girls.

Country	Measure	1980-1985	1990-1995	2000-2005	2010-2015
China	Child Sex Ratio	1.062	1.083	1.135	1.168
	Missing female births	0	642757	1311192	1790222
	Estimated / Expected female births	1	0.99	0.967	0.954
	Excess female deaths	162292	182901	99404	59121
	Estimated / Expected female deaths	1.056	1.058	1.091	1.126
India	Child Sex Ratio	1.072	1.083	1.111	1.114
	Missing female births	0	319497	1253772	1536338
	Estimated / Expected female births	1	0.995	0.981	0.977
	Excess female deaths	1664534	1716743	1451176	857376
	Estimated / Expected female deaths	1.194	1.243	1.303	1.286

Table 4: Levels of absolute and relative levels of missing female births and excess female deaths for group 4 countries showing addition of prenatal sex selection to postnatal excess mortality for girls.