

Son Preference, Fertility Decline and the Future of the Sex Ratio at Birth

By

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Abstract

This paper analyses the effect of fertility decline on the sex ratio at birth in various regions of the world including the states and provinces of India and China. Two important findings emerge. First, we find that there is no monotonic relationship between sex ratio and fertility decline; rather there is a distinct zig-zag pattern, worsening of the sex ratio when odd (5, 3 and 1) levels of fertility are approached and improvement when the move is towards even (4 and 2) fertility levels. This augurs well for the future of this important gender bias variable – the model forecasts that India will have little sex preference at birth when it reaches the expected fertility level of 2 in 2016. The second major conclusion pertains to the estimate of the proportion of couples practicing sex-selection at birth (the missing girl at birth). This is most often no more than 2 percent of all births, a number considerably smaller than commonly assumed.

Key Words: Sex Ratio, Fertility, Child Mortality, Son Preference, Sex-Selection, Zig-zag, Missing Girls

Introduction

It is no exaggeration to state that one of the most pressing social issues facing the world, and especially the Asian developing world, is the pre-birth elimination of girl children. Son preference has been a persistent phenomenon in Asia for the last several hundred years, but until recently this did not involve sex selection at birth. Broadly, three methods have been tried in shaping the family¹ - two traditional and one modern. The first family shaping method involved an increase in the desired family size as family size expanded to accommodate the birth of a son or sons.

The second traditional method involved a higher than normal infant (less than one year of age) and child (less than 5 years of age) mortality of girls. The absolute mortality level improves with development; what is relevant here is the higher relative female to male mortality rates. It is a biological “fact” that young boys die at a faster rate than young girls. So when mortality for young children is higher for girls then it follows that human action in terms of non-benign intervention was involved. Thus, either through female infanticide or fatal neglect of young girls, the desired family size, and shape, was achieved by the “intervening” families. If there were more children than desired, or less sons than desired, elimination of some girls made possible the achievement of the desired family size. Many families employed conscious and unconscious strategies to achieve a desired balance between resources and dependents (See Das Gupta 1995, Kaur 2008)

The modern method of shaping the family is via the use of technology to determine the sex of the child before it is born. Sex selection at birth is technology’s answer to the shaping of the family - selective abortion of the girl child following a sex determination test. This has allowed families to keep the size small while achieving the desired composition. The technology for sex-selection (ultrasound and amniocentesis) became available in the early 1980s, and has been popularly practiced since then in several Asian countries.

Historical son-preference has continued unabated into the modern era. There are several factors that have influenced this practice of son-preference. Structure and culture favour sons - sons are needed for reproducing the lineage, for inheriting the family land, for providing old age support to parents and for ritual needs. In patrilineal-patrilocal societies sons continue to stay with parents while daughters move at marriage reducing their value to the parental family. The important question today is the future of the practice of son-preference. Increased education of women, their enhanced participation in the work force, changes in family structure and the development of the middle class are all factors expected to influence a *decline* in son-preference.

But there is an important counter force – possible intensification of son-preference² with the co-incident decline in fertility. A heuristic argument for this expectation is as follows. When the fertility level is above 4, then the probability of having at least 2 sons is close to unity (see Sheps1963 for detailed calculations for different levels of son preference and expected family size). If a family continues to desire at least 2 sons, then the sex ratio at birth (SRB)³, the subject and variable of concern, would increase (worsen) with the decline in fertility. This simultaneous achievement of low fertility and the desired number of sons was not possible before, but with sex-selection technology, is possible today. Thus, a common expectation is that with the decline in fertility, the sex ratio can be expected to worsen. i.e. at a macro level, there is a negative relationship between fertility and the sex ratio at birth.

In this paper⁴, we throw new light on the expected relationship between fertility decline and the sex ratio at birth (specifically in societies with demonstrated son preference). We find that the relationship is more complex than a simple intensification of sex bias against girls as fertility declines. We show that the effect on the sex ratio is a zigzag one with a *rise* when odd numbers of fertility are approached and a decline when *even* numbers of fertility are reached. One firm conclusion that follows from this zig-zag model is that one of the large sex-of-child offenders, India, is in a “sweet spot” of fertility decline (approach towards 2) and can look forward to an improvement in the sex ratio.

Another important finding is that the “amount” of sex selection required (the percentage of families that sex select) to skew the sex ratio at birth is much smaller than commonly believed. This estimation, when conducted, has been based on survey data pertaining to *desired* number of children and *desired* sex-ratio. The actual sex-ratio data yields the result that in the aggregate and in all countries except China, only a small proportion of the population needs to sex select in order for the sex ratio at birth to advance to abnormal levels. This finding has important implications for policy efforts aimed at redressing the sex ratio imbalance.

The plan of the paper is as follows. Section 2 describes the various sources of data used for sex ratio at birth, fertility and related variables and documentation of the constancy of the sex ratio. Section 3 reports on various demographic and sociological studies that have explored the relationship between son preference and fertility. Section 4 documents examples of the operation of the zig-zag model. Section 5 provides estimates of the zigzag model relating the level and change in fertility to the sex ratio at birth. Section 6 provides estimates of the proportion of population sex-selecting in different countries, and different years. Section 7 concludes. Appendix I provides details on the estimation of sex ratio at birth for countries where such data are not available, but data for male and female children ages 0-4 are available.

Section 2: Sex Ratio at Birth - Data and constancy

Data for the sex ratio at birth for different countries of the world are generally not available on a continuous time-series basis. Even for India, one of the two major son-preference and son-selection countries, time-series data on the sex ratio at birth are available only from 1984. Census data, ages 0-6 years are available but only on a decadal basis. In a major new data release, the UN provides data for each 5 year age group, males and females, from 0 to 4 till 80 plus. These data form a major component of our studies on the determinants and evolution of the sex ratio at birth, and the sex-ratio at different age levels. For countries and provinces for which data on the sex ratio at birth and fertility are not available, UN and World Bank sources are used. The sex ratio for children 0-4 years is linked to the sex ratio at birth via the male-female ratio of infant mortality rates and the male-female ratio of child mortality rates. Appendix I describes the procedure employed to derive the sex ratio at birth for all the countries in the world, and for all the years, 1950-2010.

Thus, data have been assembled on sex ratio at birth and fertility for India, Indian states, China, China provinces⁵, and several countries with a “suspect” sex ratio at birth at one time or another in the last thirty years. Data for India and Indian states data were obtained from the Sample Registration System of India (SRS). Indian Census child sex ratio (0-6 years) data were used to adjust the SRS sex ratio at birth for India and Indian states. For countries Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Georgia and Macedonia UN data on populations of various five year age groups by sex were used to derive estimates of the sex ratio at birth. Official data were used for China, Hong Kong, India, Korea, Singapore, Taiwan and Vietnam. World Bank, World Development Indicators, data were used for fertility.

The Constancy of the Sex Ratio at Birth

One of the most important stylized facts is the near constancy of the sex-ratio at birth – for a “social” variable, its near constancy across space and time is comparable to scientific constants like the acceleration of gravity. This unusual “factoid” is extensively documented by Brian –Jaisson (2007). The authors exhaustive review of historical studies documents that estimates of the sex ratio at birth have captivated some of the greatest statistical and mathematical minds over the last three hundred years. Whether it is Laplace, Poisson, Bernoulli, or Darwin or Gini– all have at one time or another engaged in documenting, and verifying, the stylized fact of the sex ratio at birth. What each study found, and re-established, was that the probability of a child being a boy was close to 51.3 percent – yes, more boys are born than girls. A male probability of birth of 51.3 percent translates into a sex ratio at birth of 105.3⁶. To date, only one factor causing a deviation from the 105.3 constant has been identified – blacks tend to have

approximately a 1 to 1.5 percent lower sex ratio at birth. This has been found to be true for the blacks in the United States, (see Chahnazarian(1990) as well as residents of sub-Saharan Africa 1950-2010 (see Bhalla et. al. 2013)).

There are several factors at play, and behind, estimates of the constancy of the sex ratio. There are countervailing pressures - better reporting of girl births lead to a decline in the SRB, while improvement in health (decline in the male disadvantage in the very early stages of life) would lead to an increase. It appears that the two pressures have roughly cancelled out, at least for the last sixty years, for the world population excluding India, China, and the countries of sub-Saharan Africa. (see Bhalla et. al. (2013)). Thus, a safe conclusion is that while some factors do seem to play a role, the natural sex ratio at birth can be assumed to be 105.3 for most of the world's population, and for all time-periods. This constancy allows the documentation of anomalies (e.g. sex-selection) with a very large degree of accuracy. And makes possible, and credible, estimates of missing women as pioneered by Nobel laureate Amartya Sen.

Section 3: Sex Ratio and Fertility – a Zig-zag relationship

While the sex ratio at birth has stayed constant in large parts of the world, this has manifestly not been the case among the countries of Asia, and in many regions of India and China. Not only has the SRB not stayed constant, it has actually increased in India and China, and increased from already high levels. In addition, several countries of Asia that had hitherto not experienced any problematic sex ratios at birth are now showing SRB's above 110. What happened?

Two factors are seen as crucial in explaining the rising trend: the advent of sex selection technology and the decline in average fertility rates. By the early 1980s, technology in the form of ultrasound machines and amniocentesis made possible early detection of the sex of the child and subsequent abortion of the girl child. For the first time in history, the sex ratio of births could be affected - and was affected in large parts of Asia. In addition, and near simultaneous for most parts of Asia, fertility transitions were underway. The two facts – fertility decline and increase in the sex ratio at birth – are strongly correlated. “In fact, fertility decline appears to heighten such selective discrimination”. (Das Gupta 1987, p. 78)

In an important paper, Das Gupta-Bhat (1997) concluded that there were two opposing effects associated with fertility decline. The first, and one observed primarily when sex-selection technology was unavailable, was the observation that in different son-preference regions of the world, it was higher order

births that suffered from excess female *mortality*. This birth “parity” effect, the authors argued, would diminish as fertility declined i.e. the child sex ratio would improve as post-birth higher mortality was reduced. The authors posited an additional opposing “intensification” effect – “when fertility declines, the total number of children couples desire falls more rapidly than the total number of desired sons”, (1997, p.307). Hence, a worsening sex ratio at birth would be observed with fertility decline.

Given the near constancy of the sex-ratio at birth, evaluation of fertility effects on the sex ratio at birth must be separated into two components – effects when no sex-selection technology was available (hereafter technology) and when it was, mostly post 1980. In the pre-technology world, an increase in the sex-ratio at birth was not possible, so son-preference was enforced via an increase in the sex ratio of infants and children (0 and 0-4 years). Nature favors the girl in these two mortalities – a girl mortality higher than boys was clear evidence of discriminating son-preference parents. In contrast in the technology world, the sex-ratio at birth can be affected at any birth parity. Mortality rates diminish considerably in importance as most of the “burden” of son-preference falls on the sex-ratio at birth. And it is the sex-ratio at birth that begins to look abnormal, while the sex ratio of children, and/or infants, begins to approach normality.

Das Gupta-Bhat postulate that the effect of fertility on the sex-ratio will be a function of the net resolution of the parity and intensification effects – the former diminishes sex bias, while the latter increases it. However, given the introduction of technology, the two effects are for different states of the world. The postulated parity effect would exist primarily in the non-technology world, and affect the sex ratio of infants and/or children; the intensification effect exists primarily in the technology world, and affects primarily the sex ratio at birth.

Most of the factors causing fertility decline are also factors which should *diminish* sex selection, and not increase it. Prominent among these determinants is the increased education and work participation of women, changes in family structure, nuclear residence, development of the middle class and middle class values⁷ e.g. a move towards equal inheritance for daughters and independent or state supported old age security for older couples. In the two states (before and after fertility decline) it is also possible that attitudes or structures would change, and the need for sons too would change. The same couple would then act differently when they decide to have only two kids, than when they were willing to continue having children until the birth of a boy.

The continued presence of son preference is the major factor causing a worsening in the sex ratio. However questions can be raised about the likelihood of a simple monotonic relationship between fertility decline and the sex ratio at birth. Goodkind (1995, p112) argues that with sex-selection technology, there

is a likelihood of a substitution of pre-natal discrimination for post-natal discrimination i.e. the sex ratio can improve (less post-natal discrimination) and can deteriorate (pre-natal discrimination). As Das Gupta-Bhat also admit, the net resolution of these two contrasting effects can only be observed empirically.

In addition to fertility *per se*, researchers have also speculated upon the nature of relationship between the *pace* of fertility decline and the SRB. The conclusion is also the same as with the level of fertility – the relationship is assumed to be monotonic and inverse – faster the decline in fertility, the greater the rise in the sex ratio. In her analysis of the sex ratio change in Singapore, Graham states: "The two main preconditions - rapid fertility decline and strong son preference - found to be the catalysts of female deficit in the populations of China and the Republic of Korea were also present in Singapore in the 1960s and 1970s" (2007, p.90).

We present estimates of a demographic model that incorporates levels of fertility, and fertility decline, and test for their effects on the sex-ratio at birth. The model explicitly tests for a zig-zag relationship between the SRB and fertility levels. That there might be such a non-linear relationship between the decline in fertility and the sex ratio at birth can be heuristically explained as follows. Assume a high fertility situation as prevailed in the middle of the last century in most Asian economies. Most families had at least two sons in family sizes that ranged upwards from four. With fertility decline, many social conditions began to change, including higher investments in fewer children.

As the demand for children fell, and average fertility levels dropped from above four to around three, there were segments of the population that still persisted in their desire for two sons. This tilted the sex ratio upwards as fertility levels approached the odd number of three. With a further decline in fertility towards the even number of two, the desire, among those with boy preference, was to reduce the demand to just one son. When this occurred, the sex ratio at birth began to improve, and did so in the presence of declining fertility.

While this shift in demand is a continuous process, *children come in integer units*. And it is precisely this attribute that changes the direction of the relationship between fertility and the sex ratio. The next reversal in the sex ratio (part of the zigzag model) is when fertility falls to around 1. Now the demand for some couples would remain at 1 son and at 1 child which yields a sex ratio of infinity! But the fraction of those demanding one child one son is likely to be small⁸, and so after a period of time, as fertility levels drop below one, the sex ratio at birth is likely to improve⁹. This description is for a process that is independent of the availability of sex-selection technology. What technology does is to fast-forward the eventuality.

Several countries have instituted bans against the use of technology for sex selection, and the sex ratio at birth has begun to improve. Whether this improvement is due to the effectiveness of the ban on sex-selection, or due to improvement in other determinants, is one of the questions we seek to answer in related papers.

The next section explores, econometrically, the zig-zag model of son-preference and fertility decline. But first, some examples which illustrate the manner in which the zig-zag relationship has operated in different countries, and time-periods.

Section 4: Operation of the Zig-zag model: Examples from history

There are several examples of a decline in fertility being associated with an improvement in the sex-ratio. Our model contends that such an improvement would be observed when the fertility level approaches even numbers of children. The rest of the time the hypothesized relationship – decline in fertility and increase in the sex ratio – is expected to hold.

Europe, 1890-2010: Perhaps the most convincing example of reduction in son-preference with a decline in fertility is provided by a region whose history is not commonly associated with son-preference - Europe. As discussed in the World Development Report (2012), in the late 19th century, Europe did practice son-preference by the traditional method - a child mortality rate significantly higher for girls:

“In the early 20th century, European countries faced the same patterns - no girls missing at birth but high excess mortality among girls in early childhood. Between 1900 and 1930, the excess mortality vanished in almost all of them” (Cutler and Miller 2005).

Then came the great fertility transition— between the period 1890 and 2012, fertility declined from over 4 to near 2 for most parts of Europe. Our zig-zag model suggests that this approach towards a fertility level of 2 should have been associated with an improvement in gender-balance. It was not technologically possible at that time to practice sex-selection at birth; therefore an improvement in the sex-ratio could only be reflected in a decline in relative female to male mortality rates. And this is exactly what one observes – the disappearance of higher mortality rate for girls when fertility levels near 2 and the appearance of a normal post birth 0-4 or 0-6 sex ratio.

India 1980-2010: Time pattern of the sex ratio at birth

India has consistently figured among the top 2 sex ratio offenders in the world. Sex ratio transgressions of India have been much noted, and rigorously established. Indeed, Sen’s seminal article (1992) was oriented towards the practices in India and China. Interestingly, the most prominent example of a zig-zag

fertility son-preference model *is* India. Figure 1 documents the actual sex ratio at birth¹⁰ and fertility levels for India (note that the horizontal axis has the fertility rate on a reverse scale). Sex selection technology was available in the mid 1980s and got banned from use in 1994, co-incident with the first peak in India's sex ratio. There seems to have been an effect of the law for three years. However, with further assumed implementation of the ban, the sex ratio at birth rose to its highest level ever, 110.9, in 2004 (The previous peak SRB level in 1994 was 108.2). It is also the case that at the local peak of SRB, the fertility rate was very close to 3 in 2004, exactly as predicted by the zig-zag model. After this record high, the sex ratio at birth began a steep decline, coincident with a steep decline in the fertility rate to 2.6 in 2010. Note also that the best and normal SRB is observed around a fertility level of 6, and that an improvement in the SRB is observed when the fertility level dips to the even number of 4.

The aggregate Indian experience is a near perfect fit for the zig-zag model relating the SRB to fertility levels. The important question remains: does the zig-zag model hold for different states of India, provinces of China and different countries of Asia and Eastern Europe where the problem of sex selection and an abnormal sex ratio has arisen over the last thirty odd years?

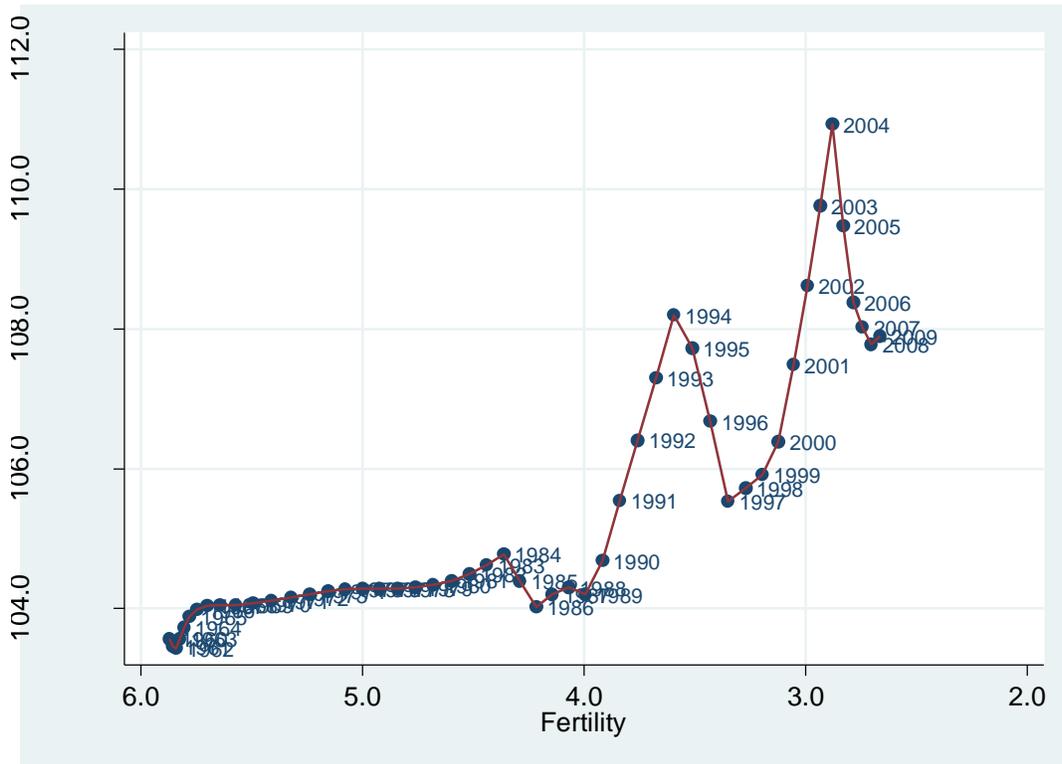
Korea: A surprise increase, and fall, in the sex-ratio

In a country where the sex ratio was never supposed to stray from normal, with fertility decline the sex ratio did go up. In 1980 Korea had a normal sex ratio level (105.3) and fertility was declining and reached a level of 2.8. Over the next decade, fertility declined to 1.6 and the sex ratio peaked at 116.5. During the same period, sex selection practice boomed in Korea. It is likely that the fertility level would not have collapsed at such a fast pace if technology were not available. Nevertheless, even in the presence of this technology, the sex ratio began to decline. Today the sex ratio at birth is near normal (106.7) and the fertility level has stabilized at around 1.2.

Vietnam: an addition to the son-preference club, 2005

In 2000, the SRB in Vietnam was a normal 104.8 against a fertility level of 2.0. Fertility had undergone a sustained decline since 1970s when the level was above 6. Somewhat inexplicably, the sex ratio started to increase post 2000 and reached 111.2 in 2010. The decline in fertility below 2 may have been partly responsible for the surprising increase in the sex ratio at birth i.e. with family size going down but remnants of son preference emerging and technology easily available for enforcement.

Fig 1: Zig-zag pattern of Sex Ratio at Birth and Fertility in India (1956- 2010)



The Caucasus countries of Armenia, Azerbaijan and Georgia

Not known for sex-selection, all the three economies have shown a dramatic increase in the sex ratio. In each of these economies, the sex ratio began to increase above 107 in the mid 1990s; in each of these three economies the fertility rate at the time of the increase was around 2, and declining; and in each of these three economies the sex ratio reached a maximum of around 118 between 2005 and 2010.

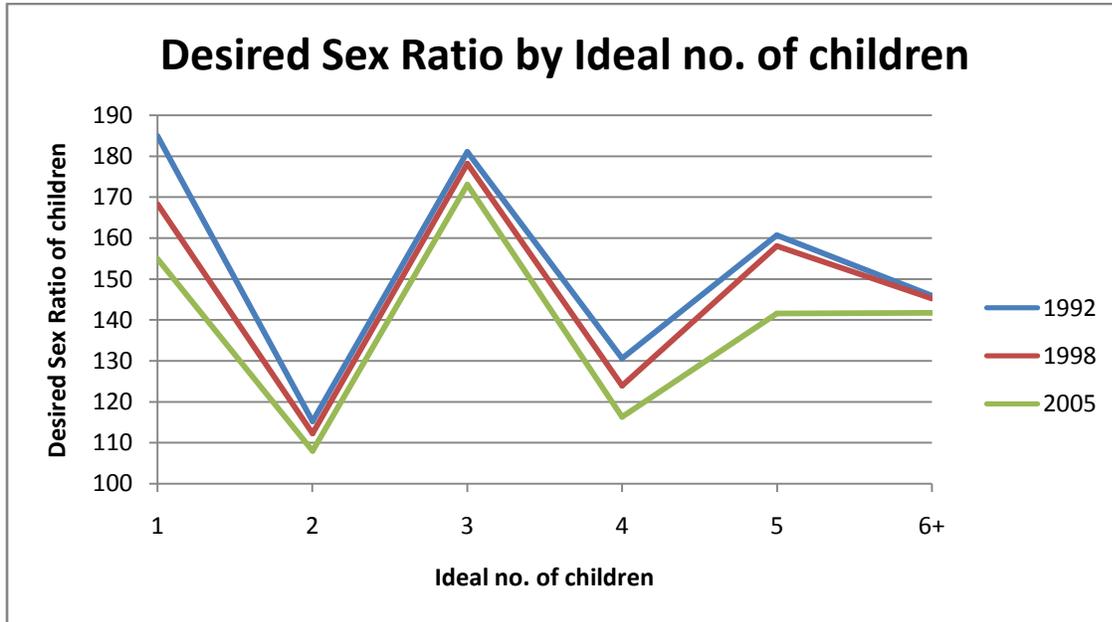
Heuristic support for zig-zag from data on desired fertility and desired sex-composition

The zig-zag model of fertility and sex-ratio has not been previously estimated. However, in a paper that has got less attention than it deserved, Bhat and Zavier (2003) examine theoretical or *desired* family sizes and relate them to the *desired* sex of children; and for this desired construct they observe a zig-zag relationship. They examine data from the National Fertility Health Survey for 1991/92 and 1998/99 and conclude that (i) “proportion of women who wanted more boys than girls was substantially higher among those who reported their ideal family size in odd numbers, and (ii) when the odd and even numbers are considered independently, there is a clear indication that the preference for sons falls with declines in the ideal family size”.(p.640)

Figure 2 plots the derived and theoretical sex ratios at birth from the three NFHS surveys, 1991/92, 1998/99 and 2004/5. Each of these surveys asked questions pertaining to desired fertility and the desired sex ratios at birth. From these data, the desired sex ratio can be derived for the desired family size (desired fertility). Three conclusions emerge. First, that a near identical zig-zag pattern is observed for all the three surveys. Second, that there is a systematic decline in the *desired* sex ratio at birth – from 144 in 1992/93 to 127 in 2004/5. Third, that for all the three years, the all India desired SRB is considerably above levels actually observed.

The few snapshots reported above suggest that it is likely that the relationship between the sex ratio at birth and fertility is not monotonic, and that the zig-zag relationship may hold across societies and time-periods. This hypothesis is put to a stricter test in the next section.

Figure 2: India: The Zig-Zag relationship between desired fertility and the desired sex ratio



Section 5: The Zig-Zag Fertility Sex-ratio Model – Estimates

The zig-zag model of fertility decline and the sex-ratio at birth is tested with respect to fertility level data for 16 states of India, 27 provinces of China and 16 countries where the sex ratio has worsened to levels well above the normal rate of around 105. Data on fertility and sex ratio (when available) span the sixty year period 1950 to 2010.

The model identifies, and estimates, separate effects for five different ranges of fertility decline. The movement from high fertility levels to 5, from 5 to 4, from 4 to 3, from 3 to 2 and from 2 to the lowest value observed in our sample, 0.8. For each range in fertility, annual averages are computed for each “locality” (state, province or country) for three variables: the sex ratio at birth (SRB), the fertility level (Fert), and the log percent change in the fertility level (yFert). The three variables are hypothesized to relate to each other as follows:

$$(1) \quad \text{SRB}_{it} = \alpha + \beta * \text{Fert}_{it} + \delta * \text{yFert}_{it} + \varepsilon_{it}$$

where i refers to the region and t refers to the time-period (year or period). Both the level and (log) change in fertility enter into the model. This is another way of incorporating lags into the determination of the sex ratio at birth¹¹.

According to a “traditional” expectation, the sign on the fertility coefficient, β , is expected to be negative i.e. as the fertility level reduces, the SRB will have a tendency to increase (the intensification effect). The coefficient of the speed of decline in fertility, δ , is also expected to be negative. A decline has a negative value and fertility declines are expected to increase the sex ratio.

According to the integer child formulation, fertility decline should have a negative impact in the approach towards 5, 3 and 1 and a positive impact in the approach towards 2 and 4. It is rare in deterministic models for coefficients to change sign, and to do so with statistical significance. When they do so, it is indicative of a robust theoretical model. Most of the observations in the post 1980 period and post the introduction of sex selection machinery involve fertility levels in the range 3 and below.

Tables 1 and 2 report the means associated with the different ranges of fertility decline and the regression coefficients for the zig-zag model. Striking confirmation is obtained for the theoretical model, with the coefficient on fertility changing signs, and retaining statistical significance, almost exactly as predicted.

Table 1 documents the means of the various variables as well as the percentage sex selecting at birth. The highest fraction of sex selection is the large 5.5 percent which is associated with the fertility range 2 and below. As shown later, this large sex-selection primarily occurs in the provinces of China, regions that were subjected to an “artificial” reduction in fertility due to the forcible introduction of the one-child policy.

The results below are reported for two groups – the approach towards even and odd numbers of fertility.

When fertility decline leads to a worsening of the sex ratio at birth

Fertility approaching odd levels of 5, 3 and 1

Fertility level: In these three instances, the results show that the sign of the fertility coefficient is as expected, negative, and significant at the 1 percent level in two instances (fertility towards 5 when outlier Bihar is excluded from the regression), and the move of fertility from 2 to 1. For fertility movements from 4 to 3, the coefficient is significantly negative at the 10 percent level.

Speed of fertility decline: The coefficient is not negative as presumed. It is ambiguous. In the intermediate stage of fertility decline (4 to 3) the coefficient is positive, at the 1 percent level, suggesting that as the decline in fertility took place, the sex ratio improved, *ceteris paribus*. (Recall that the pace of fertility change has a negative sign).

Haryana is the main reason why the negative fertility coefficient is significant at more than the 5 percent level (approach towards 4 and 3). Exclusion of Haryana makes the fertility coefficient significant at less than the 5 percent level for both these regressions. Also note the pattern fits the China regions before the advent of the one-child policy and other parts of the world equally well.

Fertility decline below 2 (approach towards 1 and below) is where most countries of the world can expect to be in the coming decade. The zig-zag theory suggests that the sex ratio at birth can increase with fertility approaching the odd number of 1, and below. However, at these levels of fertility, accompanying changes in female education and female work participation can neutralize the bias towards an increase in son preference. This neutralization is supported by the coefficient on fertility being not significant at all (t-statistic of -0.79). A second regression is reported for this range – the same sample but excluding two China provinces, Guizhou and Jiangxi. This increases the statistical significance of the fertility coefficient to -1.72, or significance at the 9 percent level.

Table 1: Means of country and region data used for regressions

Fertility Decline Range	Sex Ratio at Birth	Fertility	Log change in Fertility (%)	% sex selecting
Country Level Data				
2 to 1	117.5	1.7	-1.4	5.6
3 to 2	109.0	2.6	-2.5	2.0
4 to 3	106.4	3.5	-5.6	0.5
5 to 4	105.4	4.5	-4.9	-0.2
>5 to 5	105.5	5.7	-0.6	0.0
Total	108.5	3.5	-3.2	2.0
Indian States				
2 to 1	106.6	1.9	-1.8	0.6
3 to 2	108.4	2.5	-2.3	1.4
4 to 3	107.7	3.5	-2.6	1.1
5 to 4	106.9	4.4	-1.4	0.7
>5 to 5	104.6	5.2	-1.3	-0.4
Total	107.4	3.4	-2.1	1.0
Chinese States				
2 to 1	119.2	1.4	-3.0	6.2
3 to 2	111.3	2.5	-4.0	2.8
4 to 3	109.5	3.2	-2.1	1.9
5 to 4	104.7	4.3	-4.5	-0.3
Total	116.4	1.8	-3.2	5.0
All Observations				
2 to 1	117.3	1.6	-2.1	5.5
3 to 2	109.7	2.6	-2.7	2.1
4 to 3	107.1	3.5	-3.2	0.8
5 to 4	105.5	4.5	-2.6	0.1
>5 to 5	105.4	5.6	-0.7	0.0
Total	110.5	3.1	-2.3	2.4

Source: UN(2012), national statistics, and own computations. See Appendix I

Notes: The sample consists of 16 Indian states, 27 provinces of China, 7 countries for which data on the sex ratio at birth are readily available, and 6 countries for which the sex ratio at birth is derived from the UN data on the sex ratio for the population 0-4 years and infant and child mortality data. See Appendix I for details.

Table 2: The Zig-Zag relationship between Fertility and the sex ratio at birth

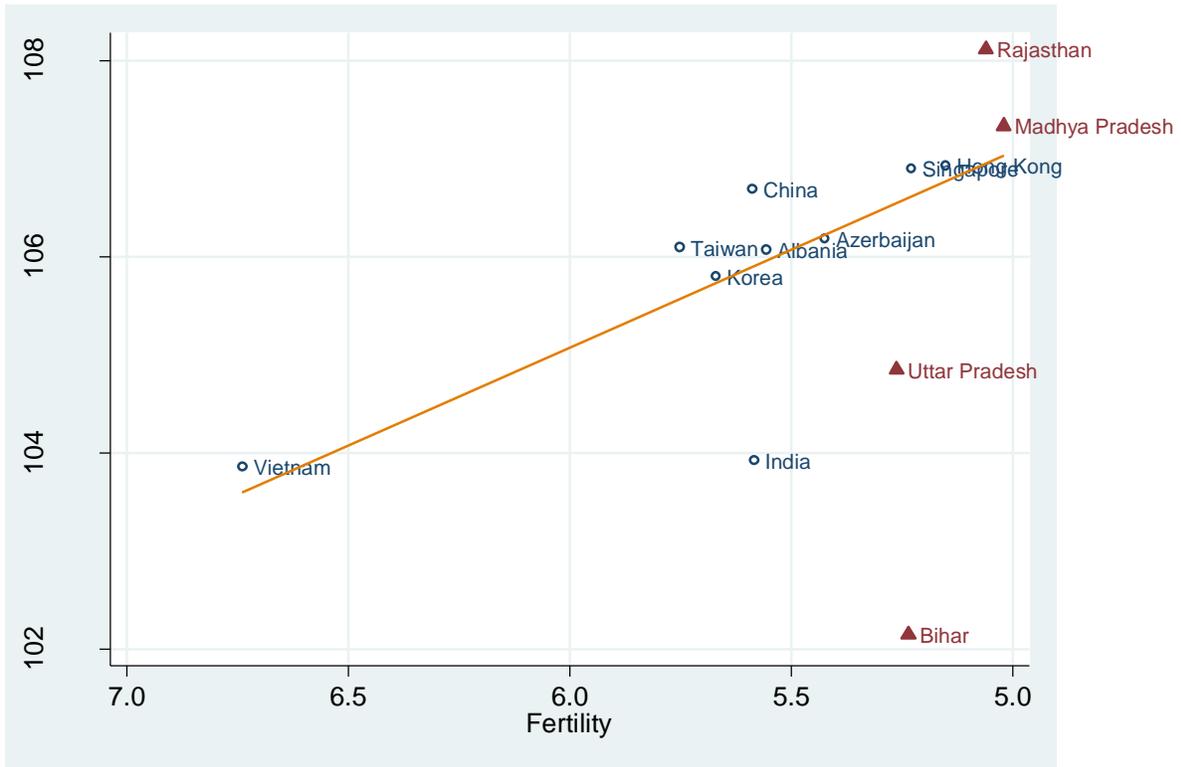
Fertility Decline		Coefficients (t-stat)			sex ratio range		Number of observations	R ²
from	to	Constant	Fertility	Log change in Fertility	min	max		
>5	5*	116.7	-1.96 (-4.26)	-0.08 (-.34)	103.9	108.1	11	0.457
>5	5	113.0	-1.28 (-1.52)	0.18 (0.44)	102.1	108.1	12	0.141
5	4	77.3	6.49 (2.0)	-0.03 (-0.15)	98.4	111.7	21	0.223
4	3	130.0	-5.95 (-1.81)	0.57 (2.42)	102.7	121.1	40	0.176
3	2	88.2	7.91 (2.42)	-0.39 (-1.0)	102.9	125.6	48	0.090
2	1	114.8	-3.1 (-0.79)	-1.70 (-1.73)	104.6	131.7	46	0.074
2	1*	118.9	-5.8 (-1.72)	-1.46 (-1.54)	104.6	128.4	44	0.117

Source: Authors calculations; for sample of countries, regions etc see Appendix I

Notes:

- (1) Two regressions for the fertility range 5 to above are shown – the “normal” regression and one (marked with an asterisk) excluding the outlier Bihar which averages an abnormally low sex ratio of only 102.1 for years when its fertility rate was above 5. See Fig. 3a.
- (2) Two regressions for the fertility range 2 to 1 are reported – the “normal” regression and one (marked with an asterisk) excluding two provinces of China, Guizhou and Jiangxi. See Fig. 3c.

Fig. 3a: Sex Ratio at Birth and Fertility Decline (from >5 to 5)



Source: UN(2012), national statistics, and own computations. See Appendix I

Note: The fitted line is drawn without Bihar.

Fig 3b: Sex Ratio at Birth and Fertility Decline (from 4 to 3)

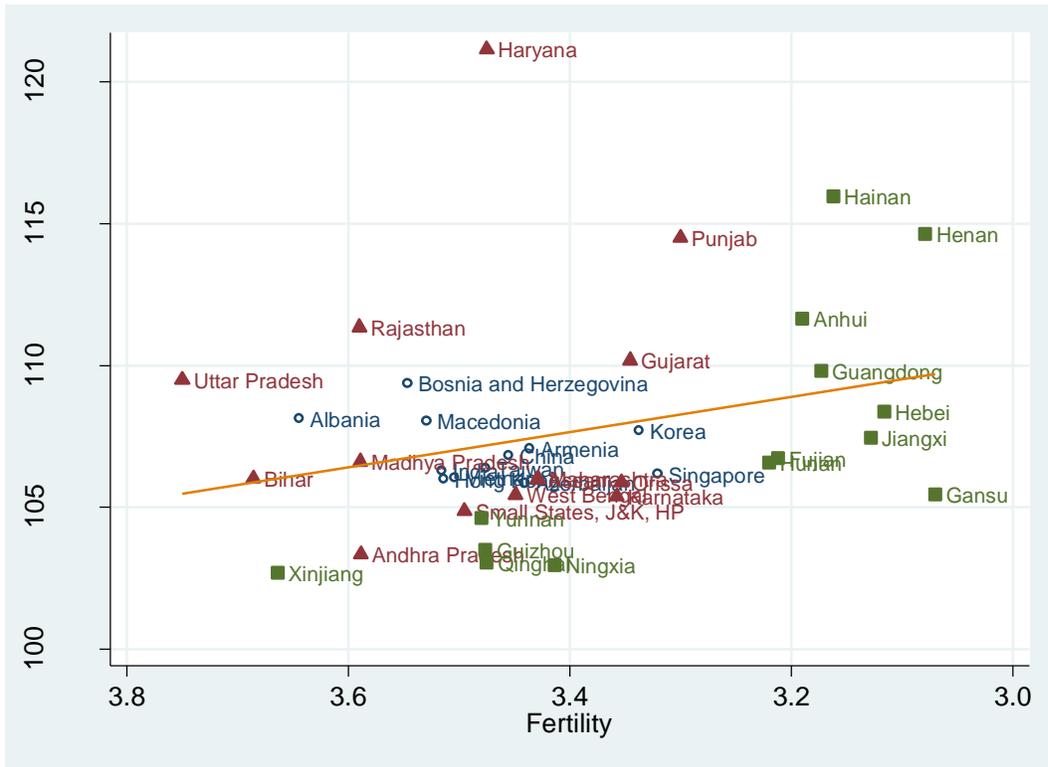


Fig. 3c is a partial scatter plot between the sex ratio at birth and average fertility levels when regions and/or countries have a fertility level less than 2 and approaching one and below. Note the bunching of only China provinces at very high (> 120) sex ratio levels. From the graph it appears that the forced one-child policy states of China are the major contributors to the observed upward trend in the sex ratio at birth. If these states are excluded from the regression, the regression model has no coefficient as significant (neither the level nor the change in fertility) and the magnitude of the fertility coefficient changes sign from -3.1 to $+0.88$. However, there is no explanatory power in the equation. This suggests that the sex-ratio is likely to stabilize, and perhaps even improve, as fertility drops below 2. Excluding states of China, the population weighted sex ratio at birth for fertility levels between 2 and 3 is 108.53; for fertility levels below 2 the mean is a slightly lower (improved!) 108.08.

When fertility decline leads to an improvement in the sex ratio at birth

Fertility approaching even levels of 4 and 2

Fertility level: In these two instances, the results show that the sign of the fertility coefficient is positive, significant at a minimum of 5 percent level, and in both instances the coefficient is comparable - 6.5 and 7.9. Thus, for each 1 point decline in fertility in these ranges (5 to 4 and 3 to 2), the sex ratio declines (improves) by about 7 percentage points. This is contrary to traditional expectations but completely in sync with the zig-zag explanation.

Speed of fertility decline: The coefficient is not significant in either case – the speed of fertility decline has no effect on the sex ratio.

The speed of fertility decline results strongly support an adjustment and adaptation model of fertility and sex-selection behaviour. As aggregate fertility levels decline, individuals change their expectations and plans. There are leads and lags in behaviour with the attitude towards number of children most likely leading changes in the attitude towards the sex composition of children. The latter has to adjust which is why one observes the rather robust zig-zag pattern.

An unexpected and rather tight fit is observed for this range in fertility (approach towards 4, Fig. 4a). The general expectation is that the decline in fertility would lead to a deterioration in the sex ratio. The decline towards an even number of 4 suggests otherwise; the “surprise” relationship is even stronger without the outlier state of Haryana. The decline in fertility towards 2 reinforces this surprise result (Fig. 4b); again, the graph includes outlier states.

Fig 3c: Sex Ratio at Birth and Fertility Decline (from 2 to 1)

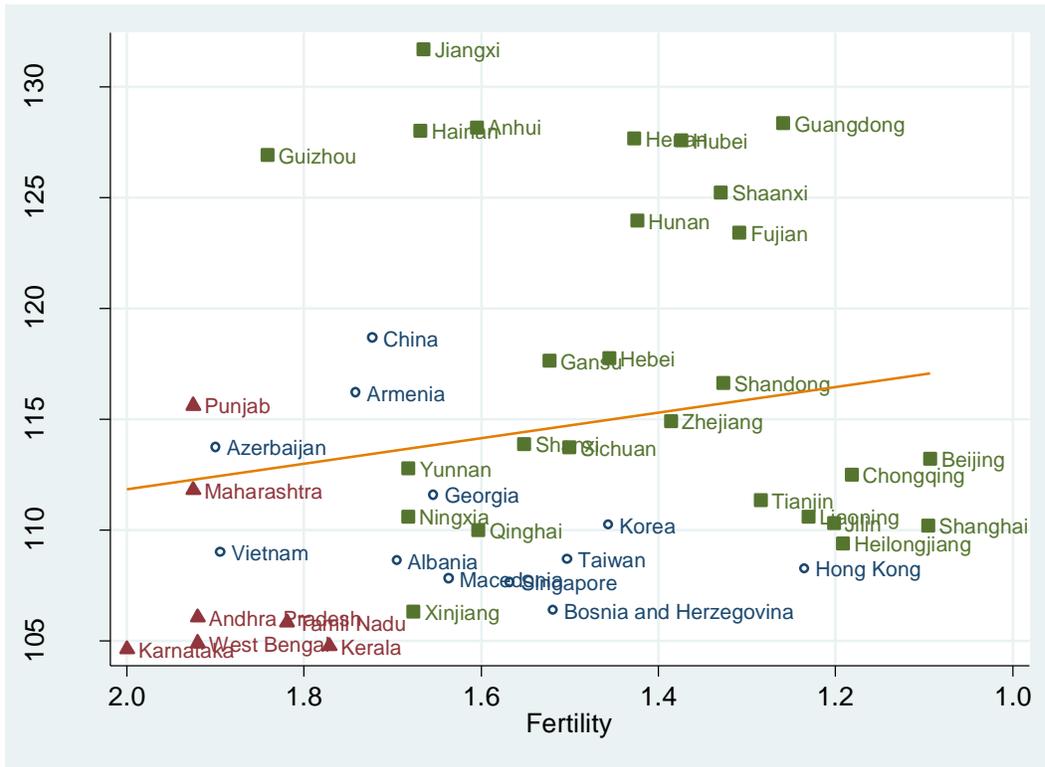
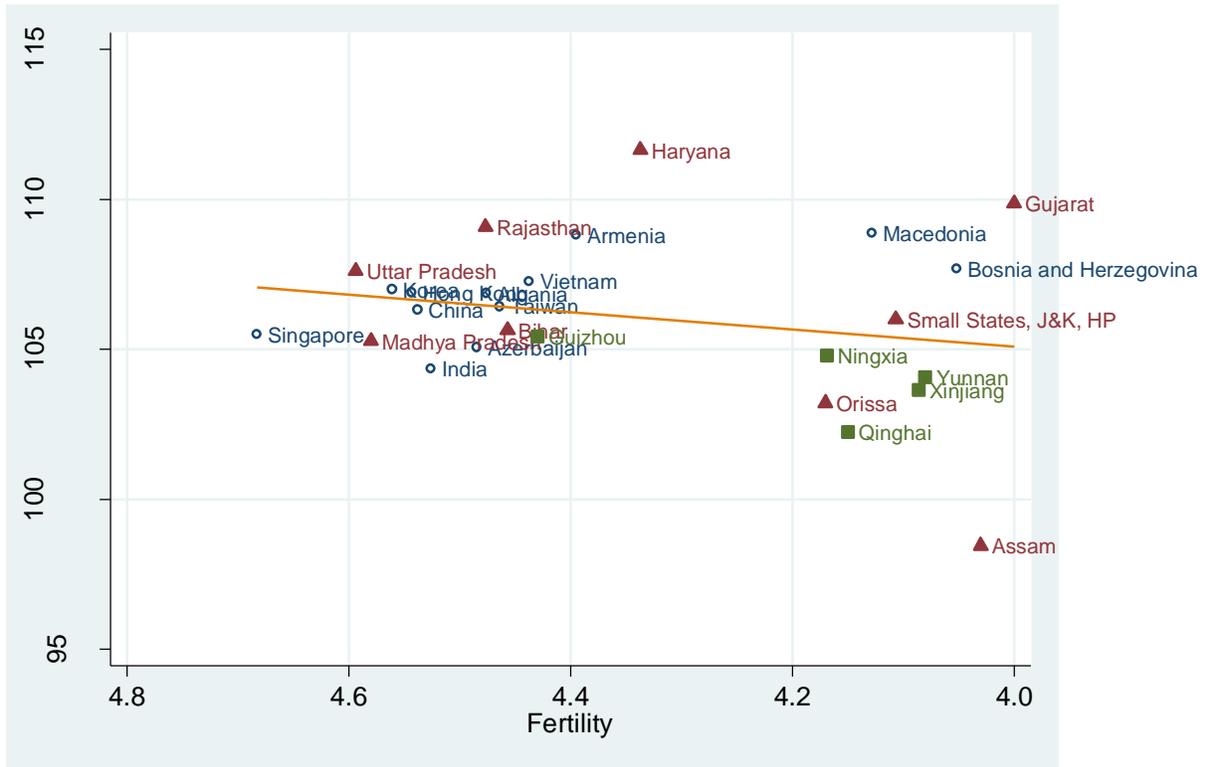


Fig 4a: Sex Ratio at Birth and Fertility Decline (from 5 to 4)



The coefficient for the fertility level is 7.9 with a t-statistic of 2.4 when the approach of fertility is towards 2. If just two outlier observations (Hainan and Assam) are removed from the above large sample of 48 observations, the coefficient increases to 10.52 and is now significant at less than the 1 percent level of confidence (t-statistic = 3.53). For the zig-zag model, this particular regression is the most relevant. This is the level of fertility that India will be approaching over the next several years. The expectation of most is that the sex ratio at birth is likely to increase in India with this expected decline in fertility; our results suggests that the next 0.6 decline in fertility (from 2.6 to 2) will be accompanied by a decline in the sex ratio at birth to around the neutral 105.3 levels. This is in the aggregate; at the state level, a more chequered picture is likely – large improvements in some states and a deterioration in the states moving towards a fertility level of 3 e.g. Bihar, Rajasthan and Uttar Pradesh.

The future in the other son-preference country, China, is also for a more optimistic future. The worst effects of the one-child policy may have played out; further, there is talk of the one-child policy being reviewed and revised. The beginning of the end of the missing girls era may be at hand.

Section 6: Sex Selectors – Smaller Proportion than “expected”

There are several determinants of the sex ratio at birth. Data on SRB indicates that sex-selection is taking place; the question that demographers and sociologists have contended with is the following – who sex-selects, why, and in what proportion. The concentration has been on the first two questions. In what proportion is not a question commonly asked. But knowledge of this parameter would aid in the making of policy, and in predictions about the future.

There are several studies available for the number of missing girls or women. Sen (1991) contended that a 100 million women were missing in the world, with a huge concentration in South Asia. He did this analysis by comparing the sex ratio of the entire population in Asia and compared it with the population sex ratio prevailing in sub-Saharan Africa and/or the Western world. The latter provided the benchmark, the “neutral” level with no discrimination against females. Several others have improved upon the estimated proportion of missing girls (e.g. Coale (1991), Klasen (1998, 2003)). In a companion paper, Bhalla-Agrawal- Kaur (2013) provide updates on missing women.

If the sex ratio at birth is known, as well as the magnitude of a neutral non-discriminatory sex-ratio, then the number of missing girls at birth can be estimated. Equivalently, the proportion of couples practicing sex-selection can be estimated with a reasonable certitude. Such an estimate can be useful, both for understanding the magnitude of the problem, as well as in the formulation (or non-formulation) of appropriate policies.

Table 3 provides estimates for selected countries for the sex ratio at birth, and associated parameters. One such variable is the missing girls at birth (MGB) ratio. The formula for the missing before birth ratio is easily derived as follows. Let χ be the fraction of children born normally; hence, $(1 - \chi)$ is the fraction born via sex-selection and assume that all children born via sex-selection techniques are boys. Let the probability of a boy being born be .513 percent; the probability of a girl being born is therefore .487 .

The sex ratio at birth is :

$$\begin{aligned} (2a) \quad \text{SRB} &= \text{Number of males born} * 100 / \text{Number of females born} \\ &= 100 * [(1 - \chi) * .513 + \chi] / [(1 - \chi) * .487] \end{aligned}$$

Simplifying, the missing percentage before birth, MGB (which is 100 times the fraction missing, χ)

$$(2b) \quad \text{MGB} = 100 * (\text{SRB} - 105.34) / (\text{SRB} + 100)$$

Table 3: Sex Ratio at Birth and Sex-selection percentages for selected countries, 1980 – 2010

Country	Sex Ratio at Birth	Fertility Level		Sex selection %	
		Mean	Minimum	Mean	Maximum
Albania	108.1	2.8	1.6	1.3	2.3
Armenia	110.4	2.1	1.7	2.3	6.0
Azerbaijan	110.8	2.5	1.8	2.5	6.0
Bosnia and Herzegovina	106.4	1.6	1.2	0.5	1.6
China	115.5	2.0	1.6	4.7	7.2
Georgia	108.8	1.9	1.6	1.6	5.6
Hong Kong	108.2	1.2	0.9	1.4	2.3
India	106.7	3.5	2.7	0.6	2.7
Korea	109.8	1.6	1.1	2.1	5.2
Macedonia	107.2	1.9	1.4	0.9	2.2
Singapore	107.6	1.5	1.2	1.1	1.6
Taiwan	108.5	1.6	0.9	1.5	2.2
Vietnam	107.5	2.9	1.8	1.0	3.2
<i>Son-Preference World</i>	<i>111.8</i>	<i>2.6</i>	<i>0.7</i>	<i>3.0</i>	<i>7.2</i>
<i>Son-Preference World excl India & China</i>	<i>108.5</i>	<i>2.2</i>	<i>0.9</i>	<i>1.5</i>	<i>6.0</i>

Estimates of the average and minimum fertility levels, the average sex ratio at birth, and the mean and maximum missing percentages are reported for time-period, 1980-2010 (Table 3). Some results. Most importantly, the percentage of couples practicing sex-selection is on the low side, certainly the low side of common expectations. The overall missing ratio at birth in the problematic developing world: 3.0 percent a year since 1980. But excluding India and China, the average is half, at 1.5 percent a year. Without these two countries, the average SRB is 108.5 for the selected “bad” countries¹² for the entire post 1980 period. The average values for India and China are 106.7 and 115.5 respectively. Inclusion of these two countries increases the overall son-preference country average to 111.8. And this is primarily due to the sex-selection practices induced by China’s one child policy. Note that for a traditional son-preference country, India, the average percent of couples practicing sex selection is 0.6 percent, while for China it is almost eight times as large, 4.7 percent.

The final column reports the maximum missing percentage observed for each country in any year during the sex selection technology availability period 1980-2010. Some of these estimates are disturbingly on the high side. There are five countries with the maximum MGB ratio above 3 percent – Armenia, Azerbaijan, China, Georgia and Korea. China, via its one child policy is a clear outlier with a maximum percentage of 7.2 percent.

Table 4 documents the missing ratio associated with several sex ratios at birth levels. The worst overall sex ratio level in the world was reached in the Chinese province of Jiangxi in 2000 - a sex ratio level of 138, implying a missing ratio of 14percent i.e. fully 14 percent of couples in Jiangxi in 2000 sex-selected. The levels for different birth parity levels (not the aggregate) are even higher and the recorded peak (200.3) is for a birth order of 3 in Korea in 1992. This implied that one out of every third birth in Korea in 1992 (among families who already had two kids) was due to sex-selection – a year when sex-selection technology was being extensively used in large parts of Asia.

Table 4: Sex ratio at birth and sex-selection percentages

% of Population		Sex Ratio- International	Sex Ratio - Indian	Region, Year	Fertility Level
Not sex- selecting	sex- selecting				
All Births					
100	0	105.1	951	UK, 2009	1.9
97.3	2.7	110.9	901	India, 2004	2.9
95.2	4.8	115.7	865	Rajasthan, 2004	3.7
93.2	6.8	120.2	832	China, 2007	1.6
91.2	8.8	125.1	800	Haryana, 1992	3.9
89.2	10.8	130.1	768	Hubei, 1997	1.4
87.4	12.6	135.0	741	Hainan, 2000	1.8
86.3	13.7	138	725	Jiangxi, 2000	1.8
Parity order births only					
78.9	21.1	160.3	624	Birth order 3, China, 2010	1.2
76.0	24.0	170.2	588	Birth order 3, Korea, 1988	1.6
73.3	26.7	180.1	555	Birth order 4, Armenia, 2001-08	1.7
70.8	29.2	190.0	526	Birth order 4, Korea, 1988	1.6
68.4	31.6	200.2	499	Birth order 3, Korea, 1992	1.8

Source: Sex Ratio by birth order for different regions taken from United Nations, 2012b. Other sex ratio and fertility data are own computation from UN data; see Appendix I and text.

Section 7: Conclusion

The review of the extensive literature on the sex ratio at birth yields some important findings – most definitively, that the sex ratio at birth is centered in a narrow range at birth, with the probability of a boy being born being 5 percent more than a girl. Human intervention in the form of son-preference has affected this natural pro boy event in many parts of the world, and for a long period of time. Traditionally, this intervention took the form of better health care for the boys or equivalently, worse than “normal” health care for the girls. The male bias has been especially dominant in Asian societies, and within Asia, the two most populous countries, China and India.

This problem became worse with the introduction of sex-selection technology around 1980. Just a few years prior to this technological advance, China had introduced its one-child policy. In a son-preference country, this policy and technology conspired to make “easy” the elimination of the girl child before birth. At a national level, in China, the excess probability of a male birth rose to above 7 percent in 2004.

In other parts of Asia, fertility decline was occurring on a natural basis, though not in as draconian a manner as in China. With technology also available, sex ratios at birth began to rise in countries which heretofore had not experienced an abnormal sex ratio at birth e.g. Korea. This association of fertility decline with a technology supported sex ratio at birth led scholars and policy makers to believe that the future of the missing girl child was worse than ever before.

In this paper, we have tried to present evidence that is somewhat contrary to these expectations. In particular, we offer a zig-zag model relating the sex ratio at birth to fertility i.e. as fertility reaches odd number of children, the sex ratio increases and as fertility approaches even number of children (2 and 4), the sex ratio declines. The availability of recent UN data on male and female populations in different five-year age groups from 1950 to 2010 allows us to test the zig-zag model. In addition, state or province level data for India and China allows for a rigorous test of the model.

The results strongly favor the reality of the zig-zag model. Fertility does have an impact on the sex ratio, and improvement is observed when fertility approaches 4 and 2. In addition, the sex ratio is seen to be unaffected when fertility declines towards 1 and below. This result occurs when China and Chinese provinces, affected by the one-child policy, are excluded from the analysis. This augurs well for the future of the sex ratio in different parts of Asia. In China it is unlikely to worsen from present levels and likely to improve if the one-child policy is even partially abandoned. And in India, our model suggests a continuous improvement in the sex ratio. The fertility level in India is expected to reach 2 by 2016; the model predicts that the sex ratio at birth will improve from the present 2009 level of 107.9 (927

according to the female to male ratio) to around 105.5 levels (948 female male ratio) by 2016. The future is likely to be much better than the past.

An additional less commented on result is that the son-preference problem, in the aggregate, is not as intractable as commonly believed. At the worst levels of son-preference observed in 2004, only 2.7 percent of the couples in India practiced son-selection. In 2009, with the sex ratio at birth of 107.9, the practicing girl missing couples were down to only 1.2 percent. This is 1.2 percent too many; but it is encouraging to note that the problem is tractable.

Appendix 1 - Calculation of Implied Sex Ratio at Birth from Child Sex Ratio data

Data for the sex ratio at birth are not easily available for most countries in the world. However, the UN (UN World Population Prospects: The 2010 Revision, 2012) has recently made available data for the male and female populations for each year for the preceding *five* years, from 0-4 age group to 80 plus, in all the countries of the world for the period, 1950 to 2010. These data, when combined with infant and child mortality rates (data separately available from UN sources, (UN Inter-agency Group for Child Mortality Estimation (IGME), updated 2012) can yield a consistent series of the sex ratio at *birth* for all countries and for all the years since 1954. This method is near identical to the method employed by Kulkarni (2007) and other demographers to arrive at estimates of sex ratio at birth from census data on the sex ratio of children (0 to 6 years in the case of India). The table below documents that this method yields results very close to official data for the sex ratio at birth for countries for which such data are available.

The sex ratio for 0-4 years age group (sr04) provided by the UN data is the *initial* estimate of the sex ratio at birth. Given the number of children born (from child birth rate statistics), the number of female and male births are allocated according to the assumed sex ratio at birth. In 2004, for South Korea, the number of births is estimated as 471,000, given a population of 48 million and a crude birth rate of 9.8 per 1000 births. This estimate of total births is allocated to male and female births according to the initial estimate of the sex ratio at birth, sr04 equal to 108.1. The initial estimate of male and female births is therefore 244,563 and 226,278, respectively. The child mortality rates for male and females in this year is reported as 5.6 and 5.2 deaths per 1000, yielding a female to male mortality rate of 0.923. Assuming the same *relative* mortality rates for infants, infant and child “survival flow” till age 4 is given by the following:

$$m04_{2004} = mb_{2006} * (1-imr_m) * (1-cmr_m)^4 + mb_{2001} * (1-imr_m) * (1-cmr_m)^3 + mb_{2002} * (1-imr_m) * (1-cmr_m)^2 + mb_{2003} * (1-imr_m) * (1-cmr_m) + mb_{2004} * (1-imr_m)$$

$$f04_{2004} = fb_{2006} * (1-imr_f) * (1-cmr_f)^4 + fb_{2001} * (1-imr_f) * (1-cmr_f)^3 + fb_{2002} * (1-imr_f) * (1-cmr_f)^2 + fb_{2003} * (1-imr_f) * (1-cmr_f) + fb_{2004} * (1-imr_f)$$

where m04 and f04 are the estimated male and female populations in the 0-4 year age group; mb and fb are male and female births, respectively; subscripts m and f refer to males and females; and imr and cmr are the infant and child mortality rates.

For the five-years ending in 2004, there are now two estimates for males and females, 0 to 4 years - the benchmark figure given by the UN data, and an estimated figure (based on assumption that the sex ratio at birth was the same as the sex ratio for 0-4 years) given by the ratio of $m_{04_{2004}}$ and $f_{04_{2004}}$.

For Korea, in 2004, the adjustment factor is 0.9980 and the initial estimate of the sex ratio at birth was 108.1. The second estimate of the sex ratio at birth is the product of these two numbers, 108.1×0.9980 or 107.9. A three year average of this second estimate, centered on the middle year, yields 108.3. This is the estimated sex ratio at birth and is used to correctly allocate the births. Given the use of the adjustment factor, the new series of m_{04} and f_{04} estimated as above correctly matches the UN numbers. Thus, at the end of the exercise, the sex ratio 0-4 years is exactly as that of the UN *and* a sex ratio at birth series is obtained, for each country and each year.

One side result from our estimation exercise is that infant mortality rates have a much larger impact on the sex ratio 0-4 years than child mortality rates. This occurs for the simple reason that infant mortality rates are roughly 4 to 5 times higher than child mortality rates.

The UN has also provided estimates for the sex ratio at birth for all countries for the time-period 1950-2100 – see <http://data.un.org/Data.aspx?d=PopDiv&f=variableID%3A52> . The reason for our calculation is that for several countries the UN estimate is a constant point estimate for all the years. For example, for Hong Kong just one estimate, 106.7, is presented for all the years; for Singapore, 107.3. For Hong Kong, Wong et. Al. (2010) report the sex ratio at birth, for Hong Kong based Chinese, to be 107.8 for the period 2003 to 2007.

For some countries official data for the sex ratio at birth exists. In the case of India and Indian states, the Sample Registration System (SRS) provides estimates of the sex ratio at birth as moving three year averages. In addition, decadal census data yields data on the sex ratio of the population aged 0-6 years. We match the two series, via the same method mentioned above, to estimate an adjusted sex ratio at birth for India and Indian states for the period 1984 to 2010.

How accurate are our estimates compared to official estimates obtained from birth registration, sample surveys, and/or censuses? Very accurate. The table below documents the different estimates of the sex ratio at birth for eleven countries for the ten year period 2000 to 2009. (Vietnam is excluded from this comparison since the latest census data reveals a very different “performance” for the last ten years than that assumed by the UN data, see Guilмото (2012).

Korea's National Statistical Office publishes annual estimates of the sex ratio at birth. Our ten year average, 108.9 is near identical to the official estimate of 108. Ditto the case for most other countries. The largest variation is for China (2.1 percent) and Macedonia (1.2 percent). On an aggregate basis, the variation with respect to the official figures is less than 1 percent (0.8 percent). The correlation (for the 39 countries of South and East Asia and the countries listed in the table) between the UN provided estimates of the sex ratio at birth and ours for the period 2000-2009 is 0.957.

If this accuracy of this method is accepted, then it can be used to identify potential sex selector economies. The known countries are identified below and used in the analysis. Some other sex ratio at birth problematic countries (with population above 1 million) are Kuwait, Papua New Guinea, Ghana and Nigeria. Among small countries, there are several possible candidates – in particular, Barbados, Iceland, Luxembourg, Macao, Maldives, Malta, and Western Samoa. Only in-depth research can establish whether these countries do in fact sex-select.

Final selection of countries/regions for analysis:

- (1) All the countries listed in the table below plus Vietnam and Taiwan.
- (2) Data for small states of India e.g. Goa, have been combined with Himachal Pradesh to yield a population weighted average for each year. Total count of Indian states: 17
- (3) All the 29 provinces of China excluding Tibet, a region for which the sex ratio at birth seems unusually low – for most of the 1990s the ratio was below 100.

Exclusion of states/provinces:

- (4) Three regions have been excluded because of “problematic” data on one of the independent variables of analysis – fertility. The three regions are Delhi in India and the provinces of Guangxi and Jiangsu in China. Delhi shows a constant fertility level of 1.6 for the years 1984 to 1996; Guangxi was excluded because it shows a constant fertility level of 1.8 for all the years 1995 to 2010; and Jiangsu for showing a constant fertility rate 2000 to 2010.

Appendix Table 1: Sex ratio, various estimates, 2000-2009

Country	Initial	First estimate	Avg. 3 years	UN estimate	Official figures
	UN Sex ratio 0 - 4 years	Sex ratio at birth	Sex Ratio at birth	Sex Ratio at birth	Sex ratio at birth
Albania	107.8	109	108.7	107	108.6
Armenia	116.3	116.5	116.6	116.2	117.2
Azerbaijan	114.9	117	115.8	116.8	116.7
Bosnia and Herzegovina	106.7	108.2	107.7	107.2	106.8
China	121.2	122.4	121.8	120.5	119.3
Georgia	112.5	115.2	114.2	111	113.7
Hong Kong	107.1	106.7	107.3	106.7	107.1
India	108.6	108.1	108	108	108.5
Korea	108.8	108.9	108.9	110	108
Macedonia	107.7	109.5	109	108	107.7
Singapore	107.2	107.8	107.6	107.3	107.7
Average	114.9	115.3	114.9	114.3	114

Source: official figures from various sources; UN data from UN(2012); other columns, author calculations

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¹ This research is part of an ongoing research project of one of the authors (Ravinder Kaur). Shaping the family, and the consequences both desired and unintended of sex-selection are discussed in varying detail in Kaur (2004,2007,2008,2010).

² See Das Gupta and Bhat (1997). The authors outline the co-existence of two forces affecting son-preference in the context of sex-selective abortions. The parity effect which means increased sex-selection at higher birth orders (parity) and an increased sex selection at lower levels of fertility (intensification).

³ The sex ratio at birth is defined as the number of boys born per 100 girls. In India the ratio is expressed as the inverse – the number of girls born per thousand boy births, or 951.3. The convention followed in the rest of this paper is number of boys being born for each 100 births of a girl child.

⁴ This paper forms part of a larger study on the evolution of the sex ratio in India, the phenomena of missing girls, the adoption of modern sex selection techniques, the role of the middle class in affecting son-preference, and the role of fertility decline. See the companion pieces on missing women, Bhalla et. al. (2013), and the middle class and the sex ratio, Kaur et. al. (2013).

⁵ We are grateful to Shuzhuo Li for kindly providing the data for China and China provinces (fertility and the sex ratio at birth).

⁶ The probability of a boy being born of 51.25 percent means that the probability of a girl birth is 48.75 percent. The ratio of the two (multiplied by 100) is the sex ratio at birth, 105.1.

⁷ See Kaur(2011) for an initial exploration on this issue; also see Bhalla-Kaur(2011a,2011b) for evidence and a partial explanation for the improvement of the sex ratio at birth in India in the first ten years of this century; also see Kaur-Bhalla-Agrawal(2013) for a detailed analysis of the role of middle class, especially the emerging middle class, in affecting sex ratios in India since the mid 1980s.

⁸ Section 5 documents how the proportion of women practicing sex-selection at birth is likely to be small in all economies except China and some regions of India, e.g. Haryana. A sex ratio at birth of 111 (the peak observed in India) yields only 2.7 percent of women practicing sex selection. The argument is not that 2.7 percent is not too many; the argument is that the fraction is small and amenable to self-correction.

⁹ See Kaur (2008) on preference for a one son family among Jats in Punjab and Haryana and Gounders in Tamil Nadu.

¹⁰ The sex ratio at birth is the sample registration survey estimate adjusted with respect to census data. See Kulkarni(2007) and the Appendix.

¹¹ Assume that the sex ratio at birth (SRB) is affected by both the level of fertility in the present year, t , as well as the level of fertility in the earlier year $t-1$. SRB can be written as a linear combination of fertility in the present and lagged one period i.e.

$$SRB = a_1 * FERT_t + a_2 * FERT_{t-1} \quad (a)$$

Equation (a) can also be written as a function of fertility in the present period and the change in fertility between the present and last period i.e.

$$SRB = c_1 * FERT_t + c_2 * (FERT_t - FERT_{t-1}) \quad (b)$$

But equation (b) is simply a linear transformation of equation (a) with a_1 as $(c_1 - c_2)$ and a_2 as c_2 .

¹² The countries were selected on the basis of some evidence that a son-preference sex-selection problem existed in these economies.