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Sex ratios at birth and future marriage squeeze in China and India, 2005-2100

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Abstract

This paper examines the potential impact of the anticipated future marriage squeeze on nuptiality patterns in China and India during the 21st century. We use population projections from 2005 to 2100 based on three different scenarios for the sex ratio at birth (SRB). Due to the limitations of cross-sectional methods commonly used to assess the severity of marriage squeezes, we use a two-sex cohort-based procedure to simulate marriage patterns over the 21st century based on the female dominance model. We also examine two variants based on delayed male marriage and on the harmonic mean model respectively to illustrate the potential impact of changes in marriage schedules as a response to the marriage squeeze.

Longitudinal indicators of marriage squeeze indicate that the number of prospective grooms in both countries will exceed that of prospective brides by more 50% for three decades in the most favorable scenario. Rates of male bachelorhood will not peak before 2050 and the squeeze conditions will be felt several decades thereafter, even among cohorts unaffected by adverse sex ratio at birth. If the SRB is allowed to return to normalcy by 2020, the proportion of men unmarried at age 50 is expected to rise to 15% in China in 2055 and to 10% in India in 2065, and the marriage squeeze will remain perceptible until 2100. India suffers from the additional impact of a delayed fertility transition and its impact on age structures.

The application of alternative nuptiality models indicates that delayed male marriage represents a partial, but sociologically more plausible response to the forthcoming marriage squeeze. An additional one-year delay in male marriage would lower the male singlehood rates at age 50 by about 2%, resulting in a considerable reduction of the numbers of men unable to marry. We conclude the paper with a synthesis of the results and a discussion of some implications of our findings.

Key-Words : India, China, sex ratio, masculinity, marriage squeeze.

Introduction

The proportion of male birth cohorts has reached unusually high levels over the last 20 years in several Asian countries[1]. In many countries, the sex ratio at birth (hereafter SRB) has increased above the standard range of 104-106 male births per 100 female births and has reached values above 110 or even 120. This process of demographic masculinization stems mostly from the increasing frequency of sex-selective abortions across Asia, from Caucasus to South and East Asia. While discrimination

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[1] The literature on the sex ratio issues in Asia is now abundant and describes in particular determinants of gender discrimination. On the diversity of situations across Asia, see Croll (2000), Miller (2001), Attané and Guilmoto (2007), and UNFPA-sponsored case studies (UNFPA, 2007).

against unborn girls today is a dismal reflection of the status of women, sex imbalances may also lead tomorrow to the potential disruption of marriage systems set off by the unavoidable shortage in prospective brides.

This paper aims at both evaluating the potential severity of the marriage crisis and at exploring the potential responses of nuptiality systems to future changes in sex composition of China's and India's population until the end of the 21st century. These two countries have been selected because of their demographic weight in the world and the early rise in SRB observed over the last two decades. Compared to previous studies, the study period has also been extended from the conventional 2050 year to 2100 in view of especially long-term impact of SRB imbalances on marriage patterns and demographic parameters have been updated. But the most important difference with previous research is to use a longitudinal simulation procedure to simulate future male and female marriages rather than rely on cross-sectional indicators of sex ratio imbalances. The paper starts with a presentation of the data and models used to simulate future marriage patterns. Taking 2005 as baseline year, our simulations rely on various population projections based on three scenarios of change in sex ratio at birth (SRB) over the coming decades. We also describe the different marriage models used in the simulations. The next part of the paper includes results from our simulations, starting with new estimates of the extent of the marriage squeeze and the analysis of the respective contribution to it of changes in age structures and in birth masculinity. Two additional simulations illustrate the extent to which mere changes in marriage timing could reduce the intensity of the marriage squeeze. The paper concludes with a synthesis of the results and a review of some of the implications of our findings.

Data and models for marriage simulations

The simulation of marriage patterns in China and India requires first a set of population projections based on different SRB scenarios for the future. Since long-term trends in cohort size may also affect the marriage sex ratio because of the age difference between spouses, we also develop a set of projections without rise in SRB levels. We examine two dimensions of population change in the first sections and describe the parameters used in our population projections. We then discuss the limitations of the cross-sectional sex ratio indicators of marriage squeeze and present a more realistic indicator of marriage squeeze based on longitudinal marriage simulations. These simulations are based on specific parameters for projecting female marriage patterns in the future. At the end of this part, we also explore what alternative responses of male nuptiality to the increasing marriage squeeze conditions could be by presenting two alternative marriage functions.

Impact of population structures on sex imbalances

Since men usually marry younger women, the birth cohorts of future husbands tend to be older (McDonald, 1995; Esteve and Cabré, 2005). But the size of these birth cohorts stems also from long-term trends: the number of annual births tends in particular to increase during the first phase of the demographic transition, but decreases later after prolonged fertility decline. India's case is probably emblematic of this situation: the number of births recorded a regular increment till 1990 and during the 1970s, the annual increase in the birth cohort size reached 1.5%, which means that there was on average 7.7% more prospective wives born during this period than that husbands born 5 years earlier (age difference at marriage observed today)[2]. Incidentally, this disequilibrium in the past is often associated with the concomitant rise in dowry observed in India after independence (Bhat and Halli, 1999). But with fertility coming down and further changes in age structures, the number of births started declining in the 1990s and according to our population projections, this reduction in the size of birth cohorts is expected to accelerate in the future: by 2025, an average birth cohort in a given year would for instance be 7% larger that the cohort born five years later. Without any rise in the sex ratio at birth, male adults would therefore become more numerous than their prospective brides.

China presents undoubtedly a more complicated picture because of the irregular size of its birth cohorts since the 1950s. While the number of births has on the whole decreased since the 1980s, this decline is less rapid than in India, and also disturbed by the regular ups and downs that are a legacy of China's volatile demographic past. Short-term fluctuations have therefore a marked effect on age and sex distributions in China and will directly influence the sex ratio of adults –a point highlighted by Goodkind (2006) and Rallu (2006). But the decline in the number of births will also be pronounced in China, especially during 2020-35[3]. As a result, the impact of skewed SRBs in China and India on adult sex ratios is likely to be compounded by future age-structural transformations. We will therefore insert a separate projection set designed to assess the potential influences of changes in age structures on marriage imbalances.

Birth imbalances in the future

Our demographic projections for China and India will start from 2005 and extend to 2100. They are based on the most recent demographic estimates as well as on assumptions that are different from previous attempts[4]. Parameters for these projections have been mostly borrowed from the 2006 prospects by the United Nations Population Division, but several adjustments and corrections have been made (see Appendix 1).

SRB level for the future decades are also essential to our projections. Sex ratio at birth started to increase above normal values twenty years ago in China and India[5]. As available data indicate, sex ratio at birth has risen to a level of over 115 in many Asian countries, from Armenia to China, and seems to have leveled off since 2000. There are, in fact, reasons to believe that SRB levels will not increase indefinitely and may ultimately decline. Both China and India during the last decade have introduced or strengthened comprehensive programmes to tackle sex-selective abortions (Li *et al.*, 2007; Joseph, 2007). Moreover, recent trends indicate that in several areas, the SRB may be about to level off or to decline. For instance, data for China based on the 2000 census (long form) and on the 2005 1% sample survey reflects a near stagnation of the national average from 119.9 in 2000 to 120.5 in 2005, which has already been interpreted as the beginning of a turnaround, with a significant decline

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[2] Data used in this section are based on United Nations estimates for 1950-2005 complemented by our projection results for the period beyond 2005.

[3] According to our projections, the overall yearly decline in birth cohort size during the 2005-2100 period is 0.25% in China and 0.4% in India (rapid transition scenario).

[4] No projection exists for India, and forecasts of China's future sex imbalances are found in Tuljapurkar *et al.* (1995) and Attané (2006), based on respectively on 1990 and 2000 census data. Results from these two studies are not exactly comparable with our projections, since they postulate fixed fertility and mortality patterns during the 21st century and do not extend beyond 2050. Estimates provided by Jiang *et al.* (2007) are based on a more realistic demographic scenario.

[5] On China, see for instance Zeng *et al.* (1993), Banister (2004) and Li *et al.* (2007). On India, see Bhat (2002) and Patel (2006). Comparative estimates for various countries are found in Guilmoto (2009).

in birth masculinity has been observed in southeastern provinces such as Guangdong or Guangxi. There has been also a perceptible shift in SRB since 2002 in several States of North-West India such as Haryana, Delhi, or Punjab[6]. In addition to these concordant traces of moderate decrease, the remarkable experience of South Korea –where SRB first rose to 116 in 1990 and then gradually declined back to 106 in 2008– and the stagnation or declined also observed in Caucasian countries (Azerbaijan, Armenia, Georgia) suggest that sex ratio at birth may follow typical transitional patterns, with an initial rise followed by a later decline (Guilmoto, 2009).

In order to explore the possible consequences of future gender imbalances, it seems thus crucial to consider several different SRB scenarios. According to a first *no-transition scenario*, sex ratio at birth will remain at its current level until 2100: the SRB would therefore stay at 120 in China and at 113 in India during the entire 21st century. According to a second *rapid-transition scenario*, the SRB starts on the contrary decreasing immediately after 2005 and comes down to a normal 105 level in 15 years –at a pace slightly faster than that observed in South Korea after 1990. This is admittedly a rather optimistic transitional scenario in which birth imbalances would have vanished by 2020. Both scenarios are deliberately extreme. The first, "business-as-usual" scenario implies, for instance, that a high sex ratio at birth would remain sustainable, in demographic and social terms, during the entire century, a proposition that seems rather implausible in view of the implications of abnormal sex ratios in the long run. In contrast, the second, transitional scenario would, require a complete change in gender attitudes in 15 years, something that government interventions or spontaneous social change may not be able to achieve. But taken together, these first two scenarios may reasonably be seen as the upper and lower limits for simulating sex-transitional change in China and India.

We have also added an entirely different scenario based on the hypothesis of the absence of any sex ratio imbalance since 1980: this third scenario of *normal SRB* posits a constant SRB of 105 and will serve to highlight the specific impact on marriage imbalances of age structural changes caused in particular by the process of fertility decline in China and India (see Appendix 1 for detail).

Measuring marriage squeeze

Adult sex ratios weighted by marriage rates provide the usual index to assess the intensity of demographic disequilibria in the marriage market. These indicators allow us to incorporate in our computation both the size of specific cohort and the effects of age specific nuptiality rates. This indicator, however, presents serious limitations for the appraisal of the actual impact of sustained gender imbalances, its imperfection lying in the strictly cross-sectional approach of weighted sex ratios.

Sex ratios are strictly synchronic indicators affected by existing age structures and marriage rates and reflect all fluctuations in cohort size, even if short-duration marriage squeezes are most likely to be canceled out by instantaneous adjustments in marriage rates. But more worryingly, they do not take the potential effects of the preceding situation into consideration and cannot therefore reflect adequately the actual impact of long-term disturbances. When surplus male bachelors fail to marry in a given year, they will unavoidably inflate the pool of potential grooms in the following year, and if the sex disequilibrium does not reduce rapidly, unmarried bachelors will accumulate in the "marriage

[6] The recent SRB downturn in India is analyzed in Kulkarni (2009). See also Sharma and Haub (2008). Chinese trends are described in Das Gupta *et al.* (2009) and Goodkind (2008). Comparative data are found in Guilmoto (2009). Original data are found in the reports of the 2000 census and of the 2005 1% sample survey for China, while Indian data are from the annual reports of the Sample Registration System.

market" and further aggravate the initial squeeze conditions. This is a direct application of a basic law in queuing theory according to which the number of people in a system (here the marriage market) is a function not only of arrival rates (cohort size), but of also the queuing time (number of years unmarried)[7]. Usual cross-sectional sex ratio indicators fail completely to reflect the cumulative impact of the marriage squeeze and the possibility of a backlog of unmarried men.

A more appropriate solution to this conundrum is the two-sex cohort-based simulation of marriages. In this approach, we try to match the number of first unions to the available pool of male and female singles during each five-period starting from 2005. In so doing, we can deduce the size of the unmarried population at the end of each period and use it to compute marriages taking place during the next period. This approach is longitudinal as we follow individual cohorts over the years in order to factor in the cumulative effects of past imbalances in the marriage market on potential marriage rates. As the weighted sex ratios, this simulation technique is based on a set of age specific nuptiality rates to compute the expected number of first marriages. But another key component in our simulations is the adjustment function used to quantify the number of marriages occurring in case of marriage squeeze, when the expected numbers of male and female marriages differ (see next paragraph). Both methods vary in their applications of the nuptiality rates. The weighted sex ratio is computed from projected age distributions-irrespective of the actual marital status of each age and sex group-and corresponds to a specific date. In contrast, the longitudinal indicator of marriage squeeze for each five-period period is computed from the simulated population single at the beginning of the period. Not only does this index refer to the preceding period, but it is also affected by the nuptiality history of each birth cohort. If a cohort has previously been unable to marry in expected proportions, the number of expected marriages computed from the single population will automatically increase –as long as the cohort is aged less than 50 years. While weighted sex ratios are a direct reflection of projection and nuptiality parameters, the longitudinal indicator of marriage squeeze is based on the past nuptiality experience. Apart from being more realistic, the simulation procedure also leads to the estimation of the mean age at marriage during each period and of the proportion of people unmarried at age 50.

The main marriage function used in our simulations is the so-called female dominance (FD) model, in which surplus males adjust downwards their nuptiality rates to the numbers of available unmarried women[8]. The FD model presupposes that female marriage rates will follow a fixed trajectory, irrespective of the pool of unmarried men: the timing of first female marriages will in particular not be affected by variations in the number of unmarried men as long as there is a male surplus. Similarly, the age difference at marriage between men and women is assumed to remain the same. Since this model depends almost exclusively on female nuptiality behaviour, it is crucial to delineate appropriately the most likely course of female marriage patterns over the coming decades.

Simulating female nuptiality in Asia

It would be rather unrealistic to assume that current female nuptiality patterns will remain unchanged in China and India until 2100. On the contrary, Asian marriage systems are today characterized by rapid and deep transformations: under the impact of various factors such as prolonged education,

[7] Little's law states that the average number in a given stable system is equal to the rate of new arrivals in the system multiplied by their average time in the system (Tijms, 2003: 50-52).

[8] See Keyfitz and Caswell (2005) and Iannelli *et al.* (2005) for a broader discussion of marriage models. In addition to the FD model, other marriage functions are introduced further below.

urbanization, access to formal employment, and increasing social autonomy, women have delayed their marriages in many East Asian countries or metropolitan areas[9]. New phenomena such as the end of universal marriage or, to a lesser extent, cohabitation have even emerged over the last fifteen years. The first component of this change relates to delayed marriages. In countries such as Thailand and the Philippines, metropolitan cities like Djakarta or Seoul, and among groups such as ethnic Chinese of Malaysia or Goanese women in India, more than 15% of women nowadays are still single at age 30.

In India, women still marry rather early –19.8 years is the latest estimated average age at first marriage (see Appendix 2). Such a low figure may appear at first sight to reflect the permanence of traditional matrimonial arrangements privileging early female union soon after menarche. Up to the 1930s, the country was indeed characterized by very early marriages, with a large proportion of women betrothed before reaching physiological maturity. But the pace of change observed in India has been remarkable and age at first marriage has regularly increased ever since[10]: it went up from 13 to 15 years in 1951, reaching 18.3 in 1981 and 20.2 in 2001 (census-based estimates). The progress in female age at first marriage –one additional year per decade since 1931– has in fact been strictly linear in India[11]. Moreover, recent NFHS data (IIPS, 2007) demonstrate that age at marriage in today's India is also closely correlated to education levels as well as to urban residence and socioeconomic status. With such covariates of late female marriage, current trends in rapidly modernizing India suggest further gains in mean age at marriage in the future. A plausible hypothesis for India consists thus in positing a gradual rise in female age at first marriage in India as a result of growing affluence, longer duration of schooling, gradual change in gender roles and other aspects of socioeconomic transformations. We will therefore assume that age-specific first marriage risks will regularly decrease for women up to 2050 and the mean age at first marriage will reach 23.5 years at the middle of the century, at a level similar to what is observed today in China[12]. We have also posited a gradual leveling of remarriage rates between men and women in 2005-50[13].

In 2005, Chinese women married on average at the age of 23.5 years, a value significantly above the legal age at union (20 years), but with only 2% women still unmarried in the 30-34 age group. The proportion single at 50 was as low as 0.2%. Female age at first marriage was 22.4 years at time of the 1982 census and it has only marginally increased since then. Jones (2007: 466) attributes these features to both institutional and structural factors. Among men, the average age at first marriage is 25.1 years and has remained constant over the same period. However, since the experience of neighboring countries such as South Korea and Japan suggests that female age at marriage may rise in the future, we have also postulated a gradual increase in age at marriage among Chinese women up to 26.5 years in 2050, a pace of change comparable to that hypothesized for India[14]. It may be observed that the

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[9] Jones (2007) provides the most recent comprehensive synthesis of nuptiality in East Asia. Detailed statistics and case studies are also available in Jones and Ramdas (2004) and Xenos et al. (2006), as well as in United Nations (1990) for trends prior to the 1990s. See also Retherford *et al.* (2001) on Japan and Kwon (2007) on South Korea.

[10] The so-called Sarda Act of 1929 raised the female age of consent from 12 to 14 years (14 to 18 for men). The minimal female age at marriage was further increased to 15 after Independence and finally to 18 in 1978.

[11] It may also be observed that male age at marriage has followed an almost parallel course, with a regular increase of about 0.8 year per decade since the 1930s.

[12] This figure is slightly above that of Kerala women today, but still distinctly below that of Sri Lankan women (Caldwell, 2005).

[13] Besides the influence of secular social change, higher remarriage rates among men than women represent a rather untenable hypothesis for the 21st century in view of mounting surplus of unmarried men. On remarriage in India, see Chen (2000) and Bhat and Halli (1999).

[14] I am grateful to the suggestion of an anonymous reviewer on this point.

projected female age at first marriage for China in 2050 remains significantly below the current figures for Japan or South Korea where women today marry on average at 29. We have nevertheless refrained from increasing the proportion unmarried at age 50 in 2050 from its very low 2005 level, even if the rise of female singlehood is also a distinct possibility in tomorrow's China.

Alternative marriage models

The FD model corresponds to a reasonable scenario of future marriages based on both nuptiality changes among Asian women and a parallel rise in male bachelorhood. Yet, this system allows for almost no flexibility in marriage patterns since both female and male marriage schedules are fixed. We will in this section relax some of these assumptions and explore two alternative ways in which the marriage market may adjust to gender imbalances though changes in nuptiality schedule. The two main ways to reduce the intensity of the marriage squeeze consist in delayed marriage among surplus men, or in a symmetrical adjustment by both men and women to marriage imbalances (see methods and parameters in Appendix 2).

The first response of nuptiality system to mounting gender imbalances could correspond to a quicker rise in the average male age at first marriage. While in the previous FD model, the age difference between spouses remains constant, we postulate in this modified model that the nuptiality system will adjust to the mounting deficit of brides through an increase in male age at first marriage. To simulate such conditions, we will modify the FD model by positing a more rapid increase in male age at marriage corresponding to an increase by two years of the age gap at first marriage between men and women. Doing so will in particular favor the male population above 35 years, among which nuptiality rates have long been rather low in both China and India. The hypothesis of a delayed male marriage (DMM) presupposes that women would accept to marry older men than in the past, suggesting that social status or accumulated assets of old men compensate the age difference. This could also be interpreted as a lengthened search period among unmarried men caused by the diminishing number of prospective brides.

An entirely different response of nuptiality systems presupposes changes in both male and female marriage schedule. It is based on the harmonic mean (HM) model, probably the most commonly used marriage matching function[15]. This method provides the basis for a self-regulatory marriage system in which the surplus sex is assumed to temporarily defer union while the deficit sex is expected to marry earlier. According to this model, the deficit sex takes advantage of the relative surplus of the opposite sex by marrying earlier since their pool of prospective spouses has momentarily expanded. In other words, union is regarded as partly constrained by the number of suitable partners and marriage probabilities are expected to rise when the relative size of the unmarried population of the opposite sex increases. Since union has long been nearly universal among women in China and India[16], there is no pool of available unmarried women and the application of the HM model entails basically a reduction in female age at marriage. Such a short-term adjustment may be conceivable if current constraints on marriage –such as intense dowry negotiations in India or prohibition of early marriage in China– were relaxed. Similarly, the abundance of marriageable men could also improve the

[15] See Schoen (1981). Recent examples are found in Qian and Preston (1993); Raymo and Iwasawa (2005); Okun (2001). Some of its limitations of the harmonic mean method relate to the spillover effects (Choo and Siow 2006).

[16] This of course stands in complete contrast with the "Western" marital regime characterized by a sizeable and variable proportion of women remaining single at age 50, features that confer to this system a higher degree of flexibility.

probability of women of finding suitable partners by shortening the search period[17]. The analysis of past gender imbalances has indeed shown that flexibility of marriage patterns has allowed cohorts to adjust to short-term crises such as the consequences of war[18].

Results

Our simulations rely on three different population projections based on SRB parameters, namely the no-transition scenario, the rapid-transition scenario, and the normal-SRB scenario. These three scenarios lead to three different sets of age and sex distributions for the period 2005-2100. Based on these projected populations, we will examine in the first section below the extent of the marriage squeezes as measured by cross-sectional and longitudinal indicators. Since SRB may be over-estimated in China, we have also added the results of a sensitivity analysis based on lower SRB levels for this country (Appendix 3).

The results of marriage simulations presented in the following section are based first on the female dominance, which assumes that the nuptiality regime will be in future determined by the future course of female nuptiality. The outcomes of these simulations are given in terms of marriage tempo (age at marriage) and intensity (unmarried men at age 50). Finally, we use two additional marriage functions to study the different ways in which male and female nuptiality may adjust to the marriage crunch. These two models respectively correspond to the hypothesis of delayed male marriage and of symmetrical adjustment by both male and female nuptiality schedules.

A new look at the marriage squeeze

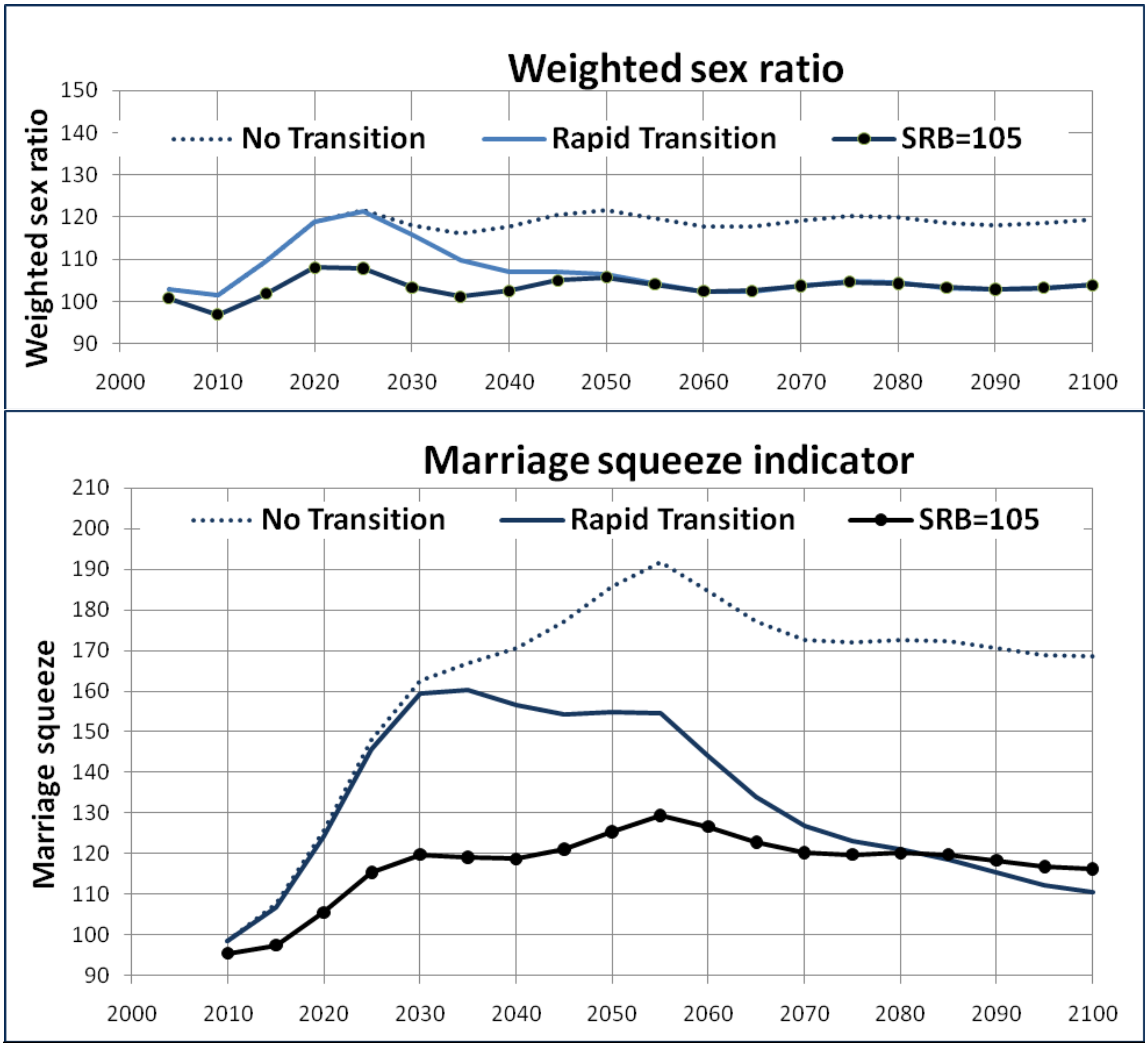
We start with the usual index of marriage squeeze computed as weighted sex ratios. As figure 1 indicates, the rise in the weighted adult ratio in China is rather abrupt after 2010 in both SRB scenarios. And the sex ratio reaches 122 in 2025. Results based on normal SRB scenario shows, the imbalance was bound to increase to 108 in 2020 because of the past fluctuations in birth cohort size in China[19]. Following the transitional scenario, the adult sex ratio will record an equally rapid fall after

[17] Better marriage opportunities for women and lower dowry costs in high sex-ratio societies are among the hypotheses put forward by Guttentag and Secord (1983) in a study devoted to the multifarious impact of skewed sex ratios on social institutions.

[18] See for instance both the pioneering studies by Louis Henry (1966, 1975) on sex imbalances and the impact of the First World War and of fertility decline in France. Similarly, marriage patterns among Japanese women have not been severely disrupted after the Second World War in spite of the deficit of male adults (Dixon, 1978).

[19] The number of births jumped in China after 1985 when post-famine "baby boom" cohorts –born in the mid-sixties– reached reproductive age. See also Goodkind (2006).

Figure 1 – Two indicators of marriage squeeze according to three SRB scenarios, China, 2005-2010



See text for details on SRB scenarios and indicators used

2025 and will oscillate around 104 during the second part of the century. As expected, the difference between the normal and rapid-transition scenarios reduces gradually and both series are similar in 2050 when the impact of surplus male births born before 2020 disappears. In contrast, the no-transition scenario suggests that the weighted adult sex ratio in China would not return to normal levels and would instead oscillate after 2025 around a high level of 119. Our results agree with findings already found in the literature on China suggesting that the marriage squeeze will peak in 2030[20]. In addition, our results also demonstrate that a significant part of the rise in weighted sex ratios observed before 2050 resulted from age structural effects.

[20] See for instance Jiang *et al.* (2007: 357). Zeng (2007) provides the only nuptiality estimate not based on cross-sectional indicators.

When measured through marriage simulations, the marriage squeeze in the future appears rather different from the preceding picture (Figure 1, Table 1)[21]. The marriage squeeze is notably far more intense and protracted than suggested by sex ratios computed on cross-sectional figures. In the more favorable rapid-transition scenario, marriage squeeze peaks at 160 in 2035, and does not decline substantially before 2060. We can also observe the sizeable impact of mere changes in age structures, with a marriage squeeze indicator reaching 130 in 2055 according to the normal-SRB scenario. If the sex ratio were on the contrary to remain stable at 120 (no-transition scenario), the marriage would be allowed to grow up to 190 and stabilize in later decades to 170. In each scenario, the apparent congestion in the marriage market appears significantly more intense than the initial disturbance (with SRB = 120).

Table 1 – Marriage indicators according to three SRB scenarios, China and India, 2010-2100

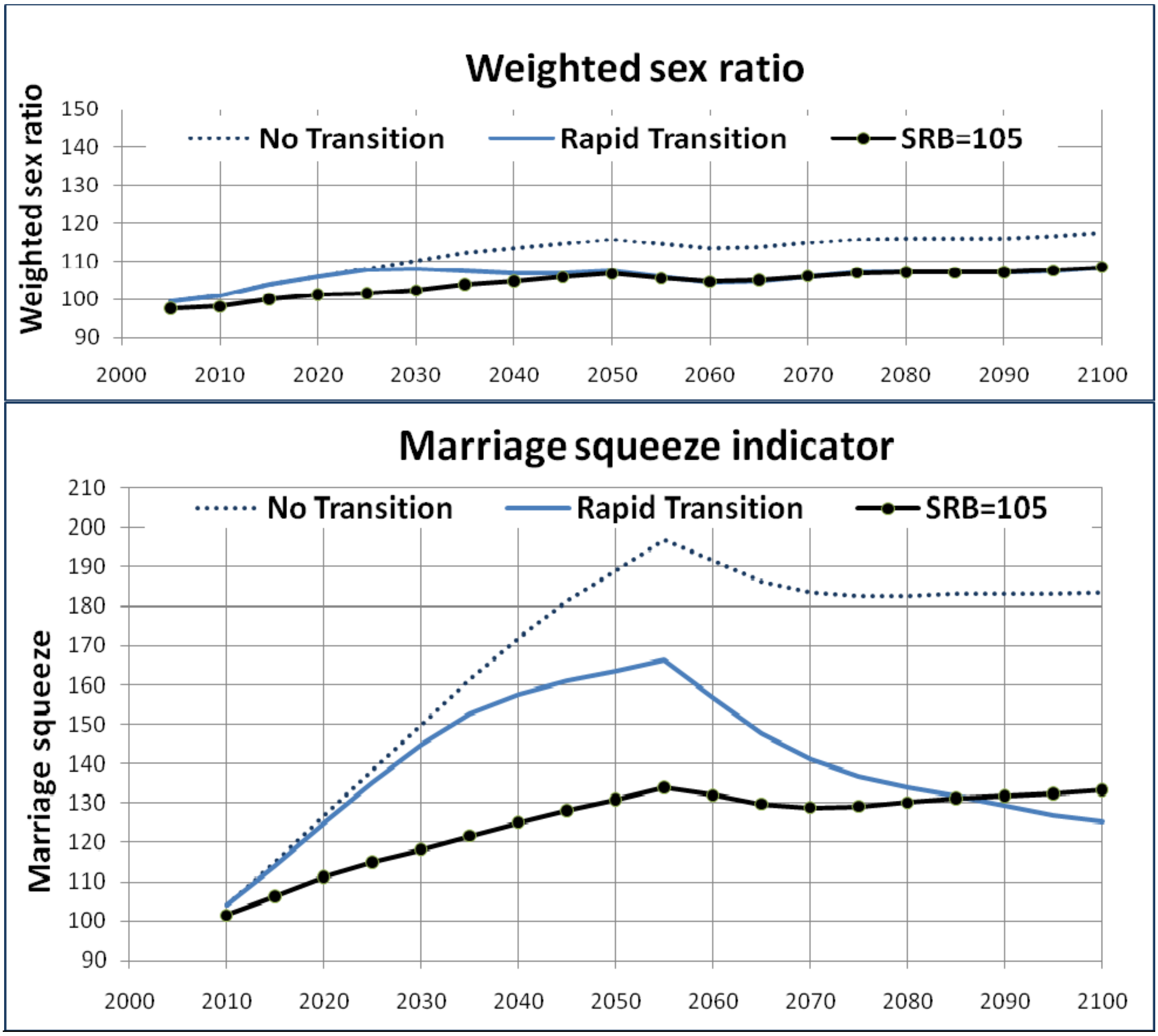
	Marriage squeeze indicator	Mean age at marriage		% single men at age 50	Marriage squeeze indicator	Mean age at marriage		% single men at age 50	Marriage squeeze indicator	Mean age at marriage		% single men at age 50
		Male	Female			Male	Female			Male	Female	
China	*No SRB transition*				*Rapid SRB transition*				*Normal SRB*			
2010	98.6	25.6	23.3	3.3%	98.6	25.6	23.3	3.3%	95.4	25.6	23.2	3.3%
2020	125.7	26.0	24.2	3.3%	124.1	26.0	24.2	3.2%	105.5	25.9	24.2	3.0%
2030	162.5	27.4	24.7	4.3%	159.5	27.6	24.7	4.1%	119.8	27.2	24.6	2.6%
2040	170.6	27.6	25.1	10.0%	156.6	28.0	25.0	9.3%	118.7	27.3	25.0	4.2%
2050	185.8	28.3	26.1	16.7%	154.8	28.6	26.0	14.5%	125.4	28.2	26.0	6.0%
2060	184.5	28.7	26.5	19.7%	143.9	28.8	26.5	14.6%	126.6	28.8	26.4	6.8%
2070	172.7	28.5	26.5	21.4%	126.8	28.5	26.4	12.8%	120.2	28.6	26.4	7.8%
2080	172.7	28.7	26.7	20.4%	121.0	28.7	26.7	9.6%	120.2	28.8	26.7	7.6%
2090	170.6	28.7	26.6	18.9%	115.4	28.8	26.5	7.2%	118.3	28.8	26.5	7.1%
2100	168.7	28.7	26.5	18.5%	110.4	28.8	26.5	6.0%	116.2	28.7	26.5	6.8%
India	*No SRB transition*				*Rapid SRB transition*				*Normal SRB*			
2010	104.0	24.3	19.5	1.1%	104.0	24.3	19.5	1.1%	101.5	24.3	19.5	1.1%
2020	126.9	25.0	20.2	1.3%	125.1	25.0	20.2	1.3%	111.3	24.9	20.2	1.2%
2030	149.9	26.1	21.2	2.5%	144.9	26.2	21.1	2.4%	118.2	26.0	21.1	1.6%
2040	172.0	27.2	22.1	5.4%	157.7	27.3	22.1	5.0%	125.0	27.0	22.1	2.7%
2050	189.0	28.1	23.1	9.3%	163.6	28.1	23.0	8.0%	130.8	28.0	23.0	4.1%
2060	191.4	28.7	23.5	12.9%	156.8	28.6	23.5	10.0%	132.0	28.7	23.5	5.6%
2070	183.4	28.7	23.6	14.9%	141.2	28.5	23.6	10.2%	128.8	28.7	23.6	6.7%
2080	182.6	28.6	23.7	14.9%	134.0	28.5	23.6	8.6%	130.1	28.7	23.6	7.0%
2090	183.2	28.7	23.6	14.3%	129.2	28.6	23.6	7.2%	131.8	28.7	23.6	6.9%
2100	183.6	28.6	23.6	14.2%	125.3	28.7	23.6	6.5%	133.3	28.6	23.6	7.1%

Notes:
- Marriage squeeze indicator: sex ratio of expected first marriages (per 100).
- Mean age at marriage computed on simulated marriages (Female dominance model) during the five preceding years.
- SRB scenarios and marriage simulation procedure described in the text and in Appendices 1 and 2.

[21] The intensity of the marriage squeeze is now computed as the sex ratio of expected first marriages –the ratio of expected male marriages to expected female marriages.

India's weighted sex ratios (Figure 2, Table 1) determine a smoother profile because of the country's far more regular age distributions and do not reach 110 in the transitional scenario. But we can at once notice the sizeable contribution of changes in age structures, which accounts for more than half of the rise in weighted sex ratios from the 2030s. The analysis is, however, more accurate when based on the longitudinal indicator of marriage squeeze. In the rapid-transition scenario, the index rises gradually up to 165 in 2055, in spite of the sex ratio transition completed in 2020. This rise has been obviously aggravated by shrinking birth cohorts as the marriage squeeze indicator in the normal-SRB scenario reaches 130 in 2050 and stays at this level until the end of the century. The more pessimistic scenario of high SRB results in a continuous rise in marriage imbalances until 2055, after which our indicator remains above 180 during the following decades.

Figure 2 – Two indicators of marriage squeeze according to three SRB scenarios, India, 2005-2010



See text for details on SRB scenarios and indicators used

Measurements based on marriage simulations in China and India correct the lower and shorter trends derived from the weighted sex ratios. We see in particular that because of the queuing effect, the marriage squeeze captured by this ratio is likely to be more intense than usually predicted and may not decline before 2060. Even in the more optimistic SRB scenario, the number of prospective grooms exceeds that of brides by more than half for three decades in a row in both countries. These results also contradict the somewhat reassuring picture for India where the weighted sex ratio remains below 110 in the rapid transition scenario. Even with SRB back to normalcy in 2020 and the last affected birth cohorts aged above 40 by 2060, the marriage squeeze remains elevated in India until the end of the century. This is an obvious consequence of the long-term impact of shrinking birth cohorts on marriage balances in India, which also explains why the marriage squeeze may become higher than China's after 2050 in spite of lower SRB levels.

Female dominance and the rise in male non-marriage

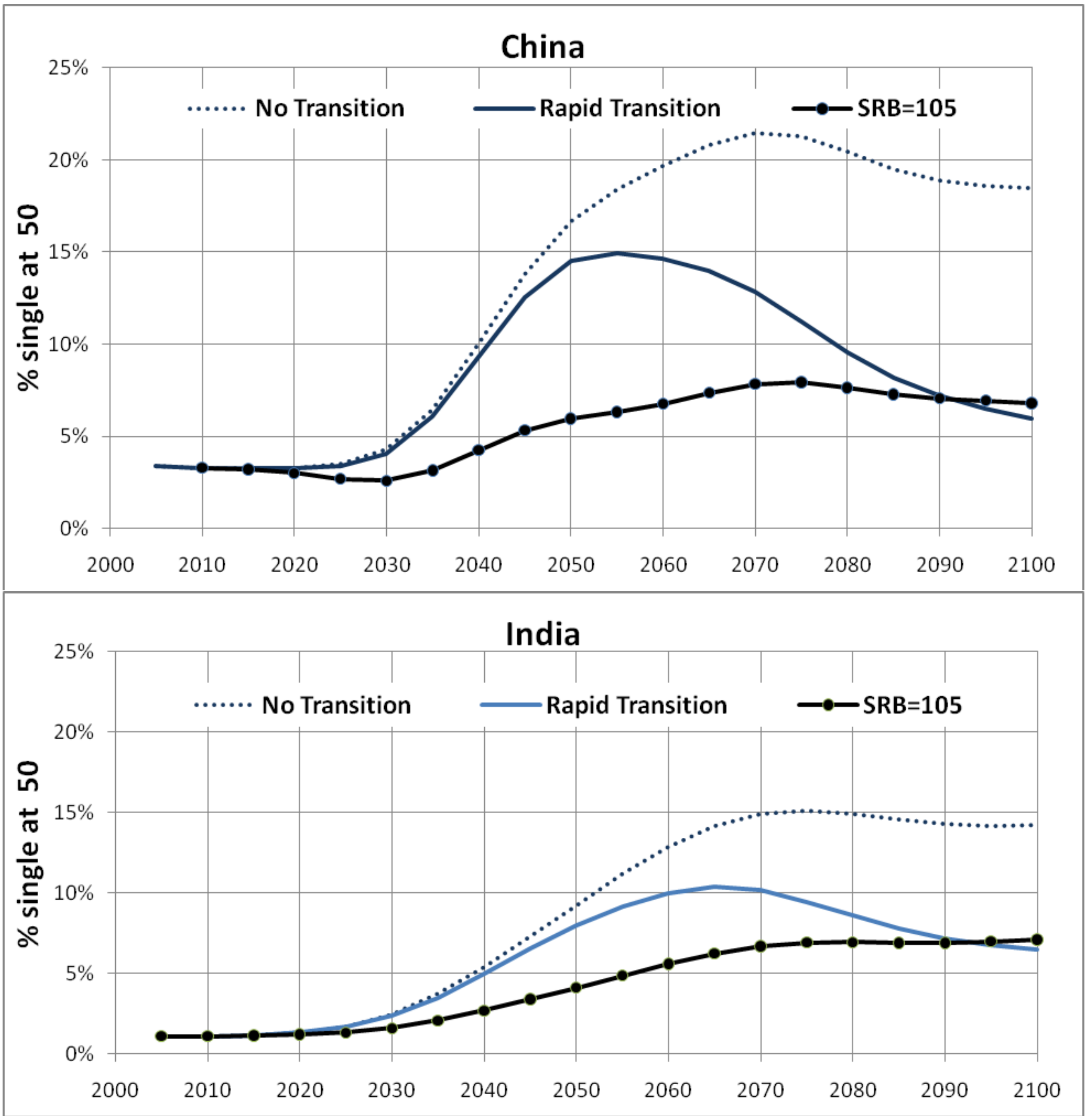
The next set of results translates the sex imbalances in the marriage market into proportions of men remaining single at age 50 (Figure 3). Starting with the Chinese case, we notice that the sex disequilibrium is not felt before 2030 in spite of the SRB rise observed since 1990. This suggests that older birth cohorts reaching the age 50 before 2030 are not affected. Our simulation however demonstrates the suddenness of changes after this date: the proportion of men never married reaches almost 10 percent in both scenarios during the ten following years. Irrespective of the scenario envisaged, the impact of gender imbalances at birth appears considerable during the 2030-2050 period. The proportion of unmarried men aged 50 rises from 3% before 2030 to 17% in 2050 and reaches 20% in 2060 in the no-transition scenario, an overall increase that parallels the long-term 120 SRB level assumed in this pessimistic scenario. As figure 3 also illustrates, a rapid SRB decline in China will not invert trends in male singlehood before 2055. It may be noted that the estimated proportion of bachelors at age 50 will only rise by 12% (from 3% to 15%). While the proportion decreases after 2055, the curve is skewed towards the right and the decline is slower than the initial rise because of the lingering marriage squeeze conditions.

Turning to India's case, results are on the whole parallel to China, although slightly more favorable because of the current gap in SRB levels (113 in India vs. 120 in China). The share of never married men at age 50 increases from 2030 onwards and attains 15% mark by 2070. In the rapid-transition scenario, this proportion of unmarried men would on the contrary reach only 10% in 2060 and decline slowly thereafter. In view of their respective SRB trends in the past, this maximal increase (from 1% to 10%) in India is late and proportionally larger than in China. The specific role of age structural factors in India is again attested by the simulations from the normal-SRB scenario in which age-structural changes would account for more than half of the simulated rise in male singlehood after 2050. In addition, the persisting gap between these simulations and the rapid-transition scenario also confirm that the disturbances in marriage systems caused by excess SRB in the early 21st century will be felt until the 2080s in both countries.

The alleviating effects of changing marriage patterns

We have run another set of simulations according to these two alternative scenarios of nuptiality adjustment. The results shown in table 2 and figure 4 also include results from the standard FD simulations discussed in the previous section. Out of simplicity, we have restricted our discussion to the rapid transition scenario.

Figure 3 – Proportion of single men at age 50 according to two SRB scenarios, China and India, 2005-2010



NT : No-transition scenario; RT : Rapid-transition scenario (see text for details)

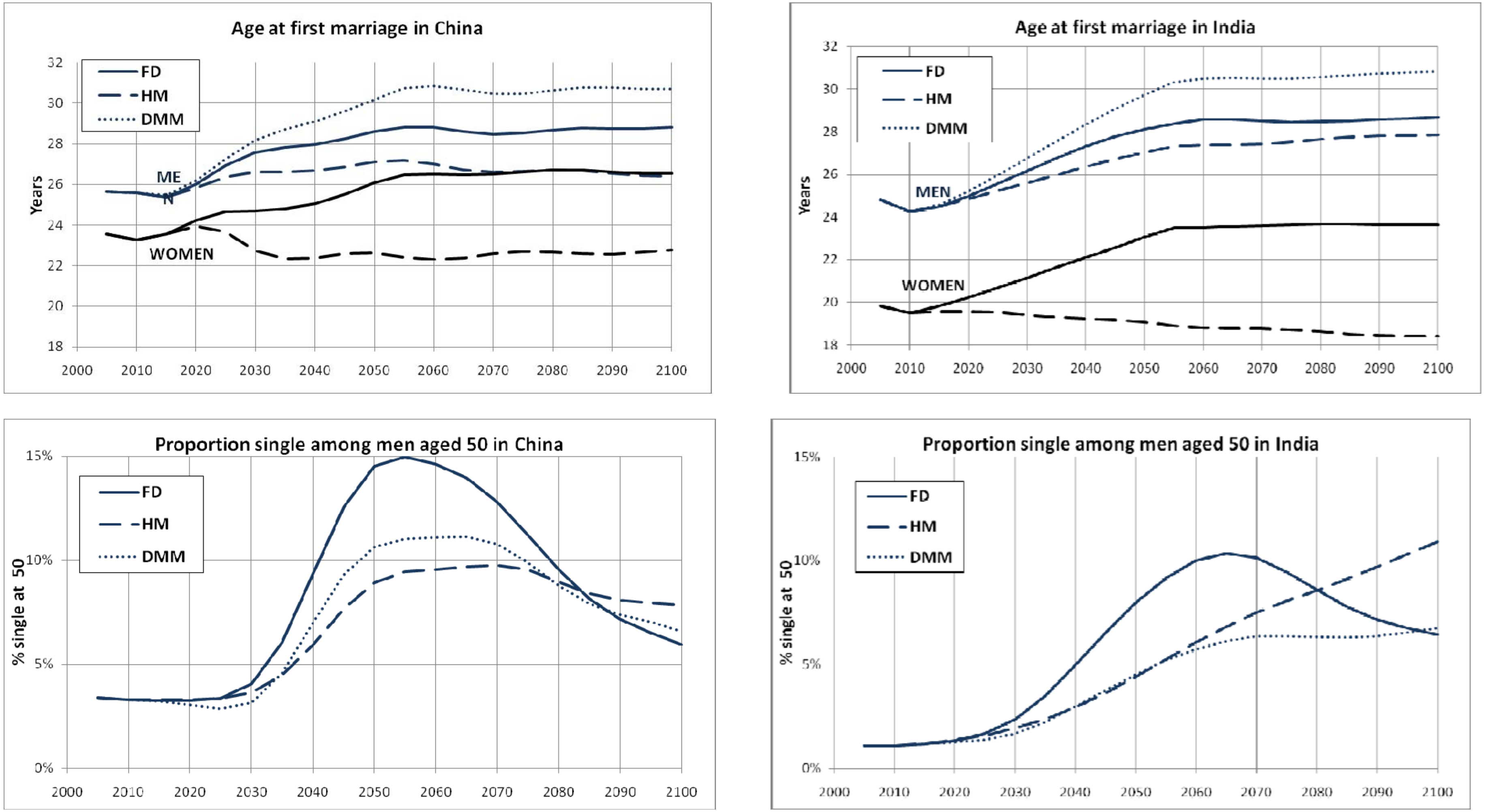
Table 2 – Marriage indicators according to two alternative marriage models, China and India, 2010-2100

	Marriage squeeze indicator	Mean age at marriage		% single men at age 50	Marriage squeeze indicator	Mean age at marriage		% single men at age 50
		Male	Female			Male	Female	
China	*Harmonic mean model*				*Delayed male marriage*			
2010	98.6	25.6	23.3	3.3%	98.6	25.6	23.3	3.3%
2020	117.2	25.8	24.0	3.3%	117.0	26.2	24.2	3.1%
2030	157.5	26.6	22.7	3.7%	148.0	28.2	24.7	3.2%
2040	156.3	26.7	22.4	5.9%	144.1	29.1	25.0	6.9%
2050	162.6	27.1	22.6	8.9%	144.9	30.2	26.0	10.6%
2060	157.2	27.0	22.3	9.6%	139.6	30.9	26.5	11.1%
2070	144.4	26.6	22.6	9.8%	124.1	30.5	26.4	10.8%
2080	145.8	26.7	22.7	9.0%	122.0	30.6	26.7	8.8%
2090	139.9	26.5	22.6	8.1%	117.7	30.8	26.5	7.4%
2100	135.8	26.4	22.8	7.8%	112.5	30.7	26.5	6.6%
India	*Harmonic mean model*				*Delayed male marriage*			
2010	104.6	24.3	19.5	1.1%	104.0	24.3	19.5	1.1%
2020	112.3	24.9	19.6	1.4%	111.5	25.2	20.2	1.3%
2030	123.5	25.6	19.4	1.9%	118.4	26.7	21.1	1.7%
2040	134.3	26.4	19.2	3.0%	121.9	28.3	22.1	3.0%
2050	145.1	27.0	19.1	4.4%	122.5	29.7	23.0	4.5%
2060	150.2	27.4	18.8	6.1%	120.5	30.5	23.5	5.7%
2070	156.9	27.4	18.8	7.5%	115.8	30.5	23.6	6.4%
2080	169.7	27.6	18.6	8.6%	117.1	30.5	23.6	6.3%
2090	177.4	27.8	18.5	9.7%	118.8	30.7	23.6	6.4%
2100	184.7	27.9	18.4	10.9%	119.3	30.8	23.6	6.7%

Notes:

- Marriage squeeze indicator: sex ratio of expected first marriages (per 100).
- Mean age at marriage computed on simulated marriages during the five preceding years.
- M= male; F= female
- Rapid transition scenario used in these simulations
- Harmonic mean model: symmetrical adjustment of male and female marriage rates (see text and Appendix 2)
- Delayed male marriage: gradual increase by 2 years of the male-female age difference at marriage by 2050 (see text and Appendix 2).

Figure 4 – Mean male age at first marriage and proportion single at age 50 according to three marriage models, China and India, 2005-2010 (rapid transition scenario)



FD: Female dominance model; HM: Harmonic mean model; DMM: Delayed male marriage model (see text for details

The delayed male marriage model is the easiest to interpret as no additional change is postulated in female nuptiality. In China, the male age at first marriage would rise by an extra two years in 2050 and would fluctuate thereafter around 30.7 years. Our simulations demonstrate that this further delay in male marriage would cause a significant decline in the number of men unable to marry. The gain is already perceptible in 2030, but swells during the next two decades. It peaks in 2050 when the male singlehood rate reaches 10.6% –against 14.5% predicted in the standard model. In India, the gain in male nuptiality is also considerable, but tends to peak later on: in 2070, the DMM model corresponds to a decline of 4% in the male singlehood rate at age 50. In both countries, higher age at marriage among men also reduces the marriage squeeze (Table 2). This strategic trade-off between tempo and intensity of male nuptiality is only temporary and gradually dissipates during the second part of the century. At the end of the century, increased age difference between spouses may in fact become a disadvantage because of age-structural changes.

The harmonic mean model illustrates a more complex readjustment process since it affects both men and women. Our results confirm in particular that higher marriage probabilities among women would slow down substantially the overall impact of the forthcoming male surplus in the marriage market. In China, the HM model corresponds to a slower increase in male age at marriage, reaching 27 years in 2060, while in contrast, the average age at first marriage among women falls down after 2020 to 22.5 years and oscillates around this value during the following decades. The age gap between spouses would rise to 4 years. In terms of male nuptiality intensity, the impact in China appears considerable since the singlehood rate at age 50 remains below 10% during the entire century, at levels that are 5% below our standard simulations in 2060. But during the last quarter of the century, the HM model leads to rather disappointing results as the male singlehood rate fails to decline significantly. In fact, the elevated age difference caused by the HM assumptions becomes detrimental to men and yields a higher proportion of unmarried men at the end of the century than the standard FD model. Results of the application of the HM model to India similarly point to a reduction of the sex ratio crisis as in the DMM model. After 2060, the HM model leads, however, to an unstable system in which singlehood rates continue to rise in spite of the rapid disappearance of the original sex imbalance at birth. In the meantime, the age gap between men and women is also allowed to progressively rise to almost 10 years, resulting in a severe structural disequilibrium between cohorts of prospective brides and grooms.

We may conclude at this point that the harmonic mean method is probably not the appropriate technique for simulating the response of nuptiality systems to long-term sex imbalances. For all its algebraic elegance, the HM model does not appear to be sociologically plausible. Symmetrical short-term adjustments in nuptiality patterns remain in theory possible, but mounting sex imbalances are unlikely to lead to a durable reduction in the female average age at first marriage. Results pointing for instance to a female age at marriage below 19 in India appear highly inconsistent with the nuptiality trends documented in a previous section. There are therefore strong reasons to believe that the harmonic mean model –and possibly other homeostatic models based on symmetrical marriage flexibility– is not applicable in our case[22].

[22] As Hinaba (2000: 395) succinctly puts it, “Intuitively it would be difficult to believe that a simple mathematical function Ψ such as harmonic type could well describe the real marriage behaviour of humans.” For critical discussion of the harmonic model, see also Iannelli et al. (2005: 38-41). A long-term study of nuptiality patterns in Spain using on the harmonic mean model concludes that most changes were driven more by behavioural factors than by age-sex compositional changes (Esteve et Cabré, 2009).

Synthesis of the results

We believe that the results of our simulations shed new light on the current masculinity crisis in Asia by translating demographic projections of skewed population structures into specific outcomes of future nuptiality change. Based on a new set of population projections, we have favored here a cohort-based procedure to simulate marriage patterns in 21st century's Asia. Since based on simulation, our findings remain heuristic rather than predictive, but we have selected SRB and marriage parameters in keeping with the current literature on demographic change in Asia. It may be added that while China is usually the centre of attention, the inclusion of India in our exercise demonstrates the seriousness of gender imbalances in this country and the potential contribution of age structural changes in the forthcoming deficit of marriageable women.

While straightforward projections suggest the inevitability and the magnitude of future gender imbalances, the simulation approach yields better estimates of the potential timing and the final impact on marriage patterns than usual cross-sectional measurements. It shows in particular that even cohorts born after a rapid decline in birth masculinity may be affected by substantial disruptions in nuptiality patterns and that the surplus of men is likely to affect both countries during the second part of the century. Using the normal-SRB projections, we can evaluate the consequences related to long-term changes in age structures and demonstrate in particular that differences between China and India are not reducible to their current difference in SRB levels.

Beyond methodological issues, the first lesson of these simulations is the extent of the impact of skewed sex ratios at birth on demographic structures, and the additional influence of fertility decline and the ensuing age structural changes. The number of men unable to find a spouse is going to rise only in twenty years, but the increase would probably be abrupt in the absence of change in marriage schedule among them. Our estimates for China point to a jump of the proportions single at age 50 from 3% now to 15-21% in 2060, depending on the date of an eventual SRB decline. Marriage simulations show that even if the sex ratio at birth is allowed to come back to 105 by 2020, a rather optimistic assumption, gender imbalances will severely affect the marriage market and the nuptiality patterns of male cohorts during the second half of the century. A rapid transitional scenario corresponds to about 15% of China's male population born during the first decade of the century remaining single. Lower SRB levels observed today in India tend to suggest a better situation, with singlehood rates remaining below 10% if the birth masculinity were to decrease within the next 15 years, but the future reduction in birth cohort size would slow down the recovery after 2050.

When converted in population figures, the current SRB crisis in China corresponds to an extra 8.1 million single men reaching age 50 during the 2050 decade. The cumulated number of these additional bachelors over the 2020-2080 period should exceed 32 million. In India, the situation would be hardly more favorable since Indian population cohorts will be significantly larger than China's[23]. As a result, the cumulated number of additional men remaining single during 2020-2080 could be closer to 40 million in India according to our simulations. In addition, it should be remembered that were a significant proportion of women in China and India to renounce marriage–as seen today in Japan or South Korea–or to opt for younger rather than older partners, the proportion of men remaining single would obviously rise even further than suggested here. Any delay in the ultimate SRB decline would

[23] These estimates are derived from the difference between the proportion single as in 2005 and the simulated figure in the rapid transition scenario (female dominance model).

have similar consequences. In this respect, our simulations represent a somewhat conservative scenario of female nuptiality in future. But this also suggests that future female nuptiality in Asia will hold the key to the gender imbalances during the 21st century.

Implications

The social consequences of sex imbalances on marriage patterns remain unpredictable for several reasons. It may first be noted that no such massive surplus of adult males has been recorded in the recent past. Many areas or countries, in the wake of large-scale conflicts or mass out-migration of men, were indeed affected by male deficits[24]. Yet SRB distortions over a period of more than two decades as observed in several Asian countries involve a much larger population and the extent of the resulting deficit may rise into tens of millions. An additional difficulty in envisioning the consequences of current masculinization processes stems from our limited understanding of Asian family systems' capacity to cope with the forthcoming marriage squeeze.

Among the potential adjustments within the current marriage system, late union among men is a more plausible response than early female marriage. If being older is perceived as an additional advantage for men in the marriage market because of its correlation with personal assets and earning capacity, a much larger proportion of men than before may end up marrying after 35 years. It has recently been observed that sex ratio imbalances may generate a subsequent increase in saving rates – as a response to the increasing competition among men in the marriage market (Wei and Zhang, 2009). The decrease in male singlehood attributable to later marriage can be computed from our simulations: an increase by one year in male age at marriage would reduce singlehood rates at age 50 by nearly 2% (1.7% in China and 2.3% in India). This result is by no means negligible in view of the number of years affected and the average cohort size: the reduction of the marriage squeeze caused by delayed male nuptiality illustrated by the DMM model would indeed reduce the cumulated numbers of unmarried men at 50 in China and India computed previously by 11 and 19 million respectively.

Higher male age at first marriage is therefore susceptible to alleviate the marriage squeeze for several decades. But it will not be sufficient to entirely cancel out its impact. There are of course many other ways in which nuptiality system could in theory adjust to the growing gender disequilibrium: higher rates of divorce and remarriage among women, polyandry, same-sex unions among men, etc. Some of these changes would obviously require major transformations in society and their impact may be modest or marginal. But increased marriage mobility is another option, especially since traditional marriage systems in Asia are quite rigid and impose fixed constraints on when, where and whom to marry[25]. Recent research and press reports have already documented changes in marriage systems in the most affected regions of South Asia (Kaur, 2004, 2008). Trafficking of brides has also increased dramatically in specific regions in direct relation to local skewed sex ratios (Shakti Vahini, 2003; Young and Yang, 2005).

[24] For instance, the case of Viet Nam in the 1980s combines both factors: excess war-related male mortality and high rates of male emigration (Goodkind, 1997).

[25] This is notably true of India, where strong sub-caste endogamy has long resulted in geographically narrow migration fields (Libbee, 1980). In China, though the role of family networks and of professional brokers is still prominent in marriage arrangements, interregional marriage migrations of women have become more common over the last 20 years (Davin, 2005; Fan and Huang, 1998).

Large-scale international migrations may also appear as an effective solution to the gender gap. After all, both countries are already the biggest providers of out-migrants in the world. But the annual volume of net migration is currently much smaller (0.38 and 0.27 million respectively for China and India) than the projected gender gap, that will soon amount to about 1.1-1.2 million per year in China and in India[26]. Higher out-migration rates in the future appear therefore rather improbable within the current international migration system. Reverse migrations of brides towards China and India, a phenomenon observed in more advanced South Korea or Taiwan (Kim, 2008), have mostly taken the form of cross-border trafficking of women involving countries such as Nepal, Bangladesh, Viet Nam, Mongolia or North Korea (Le Bach *et al.*, 2007; Blanchet, 2005; Davis, 2006; ADB, 2002), but they are unlikely to fill the gap.

It seems therefore ineluctable that men in China and India will, on average, spend an increasing span of their adult life unmarried and that gender imbalances will toll the knell for universal marriage among them. There are already doomsday scenarios related to what this prolonged bachelorhood would entail, especially in terms of disruptive behaviour and social anomy (Hudson and Boer, 2004). Such reasoning envisage the situation in which men unable to marry give up the marriage market and withdraw from traditional societal roles, such as head of household or breadwinner, to adopt risky behaviour of various kinds including protest and violent activities, increased mobility, etc. But contemporary Asian small-family settings are very different from those of the past in which younger brothers, often deprived of family rights, had to fend for themselves away from the community. For both social and emotional reasons, parents would today be less likely to allow their only sons to withdraw from the household. A more worrying scenario corresponds to a potential clustering of bachelorhood in a few socially disadvantaged groups whose women marry out.

Regarding women, changes in the demographic equation may not improve their status in all domains. The marriage market may sound favorable, offering them in theory a larger range of prospective spouses. But tensions felt by surplus males have already resulted in increasing gender-based violence and abuse such as forced marriage, abduction, and trafficking. Other indirect unintended consequences, such as increase in crime rates and spread of HIV observed in China may affect both sexes (Tucker *et al.*, 2005; Tucker and Poston, 2009; Edlund *et al.*, 2007).

At the same time, there is no reason for social systems to remain unable to absorb a part of this rise in male bachelorhood even if this disrupts the traditional patriarchal set-up. The proportion of bachelors in Japan has for instance increased during the last 20 years to levels above 15%, without any subsequent social unrest. There are many examples in Europe of elevated singlehood rates. It seems therefore somewhat hazardous to ponder at this stage on the actual behavioural changes caused by the rising risk of no-marriage among men, especially as in-depth field research describing how individuals and families cope with the changing demographic equation has hardly begun. In fact, no finer analysis of the local processes of social change induced by demographic imbalances will be possible without insights from quantitative and qualitative surveys conducted in the most affected areas of China or India to understand how individuals and family systems cope with the growing sex imbalances and how marriage patterns are likely to evolve.

[26] Estimates of net international migration in 2000-05 are from the United Nations database (United Nations, 2007). These migration figures include, however, a large proportion of women.

Appendices

Parameters for population projection

Table 3 sums up the parameters used for the projections of China's and India's populations till 2100. Projections were done with the cohort-component method of the software package Spectrum (DemProj model) and we have assumed no international migration during the period under examination. Population figures and demographic parameters were borrowed from the medium variant of the world projections by the Population Division (United Nations, 2007). For the 2005 baseline year, population and demographic parameters come from the United Nations estimates and these parameters incorporate in particular the current level of female excess mortality among children. However, two adjustments had to be made for China:

- The sex distribution derived from the 2005 1% survey –in which male adults are severely underestimated– was corrected by using the estimated sex ratio for the entire population in 2005 and the cohort-specific sex ratio for adults aged 15-54 during the 2000 census.
- China's fertility in 2005 was taken as 1.6 children per woman, a medium value derived from available TFR estimates by Retherford *et al.* (2005), Lutz *et al.* (2007), Zeng (2007) and Cai (2008).

Values used for the 2050-2100 period were derived from two different sets of long-term projections prepared by IIASA (Lutz *et al.*, 2008) and by the Population Division (United Nations, 2004).

Table 3 – Parameters used for demographic projections, 2005-2100

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="4">China</th><th colspan="4">India</th></tr>
<tr><th>2005</th><th>2020</th><th>2050</th><th>2100</th><th>2005</th><th>2020</th><th>2050</th><th>2100</th></tr>
<tr><td colspan="2">Total fertility</td><td>1.60[a]</td><td>1.68[a]</td><td>1.85</td><td>2.1[a]</td><td>2.96</td><td>2.23</td><td>1.85</td><td>1.85[a]</td></tr>
<tr><td rowspan="2">Life expectancy</td><td>Male</td><td>70.9</td><td>73.4</td><td>78.0[a]</td><td>82.0[a]</td><td>62.4</td><td>66.9</td><td>74.0[a]</td><td>82.0[a]</td></tr>
<tr><td>Female</td><td>74.2</td><td>77.1</td><td>82.0[a]</td><td>86.0[a]</td><td>65.3</td><td>70.6</td><td>78.0[a]</td><td>86.0[a]</td></tr>
<tr><td rowspan="2">Baseline 2005 population</td><td>No transition and rapid transition</td><td colspan="4">Corrected 2005 distributions[b]</td><td colspan="4">United Nations 2005 estimates</td></tr>
<tr><td>Normal SRB</td><td colspan="4">Estimated 2005 distribution[c]</td><td colspan="4">Estimated 2005 distribution[c]</td></tr>
<tr><td rowspan="3">SRB</td><td>No transition</td><td>120</td><td>120</td><td>120</td><td>120</td><td>113</td><td>113</td><td>113</td><td>113</td></tr>
<tr><td>Rapid transition</td><td>120</td><td>105</td><td>105</td><td>105</td><td>113</td><td>105</td><td>105</td><td>105</td></tr>
<tr><td>Normal SRB</td><td>105</td><td>105</td><td>105</td><td>105</td><td>105</td><td>105</td><td>105</td><td>105</td></tr>
</table>

- **Units**: Fertility in children per woman; Life expectancy at birth in years, Sex ratio at birth in male births per 100 female births.
- **Sources**: Mortality and fertility estimates are from the Population Division (United Nations 2007), except for: [a] estimated by the author or derived from Lutz *et al.* (2008) and United Nations (2004); [b] Correction method described in Appendix 1.[c] Corrected population structures with SRB constant at 105 since 1980 described in Appendix 1
- All intermediary values for 2005-2100 are interpolated

The first two SRB scenarios described in the text are used to calculate the share of male and female births in each five-year birth cohort in 2005-2100. SRB figures used for 2005 (120 for China and 113 for India) are taken from the 2005 1% survey for China and from estimates by the Sample Registration System for India. The most recent estimate by China's National Bureau of Statistics puts the SRB at 121 for 2008. It remains that SRB levels used here are only estimates in view of the possibility of girl underenumeration in China and of sample issues in India[27]. We have not attempted here to provide an alternative set of SRB estimates and only the next round of censuses in both countries will provide the more detailed figures required to re-estimate SRB levels. But in order to account for the possibility of female underregistration in China, we have also run a set of simulation with lower SRB (see Appendix 3).

For the simulation based on normal SRB (with SRB constant at 105), we have also corrected the 2005 baseline data for China and India as they are affected by past SRB imbalances. To do this, we have modified the 2005 sex distribution of the population below 25 years in order to reflect a normal sex ratio distribution. For India, we have computed correction factors for each five-year period since 1980 based on SRB estimates (see Kulkarni, 2009) and we have applied them to the 2005 sex ratio for all age groups below 25 to compute the corrected sex and age distributions used in this projection. In the absence of a similar series for China, we have used the average sex ratios of five-year age groups computed from United Nations estimates for the world after removing China and India. The resulting 2005 baseline populations used in the normal-SRB scenario are therefore different from the other baseline populations only for sex distribution of the population below 25.

Parameters and procedure for marriage simulations

The nuptiality parameters are given in table 4, starting with estimates for 2005. As neither China nor India publishes marriage rates by age, we had to resort to indirect estimates based on successive age and sex distributions by marital status to compute the nuptiality table for 2000-2005 by five-year age group from age 15 to 50. The marriage schedules for China were computed longitudinally by combining the distributions from the 2000 census and from the 2005 1% survey. Similarly, we used the two NFHS rounds of 1998-99 and 2005-06 (IIPS, 2007) for India. These 2005 marriage rates from 15 to 50 have been used to compute the weighted adult sex ratio (computed on age distributions weighted by age specific marriage rates) displayed in figures 1 and 2[28].

To simulate marriages in five-year cohorts, we used the marriage probabilities derived from marriage schedules as well as remarriage correction factors in order to account for remarriage (below age 50). These correction coefficients for remarriage were derived from two sources: the proportion remarried in the 2000 and 2005 Chinese surveys and the proportion of remarried men and women in India according to the latest NFHS data for India. From the standard marriage schedules, we also derived other marriage schedules used in our models for the second half of the 21st century by increasing the proportion marrying after age 25 (women) and 30 (men). All marriage and remarriage parameters between 2005 and 2050 are interpolated. The marriage simulations are limited to unions occurring before the age of 50.

The simulation process starts from the 2005 five-year age distributions by sex and marital status. Marriage probabilities derived from marriage schedules are first applied to the single population in

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[27] A more detailed discussion on SRB estimation issues for China and India may be found in Goodkind (2008) and Kulkarni (2009).

[28] For weighted sex ratios corrected for remarriages, see Jiang *et al.* (2007: 357).

2005, yielding the number of expected first marriages for men and women in 2005-10[29]. The marriage squeeze indicator (Figures 1 and 2) is then computed as the sex ratio of these expected first marriages after correction for remarriages. Because of the male preponderance, this ratio is usually above 100 and the final number of simulated first marriages is determined by using one of the marriage models described below. The number of men and women remaining single in 2010 is then computed for each cohort from the projected populations and the simulated numbers of first marriages during 2005-10 according to each marriage function. With the computed 2010 distributions by age and marital status, the same procedure is then repeated successively until 2100 with specific nuptiality parameters for each five-year interval (Table 4).

Table 4 – Nuptiality parameters used for marriage simulations, 2005-2100

		China			India		
		Mean age at first marriage	**Never married at 50**	**Remarriage correction [a]**	**Mean age at first marriage**	**Never married at 50**	**Remarriage correction [a]**
2005	**Male**	25.7	3.5%	103.1%	24.8	1.1%	108,0%
	Female	23.5	0.2%	103.6%	19.8	0.6%	102.5%
Female dominance 2050-2100	**Male**	28.7	Same as in 2005		28.5	Same as in 2005	102.5%
	Female	26.5	Same as in 2005		23.5	0.2%	102.5%
Delayed male nuptiality 2050-2100	**Male**	30.7	Same as in 2005		30.5	Same as in 2005	102.5%
	Female	26.5	Same as in 2005		23.5	0.2%	102.5%
Harmonic mean model 2050-2100	**Male Female**	Same as in 2005			Same as in 2005		

- **Sources**: Derived from 2005 age distributions by marital status (see Appendix 2 for detail).
- **Notes**: [a] Remarriage correction=All marriages as proportion of first marriages.
- All intermediary values for 2005-50 are interpolated

Marriage models used in this paper are the following:

- In the *female dominance model* (Table 1), the number of simulated marriages is set by the number of expected female marriages. In case of male surplus, male marriages are uniformly reduced across all age groups to match the available supply of brides. In this model, female nuptiality patterns are also allowed to change gradually over 2005-2050 (rise in age at first marriage in China and India, change of remarriage coefficients in India), but the difference in age at marriage between men and women remains constant throughout.
- The *delayed male marriage model* (Table 2) is a variant of the previous *female dominance model*, in which the male age at marriage is made to rise faster than the female age at marriage: the average age difference between men and women increases by two years in China and India from 2005 to 2050 and remains constant afterwards.
- In the *harmonic mean model* (Table 2), the simulated number of marriages is the harmonic mean of male and female expected marriages (Keilman, 1985). With M the expected number of male marriages and F for female marriages, the actual number of marriages μ is computed as $\mu =$

[29] Age specific marriage rates have to be adjusted in the FD model in order to achieve the desired age gap between men and women The specific age distributions of unmarried men and fluctuations in cohort size (especially in China) tend to distort the observed age at first marriage among men.

(2.*M*.*W*)/(*M*+*W*). The adjustment ratio (simulated number/expected number) is applied to expected marriage rates by age and sex. The adjusted probability of marriage is capped to one in each age group.

Sensitivity analysis of female birth underreporting

As indicated previously, SRB levels used here are only estimates since data for China and India are not based on exhaustive civil registration sources and our simulation exercise remains therefore potentially sensitive to the quality of the estimates. To assess the sensitivity of our model, we have run a different set of population projections and marriage simulations based on lower SRB levels. We have restricted our analysis to China where SRB is both higher and more likely to be affected by estimation issues than in India. In particular, Chinese fertility is notoriously underestimated by recent surveys and censuses and female births might be more underreported than male births, resulting in exaggerated SRB estimates.

Based on this hypothesis, we postulate here that the real SRB is 113 in 2005, with male and female underreporting rates respectively of 15% and 20%. This corresponds to an excess of 5% in underreporting rates for female births. The impact of this rather high level of selective female under-registration will help to assess the sensitivity of our simulations. All other population and marriage parameters are kept similar to those of the rapid transition scenario shown in table 4. In particular, the SRB level is expected to return to normalcy in 2020.

Results in table 5 demonstrate that a lower SRB contributes to reducing the male excess in the marriage market and to increasing the male probability to marry. However, the overall impact of lower SRB (113 in 2005) is barely visible before the 2040s and remains modest thereafter. For instance, the marriage squeeze indicator diminishes from 156.6 in 2040 to 151 according to the lower SRB scenario. The difference between the two series almost disappears after 2060. The estimated proportion of unmarried men at 50 also rises more slowly during 2050-80 with these parameters, but the difference with the standard SRB scenario never exceeds 1%. This sensitivity analysis suggests therefore that SRB overestimation appears to have but a minor effect on our marriage simulation.

Table 5 – Marriage squeeze indicators and proportion of unmarried men at age 50 according to lower SRB estimates, China, 2005-2100

China	Rapid transition		Same with lower SRB estimates	
	Marriage squeeze indicator	% single men at age 50	Marriage squeeze indicator	% single men at age 50
2010	98.6	3.3%	98.6	3.3%
2020	124.1	3.2%	124.4	3.3%
2030	159.5	4.1%	157.6	4.1%
2040	156.6	9.3%	151.0	9.3%
2050	154.8	14.5%	150.8	13.9%
2060	143.9	14.6%	141.0	13.7%
2070	126.8	12.8%	125.5	12.1%
2080	121.0	9.6%	120.0	9.1%
2090	115.4	7.2%	114.5	6.9%
2100	110.4	6.0%	110.0	5.8%

Notes:

- Rapid transition of SRB postulated in both models
- Rapid transition results taken from Table 1
- Lower SRB scenario based on a 5% female excess in underreporting rates (see Appendix 3 for details).

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