Son Preference, Sex Ratios, and Marriage Patterns

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Preference for sons over daughters is widespread in many Asian countries, for example, India, China, and South Korea. This paper models endogenous sex choice and shows that unbalanced sex ratios are but one of several possible consequences of a preference for sons. In particular, if parents want children who reproduce, nonrandom mating may cause women to be consistently born into low-status families and thus relegated to a permanent underclass. The paper also discusses possible links between son preference and marriage patterns such as spousal age gaps, hypergamy (women marrying up), caste endogamy, and cousin marriages.

I. Introduction

The biologically normal population sex ratio (sons to daughters) at birth ranges from 1.03 to 1.06. In 1986 the figure for China was 1.11 (Hull 1990); four years later it had risen to 1.14 (Tuljapurkar, Li, and Feldman 1995), which could imply that for every 100 girls born, at least nine are missing. China is not an isolated example; other

Many thanks to Tore Ellingsen, whose support and advice have been absolutely instrumental. The paper has benefited from comments by Marcus Asplund, Gary S. Becker, Ted Bergstrom, Jonas Björnerstedt, Ronald Findlay, Mia Horn af Rantzien, Ari Kokko, Johan Lagerlöf, Casey B. Mulligan, Åsa Rosen, Anna-Maria Oltorp, Xavier Sala-i-Martin, Örjan Sjöberg, Anna Sjögren, Joakim Stymne, Robert Topel, seminar participants at Lund and Umeå University and the Stockholm School of Economics, as well as two anonymous referees. The paper is based on a chapter in my Ph.D. dissertation at the Stockholm School of Economics. Financial support from the Swedish Council for Planning and Co-ordination of Research and Jan Wallander and Tom Hedelius's Foundation for Social Science Research is gratefully acknowledged. All remaining errors are mine.

[*Journal of Political Economy*, 1999, vol. 107, no. 6, pt. 1]

countries, notably India and South Korea, have recorded an even higher deficit of daughters. Traditional methods for sex targeting—for example, coital timing, infanticide, or neglect and abuse of daughters—are unreliable (e.g., James 1997), costly, or both. Modern technology offers a more convenient solution—prenatal sex determination. The need to curb population growth and to control the ''quality'' of the population has prompted China and India to promote increasing usage of ultrasound examination of fetuses. Today, one of its main uses is to ensure male offspring; banning of the practice has proved ineffectual (e.g., Banister 1987; Das Gupta 1987; Royston and Armstrong 1989; Johansson and Nygren 1991; Li 1992; World Health Organization 1992; Zeng et al. 1993).

It is widely believed that prenatal screening could eventually favor females, even if used to exercise preference for sons. For instance, men could be the ultimate losers as women become increasingly scarce (e.g., Park and Cho 1995). And even if one ignores the marriage market, females might benefit from scarcity as suggested by Samuelson (1985) and Davies and Zhang (1997). Moreover, it has been suggested that daughters might actually fare better under prenatal selection (Goodkind 1996), the argument being that postnatal discrimination is thus made redundant.

This paper takes a less sanguine view. I shall argue that the greatest danger associated with prenatal sex determination is the propagation of a female underclass.[1] My point of departure is that if people want not only sons but sons who marry, there must be daughters somewhere.[2] If one assumes that a woman faced with two marriage proposals will choose the most attractive of the two men and that social position and wealth are important components of attractiveness, then the risk of celibacy could be greater for sons from low-status families.[3] Provided that parents care about the marital status of offspring, low-status parents might therefore opt for daughters despite a preference for sons. Still, not all women need to end up at the bottom half of the social spectrum if parents prefer a daughter who could marry up to a son who would marry down.

Hence this paper claims that son preference can propagate social stratification by sex, stratification that in turn has further conse-

[1] Examination of the consequences of son preference may be viewed as a complement to the existing literature on its origins (e.g., Rosenzweig and Schultz 1982; Dasgupta 1993).

[2] For instance, Confucianism pivots around the father-son relationship, a chain in obvious need of women for maintenance.

[3] In South Korea, the deficit of women has primarily hit young rural men, many of whom have turned to importing brides from China (Park and Cho 1995). In China, the hinterland has become a net exporter of brides to the more advanced coastal areas (Fan and Huang 1998).

quences for marriage patterns. Obviously, if women are born in families of lower status than men, women will marry up. In fact, hypergamy is the socially more accepted, and presumably more common, form of mixed-class unions.[4] Spousal gaps are not restricted to status. Throughout the world, men tend to marry younger women. The age gap is narrowing in developed countries but remains high in many developing ones. In Asia and the Middle East, the largest (average) age gap for first marriages is found for Bangladesh (7.2 years), followed by Egypt (5.5), Pakistan (5.1), Morocco (4.9), and India (4.7) (Bergstrom and Bagnoli 1993, table B1). These are also countries in which the preference for sons is well documented (e.g., Das Gupta 1987; Royston and Armstrong 1989). We shall see that son preference can produce a backlog of unmarried men who, if eventually married, drive up the average age gap. Furthermore, the paper shows that if son preference is mitigated by a desire to marry children well, caste endogamy as practiced in, for example, India or cousin marriages, common throughout the Middle East and parts of Asia and Africa (e.g., Murphy and Kasdan 1959), may result.[5]

The paper is organized as follows. The remainder of this section gives a brief background on the relationship between family status and sex ratio of offspring among humans. Section II formulates the basic model for endogenous sex choice under son preference. Subsections treat spousal age gaps and caste like marriage patterns. Section III looks at possible effects of social mobility. Section IV concludes the paper.

Trivers and Willard (1973) is the seminal paper on parental ability to vary the sex ratio of offspring. The authors hypothesized that natural selection would favor species that adjust the sex ratio of offspring in accordance with the expected reproductive success of male and female offspring. They observed that ‘‘a male in good condition . . . is expected to outreproduce a sister in similar condition, while she is expected to outreproduce him if both are in poor condition’’ (p. 90). If the condition of offspring adults is partially determined by parental condition, parents in good condition may expect a similar condition for their offspring and hence would favor male offspring.

[4] In polygynous societies, most women would be married as opposed to only the high-ranking men. Consequently, if there were equally many males as females at each level of the social hierarchy, polygyny would lead to hypergamy. However, hypergamy is also the socially accepted form of mixed-class unions in monogamous societies.

[5] Sociological studies of endogamy (or exogamy) typically focus on documenting the incidence or the social functions of such a rule (e.g., Dumont 1966; Khuri 1970). Economic models readily predict endogamy from the assumption of assortative mating (e.g., Laitner 1991). Hypergamy, however, need not follow from marriage market sorting

Conversely, parents in worse condition would favor female offspring. Adapted to humans, this hypothesis posits a positive correlation between socioeconomic status and maleness of offspring. The Trivers and Willard hypothesis has been confirmed in a large number of studies of animal species (including humans) over the past 25 years. To my knowledge no study has found evidence against it. Below follows a short summary of some of the findings for humans.

The mechanisms governing the link between social status and sex ratio of offspring fall into two categories: prenatal and postnatal. Prenatal sex selection can be classified as either behavioral or pertinent to personality traits. Coital frequency is a well-known form of behavioral sex selection. In short, high coital frequency favors conception early in the cycle, which in turn increases the chances of a male offspring, and there is evidence that high-status men have higher coital frequency (Kemper 1994). With regard to the influence of personality traits, James (1994) found that parental dominance rank (social status) among mammalians (including humans) is associated with the sex ratio of the offspring. He concluded that high parental testosterone levels are associated with a high proportion of sons and high parental dominance levels. Grant (1996) reported on six (out of six) studies carried out in the course of over 20 years that found more dominant mothers to be more likely to bear sons.

James (1995) proposed that parental perception of the adult sex ratio influences the offspring sex ratio. He argued that a shortage of partners may be stressful. Among men, stress lowers the testosterone level, whereas among women the relationship is reversed. Among both sexes, high testosterone levels are associated with a higher propensity to produce male offspring. Hence, partner availability may influence the sex ratio. A case in point might be the rise in sex ratios at birth following World War I and II. War-related mortality affected men in reproductive ages disproportionally. Hence, on average, male survivors faced a situation of relatively good availability of partners. A possible explanation for the rise in the sex ratio could be that with a surplus of females, male and female hormone levels adjusted so as to favor the conception of male offspring (James 1995). A similar mechanism may also operate within a population. Typically, partner availability is greater for high-status men. Hence a combination of behavioral, psychological, and physiological factors may help explain the positive correlation between parental social status and maleness of offspring at birth. Still, even if these correlations are statistically significant, the order of magnitude is quite small relative to observed variations in the sex ratio. We therefore turn to far more effective methods: postnatal discrimination.

TABLE 1

Ratio of Sons to Daughters at First Birth by Mother's Education, 1990

Mother's Years of Education	Sex Ratio at First Birth: Sons/100 Daughters	Observations
<1	99.2	16,484
1–5	104.3	61,631
6–8	107.5	68,032
≥9	108.1	25,407

Source.—Li (1992), table 3.
Note.—Sex ratio of surviving children aged 0–1.5 years born in 1989 and the first half of 1990. The table is calculated from a 1 percent sample of China's 1990 census data.

Differential child mortality may be the quantitatively most important determinant of variations in the offspring sex ratio. Child mortality is linked to the parental investments in the health of the child.[6] In a study of contemporary North American mothers, Gaulin and Robbins (1991) found that low-income mothers invested more in daughters than in sons, whereas high-income mothers invested more in sons than in daughters. Their measures of maternal investment included birth weight, interbirth interval, and lactation periods. Voland (1988), using demographic data from Ostfriesland (Germany) for 1669–1879, studied the mortality rates of children orphaned in their first year. He found that widows clearly favored daughters, whereas no differences between the survival chances of sons and daughters were detected if the father was the surviving parent. Under the assumption that the death of the father entailed a greater reduction in the material resources available to the family than the death of the mother, these findings are in line with the Trivers and Willard hypothesis in that the worse-affected families favored daughters.[7] Cronk (1989) found pronounced daughter preference among a low-status African tribe, as evidenced by both the sex ratio of the 0–4 age group and nursing and caring practices. Further evidence is provided from contemporary China. The 1990 census revealed that not only did the sex ratio at first birth increase with mother's years of education, it was also the case that the poorest-educated women seemed to discriminate against sons (table 1).

[6] Both female and male infanticide have been documented. For the former, see Williamson (1976) and Cronk (1989).

[7] These findings do not seem to be the result of differences in overall child mortality rates (boys being more afflicted than girls) since child mortality was substantially higher for children who had lost their mother.

Moreover, it has long been known that sex ratios in Tibet (largely populated by minorities) are unusually low. The population sex ratio was only 0.98 in 1982 compared with that of 1.05 for all China. At the county level, the sex ratio was as low as 0.91 (China Financial and Economic Publishing House 1988).

Despite the popular view that Indian society is steeped in son preference, several studies suggest that it is mainly the upper social strata that indulge their preference. Sex ratios among minorities in India have been known to differ from the general pattern of male overrepresentation. Discrimination of girls has been found to increase with prosperity (Sen 1985; Murthi, Guio, and Dreze 1995) and education level of mothers in India (Miller 1981; Das Gupta 1987). Extremely male sex ratios at birth have been a phenomenon largely confined to high-caste groups in the northwest of India (Miller 1981; Oldenburg 1992), and female infanticide is known to be a high-caste phenomenon (Tambiah 1973).

II. The Model

Consider a population of males and females. In period t there are M_t males and F_t females who live one period. Hence, population size is $N_t = M_t + F_t$. Men and women marry in order to reproduce, and I assume monogamy and no remarriage. All couples have the same number of children. For simplicity and without loss of generality, the discussion will be carried out as though each couple produced only one child.

People prefer sons, provided that sons marry. Let (superscript) $g \in \{0, 1\}$ indicate the marital status of offspring, with 1 for married. Preferences over sex and marital status of offspring are ordered as follows: a married son is better than a married daughter, and an unmarried son is better than an unmarried daughter.[8] Finally, a married daughter is better than an unmarried son.[9] I write the parents'

[8] Whether an unmarried son is preferred to an unmarried daughter is an empirical question. Unmarried daughters are rare in countries running a surplus of sons, which may contribute to the attachment of a greater stigma to unmarried daughters than to sons. Although a son may be a better provider than a daughter, an unmarried daughter has an advantage over an unmarried son. Unmarried mothers by default have parental rights to their children, whereas this is not true of unmarried fathers (see, e.g., Edlund 1999). Thus an unmarried daughter can deliver socially recognized grandchildren. This paper focuses on the consumption motive for having children and abstracts from the investment motive. A reduction in fertility, forced or voluntary (e.g., from economic development), is a factor likely to reduce the importance of children as investments. For instance, if allowed only one child, parents are probably even more anxious for the child to marry.

[9] Otherwise the decision problem would be trivial. Everybody would go ahead and have sons.

utility of the child as $U(s^g)$, $s \in \{m, f\}$, with m for male and f for female, where

$$U(m^1) > U(f^1) > U(m^0) > U(f^0) > -\infty.^{10} \quad (1)$$

I normalize the utility of offspring by setting $U(m^0) = 0$.

There are two technologies for producing offspring, p_m and p_f. The male technology, p_m, delivers a son with probability p, $p \in [.5, 1]$, and of course a daughter with probability $1 - p$. Likewise, p_f delivers a daughter with probability p and a son with probability $1 - p$. I shall refer to the technology as *perfect* if $p = 1$, *ineffective* if $p = .5$, and *imperfect* if $p \in (.5, 1)$. To simplify the exposition, I assume that these sex choice technologies are costless.

In the case of uncertainty as to whether a child will marry, I shall assume risk neutrality:

$$U(s) = \pi_s U(s^1) + (1 - \pi_s) U(s^0), \quad (2)$$

where π_s denotes the probability that a child of sex s marries.

Couples decide on which technology to use for the production of their offspring; $p_s \in \{p_m, p_f\}$ is a couple's reproduction strategy. A strategy profile is a set of strategies, one for each couple. An equilibrium is a strategy profile such that no couple would obtain higher utility from another sex choice technology, given the other couples' strategies. In keeping with the spirit of the paper, parents employ the male technology if the male and the female strategies yield equal expected utility.

I assume individuals to be unambiguously ranked within a generation. The rank index $r_t \in \{1, 2, \ldots, N_t\}$ denotes status, where person 1 has the highest status. Male ranking is indicated by superscript m: $r_t^m \in \{1, 2, \ldots, M_t\}$, and analogously for females, $r_t^f \in \{1, 2, \ldots, F_t\}$. Ranking determines marriage market attractiveness, and it is a well-known result from the matching literature that it is the least attractive who do not marry if there is a surplus of one sex. Hence, the set of unmatched individuals is the same in all stable matchings, provided that preferences are strict (Roth and Sotomayor 1990).

I denote rank at birth by subscript b: $r_{b,t} \in \{1, 2, \ldots, N_t\}$, and I shall assume that the rank at birth is simply the father's rank, $r_{b,t} = r_{t-1}^m$. Social status is a ranking of individuals according to their consumption, which in turn is determined by an endowment $e(r_{b,t})$, $e'(r_{b,t}) < 0$,[11] and a random term ϵ drawn from a symmetric and

[10] Hence, I rule out the possibility that unmarried daughters are "infinitely bad."

[11] There are no bequests or gifts in the model. One may think of the endowment as inherited social capital.

single-peaked distribution with mean zero and finite standard deviation σ as follows:

$$c = e(r_{b,t}) + \epsilon, \quad \epsilon \sim (0, \sigma). \tag{3}$$

People care about the sex of offspring, whether the child marries, consumption c, and, possibly, the social standing of a child-in-law. With abuse of notation, for a parent generation $t-1$, I indicate the rank index of a child-in-law by $r_{s,t}$, where the subscript $s \in \{m, f\}$ refers to the sex of the proper child; that is, a daughter-in-law's rank index is $r_{m,t}$. I assume utility to be additively separable in the sex of offspring, consumption, and the status of the child-in-law. Formally, I write utility as

$$W(s^g, c, r_{s,t}) = \begin{cases} U(s^1) + V(c) + \kappa(N_t - r_{s,t}) & \text{if } g = 1 \\ U(s^0) + V(c) & \text{if } g = 0, \end{cases} \tag{4}$$

where κ is a nonnegative constant.

Utility is increasing and concave in consumption, $V'(c) > 0$ and $V''(c) < 0$. Furthermore, I assume that utility from marrying a child well is proportional to rank index. Since a high rank index corresponds to low social status, $r_{s,t}$ enters negatively in (4). The term N_t is there only to ensure that a married child gives higher parental utility than an unmarried child.

For simplicity, let us assume that the population is a multiple of two, $N_t = 2A_t$.

DEFINITION. (i) Individuals $r \in \{1, 2, \ldots, A_t\}$ make up an *upper class* and individuals $r \in \{A_t + 1, A_t + 2, \ldots, 2A_t\}$ an *underclass*. (ii) Under *complete segregation*, one sex constitutes an underclass and the other an upper class.

A. *Narrow Gender Considerations*

In this subsection I make the simplifying assumption that rank as an adult is determined solely by status at birth and that parents do not care about the rank of a child-in-law; that is, $\sigma = 0$ and $\kappa = 0$. Utility and consumption are hence, respectively, $W(s^g, c) = U(s^g) + V(c)$ and $c = e(r_{b,t})$.

I now state our first results.

PROPOSITION 1. For large N_t, all Nash equilibria have the following property. There is an $X_t \geq A_t$ such that individuals of rank $r_t \in \{1, 2, \ldots, X_t - 1, Z\}$, $Z \in \{X_t, \ldots, N_t\}$, choose the male technology, and $r_t \in \{X_t, X_t + 1, \ldots, Z - 1, Z + 1, \ldots, N_t\}$ choose the female technology.

COROLLARY 1. For all Nash equilibria, (i) sex ratios balance for both perfect and ineffective sex choice technologies, and (ii) a surplus of males results if sex choice is imperfect.

PROPOSITION 2. For large N_t and imperfect sex choice, the sex ratio increases in son preference.

Propositions 1 and 2 and corollary 1 are proved in Appendix A.

The essence of proposition 1 is that the upper class will try for male offspring. The effectiveness of the sex choice technology determines the actual concentration of males in the upper class as well as the cutoff point X_t. If sex choice is perfect, no Nash equilibrium could have a surplus of one sex since a married child is preferred to an unmarried child. Moreover, complete segregation with sons born to the upper class and daughters to the underclass is obviously a Nash equilibrium in this case. If sex choice is imperfect, however, more than half of the population will choose the male technology (corollary 1). The reason is that even if the upper class were to choose the male technology, the upper class would not be all male. This means that some parents in the underclass could have sons who would marry with certainty. In effect, when sex choice is imperfect, a son's probability of marrying is continuous and decreasing in rank, and parents choose the male technology if a son's probability of marrying is greater than the ratio of the utility of a married daughter to that of a married son. Consequently, the higher the son preference, the greater the fraction of parents choosing the male technology and, of course, the higher the sex ratio (proposition 2).

Note that imperfect sex choice produces a surplus of sons over daughters. The bachelor count is made up of two groups. Since parents aim for sons even if a son's probability of marrying is less than one, the lowest-ranking sons produced by the male technology may not marry. The second group of bachelors are sons produced by the daughter technology. These sons are accidental in both an ex ante and ex post sense. An immediate implication is that a higher incidence of unmarried sons could result without an auxiliary assumption that unmarried sons are preferred to unmarried daughters.

The intuition from the case of costless sex choice may guide our thinking about what costly sex choice would entail. If sex choice were costly, in moral, psychological, or material terms, it seems reasonable that either of the two following scenarios would happen. If cost is high, the top couples would employ the male technology to improve their chances of having sons; the rest of the population would do nothing (cf. infanticide among high castes). Among those doing nothing, however, there are people who would be willing to pay for others to employ the female technology, so that they themselves could improve their chances that a son will marry. Moreover, low-status people would be willing to employ the daughter technology if it were cheap enough since only daughters marry. This leads us to the second scenario, with ''modest'' cost. In this case, essentially the same situation as in the case of costless technology would arise, with the wrinkle that the rich would pay the poor to use the daughter technology. Mechanisms that come to mind are subsidized health services and monetary rewards to parents of daughters. It is slightly ironic that the latter has been proposed as a means to combat discrimination against daughters.

Payments between parents of sons and daughters beg the question of bride-prices and dowries (negative bride-prices).[12] It is straightforward to see that allowing for a market mechanism would work toward social stratification by sex. Consider a market price for a bride such that one-half of the population would choose sons and the other half would choose daughters (and sex choice is perfect). For any given price, the poor would be more inclined to give up having a son (who would have to pay the market price to get married) in favor of having a daughter (and cash in). In equilibrium, the price would be positive and just enough to make the middle person indifferent between a boy and a girl.

With perfect sex choice, would the complete segregation result still hold if parents also cared about the sex of grandchildren? Assume that preferences over grandchildren are ordered according to the same principle as those over children. Under perfect sex choice and positive assortative mating, the highest-ranking quartile of the population would have sons and grandsons. The second-highest quartile would have sons and granddaughters. Grandsons can be obtained only if they had chosen daughters instead. Under positive time preference, the second quartile cannot do better than under complete segregation. Since the first two quartiles opt for sons, the last two quartiles cannot do better than to choose daughters. Hence I conclude that if grandchildren carry less weight in the utility function than own children (e.g., from impatience or a lower degree of genetic closeness), the complete segregation result, with men in the upper class, would hold.

The results above hinge on there never being unmarried daughters in equilibrium. The way I justified this was that for a large population, the risk of having an unmarried daughter is small. Hence, even if the associated disutility were huge, low-status parents try for females knowing that daughters always marry. One might be curious

[12] Note that adoptions and child marriages could be viewed as examples of ex post trading (emanating from imperfect sex choice). Child marriages in China were contractual arrangements by which parents of a son secured a daughter-in-law, against a compensation to the parents-in-law. It is of particular interest to note that it was mainly the poor who thus sold daughters (Cheung 1972).

to know how the results would fare if sex ratios were balanced or an overall surplus of sons were not a sufficient condition for a daughter to marry. A possible reason for single females might be search friction in the marriage market.[13] Allowing for search friction, I find that if an unmarried daughter brings great disutility and the risk of not marrying a daughter is large enough, everybody chooses the male technology. Otherwise the qualitative results of the previous section remain the same, with the exception that for perfect sex choice there is an intermediate case. If the risk that marriage will not happen is high enough to rule out proposition 1 but low enough to prevent everybody from choosing sons, the equilibrium is characterized by a top layer of parents who choose males. The rest of the population produces the daughters for this upper layer, but the origins of these daughters are indeterminate. These results are derived in Appendix B.[14]

B. *Spousal Age Gaps*

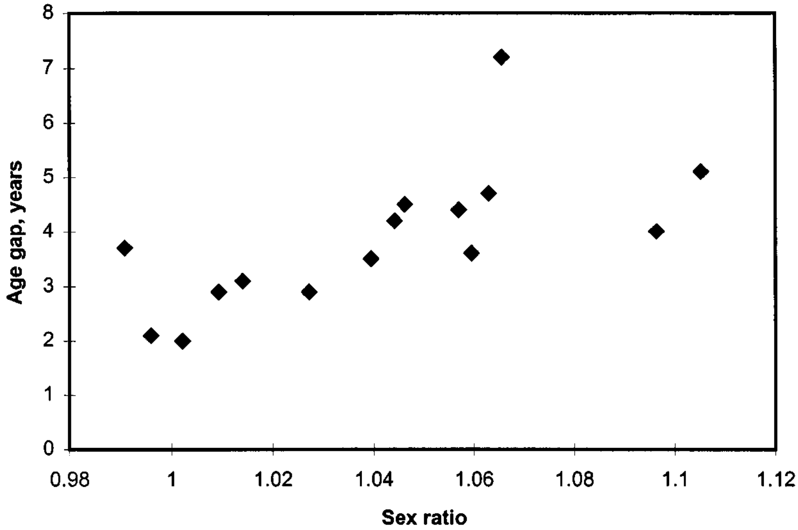
Women's marrying up is not restricted to status. Typically, grooms are older than their brides, and the age gap is particularly pronounced in some of the less developed countries, where the preference for sons is strong. We already saw that if sex choice is imperfect, son preference produces a surplus of men in each cohort. This section extends the analysis by allowing people to live and marry in several periods, and we shall see how unbalanced sex ratios, current and past, can be a factor behind spousal age gaps. Figure 1 plots the average age gap at first marriage against the sex ratio in Asian developing countries. Panel *a* plots the age gap by population sex ratio, and panel *b* plots the age gap by sex ratio for 15–19-year-olds.[15] Without providing conclusive evidence, figure 1 suggests that although current sex ratios alone cannot explain age gaps, a surplus of males seems to preclude low spousal age gaps. A possible reason

[13] The prevalence of matching failures may be evaluated in light of the fact that both India and China are large and densely populated countries. The use of intermediaries such as matchmakers is common, and, if necessary, spouses can be sourced from far afield (e.g., Rosenzweig and Stark 1989; Fan and Huang 1998).

[14] If the population is very small, then one cannot rule out equilibria with women at the top. Appendix C gives an example.

[15] It is notoriously difficult to assess what age groups to include in a marriage market (actual age at marriage cannot be used since it is endogenous to overall demographics). I therefore present the sex ratios for the whole population and 15–19-year-olds. The reason for looking at the latter age group is that it is likely to reflect the sex ratio among entrants into the marriage market; if previous cohorts exhibit similar sex ratios, it can be viewed as a proxy for the marriage market sex ratio. The reason for not using an older age group is that I would thereby lose people who have died but nonetheless were in the marriage market.

a



b

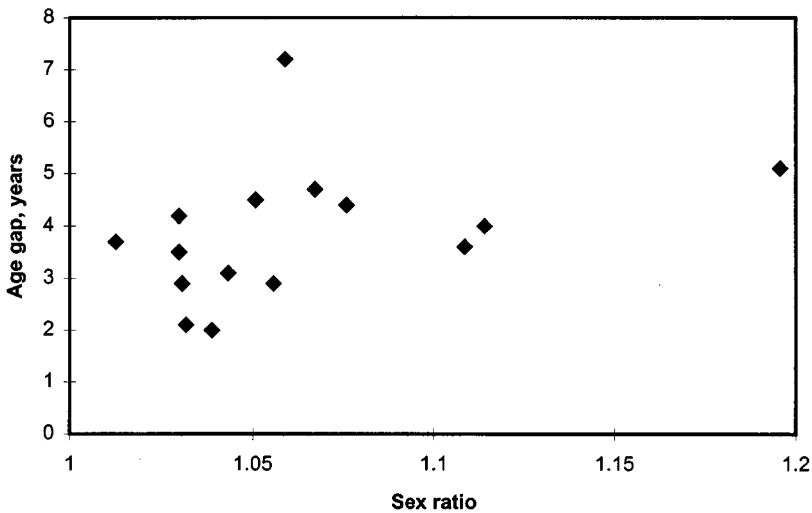


FIG. 1.—Asian developing countries, 1980s. *a*, Spousal age gaps by population sex ratios. *b*, Age gaps by sex ratio, 15–19-year-olds. Age gaps are taken from Bergstrom and Bagnoli (1993, table B1). Population sex ratios are taken from United Nations (1992, table 7). Data pertain to the period 1981–90. Data availability restricted the sample to the following countries: the Philippines, Indonesia, Malaysia, Thailand, Sri Lanka, Bangladesh, Nepal, India, Pakistan, Iran, Iraq, Jordan, Syria, Turkey, and Cyprus. The sex ratio for 15–19-year-olds for Bangladesh (age gap 7.2 years) pertains to the age group 15–49.

is that if women are scarce, unmarried old men remain in the population, and it suffices that one of them eventually marries to drive up the average age gap. Of course, it must be true that older bachelors do marry. One reason why they would is that time can be useful for advancement up the social ladder; luck, talent, or plain savings need time to bear fruit. This mechanism predicts a negative correlation between age at marriage and social status; men from good families marry earlier than men from a less sterling background, and if sex choice is less than perfect, the lowest-status men never marry. To the extent that social status is positively correlated with human capital, this result differs radically from the results of both Bergstrom and Bagnoli (1993) and Siow (1998) but seems to square well with empirical findings for some less developed countries (e.g., Parish and Whyte 1978) and developed countries not so long ago (e.g., Becker 1991, p. 122).

Understanding marriage age is of wider interest since it may be argued that age at marriage and spousal age gaps influence other facets of society. For example, it has been suggested that large age gaps could contribute to female marginalization in marriage (Caldwell, Reddy, and Caldwell 1983). Moreover, son preference in India is commonly linked to the financial burden daughters are assumed to impose on their parents, and it has been suggested that exogenous age gaps could be behind this century's rise in dowries (Rao 1993). A tangent issue is the social stigma attached to unmarried daughters beyond a particular age.[16] It has been suggested that dowries are high partly because daughters have a small window of eligibility, which forces parents of daughters to settle for less in dowry negotiations (see, e.g., Rao 1993). Since parents of daughters risk either financial ruin or social scorn, daughters are avoided, or so the argument goes. But these age restrictions seem costly, not least to the men thus barred from marriage. This section points to the possibility that marriage age is determined by the demographic structure. For instance, consider the situation in India of an endemic surplus of males. It may then be quite conceivable that all reasonably fit women marry at the earliest eligible age, social stigma notwithstanding.

The main modification in this section is that in order to model age gaps, I let people live until age $H > 0$. People of the same age form a cohort. There are equally many people in each cohort, and I drop the subscript t. Moreover, I assume a continuous inflow of newborns and outflow of age H cohorts. Within each cohort, people

[16] Average female age at first marriage in India was 18.7 years in 1990 (Bergstrom and Bagnoli 1993).

are unambiguously ranked by the rank index r. Throughout this section, r refers to ranking within a cohort. I shall assume that cohorts are sufficiently large that r can be treated as a continuous variable uniformly distributed on the unit interval $r \in [0, 1]$, where $r = 0$ denotes the highest-ranking person in a cohort. People can marry at any age $\eta \in [0, H]$. To keep things simple, I shall ignore time preference, there is no social mobility (i.e., $\sigma = 0$), and I abstract from concern about the status of in-laws (i.e., $\kappa = 0$).

Let us consider a strategy profile for cohort α such that $r < r^*_\alpha$ choose the male technology and $r > r^*_\alpha$ the female technology. As before, the marginal parent is indifferent between a son and a daughter; hence r^*_α must be such that $\pi_m(r^*_\alpha) = U(f^1)/U(m^1)$.[17] The backlog of unmarried men is stochastic, which means that typically $r^*_\alpha \neq r^*_{\alpha+i}$, $i \neq 0$. However, note that for the proposed strategy profile, the rank interval for which $\pi_m(r) \in (0, 1)$ decreases as the number of people in a cohort increases. Moreover, the distribution of the success rate of the sex choice technology collapses at p. Hence, for large cohorts I can approximate r^*_α with r^*, where r^* is the greatest r for which $\pi_m(r) = 1$, and in the steady state, I may treat r^* as constant across cohorts.

There will be a latent deficit of females. Hence, women will always marry at age 0, and we can concentrate on the male age of marriage. I assume that aging improves social standing at the rate $\lambda > 0$ so that a man of age η' and rank r' is as attractive as a man of age η and rank

$$r = r' - \lambda(\eta' - \eta). \tag{5}$$

The last parent choosing the male technology, r^*, expects the son to marry at the latest possible age, H. Plugging this into (5), we can express male age at marriage as a function of rank:

$$\eta(r) = \max\left\{0,\ H - \frac{r^* - r}{\lambda}\right\}, \quad r \leq r^*. \tag{6}$$

Clearly, $\eta'(r) \geq 0$; that is, higher-status men tend to marry at a younger age. Moreover, note that male age at marriage increases in λ, the rate at which aging improves marriageability. Poorly functioning capital markets could make accumulated savings a factor boosting eligibility, which suggests a possible link between underdeveloped financial markets and large spousal age gaps, both prominent features of some developing countries.

[17] See the proof of proposition 1 in App. A.

It remains to establish r^*. In the steady state, the inflow of men who may expect to marry must equal the outflow of men who marry. The latter equals the inflow of unmarried females; hence $pr^* = (1 - p)r^* + p(1 - r^*)$, and solving for r^*, we get

$$r^* = \frac{p}{3p - 1} \in [.5, 1]. \tag{7}$$

This section's results can be summarized as follows.

Proposition 3. Consider a large constant population consisting of continuously aging, finitely lived, cohorts; within each cohort the rank index r is uniformly distributed on the unit interval, $r \in [0, 1]$. Then the steady state is characterized by an $r^* \in [.5, 1]$ such that $r \leq r^*$ choose the male technology and $r > r^*$ the female technology; grooms are older than their brides; male age at marriage and status are inversely related; the lowest-status men never marry; and all women marry at the youngest possible age.

Proposition 3 describes steady-state behavior. It is of additional interest to look at the transitory effect of better sex choice. As a result of better sex choice, initial cohorts run a deliberate surplus of males, who take their wives from future cohorts. The initial jump in the sex ratio produces a permanent backlog of unmarried males, which, once in place, puts downward pressure on the sex ratio of future cohorts. In the steady state, cohorts behave as in the one-period game. This suggests that the recent rise in sex ratios at birth in countries such as India, China, and South Korea may be transitory.

In the remainder of the paper, the formal discussion will focus on the special case of perfect sex choice technology, that is, $p = 1$.

C. *General Status Considerations—Caste Systems*

This subsection allows parents to also care about how well their child marries. We shall see that for perfect sex choice technology, $p = 1$, such preferences can result in something familiar, namely a caste structure. I model parental concern for status of in-laws by assuming $\kappa > 0$. Moreover, I shall assume that parents arrange the marriages of their child, an assumption that at least for the Indian context is quite consistent with the actual situation.[18] I shall abstract from side payments so that consumption is given by initial endowment. Every-

[18] This is to produce positive sorting. Allowing for child's status to depend on both parents' rank (as opposed to father's only) could produce positive sorting without the shortcut used here.

thing else is as in subsection *A*. Let us denote the difference between how well a daughter would marry compared to a son by

$$\Delta = r_m - r_f \tag{8}$$

and let *relative* son preference be

$$\Delta^* = \frac{1}{\kappa}[U(m^1) - U(f^1)]. \tag{9}$$

Sons are preferred to daughters if $W(m^1, c, r_m) \geq W(f^1, c, r_f)$, which rearranged yields the condition

$$\Delta \leq \Delta^*. \tag{10}$$

For the purpose of this subsection I define a *group* to be a set of individuals of consecutive rank (individuals 1, 2, and 3 make up a group whereas 1, 3, and 4 do not), and a one-sex group is a *layer*. Finally, a *caste* is a two-layer, endogamous, group. I can now state the next result.

Proposition 4. Consider a relative son preference Δ^* that falls in the interval $[2k - 1, k + 2)$, where k is a positive integer. Then there is a steady-state population size $N = 2bk$, which has a social structure with b castes such that, for $i = 0, 2, \ldots, 2(b - 1)$, $r \in \{ik + 1, ik + 2, \ldots, ik + k\}$ is male and $r \in \{(i + 1)k + 1, (i + 1)k + 2, \ldots, (i + 1)k + k\}$ is female.

Proof. From (4) and the assumption that parents arrange the marriages of their offspring, it follows that matchings are positive assortative. Assume that, for $i = 0, 2, \ldots, 2(b - 1)$, $r \in \{(i + 1)k + 1, (i + 1)k + 2, \ldots, (i + 1)k + k\}$ is female and that all but one, say j, $r \in \{ik + 1, ik + 2, \ldots, ik + k\}$ are male. It must be true that person j would give parents higher parental utility if male than if female. From (10) we know that this is true if $r_m - r_f \leq \Delta^*$. The left-hand side is greatest for $j = ik + k$. If j were a son, he would marry woman $(i + 1)k + k$; hence $r_m = (i + 1)k + k$. If j were a daughter instead, she would marry man $ik + 1$; hence $r_f = ik + 1$, which yields $r_m - r_f = 2k - 1 \leq \Delta^*$.

Next, no parents of daughters must regret their sex choice, given the other parents' actions. Assume that, for $i = 0, 2, \ldots, 2(b - 1)$, $r \in \{ik + 1, ik + 2, \ldots, ik + k\}$ is male and that all but one, say j, $r \in \{(i + 1)k + 1, (i + 1)k + 2, \ldots, (i + 1)k + k\}$ are female. Again, person j must give higher parental utility as a daughter than as a son. We start by looking at the lowest-ranking layer of females, $i = 2(b - 1)$. If one of them were a son, he would not marry at all. From (1) and (4) we know that their parents prefer them to be daughters.

For $j \leq 2(b - 1)k$, it must be true that $r_m - r_f > \Delta^*$. The minimum for the left-hand side is obtained for $j = (i+1)k + k$, $i = 0, 2, \ldots, 2(b-2)$. If a daughter, she would marry man $ik + k$. If a son, he would marry woman $(i+3)k + 2$ (provided that $k > 1$; it is left to the reader to verify that the results would go through for $k = 1$); hence we have the condition that $2k + 2 > \Delta^*$.

To establish the caste structure, suffice it to note that the proposed equilibrium has k men followed by k women, and so on. Sorting is positive; thus the first k men marry the first k women, and so forth. Hence, each group is endogamous. Q.E.D.

Proposition 4 says that alternating, equal-sized, male-female layers is an equilibrium. The first layer has k males and the second layer has k females, and since marriages are positively assortative on status, we know that they marry each other. As before, women marry up. Note that this equilibrium has the characteristics of a hypergamous caste system.[19]

Proposition 4's result of endogenous endogamy hinges crucially on two adjacent layers being of the same size, which in turn depends on the sex choice technology being perfect and freely available. This has clearly not been the case for most of the period forming the caste system as we know it in India. Still, caste systems could have stemmed from concern with the status of in-laws. Suppose that sex choice is imperfect. Then the top parents would try for sons, but further down the social spectrum, daughters become increasingly attractive because a daughter would marry increasingly better than a son. So at some point parents will switch to aiming for daughters. As one continues down, this effect vanishes since with enough people trying for daughters, parents can no longer hope to marry their daughters sufficiently well, this starts off a new layer of parents aiming for sons, and so forth. The same mechanism that previously produced a surplus of sons if sex choice were imperfect will make the top layers of parents trying for sons greater than the subsequent layers trying for daughters. Notable features of the caste system sketched above are that (i) women tend to take lower slots, and hence they marry up; (ii) no social group is entirely endogamous; in particular, there will be elite men who marry pauper women; (iii) there are more men among the elite than among paupers; and finally, (iv) there are more men than women in the entire population—all of which seem to have been salient features of the Indian caste system (Dumont 1966). Also note that if the sex choice technol-

[19] The caste equilibrium may unravel if the population is not a multiple of $2k$. However, note that the Indian caste system was characterized by a bottom "residual" of casteless individuals. The existence of such a bottom buffer would restore the possibility of a caste equilibrium in our model, and one may only speculate that it played a similar role in real life.

ogy is poor, caste exogamy will be rare since the surplus of males the elite can produce is limited.

With perfect sex choice, inspection of (9) shows that the number of castes in a society depends positively on κ, that is, the extent to which marrying offspring well matters. For high values of κ, daughters can be more attractive by virtue of the fact that they would marry up, and hence there will be daughters in the upper class. On the other hand, for low κ, we approach the complete segregation case, with men in the upper class and women in the underclass. Note that there is an upper limit to the importance of rank consideration relative to the preference for sons; if the rank is very high, the logical thing for parents would be to balance sex ratios and marry brother to sister (provided that there is an even number of offspring). Sibling incest is, however, rare.[20] The second-closest thing would be for siblings' children to marry each other. Cousin marriages are known to have been common in many societies and are still widely practiced in the Middle East and parts of South Asia. While previous studies of cousin marriages typically have focused on documenting the incidence or the social functions—such as strengthening of kinship loyalty—of such a rule,[21] proposition 4 suggests that cousin marriage and caste endogamy could be related phenomena, and both might be driven by a general preoccupation with the status of in-laws.

III. Uncertainty and Unbalanced Sex Ratios

This section maintains the assumption of perfect sex choice and discusses how the result of men at the top and women at the bottom would fare in the face of social mobility. No longer would parents know with certainty the social status of their offspring and thus whether a son would marry. We shall see that in this case, perfect sex choice need not imply steady-state balanced sex ratios. The intuition is that a looser link between parental and child status may encourage low-status parents to opt for sons. Sons carry option value since in the case of a good draw (high status of offspring) a son turns into a married son.

Again, people live and marry in only one period and show no regard for the status of a child-in-law (i.e., $\kappa = 0$), and sex choice

[20] See, e.g., Pastner (1986). The best-documented incidents thereof stem from ancient Egypt and pre-Columbian South America and are confined to the royal or ruling family. The kings, being sons of gods and hence divine, married their sisters instead of mere humans. It might be telling to note that these societies were highly hierarchical, and the social distance between the ruler and the second in line was probably nontrivial.

[21] For further references, see, e.g., Khuri (1970).

is perfect. I assume that r is continuous and is uniformly distributed on the unit interval, where $r = 0$ for the highest-ranking person. Recall that offspring are ranked according to the realization of $e(r_b) + \epsilon$, where r_b is simply father's rank and $\epsilon \sim (0, \sigma)$ is a random variable from a symmetric and single-peaked distribution with mean zero and standard deviation $\sigma > 0$. It follows that, in expectation, rank at birth is also rank at marriage age.

For a parent of rank r, I express utility from a son as $\pi(r, \sigma)\, U(m^1)$, where $\pi(r, \sigma)$ is the probability that a son marries, to be compared with the utility of a daughter, who marries with certainty, $U(f^1)$. Again, let r^* be the rank of the last parent choosing a son. For the marginal parent it must be true that

$$\pi(r^*, \sigma)\, U(m^1) \equiv U(f^1). \tag{11}$$

Note that the value of the cutoff point, r^*, implies the sex ratio. From $\epsilon \sim (0, \cdot)$, we know that

$$\frac{\partial \pi(r, \sigma)}{\partial r} < 0 \quad \text{for } \sigma < \infty. \tag{12}$$

It will prove convenient to define $\chi = U(m^1)/[U(f^1) + U(m^1)]$.

PROPOSITION 5. For a large population uniformly distributed on the unit interval, $r \in [0, 1]$, and $\sigma < \infty$, in the Nash equilibrium the top r^* parents choose sons and the bottom $1 - r^*$ choose daughters, where $r^* \in (.5, \chi)$. The sex ratio increases in social mobility and tends to $U(m^1)/U(f^1)$.

Proof. If $r^* \in (.5, \chi)$, the proposed strategy profile as the unique Nash equilibrium follows from (11) and (12). To see that $\sigma < \infty$ implies $r^* \in (.5, \chi)$, note that $\pi(\cdot)$ must be such that the expected number of marriages equals the number of women in the population, that is,

$$\int_0^{r^*} \pi(r, \sigma)\, dr \equiv 1 - r^*. \tag{13}$$

To establish that $r^* > .5$, assume the contrary (e.g., $r^* = .5$). This yields a contradiction since the left-hand side of (13) is

$$\int_0^{.5} \pi(r, \sigma)\, dr < .5$$

and the right-hand side is .5. To see that $r^* < \chi$, assume the contrary (e.g., $r^* = \chi$). Then

$$\int_0^{\chi} \pi(r, \sigma)\, dr > 1 - \chi$$

and $1 - r^* = 1 - \chi$, which is not consistent with (13). Since both the right- and left-hand sides of (13) are continuous and monotone in r^*, we conclude that there exists a unique $r^* \in (.5, \chi)$ such that (13) holds.

We also need to show that

$$\frac{\partial^2 \pi}{\partial r \partial \sigma} > 0 \quad \text{for } \sigma < \infty; \tag{14}$$

that is, the head start given children with a lower rank index at birth decreases as the standard deviation of ϵ increases. Consider two children of adjacent ranks at birth, r' and r'', where $r' < r''$. The probability that r'' will be as good as, or outrank, r' is the probability that r'' gets a better draw than r'. From symmetry, we know that this is equal to one-half of the off-diagonal mass of the joint probability distribution of $\epsilon_{r'}$ and $\epsilon_{r''}$. For a given interval, the uniform distribution has the greatest variance of all single-peaked and symmetric distributions. It is also true that the ''diagonal'' mass is minimized for the uniform distribution and increases as the standard deviation is reduced. This means that the probability that r'' overtakes r' increases as the standard deviation increases.

To establish that the sex ratio increases in σ, let us consider two values of σ, $\sigma' < \sigma''$. Moreover, let r' and r'' be the two values of $r^*(\cdot)$ satisfying (13) for σ' and σ''. We need to establish that $r'' > r'$. Assume the contrary, $r'' \leq r'$, which implies that $1 - r'' \geq 1 - r'$. But $r'' \leq r'$ together with (14) implies that

$$\int_0^{r''} \pi(r, \sigma'')\, dr < \int_0^{r'} \pi(r, \sigma')\, dr.$$

This yields a contradiction since (13) must also hold.

To obtain the limit sex ratio, note that

$$\lim_{\sigma \to \infty} \int_0^{r^*} \pi(r, \sigma)\, dr = \frac{U(f^1)}{U(m^1)}\, r^*.$$

Using (13), we can solve for $\lim_{\sigma \to \infty} r^* = \chi$, which implies a limit sex ratio of $U(m^1)/U(f^1)$. Q.E.D.

Figure 2 illustrates the effect of social mobility on the cutoff rank.

This section points to a straightforward link between social mobility and a surplus of males. For China, market-oriented reforms since the late 1970s have produced not only a period of remarkable growth but also a reshuffling of the social order. The turmoil may have contributed to the rise in sex ratios at births.

Proposition 5 also implies that social mobility would result in the breakdown of caste endogamy. As sex ratios no longer balance

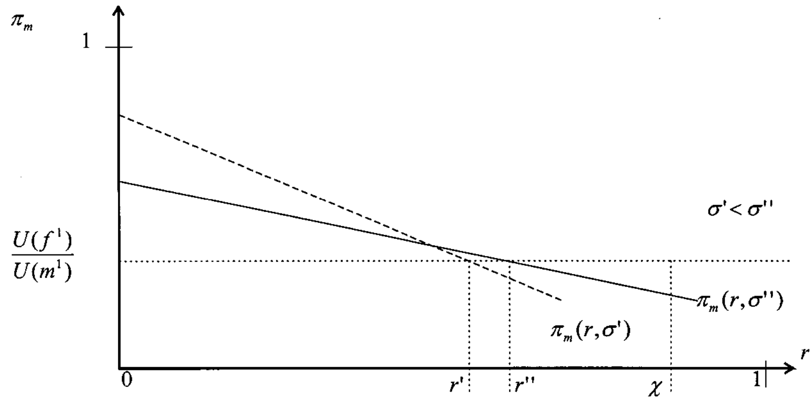


FIG. 2

within each "caste," it follows that there will be high-caste males who do not marry within their caste. As these men outrank lower-caste males, they would marry outside their caste. The importance of a static socioeconomic context for a caste system may be relevant for understanding why cousin marriages have been rare in North America, have virtually disappeared from the European and Latin American scene, but are still common in the Middle East and parts of Asia and Africa.

IV. Conclusions

The main result of this paper is that increasing availability of prenatal sex determination in societies favoring sons may lead to social segregation by sex, with men at the top and women at the bottom. This possibility has largely been overlooked in the previous literature. Instead, it has been believed that sex-specific abortions could eventually favor females even under a universal preference for sons. Not only would women be more scarce and hence coveted on the marriage market, postnatal discrimination against female offspring may decrease since all daughters carried to term would be desired. This paper discusses why these propositions may be false or of secondary importance. I show that if parents prefer married children to unmarried children and sons to daughters, sex choice can consistently result in the birth of daughters into low-status families and sons into high-status families. Effectively, intrafamily discrimination against daughters could be replaced by interfamily discrimination.

As for the supply of wives, I show that improved sex choice technology can, but need not, result in unbalanced sex ratios. In fact, if sex choice were freely available and the technology perfect, sex ratios might balance. I discuss two possible factors behind a steady-state surplus of males, imperfect sex choice and social mobility. In both cases, it is uncertainty as to a son's ranking in the male population that drives the results. A son carries option value because in the case of a good outcome, he will marry. The paper also points to the possibility that the recent rise in the sex ratio at birth in countries such as China, India, and South Korea is partly a transitory phenomenon. The proposed reason is that the introduction of better sex choice may cause initial cohorts to run a surplus of males, because surplus males can take their wives from future cohorts; future cohorts will have to consider the overhang of unmarried males when deciding on whether to produce sons or daughters. Finally, the paper takes issue with the commonly believed view that forced or voluntary quantity restrictions on offspring, such as the Chinese "one-child" policy or the South Korean case of declining fertility, have driven up sex ratios. Quantity restrictions are likely to make parents even more anxious to see all their children marry. Hence, they are likely to work toward a balancing of the sex ratio.

I show that a preference for sons could be a factor behind men's marrying younger women and the pattern of hypergamy, that is, women's marrying socially superior men. In addition, I find that hierarchically ordered endogamous groups, with women consistently marrying up, could result from relative son preference; that is, parents would prefer sons unless daughters marry sufficiently well. Also, the model suggests that caste endogamy and cousin marriage could be affine phenomena; barring sibling incest, I show that the latter could be viewed as the limit case when the status of in-laws is an important consideration. Moreover, I discuss why concern with the status of in-laws in combination with a static social environment and poor sex choice technology may have been key factors behind the evolution of caste systems in societies with son preference.

Appendix A

Proofs of Propositions 1 and 2 and Corollary 1

It is necessary to show that no parent would achieve higher utility from a different sex choice technology, given the other parents' choices. The case of $p = .5$ is trivial, and I concentrate on the case of $p \in (.5, 1]$. I shall leave $p = 1$ until later and start with the case of imperfect sex choice, $p \in (.5, 1)$.

Parents prefer a son if $\pi_m U(m^1) \geq \pi_f U(f^1) + (1 - \pi_f) U(f^0)$. If the probability that a daughter marries is sufficiently close to one, this simplifies to the following condition for the male strategy to be optimal:

$$\pi_m \geq \frac{U(f^1)}{U(m^1)}. \tag{A1}$$

It is necessary to show that a son's probability of marrying decreases with rank, that is,

$$\pi_m(r') > \pi_m(r'') \quad \text{if } r' < r''. \tag{A2}$$

We know that $\pi_m(r') \geq \pi_m(r'')$ since, from the assumption that lower-ranking men are more attractive, it follows that, for all outcomes in which r'' married, r' also married. The inequality is strict because there are outcomes in which r' marries but r'' does not, for example, when r' is the last man married.

The condition (A1) for the male technology to be optimal was derived under the assumption that female offspring marry with certainty. In order to show that this will indeed be the case, I proceed to show that more than half of the population will choose the male technology. Define $\theta = X_t/N_t$, and assume that $p_s = p_m$ for $r_t \leq X_t$, and p_f otherwise. The probability distribution for the number of males, μ_t, in the first θN_t draws is approximately normal with expectation $p\theta N_t$ and variance $p(1-p)\theta N_t$. Thus the probability of fewer than $(\theta - \varphi)N_t$ men can be written as

$$\Phi\left\{\frac{[(1-p)\theta - \varphi]\sqrt{N_t}}{\sqrt{p(1-p)\theta}}\right\}, \tag{A3}$$

where Φ is the standard normal cumulative distribution. The probability that $(\theta - \varphi)N_t$ men marry corresponds to the probability that there are at least $(\theta - 2\varphi)N_t$ women in the remaining $(1-\theta)N_t$ draws; that is, prob$[\omega_t \geq (\theta - 2\varphi)N_t]$ is

$$\Phi\left\{\frac{[(1-\theta)p - \theta + 2\varphi]\sqrt{N_t}}{\sqrt{p(1-p)(1-\theta)}}\right\}. \tag{A4}$$

Note that if $X_t = \theta N_t$, $\pi_m(X_t)$ is greater than the product of (A3) and (A4) since (the subscript t is dropped to ease notation)

$$\begin{aligned}
\pi_m(X) &= \int_1^{\theta N} \text{prob}(\mu = j)\ \text{prob}(\omega \geq 2j - \theta N)\, dj \\
&\geq \int_1^{(\theta-\varphi)N} \text{prob}(\mu = j)\ \text{prob}(\omega \geq 2j - \theta N)\, dj \\
&> \text{prob}[\omega \geq (\theta - 2\varphi)N] \int_1^{(\theta-\varphi)N} \text{prob}(\mu = j)\, dj \\
&= \Phi\left\{\frac{[(1-\theta)p - \theta + 2\varphi]\sqrt{N}}{\sqrt{p(1-p)(1-\theta)}}\right\}\Phi\left\{\frac{[(1-p)\theta - \varphi]\sqrt{N}}{\sqrt{p(1-p)\theta}}\right\}.
\end{aligned}$$

Hence $\lim_{N_t\to\infty} \pi_m(X_t) = 1$ if the arguments in (A3) and (A4) are positive. This is true for some $\theta > .5$ since all that is needed for the argument in (A4) to be positive is that

$$\theta < \frac{p + 2\varphi}{1 + p} \in (1/2 + \varphi, \min\{1, 2/3 + 4/3\varphi\}).$$

It is also necessary that the argument in (A3) be positive for some $\varphi > 0$, and inspection of (A3) yields that this is true for $\varphi \in (0, (1 - p)\theta)$. I have established that the marginal person choosing the male technology could expect a son to marry with certainty if $X_t < \theta N_t$. This combined with (A1) and (A2) implies that $X_t > .5N_t$.

Since it has been shown that $X_t = \theta N_t > .5N_t$, let us now turn to a daughter's probability of marrying. The critical person is the one with the lowest rank, and $\pi_f(N_t)$ corresponds to the probability that there are more men than women in the entire population, which can be written as

$$\pi_f(N_t) = \Phi\left[\frac{(2p - 1)(2\theta - 1)\sqrt{N_t}}{\sqrt{p(1 - p)}}\right].$$

Clearly, $\lim_{N_t\to\infty} \pi_f(N_t) = 1$ if $\theta > .5$.

The strategy profile in which $r_t \leq X_t$ choose the male technology and $r_t > X_t$ choose the female technology is the unique Nash equilibrium when sex choice is imperfect, since (A2) holds for any strategy profile and, for large N_t, each individual's strategy choice has a negligible impact on $\pi_m(r_t)$. Male marriage probability as a function of rank is illustrated in figure A1.

Let us now turn to the case of perfect sex choice. It is easily verified that $r_t \in \{1, 2, \ldots, A_t\}$ choosing $p_s = p_m$ and $r_t \in \{A_t + 1, \ldots, N_t\}$ choosing $p_s = p_f$ is a Nash equilibrium. I now proceed to show that all Nash equilibria have the following property: $r_t \in \{1, 2, \ldots, A_t - 1, Z_t\}$, $Z_t \in \{A_t, \ldots, N_t\}$, choose $p_s = p_m$ and $r_t \in \{A_t, A_t + 1, \ldots, Z_t - 1, Z_t + 1, \ldots, N_t\}$ choose $p_s = p_f$.

Let us use as the benchmark the case in which $r_t \in \{1, 2, \ldots, A_t\}$ choose

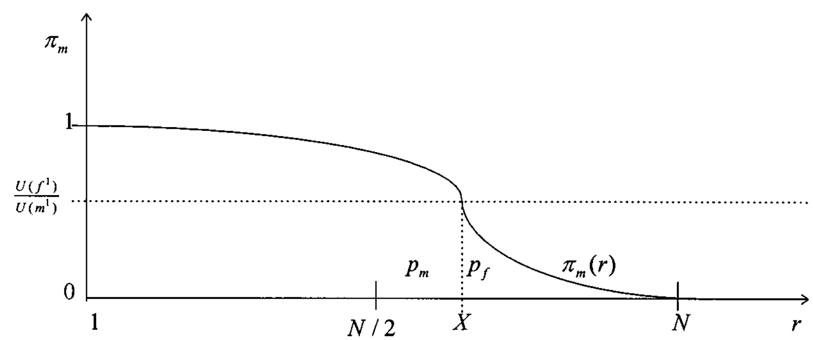


FIG. A1

$p_s = p_m$ and $r_t \in \{A_t + 1, \ldots, N_t\}$ choose $p_s = p_f$, and note that sex ratios must balance in all Nash equilibria. Thus any other equilibria would involve at least one of $r_t \in \{A_t + 1, \ldots, N_t\}$ choosing a son, matched by equally many of $r_t \in \{1, 2, \ldots, A_t\}$ choosing a daughter.

First, note that only one of $r_t \in \{A_t + 1, \ldots, N_t\}$ could have a son who would marry. Suppose the opposite, and let $n > 1$ be the number of $r_t \in \{A_t + 1, \ldots, N_t\}$ choosing sons. Then n of $r_t \in \{1, 2, \ldots, A_t\}$ must choose daughters. Let x be the maximum number of $r_t \in \{1, 2, \ldots, A_t\}$ who, given n, would choose daughters. The number of males who can marry equals the number of females in the population, that is, $A_t - n + x$. The last male among $r_t \in \{1, 2, \ldots, A_t\}$ has male rank $A_t - x$. The term x will be such that the number of men among the first A_t individuals equals the number of women in the population; hence $x = n/2 < n$. But for $n > 1$ to be a Nash equilibrium, it is necessary that $x = n$, a contradiction.

Second, note that if $n = 1$, $r_t \in \{1, 2, \ldots, A_t - 1\}$ have sons who marry. However, were $r_t = A_t$ also to choose a son, that son would be man A_t in a population with only $A_t - 1$ women. Consequently, $r_t = A_t$ is better off with a daughter, which in turn leaves room for one of $r_t \in \{A_t + 1, \ldots, N_t\}$ to choose a son. Q.E.D.

Appendix B

Equilibrium with Unmarried Daughters

This Appendix explores the possible consequences of allowing matching failures. If matching is imperfect, the availability of partners is not a sufficient condition for marriage. I maintain the assumption of a large population. It will be convenient to normalize the population to be uniformly distributed on the unit interval $r \in [0, 1]$ and treat r as a continuous variable. Let us model failure to marry by assuming that, instead of π_s, the probability of marriage is $\tilde{\pi}_s = \pi_s\gamma_s$, where $\gamma_s = \gamma(s_s) \in (0, 1)$, γ is continuous, $\gamma'(\cdot) < 0$, s_m and s_f are the respective shares of males and females in the population, $\gamma_s \to 1$ if $s_s \to 0$, and $\gamma_s \to 0$ if $s_s \to 1$. Note that γ responds to the sex ratio but is invariant to an individual's ranking.

A. *Perfect Sex Choice*

Proposition B1. If $\gamma_f(.5) > -U(f^0)/[U(f^1) - U(f^0)]$ and $p = 1$, sex ratios balance and $r \leq .5$ is male.

The proof follows from the arguments in the proof of proposition 1 in Appendix A.

Proposition B2. If $\gamma_f(.5) \leq -U(f^0)/[U(f^1) - U(f^0)]$ and $p = 1$, then there exists an $r^* \in [0, .5]$ such that $\gamma_f(r^*) = -U(f^0)/[U(f^1) - U(f^0)]$ and all Nash equilibria have the following properties: $r \leq r^*$ choose sons; and among $r > r^*$, $1 - 2r^*$ choose sons and r^* choose daughters.

Proof. Under the proposed equilibrium, $s_f = r^*$. From monotonicity of γ and the fact that $\gamma_f \to 1$ as $r^* \to 0$, there exists a unique $r^* \in (0, .5]$ such that $\gamma_f(r^*) = -U(f^0)/[U(f^1) - U(f^0)]$.

If $s_f = r^* \in (0, .5]$, then $\pi_s = 1$ for all $r \leq r^*$. Moreover, $\gamma_s > 0$. Hence, a son gives higher expected utility than a daughter for all $r \leq r^*$ if $\gamma_m U(m^1) > \gamma_f U(f^1) + (1 - \gamma_f) U(f^0)$. If we plug in $\gamma_f(r^*) = -U(f^0)/[U(f^1) - U(f^0)]$, this condition reduces to $\gamma_m U(m^1) > 0$, which clearly is satisfied.

For $r > r^*$ the choice is between a son who does not marry and a daughter who marries with probability γ_f. For $r > r^*$ to be indifferent, a son and a daughter must yield the same expected utility, which is the case if r^* is such that $\gamma_f(r^*) = -U(f^0)/[U(f^1) - U(f^0)]$. Q.E.D.

B. *Imperfect Sex Choice*

Proposition B3. If $\gamma_f(1 - p) > -U(f^0)/[U(f^1) - U(f^0)]$ and $p \in (.5, 1)$, then there exists a cutoff rank $r^* \in (.5, 1)$ such that $r \leq r^*$ choosing the male technology and $r > r^*$ choosing the female technology is the unique Nash equilibrium. Otherwise, everybody's choosing the male technology is the unique Nash equilibrium.

Proof. To simplify the exposition, let us start with some notational housekeeping. Note that under the proposed equilibrium, the cutoff rank r^* implies the population sex ratio. Therefore, when applicable, I shall write $\gamma_s(r^*)$ instead of $\gamma_s(s_s)$. Moreover, it will be convenient to define

$$K(r, r^*) \equiv \frac{U(m^1)\pi_m(r)\gamma_m(r^*) - U(f^0)}{[U(f^1) - U(f^0)]\gamma_f(r^*)}. \tag{B1}$$

Let K_{r^*} and K_r denote the partial derivatives of K with respect to r^* and r, respectively. Note that

$$K_{r^*}(\cdot) < 0 \tag{B2}$$

since higher r^* implies lower (higher) s_f (s_m), which in turn implies higher (lower) γ_f (γ_m); also note that

$$K_r(\cdot) < 0 \tag{B3}$$

(from $\pi'_m(r) < 0$; see App. A).

I now proceed to verify that the proposed equilibrium exists and is unique. If $r^* > .5$, then $\pi_f(r) = 1$ for all r (App. A). A daughter yields expected utility $\gamma_f(r^*)U(f^1) + [1 - \gamma_f(r^*)]U(f^0)$ whereas a son yields $\pi_m(r)\gamma_m(r^*)U(m^1)$. Hence, the male technology is preferred if $K(r, r^*) \geq 1$, and the female technology otherwise.

For the marginal parent it must be that

$$K(r^*, r^*) = 1, \quad r^* \in (.5, 1). \tag{B4}$$

A necessary and sufficient condition for (B4) to hold is that $K(1, 1) < 1$. To see this, let ρ be defined by the equation $K(\rho, r^*) = 1$. If ρ exists, then it is a function of r^* and $\rho'(r^*) < 0$ (from [B2]). For (B4) to hold, it is necessary that $\rho(r^*) = r$. If $K(1, 1) < 1$, then $\rho(1) < 1$ (from [B3]). Consider now an $r^* = r' < 1$ such that $K(1, r') = 1$; clearly $\rho(r') = 1$. From $\rho'(\cdot) < 0$ there exists a unique $r^* \in (r', 1)$ such that $\rho(r^*) = r^*$.

From (B3) we know that if (B4) holds for r^*, then $r \leq r^*$ choose the male technology and $r < r^*$ the female technology.

That $K(1, 1) < 1$ also is a necessary condition for $r^* < 1$ can be seen from the fact that, if $K(1, 1) = 1$, then obviously $\rho = r^* = 1$; if $K(1, 1) > 1$, (B4) cannot be satisfied (everybody tries for boys in either case).

We also need to establish that $r^* > .5$. The intuition for why this must be the case is that if $r^* \leq .5$, then $\gamma_m > \gamma_f$, and all that is needed for $r^* \leq .5$ to be untenable is that a son is preferred by some $r > .5$. A sufficient condition for this is that there exists a $\pi_m(r)$, $r > .5$, sufficiently close to one. Since this will be true (App. A), $r^* \leq .5$ cannot be a Nash equilibrium.

It remains to verify that the proposed equilibrium is unique. Again, any equilibrium will have a surplus of men; hence $\pi_f(r) = 1$ for all r, and the expected utility from a daughter is invariant to the parental status r. However, the expected utility from a son decreases in r from $\pi_m'(r) < 0$. This implies that if $\pi_m(r)$ is such that one parent is better off choosing the daughter technology, then so are all parents with a higher rank index (lower status).

Finally, I can rewrite the condition $K(1, 1) < 1$ as $\gamma_f(1 - p) > -U(f^0)/[U(f^1) - U(f^0)]$ by noting that $\pi_m(1) = 0$ and that $r^* = 1$ implies $s_f = 1 - p$. Q.E.D.

Appendix C

Small Population Size: An Example

Consider the following case: $p = 1$, $U(m^1) = 12$, $U(f^1) = 10$, $U(f^0) = -11$, $\gamma_m = F/N$, and $\gamma_f = M/N$.

If $N = 6$, then $r = 1, 2$ choosing daughters and $r = 3, 4, \ldots, 6$ choosing sons is a Nash equilibrium. But already at $N = 8$, the equilibrium with daughters at the top vanishes.

The intuition is the following: The females in the top layer are prevented from switching because if they do so, the number of males increases by one, causing a sufficient drop in γ_m to make a deviation unattractive. Clearly, this can happen only if the population is small. How large the population size needs to be to rule out women at the top depends on the parameter values.

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