Sex Selection and Gender Balance*

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Abstract

We model the equilibrium sex ratio when parents can choose the sex of their child. With intrinsic son preference, sex selection results in a male-biased sex ratio. This is inefficient due to a marriage market congestion externality. Medical innovations that facilitate selection aggravate the inefficiency. If son preference arises endogenously, due to population growth causing an excess supply of women on the marriage market, selection may improve welfare. Empirically, sex selection causes an excess of males and reduces welfare in China, and in North-Western India.

Keywords: gender bias, sex ratio, marriage market, sex selection, congestion externality, marriage squeeze.

JEL Categories: J12, J13, J16

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In many parts of the world, parents exhibit gender bias, preferring to have sons. This phenomenon is especially prevalent in South and East Asia. In Northern India, it is common to celebrate the birth of a boy and bemoan that of a girl. The community of *hijras* (eunuchs), who make their living by extorting money on joyous occasions such as the birth of a child, demand substantially larger amounts when the child is male. Gender bias is reflected in male-biased sex ratios and the problem of "missing women" (Amartya Sen 1990), a problem that was already noted in the first Indian census of 1871. Historically, sex ratio imbalances have been attributed to the relative neglect of girls, but in extreme cases, infanticide has also been practised. In Dharmapuri district of Tamil Nadu, India, infant girls were often fed uncooked rice, as a way of inducing rapid death. In Punjab (northern India), the caste of Bedi Sikhs have traditionally been known as *kudi-maar* – "girl-killer".[1]

Modern medicine has aggravated the problem by facilitating selection for boys. The development and spread of amniocentesis and ultrasound screening in the early 1980s made foetal sex determination possible, permitting sex selective abortion. Sex selective abortion is illegal in China and India, but the practice flourishes. It is hard to see how such a law can be enforced given that neither ultrasound nor abortions are illegal, so that sex selective abortion is *unverifiable*. These technological developments have been associated with a rapid increase in the sex ratio at birth in East/South Asia, from its usual norm of 105-106 boys per 100 girls. In the Indian census of 2001 the sex ratio in the age group 0-6 was 107.8, with some northern states such as Punjab having ratios as high as 120-125.[2] In the 2000 Chinese census, the sex ratio in the age group 0-4 was 120.2, with some regions reporting ratios of 130-135. These trends are mirrored in other Asian countries such as South Korea and Taiwan, which have sex ratios at birth of 108 and 109 respectively. The large increases in the sex ratios across censuses are most plausibly due to the spread of sex selection techniques.[3] Indeed, "gendericide" has become a matter of serious public concern.[4]

The marriage market consequences of these sex ratio imbalances are enormous. Our empirical estimates suggest that in China, almost one in five boys in recently born cohorts will be without brides, raising fears of social disruption and instability. This raises the question, how can such imbalances persist? Asian parents may prefer boys to girls, but surely evolution

[1] See Monica Dasgupta (1987) on discrimination in the Punjab.

[2] V. Bhaskar and Bishnupriya Gupta (2007) analyze the trends in sex ratios in infancy/childhood across different Indian states, and the extent to which these trends can be explained by the gender differentials in the effects of development upon mortality.

[3] For aggregate estimates of the extent of sex selective abortions in India, see Fred Arnold, Sunita Kishor and T.K. Roy. (2002) and Prabhat Jha et al. (2006). Claus Portner (2010) presents evidence based on Indian micro data, using information on birth spacing to infer selection

[4] On March 6 2010, the *Economist's* cover story was entitled "Gendericide: The worldwide war on baby girls".

has also endowed them with a strong desire for grandchildren? Can such sex ratios be an equilibrium phenomenon, or do they reflect myopia on the part of parents? These trends also raise the normative question, should we allow parental sex selection? The standard response, from governments, international agencies, and non-governmental organizations, is to deplore sex selection, since this reflects discriminatory preferences, that are based on ignorance and backwardness. Rather than allowing choice based on such preferences, the state has a duty to educate away such preferences. This view is squarely paternalistic, and policy is not based upon the preferences of citizens, but on those of enlightened agencies.

An alternative view, that is less common, is that sex selection may improve the position of girls, by raising their value as they become scarce. Dharma Kumar (1983) was an early and trenchant proponent of this position. She asked whether selective abortions are any worse than the neglect and infanticide of girl children, and argued that market forces will alleviate problems arising from discriminatory preferences. However, this view does not take into account possible externalities or market failure.

There is an enormous empirical literature on the subject of the sex ratio. Following Sen (1990) and many demographers (e.g. Ansley J. Coale, 1991), economists are increasingly contributing to this debate (see Emily Oster 2005; Nancy Qian 2008; Siwan Anderson and Debraj Ray 2010). However, there is very little in terms of formal economic analysis of the social implications of sex ratio imbalances arising from sex selection. Lena Edlund (1999) examines the effects of sex selection in a finite and hierarchically ordered society, and shows that the upper classes have an incentive to have only boys, while the lower classes prefer girls. However, her work does not examine welfare issues, and does not address the congestion externalities and possible market failures that lie at the heart of the present paper. Her positive analysis also yields conclusions that are different from ours, and that seem to be counter to the empirical trends – for example, with perfect sex selection, she predicts a balanced sex ratio, while our model predicts that the sex ratio would become more unbalanced. Our paper is closest in spirit to evolutionary models of the sex ratio that date back to Darwin and Ronald Aylmer Fisher (1930); however, biological models do not allow for any concerns apart from long run genetic representation, and do not deal with welfare issues.

Section 1 of this paper proposes a model of parental choice and the equilibrium sex ratio in order to address these issues. An imbalance in the marriage market sex ratio is an equilibrium consequence of gender biased preferences. At an equilibrium, the payoff difference between having a boy and a girl will be lower than in the absence of choice. This is mainly done by reducing the payoff from having a boy, through reduced marriage market prospects; the payoff from having a girl also rises, but to a smaller extent. In consequence, parents who select boys exert a congestion externality in the marriage market. Sex selection reduces welfare, where welfare is evaluated in terms of the ex ante expected utility of the typical parent. Technological improvements in selection that facilitate sex selection will worsen the sex ratio and reduce welfare. Our policy recommendation is a Pigouvian subsidy to girls, that is financed by a tax on boys – this results in a Pareto improvement.

Our conclusions are different if intrinsic gender bias is absent or mild, and if the observed preference for boys arises endogenously, from the fact that girls find it hard to marry. This may arise due to the *marriage squeeze* – the effective excess supply of girls in the marriage market, due to growth in cohort size and the fact that men marry younger women. If growing cohorts give rise to an excess supply of girls, and there is little intrinsic gender bias, then sex selection may improve welfare. Thus, the answer to the question, of whether sex selection raises or reduces welfare depends upon empirical evidence. In China, census data shows that cohort sizes are falling rapidly, so there is reverse marriage squeeze, and a large excess supply of boys. Thus selection for boys is unambiguously welfare reducing. In India, the picture is more mixed. Cohort sizes are growing, albeit slowly, and the marriage squeeze counteracts the marriage market consequences of biased sex ratios, which are not too male biased in most of the country. This is except for the North-West of India, which has very male biased sex ratios. Interestingly, in South India, there is an excess of males, due to falling cohort sizes, rather han male biased sex ratios.

The results of our model are robust to various extensions. As Joshua Angrist (2002) and Pierre-Andre Chiappori, Bernard Fortin and Guy Lacroix (2002) show, an excess of males on the marriage market will raise the bargaining power of women and shift household allocations in their favour. If parents are altruistic towards their children, this will make it more attractive for them to have girls rather than boys. They may also be able to capture a part of these gains in the form of bride prices. Such distributional effects will reduce the magnitude of sex ratio imbalances, but our qualitative conclusions continue to hold. We show this in section 2, in a model where dowries or intra-household allocations are negotiated in marriage markets that are subject to search frictions. With large gender bias, the equilibrium sex ratio is excessively biased towards boys, from a social welfare standpoint, and technological progress reduces welfare by aggravating the congestion externality.

In section 3 we consider how the incentive to select varies endogenously across social groups, so that selection decisions in upper classes will affect incentives in poorer sections. In section 4 we consider developed societies where family gender balancing is a primary motivation. Sex selection is increasingly possible via "acceptable" technologies, such as *in vitro* fertilization or preconception gender selection. Sex selection may improve individual utility; however, even if family balancing is the primary motive, a congestion externality may arise if preferences are not fully symmetric between the sexes, or if the costs of selection are gender dependent. Thus society must ensure that incentives are provided to ensure gender balance at the aggregate level. The final section of the paper concludes. The appendix provides details of the formal proofs that are not dealt with in the body of the paper.

1 The equilibrium sex ratio

The standard biological model of the sex ratio dates back to the classic work of Fisher (1930), following on ideas from Darwin. Fisher's model is one where a parent is concerned only with maximizing reproductive fitness, and predicts a balanced sex ratio. In equilibrium, there is no gender bias – parents are equally happy when a girl is born as when a boy is. However, human societies have undergone great transformations since the times of hunter-gatherers, when evolutionary preferences were shaped. With increased life expectancy, children are an important source of support in old age. Thus the economic value of offspring, beyond considerations of genetic representation, is also important. Different agricultural technologies afford varying roles for the sexes. Esther Boserup (1970) argued that the superior status of women in sub-Saharan Africa relative to Asia was attributable to their greater utility in hoe-cultivation as compared to plough-cultivation. Pranab Bardhan (1974) attributes the higher status of women (and favorable sex ratios) in rice-growing south India, relative to wheat-growing north India, to the fact that rice has greater use for female labor than wheat. More recently, Qian (2008) investigates the effects of the change in gender specific earnings caused by the Chinese economic reforms, that raised the returns to female labor in tea growing regions, and to male labor in regions with orchard fruit. She finds significant inter-regional changes in the sex ratio that are associated with regional cropping patterns.

Cultural factors may also reinforce son preference. For Hindus, a son is deemed essential, since it is he who must light the funeral pyre. Confucianism assigns a pivotal role to the son-father relationship. Economists may seek deeper explanations for these cultural phenomena; however, these historically given preferences play a role in determining current behavior.

These considerations suggest that while concerns of reproduction are important, the economic (and cultural) value of offspring is also relevant. Accordingly, we modify Fisher's model by allowing parents to have preferences directly regarding the gender of their child. Our primary focus is on the effects of "gender-bias" in preferences, possibly arising from differences in economic value of the sexes, although we also investigate "family-balancing" concerns in section 4. To this end, we assume that parental preferences are such that a boy is preferred to a girl, conditional on both having the same marital status. However, a married girl is strictly preferred to a single boy. Since marriage is uncertain, we need to consider preferences over lotteries, and we parameterize the von-Neumann Morgenstern utilities as follows. Let u_B be the base payoff to the parents from having a single boy, and let u_G be the base payoff from having a girl. We assume that each boy is ex ante identical; however, his quality in the marriage market is random and equals $\rho_G + \varepsilon$, where $\rho_G > 0$ and ε has a continuous density on support $[0, \bar{\varepsilon}]$. Thus, any girl has a payoff ρ_G from marriage, and the term ε reflects the idiosyncratic quality of her partner's quality. Similarly, all girls are ex ante identical, and her realized quality equals $\rho_B+\eta$, where $\rho_B > 0$ and η has a continuous density on support $[0, \bar{\eta}]$ with the same mean as ε. We assume that the idiosyncratic component of match value is small relative to the systematic component – this is stated precisely as Assumption A1. Assume that $u_B + \rho_B \geq u_G + \rho_G$ – for most of the paper, we assume that this inequality is strict, i.e. there is son preference. Furthermore, we shall assume that a married girl is always preferred to a single boy i.e. $u_B < u_G+\rho_G$. We assume that the quality of the child cannot be observed at conception (although gender can), but only later, on the marriage market. We also assume that parents evaluate matches in the same way that their offspring do.

We now turn to supply and demand in the marriage market, which depend not only on the sex ratio but also upon the rate of growth in birth cohort size. This is due to the fact that men are, on average, older than their wives. Data from the United Nations (1990) documents that this is true in each of over 90 countries, in each time period (between 1950 and 1985) that data is available. While an age gap at marriage may not cause any imbalances in a stationary population, it has major social consequences when cohort sizes are increasing over time, since each cohort of men is matched with a larger cohort of women. The consequent excess supply of women has been called the *marriage squeeze,* and it weakens women's' position on the marriage market. Demographers such as P.N. Mari Bhat and Shiva S. Halli (1999) have argued that the marriage squeeze is responsible for the deterioration of the position of women in India, and the replacement of the institution of bride price in many regions and communities by dowries (payment from the bride's family to the groom). Let g be the rate of growth of cohort size, and let $\bar{r}$ be the sex ratio at birth (of girls relative to boys). Let τ be the age gap at marriage, assumed to be exogenous – on page 10 we discuss the implications of endogenizing τ. Thus the ratio of women to men in the marriage market, r, is related to the sex ratio at birth, $\bar{r}$, by the equation $r = \bar{r}\gamma$, where $\gamma \equiv (1 + g)^{\tau}$. For expositional simplicity, we shall focus on the case where $g \geq 1$ – the implications of negative growth are easily inferred from our analysis.

Our analysis focuses on a dynamic steady state equilibrium, where the sex ratios at birth and in the marriage market are constant. In the marriage market, matching takes place between men born at any date t and women born at $t + \tau$, where the ratio of the measures of the latter to the former equal r, at every date t. Marriage market matching is required to be measure preserving, and *stable,* in the sense of David Gale and Lloyd S. Shapley (1962). This determines the expected payoffs from having a boy or a girl. Given this, sex selection decisions are taken optimally, so that the resulting sex ratio in the marriage market equals r.

Let M be the set of men at date t and let W be the set of women at $t+\tau$. A matching is a function $\phi : \mathsf{M} \to \mathsf{W} \cup \{0\}$ that satisfies the following properties. First, if $w = \phi(m)$, then w is not the image of any other $m' \in \mathsf{M}$ under ϕ, i.e. any woman can be matched only to a single man. Second, if $\mathsf{M'} \subset \mathsf{M}$, the Lebesgue measure of $\mathsf{M'}$ equals that of the set $\phi(\mathsf{M'}) \cap \mathsf{W}$. Third, if $w = \phi(m)$, then both m and w prefer to be matched to each other rather than being single. Finally, if $w \neq \phi(m)$, then either m prefers $\phi(m)$ to w or w prefers her current match to m.

In this context, it is well known that a stable measure preserving matching is essentially unique, and will be positively assortative. That is, if a boy of realized quality ε is matched to a girl of realized quality $\phi(\varepsilon)$, then

$$1 - F(\varepsilon) = r[1 - G(\phi(\varepsilon))],$$

where $F(.)$ and $G(.)$ denote the cumulative distribution functions of ε and η respectively. If $r < 1$, then the lowest quality boys, i.e. a proportion $1 - r$, will be left unmatched. Let $\underline{\varepsilon} = F^{-1}(1 - r)$ denote the lowest quality boy that is matched in this case. If $r > 1$, the lowest quality girls, of proportion $1 - \frac{1}{r}$, will be left unmatched. Let $\underline{\eta} = G^{-1}(1 - \frac{1}{r})$ denote the lowest quality girl that is matched. To see that this is stable, consider a boy of type $\varepsilon \geq \underline{\varepsilon}$, who is matched to a girl of type $\phi(\varepsilon)$ (a similar argument can be made for each type of girl). The only girls he prefers are those with a type $\eta > \phi(\varepsilon)$; however, any such girl is matched to a higher type boy, and will not accept his proposal. An unmatched has type $\varepsilon \leq \underline{\varepsilon}$, and is therefore weakly inferior, from a girl's point of view, than her own match.

We now turn to the payoff of the parents, given this matching in the marriage market. Since the quality of the offspring is unknown at the time of conception, the ex ante expected utility of having a boy, as function of the sex ratio, is given by

$$U(r) = \begin{cases} u_B + r[\rho_B + \mathbf{E}(\eta)] \text{ if } r < 1 \\ u_B + \rho_B + \mathbf{E}(\eta | \eta \geq \underline{\eta}) \text{ if } r \geq 1 \end{cases}.$$

Similarly, the ex ante expected utility of having a girl is given by

$$V(r) = \begin{cases} u_G + \frac{1}{r}[\rho_G + \mathbf{E}(\varepsilon)] \text{ if } r \geq 1 \\ u_G + \rho_G + \mathbf{E}(\varepsilon | \varepsilon \geq \underline{\varepsilon}) \text{ if } r < 1 \end{cases}.$$

Suppose now that sex selection is very costly, so that it is never exercised. We shall assume in this paper that the natural sex ratio at birth is 1. The sex ratio in the marriage market is given by γ. Thus the payoff difference between having a boy and having a girl is given by

$$[u_B + \rho_B + \mathbf{E}(\eta|\eta \geq \underline{\eta})] - [u_G + \frac{1}{\gamma}(\rho_G + \mathbf{E}(\boldsymbol{\varepsilon}))] \ > 0.$$

If cohort sizes are increasing, then boys are preferred to girls not only due to possible son preference (i.e. if $u_B + \rho_B > u_G + \rho_G$) but also due to the fact that girls have poorer marriage market prospects – boys will be matched for sure and secure a higher quality partner, while girls are matched only with probability $\frac{1}{\gamma}$.

Let the cost of sex selection be sufficiently small that it will be exercised. Consider first the case of ex post selection, e.g. via sex selective abortions. In this case, a pregnant mother observes the sex of foetus and can pay a cost c to have an abortion and conceive another child. Suppose that the foetus is female, and has value $V(r)$. By having an abortion and trying again, the parent gets the ex ante expected utility of a child, which is given by $\frac{1}{2}\{U(r) + V(r)\}$, minus the cost. So aborting the foetus and trying again is optimal if $U(r) - V(r) \geq 2c$, while accepting the girl child is optimal if this inequality is reversed. In the case of *in vitro* fertilization, choice is exercised ex ante, before pregnancy. If the parents select a boy, they are assured of the certain payoff, $U(r) - c$, where c now represents the cost of *in vitro* fertilization. By not exercising choice, the parents get the lottery with payoff $\frac{1}{2}\{U(r) + V(r)\}$. Thus the incentives for exercising choice are formally identical to the case of ex post selection, even though choice is associated with the uncertain outcome in the case of abortions, and with the certain outcome in the case of *in vitro* fertilization. However, the magnitude of the cost involved in selection (c) is likely to be dramatically different in the two cases, since *in vitro* fertilization is much more acceptable from a psychological, ethical and social point of view. The analysis is easily extended to the case of imperfect ex ante selection technologies, such as sperm selection – if parents can choose so that the probability of having a boy is $p > 0.5$, then the relevant cost is $\frac{2c}{2p-1}$ rather than $2c$.

Suppose that $2c < U(\gamma) - V(\gamma)$. It is clear that $r = \gamma$ cannot be an equilibrium, since the value of trying again is greater than the cost. At the unique equilibrium, the sex ratio r^* must be interior (i.e. in $(0, 1)$), so it must be the case that a parent is indifferent between accepting a girl child and trying again. This gives us the basic indifference condition:

$$U(r^*) - V(r^*) = 2c. \tag{1}$$

The intuition for this condition is straightforward: by exercising choice when one has a girl, a parent gets an improvement in value from $V(r^*)$ to $U(r^*)$, with probability one half. Indifference requires that the expected value of this equals the cost c.

Consider first a society where $\gamma > 1$, so that cohort sizes are growing, but where gender bias in preferences is mild or non-existent so that $(u_B + \rho_B) - (u_G + \rho_G) < 2c$. The equilibrium sex ratio in the marriage market, r^*, must be greater than one. To see this, assume, to the contrary, that the marriage market is balanced. Then $U(1) - V(1) - 2c < 0$, so that the payoff difference between a boy and a girl is less than the cost of selection. Since selection for boys must take place if the sex ratio is to fall below γ, the indifference condition (1) must be satisfied. Thus, the equilibrium sex ratio in the marriage market, r^*, must exceed one, while the sex ratio at birth, $\bar{r}$, will be less than one.

Now let us consider a society where there is significant gender bias in preferences, so that $(u_B + \rho_B) - (u_G + \rho_G) > 2c$. In this case, parents will prefer to select for boys when the marriage market is balanced. Thus the equilibrium sex ratio, r^*, must be less than one, and selection will aggravate the imbalance in the marriage market due to population growth rather than alleviating it.

To summarize: if cohort sizes are growing and gender bias is mild, sex selection will alleviate the imbalance in the marriage market but not entirely eliminate it. However, if there is significant gender bias in preferences, there will be an excess of boys on the marriage market. Our analysis also shows that no matter whether we have large gender bias or not, the equilibrium marriage market sex ratio r^* does not depend upon the rate of population growth, γ. This is clear from indifference condition (1) – neither $U(r)$ nor $V(r)$ depend upon γ.[5] This implies that the sex ratio at birth adjusts to variations in γ, so as to keep r^* invariant.

What is the implication of the natural sex ratio at birth being different from 0.5? This is relevant, since the natural ratio at birth in appears to be around 0.94 or 0.95, and data show that this excess of boys is not offset by differential mortality in the case of India and China (see Anderson and Ray 2010). It is also relevant in the context of the argument by Oster (2005) that hepatitis B infection raises the probability of having a boy. [6] Let p denote the probability of having a boy, as assessed by the parents. The equilibrium marriage market sex ratio r^* depends only on the assessed p, and via the indifference condition, which must be re-written as $U(r^*) - V(r^*) = \frac{c}{p}$. Thus the behavioral response by parents to natural

[5]This is subject to the caveat that we are at an equilibrium with selection; otherwise (e.g. when c is large), this is not true, since $r = \gamma$.

[6]This has been questioned by a number of authors, and qualified by Oster herself. Most compelling are the findings of Ming-Jen Lin and Ming-Chin Luoh (2008), who use Taiwanese data on the mother's hepatitis B status at the time of pregnacy, and find that this does not contribute significantly to explaining imbalances in the sex ratio at birth.

variations in the sex ratio at birth considerably reduces the impact of such variations upon the equilibrium sex ratio.

It is plausible that parents differ in their extent of son preference, and also to the degree to which they value grandchildren. If the preference parameters $(u_B, u_G, \rho_B, \rho_G, c)$ were drawn for each parent according to an atomless distribution, then some parents (e.g. those with high gender bias) would choose for sure to have boys, while others would accept a girl. Thus, almost all parents would have strict incentives to follow their equilibrium strategies, but the aggregate sex ratio would be interior. Moreover, if the heterogeneity is small, the equilibrium sex ratio is close to that in the society without heterogeneity. This corresponds, essentially, to a Harsanyi-style purification (John C. Harsanyi 1973) of the equilibrium considered here.

We have assumed that the age gap in marriage, τ, is fixed. Bhaskar (2010) analyzes how the age gap corresponding to a Gale-Shapley style stable matching responds to variations in population growth, g. Suppose that men and women have single-peaked preferences over the age gap at marriage, with men having an ideal age gap $\tau_B > 0$, while the women's ideal gap is $\tau_G > 0$. With non-transferable utility, the equilibrium age gap τ will equal the ideal point of the short side of the market. That is, it will be equal to τ_B if there is an excess supply of women in the marriage market, and τ_G if there is an excess supply of men. If the marriage market is balanced, then there can be multiple equilibria, with τ taking any value between the two ideal points. Thus our assumption that τ is fixed corresponds to the case where $\tau_G = \tau_B$. If the ideal points differ, then the age gap is *relatively insensitive* to changes in the sex ratio, since it changes only when market conditions change from excess supply to excess demand. More generally, it is not the case that the age gap adjusts to reduce excess supply in the marriage market. If gender bias is large, there will be excess supply of men in the marriage market, and the equilibrium age gap will be τ_G. There is an indirect effect of the endogeneity of τ upon r^* – women get a higher payoff since $\tau = \tau_G$, so that $V(r)$ is larger, and men get a lower payoff, i.e. a lower $U(r)$. This increases the equilibrium sex ratio r^*. Similarly, in the absence of gender bias, there will be an excess supply of women due to the marriage squeeze, and this means that $\tau = \tau_B$. This has direct effects on $\bar{r}$ and, indirectly, a negative effect on r^* by raising men's payoffs and reducing women's.

1.1 Welfare implications

Let us now examine the welfare implications of parental choice. The literature on sex selection in societies with gender bias has assumed that sex selection is immoral per se. Indeed, sex selective abortions have been termed "genocide" or "gendericide". This however begs several question. In the societies under discussion (e.g. India or China), abortion is legal and also morally acceptable, implying that these societies do not endow the foetus with an unconditional "right to life". If this is indeed the case, then why are selective abortions deemed immoral? Even if society is able to prevent sex selective abortions, it cannot ensure that the unwanted girls are loved and taken care of. Furthermore, newer selection technologies such as *in vitro* fertilization or preconception gender selection are less open to absolutist moral objections. In this paper, we assume a non-paternalistic welfare evaluation, and consider the welfare of the individual parent. As we shall see, selection can reduce welfare even using as a criterion the preferences of gender biased parents. Since all parents are ex ante identical (before the realization of the sex of their child), we take as our welfare criterion the ex ante expected utility of a typical parent – this also equals the sum of realized utilities of the parents in this society. Thus welfare, as a function of the sex ratio r, is given by

$$W(r) = \frac{1}{1+\bar{r}}U(r) + \frac{\bar{r}}{1+\bar{r}}V(r) - c\frac{1-\bar{r}}{1+\bar{r}}. \tag{2}$$

That is, a proportion $\frac{1}{1+\bar{r}}$ of parents have boys, and get utility $U(r)$, while the remainder have girls and utility $V(r)$. The third term is the cost associated with changing the sex ratio at birth from 1 to $\bar{r}$. Suppose that the social planner can choose the level of r, and consider how she might choose in order to maximize welfare – we shall see that tax/subsidy schemes can serve as instruments. The derivative of welfare with respect to r equals

$$W'(r) = \frac{[V(r) + 2c - U(r)] + \gamma(1+\bar{r})[U'(r) + \bar{r}V'(r)]}{\gamma(1+\bar{r})^2} \tag{3}$$

$U(r)$ and $V(r)$ are differentiable everywhere except at $r = 1$, with derivatives :

$$U'(r) = \begin{cases} \rho_B + \mathbf{E}(\eta) & \text{if } r < 1 \\ \frac{\mathbf{E}\left(\eta|\eta \geq \underline{\eta} - \eta\right)}{r} & \text{if } r > 1 \end{cases}.$$

$$V'(r) = \begin{cases} \frac{\underline{\varepsilon} - \mathbf{E}(\varepsilon|\varepsilon \geq \underline{\varepsilon})}{r} & \text{if } r < 1 \\ -\frac{\rho_G + \mathbf{E}(\varepsilon)}{r^2} & \text{if } r > 1 \end{cases}.$$

If $r < 1$, then an increase in r raises male utility by increasing the probability that a boy finds a partner. It also reduces female utility, since lower quality males are also matched; however, since the idiosyncratic component of match quality is assumed to be small relative to ρ_B, the positive effect on males outweighs the negative effect on females. Similarly, when $r > 1$, a reduction in r has a positive effect on females, which is greater in absolute value than the negative effect on males.

Consider the derivative of welfare with respect to r, (3), evaluated at the equilibrium r^*. The first term in the numerator equals zero, since indifference condition (1) holds at equilibrium. Thus, the sign of the derivative is the same as that of $[U'(r) + \bar{r}V'(r)]$ evaluated at r^*. This depends upon whether r^* is less than or greater than one, and given by

$$[U'(r) + \bar{r}V'(r)]|_{r=r^*} = \begin{cases} \rho_B + \mathbf{E}(\eta) - \frac{\mathbf{E}(\varepsilon|\varepsilon \geq \underline{\varepsilon} - \varepsilon)}{\gamma} > 0 \text{ if } r^* < 1 \\ \frac{1}{r}\left\{\mathbf{E}(\eta|\eta \geq \underline{\eta}) - \underline{\eta} - \frac{\rho_G + \mathbf{E}(\varepsilon)}{\gamma}\right\} < 0 \text{ if } r^* > 1 \end{cases}.$$

If we assume that the idiosyncratic component of value (ε or η) is small relative to the systematic component ρ_G or ρ_B, then the derivative will be positive when $r^* < 1$ and negative when $r^* > 1$. Thus, if $r^* < 1$, welfare is increasing in r, while if r^* is greater than one, welfare is decreasing in r. In the appendix we show that the global welfare optimum is at $r = 1$, so that if a social planner could control the extent of sex selection, she would aim for a sex ratio at birth that corresponds to a balanced marriage market. This requires an additional assumption, A1, that the idiosyncratic component on preferences is small relative to the average payoff of a boy or a girl, and that population growth is not extremely large.

Assumption A1: $\bar{\varepsilon} \leq \rho_B + \mathbf{E}(\eta), \gamma^2\bar{\eta} \leq \rho_G + \mathbf{E}(\varepsilon)$, and $u_B + \rho_B - u_G > 2c$.

Our results show gender bias results in a male biased sex ratio on the marriage market, and this is inefficient. The intuition for this inefficiency is as follows. Consider an equilibrium $r^* < 1$, and a parent who is selecting a boy. If this parent decides not to select, she suffers no loss in payoff, since she is indifferent between selecting and not selecting at r^*. However, the decision not to exercise choice has a positive effect, since at the aggregate level, two more boys will find partners for sure. That is, there is a congestion externality in the marriage market which is not taken into account by parents who select.

However, selection has positive welfare effects in societies without large gender bias, by reducing the marriage market imbalance due to population growth. In this case, selection exerts a positive externality, by reducing congestion. Here again, parents do not take this externality into account, and as a result, the equilibrium results in an unbalanced marriage market sex ratio, with too many girls.

Our welfare criterion is the expected utility of the typical parent, who may well have gender biased preferences. If we were to take into account the utility of the children, and use a utilitarian social welfare function, this would only reinforce our conclusions, since we may assume that girls do not have a preference to be boys instead. Thus the welfare gains from a balanced sex ratio would be larger in this case.

Assumption A1 is needed for the welfare results for two reasons. First, the idiosyncratic component of match value must be small enough relative to the systematic component – otherwise, it is possible that as women become scarce, their match value improves very greatly, by more than the loss suffered by men. Second, while $r < 1$ is never socially optimal, $r > 1$ could be optimal if the costs of selection are large. With population growth, marriage market balance (i.e. $r = 1$) can an only be achieved by selecting for boys. This is only optimal if the costs of selection are sufficiently small, as in A1. With large costs of selection, a social planner would prefer to tolerate an excess of women on the marriage market arising naturally from the marriage squeeze.[7]

We now consider the implications of changes in c upon equilibrium welfare, at an interior equilibrium, where indifference condition (1) is satisfied. Let $W^*(c)$ denote equilibrium welfare as a function of c, i.e., $W^*(c) \equiv W(r^*(c))$. Since it is optimal at r^* for a parent to accept the child that nature deals her, this can be written as

$$W^*(c) = 0.5\{U(r^*(c)) + V(r^*(c))\}.$$

Since the difference between $U(r^*)$ and $V(r^*)$ equals $2c$, this can be re-written as

$$W^*(c) = V(r^*(c)) + c.$$

From the indifference condition that determines r^*, $\frac{dr^*}{dc} = \frac{2}{U'(r)-V'(r)}$, so that the effect of welfare equals

$$\frac{dW^*}{dc} = 1 + \frac{2V'(r)}{U'(r) - V'(r)}.$$

$V'(r) < 0$ and $U'(r) > 0$, and so the second term is negative. Thus the effect on welfare of an increase in cost is positive when $|V'(.)| < |U'(.)|$ and negative otherwise. So when $r^* < 1$, since $|V'(.)| < |U'(.)|$, an increase in c increases welfare, since the equilibrium sex ratio becomes more balanced. In other words, technological progress that makes selective abortions easier reduces welfare if the equilibrium sex ratio already has an excess of boys. On the other hand, if $r^* > 1$, a reduction in c makes the sex ratio more balanced, and thus increases welfare.

We summarize our results in the following proposition.

Proposition 1 *If there is large son preference ($(u_B + \rho_B) - (u_G + \rho_G) > 2c$), sex selection biases the equilibrium sex ratio, and results in a socially inefficient outcome with too many boys. If there is little or no son preference ($(u_B + \rho_B) - (u_G + \rho_G) < 2c$), and the marriage market imbalance is due to population growth and the age gap at marriage, then sex selection increases welfare, since there is an excess supply of girls on the marriage market. In either case, social welfare is maximized when the sex ratio in the marriage market is balanced, provided that assumption A1 is satisfied. Technological progress that reduces the cost of*

[7] The condition in A1 is satisfied as long as $\gamma < \frac{1+\sqrt{5}}{2} \simeq 1.6$. No society appears to have such a large value of γ — for example, even with large rates of growth in cohort size in parts of India, this number is no more than 1.2.

selection, c, reduces welfare if the marriage market equilibrium has an excess of boys; it raises welfare if there is an excess of girls.

An advantage of our welfare results are that they are global, and only require knowing whether the marriage market has an excess of boys or girls. That is, they do not require assuming that the existing sex ratio is an equilibrium one. It may be plausibly argued that the recent increases in the sex ratio in China and parts of India are not equilibrium phenomena, in the sense that parents may have incorrect expectations regarding the aggregate sex ratio and future marriage prospects. Learning models suggest that societies will be able to learn rational expectations equilibria in stable environments; however, recent technological developments have been so rapid that one cannot assume that expectations are rational. Nevertheless, we may conclude that selection is welfare reducing if the marriage market has an excess of boys (and is welfare improving otherwise). Thus if expectational errors result in an over-reaction of the sex ratio to technological changes, the adverse welfare effects of selection are aggravated.

1.2 Empirical Evidence

Proposition 1 implies that the answer to question, whether sex selection reduces welfare or raises it, is an empirical one. In particular, we need to examine whether marriage markets in the countries where sex selection is prevalent are characterized by an excess of men, or an excess of women. To investigate this empirically, we modify the basic identity linking the sex ratio at birth, $\bar{r}$, and that in the marriage market, r, as follows

$$r \equiv \bar{r}(1+g)^{\tau}\frac{\Delta_G}{\Delta_B}\frac{\lambda_G}{\lambda_B},$$

where Δ_B is the survival rate for boys, between infancy and the age of marriage, and Δ_G is that for girls. λ_G is the proportion of girls who marry, while λ_B is the proportion of boys who marry.[8] Thus if the marriage market is to be balanced, r must be close to or equal to one, i.e. variations in $(1+g)^{\tau}\frac{\Delta_G}{\Delta_B}\frac{\lambda_G}{\lambda_B}$ and $\bar{r}$ must offset each other. Put differently, if the ratio of boys to girls at birth equals $(1+g)^{\tau}\frac{\Delta_G}{\Delta_B}\frac{\lambda_G}{\lambda_B}$, then the marriage market will be balanced. Thus we present our figures in terms of the *required number of boys*, R, per 100 girls, where

$$R = 100(1+g)^{\tau}\frac{\Delta_G}{\Delta_B}\frac{\lambda_G}{\lambda_B}.$$

[8] This is valid if λ_G and λ_B are the proportions who *desire* marriage. However, in empirical work, demographers use the observed proportions, and we have some reservations about this, since the actual proportions of women and men that marry will reflect marriage market conditions, i.e. will be endogenous. As we shall see, our substantive conclusions are not much affected by this adjustment.

The sex ratio at birth/early infancy gives us the actual number of boys per 100 girls, A. In consequence, the difference $A - R$ measures the extent to which there are missing girls in the marriage market.[9]

Table 1 presents our computations of R and A, based on recently born cohorts in the censuses of 2000 (China) and 2001 (India). For China, we present figures for the overall population, the majority Han population (who comprise almost 90% of the population) and for the minorities. India is more linguistically and culturally heterogeneous, and we therefore present figures for the major geographical regions.[10] Column 1 is an estimate of g, the rate of growth of cohort size. In China, the 2000 census provides data on population numbers by age, and we base our estimate of g on a regression of cohort size upon age, between the ages of 2 and 8, in the 2000 census. In the case of India, the data is less detailed, and our estimate of g is based on growth rate of population aged between 0 and 6 between the censuses of 1991 and 2001. Column 2 reports the age gap at marriage, τ – this is the difference between singulate mean ages at marriage for men and women, taken for China from United Nations (2003), and for India from the census report (1991). To allow for mortality differences between males and females until marriage, we use the estimates of age and gender specific mortality in Anderson and Ray (Table 2, 2010). These estimates imply that the survival probability of females in China between ages 5 and 24 is 0.980, while that of males is 0.963, so that $\frac{\Delta_G}{\Delta_B} = 1.017$. For India, the survival probability of females between ages 5 and 19 is 0.937, while that of males between ages 5 and 24 is 0.926, implying that $\frac{\Delta_G}{\Delta_B} = 1.012$.[11] Thus mortality differences between the sexes have quantitatively small effects on the sex ratio in the marriage market, even though it may have a large effect on the absolute numbers of missing women. Since these mortality estimates are not available region-wise for India, or separately for Han and minority groups in China, we use the aggregate estimates. Columns 3 and 4 report the singles rate. Column 5 reports our estimates of R, the required number of boys per hundred girls Column 6 reports A,the actual number of boys males per 100 girls. The final column reports the gap between required and actual number of males per 100 females.[12]

[9] In the demography literature, Donald S. Akers (1967) and Robert Schoen (1983) set out methods for computing marriage market imbalances.

[10] We have also computed these figures at state level (this is probably most appropriate for the marriage market, given that states are oganized on a linguistic basis), but do not present these for reasons of space.

[11] We consider differential mortality after age 5 since our sex ratio data pertains to the age cohort 0-4 in the case of China and 0-6 in the case of India. Anderson and Ray provide mortality estimates in 5 year intervals; since the age gap in India is 4.6 years, we consider age 24 for men and 19 for women. Since the age gap is less than 2 years in China, we consider the same time intervals for both sexes. We also do not make any adjustment for polygyny, since this is quantitatively insignificant in both China and India.

[12] We have not made an adjustment for the extent of polygyny, since this appears to be negligible in both countries. For China, see United Nations (1990). In India, polygamy is legal on only for Muslims; amongst Hindus, it has been illegal since the Hindu Marrriage Act of 1955, and data on its incidence relate

Table 1: Required & Actual Number of Boys per 100 Girls

	g	τ	% single,F	% single,M	required # boys	# boys	gap
China (total)	-5.0	1.8	0.2	4.0	96.4	120.2	23.8
China (Han)	-5.4	1.8	0.2	4.0	95.7	121.2	25.5
China (non Han)	-2.6	1.8	0.2	4.0	100.9	112.8	11.9
India (total)	0.4	4.6	0.9	1.6	103.6	107.9	4.3
West	0.5	4.5	0.1	1.4	104.7	110.4	5.8
Central	1.1	3.8	0.5	2.2	107.2	108.3	1.1
South	-1.0	5.5	1.3	1.1	95.7	104.9	9.2
East	0.7	5.0	0.8	1.4	105.7	105.2	-0.5
North East	0.1	5.6	1.6	1.8	101.6	103.5	1.9
North West	0.2	2.8	0.1	2.3	104.0	121.0	16.9

Notes: g : For China, based on a regression of cohort size upon age (between 2 and 8) in 2000 census. For India, based on growth rate of population age 0-6 between censuses of 1991 and 2001. τ : difference between singulate mean ages at marriage for men and women. For China: data from United Nations, 2003. For India: Census report (1991). Singles rates for India is the proportion "never married" in age cohort 50-54 in 2001 census; for China from UN, 2003. Indian regions comprise the following states in 1991 census: West – Maharashtra, Gujarat, Rajasthan. Central – Madhya Pradesh, Uttar Pradesh; South – Kerala, Karnataka, Andhra Pradesh, Tamil Nadu; East – Bihar, Orissa, West Bengal. North East – Assam, Arunachal, Meghalaya, Tripura, Mizoram, Nagaland. North-West – Punjab, Haryana, Himachal Pradesh, Delhi.

The results of Table 1 are striking. In China, cohort sizes are shrinking rapidly, at 5% per annum. This is so even though population growth is positive, at 0.6% per annum. Even with a small age gap at marriage, of 1.8 years, this results in a large *reverse* marriage squeeze, and the required number of boys per 100 girls is only 96.4, even though men have a substantially larger singles rate than women (if they had the same singles rate, then the required number of boys would be only 92.7). However, the actual sex at birth/infancy shows a large excess of boys, with 120 boys per 100 girls. The combination of the unbalanced sex ratio and reverse marriage squeeze implies that the marriage market of the future will have 23.6 extra boys per 100 girls. This is enormous – almost one in five boys amongst those born around the year 2000 will not find a partner in future. Since 37 million boys were in the age group 0-4, over 7 million of them would remain single. In the age group 0-9, over 16 million are predicted to remain single.

In India, cohort sizes are growing slowly. Given the age gap at marriage, this implies that one needs 103.6 boys per 100 girls for marriage market balance. Since the actual number of

to marriages formed prior to this date. Since Muslims form 12% of the population, and since the incidence of polygamy is estimated at 4.3%, this reduces the required number of men by one-half of a man.

boys per 100 girls is 107.9, there is an excess of 4.3 boys per 100 girls.

The extent of regional heterogeneity across India is striking. There is a large excess of boys in the North-West and in the South of India, but for very different reasons. In the North-West, this is mainly due to the male-biased sex ratio, most plausibly due to sex selective abortions. In South India, the sex ratio is not male-biased, but there is an excess of men on the marriage market due the falling cohort sizes and a large age gap at marriage. The imbalances in the rest of the country are smaller, since cohort size growth partially or totally offsets any imbalance in the sex ratio. However, there is an excess of boys everywhere, except in the East, where the imbalance is negligible. Since proposition 1 shows that sex selection for boys reduces welfare whenever it aggravates the marriage market imbalance, these empirical findings imply that selection for boys is welfare reducing not only in China, but also in India. It is noteworthy that due to fertility decline, the marriage squeeze on women, arising from cohort size growth, appears to have largely over. Thus selection for boys will cause greater imbalances and reduce welfare even more in the future.

The age gap at marriage, the rate of growth of cohort size, and the actual sex ratio at birth are the most important factors, quantitatively, in determining marriage market balance. The other factors are quantitatively less significant. The lower mortality rate for females adds one extra boy to R in the case of India, and 2 in the case of China. The higher marriage rate for women adds half an extra boy to R in the case of India – for China it adds 4.

Our empirical findings, both for China and India, are based on a very simple methodology. Nevertheless, they appear to be novel, and to deliver new conclusions, since they are based on the rates of growth of cohort size. Urvi Neelakantan and Michele Tertilt (2008) take into account the fact that marriage market sex ratios differ from those at birth, due to the age gap at marriage. They compute marriage market balance based on population growth figures. These, however, differ considerably from cohort size growth, for both India and China, and the difference is magnified due to compounding over the age gap. For example, in the case of India, the rate of growth of cohort size is smaller than population growth (0.4% as compared to 1.4%). In the case of China, population growth is still positive (0.6% per annum), while cohort sizes are falling very rapidly indeed (–5% per annum). To a first approximation, the current rate of growth of cohort size, g, changes due to two factors: changes in fertility and the rate of growth of cohort size s years ago, where s is the age at which women are fertile. . In China, this implies that g is likely to continue to be negative even if the one-child policy is relaxed, reflecting the past impact of the policy in the 1980s and 1990s.

This evidence implies that sex selection has adverse social consequences in both countries, so that the current policy banning sex selective abortions may be well motivated. However, a ban seems unworkable, since it is impossible to verify that a sex selective abortion has indeed taken place. However, there are alternative Pigouvian balanced budget tax-transfers that can incentivize parents to have girls. These would work by increasing the value of girls to parents while reducing that of boys, e.g. via differential school fees or by explicit subsidies. Suppose that the government subsidizes each girl by an amount s_G, and taxes each boy an amount t_B. If the levels of these are set so that $u_B + \rho_B - t_B - 2c = u_G + \rho_G + s_G$, then parents will be indifferent between boys and girls when the sex ratio in the marriage market is one. Since budget balance can be ensured by setting $\gamma t_B = s_G$, we have balanced budget tax subsidies that result in a Pareto improvement, and can ensure the socially optimal outcome.

On 3 March 2008 IANS reported that "in a move to stop female feticide and stabilize the skewed sex ratio, the Indian government announced an insurance cover for poor families with girl children that will see incentives at every step - when she is given vaccinations, sent to school and not married off before 18...The scheme would be first started in seven educationally backward states as a pilot project and later extended to the entire nation." However, this scheme seems partly motivated by redistributive considerations, since it was introduced mainly in the poorest regions in the country, where male biased sex ratios are not a serious issue – only one of the pilot regions is located in the North-West. Furthermore, as we shall see in section 3, there are theoretical reasons why selection for boys will be more significant in the upper classes than among the poor. Thus well designed tax-transfers, that are targeted to address the congestion externality directly, have yet to be introduced.

2 Dowries and the sex ratio

A shortage of women in the marriage market is likely to improve their bargaining power and their share of household resources (Gary Becker 1981). Angrist (2002) finds that a reduction in the sex ratio r in immigrant marriage markets in the US reduces the labor supply of women and raises that of men. Chiappori, Fortin and Lacroix (2002) estimate a structural model of distributional effects and find that a reduction in r reduces women's labor supply and increases their share of household resources, while raising the labor supply of men. These distributional effects have implications for parental selection decisions. If parents are altruistic, they will take into account the effects of the sex ratio upon the utility of their child. Parents whose children are on the short side of the market may also be able to capture a portion of these scarcity rents in the form of bride prices or dowries. Finally, these changes in the sex ratio may alter existing social norms and relations between children and their parents. It has been argued that parents prefer sons in India and China since traditionally sons support their parents in old age while daughters do not. If the bargaining power of daughters increases within the marriage, they may have a greater say on the pattern of inter-generational transfers and these norms may change.[13]

To model these effects, we now assume transferable utility, and allow transfers between spouses to be negotiated between the parties at the time of marriage. These transfers can be interpreted either as dowries/bride prices, or as the capitalized value of flows over the life-time of the relationship. As Shelly Lundberg and Robert A. Pollak (2003) have pointed out, the latter interpretation assumes that commitments made at the time of the marriage are binding.

Consider first a steady state equilibrium where the marriage market is Walrasian. For simplicity, we assume that there is no idiosyncratic component to quality, i.e. ε and η are both identically zero. Our focus is on a rational expectations equilibrium, where parents make their initial choices (regarding gender) anticipating a bride price that equals the realized bride price. Let t denote the transfer from boys to girls, i.e. the bride price. In a Walrasian market, the marginal agent on the long side must be indifferent between marrying at the market price and staying single. So $t = \rho_B$ if $r < 1$ and $t = -\rho_G$ if $r > 1$. If $r = 1$, then any $t \in [-\rho_G, \rho_B]$ is a market clearing price. Let us now consider a rational expectations equilibrium, where parents at each date correctly forecast a t^*, and where the choices they exercise results in a sex ratio r^* such that t^* is a Walrasian price given r^*. The only steady state sex ratio that can arise in a rational expectations equilibrium is $r^* = 1$. To see this, suppose that $r^* < 1$, so that $t^* = \rho_B$. In this case, any parent who has a girl strictly prefers not to select a boy, since the payoff from the girl is $u_G + \rho_G + \rho_B$, which is strictly greater than u_B. Similarly, one cannot have $r^* > 1$. A balanced sex ratio with $r^* = 1$ can be supported by a bride price t^* that satisfies

$$\frac{(u_B - u_G) - 2c}{2} \leq t^* \leq \frac{(u_B - u_G) + 2c}{2}.$$

In view of our findings in Table 1 of large sex ratio imbalances, the Walrasian model yields the empirically implausible conclusion that the marriage market sex ratio is always balanced. Intuitively, the Walrasian model assumes that any small deviation from sex ratio balance results in a discontinuous jump in transfers. This also seems inconsistent with the empirical evidence cited above (Angrist and Chiappori et al.), that finds continuous effects of sex ratios upon household allocations.

To ensure that transfers vary continuously with the sex ratio, we embed the bargaining process in a marriage market subject to search frictions that defines the outside options of the

[13] A caveat is in order here – since support for aged parents takes place many years after the marriage, it may be hard for commitments at the time of marriage to be enforced.

parties. Consider an infinite horizon continuous time model, where u_B and u_G now represent flow payoffs from having a boy and a girl respectively, and i denotes the interest rate. Let ρ be the flow payoff from marriage for each partner.[14] Let t be the net transfer of household resources from the man to the woman – a negative value of t corresponds to a transfer from the woman to the man. Let $\xi(t)$ be the value to the woman of this transfer. Perfect transferability corresponds to the case where $\xi(t) = t$, while under imperfect transferability, $\xi(t)$ is strictly concave, with $\xi(0) = 0$ and $\xi'(0) = 1$. We shall also assume that both partners are able to make binding commitments regarding the division of the payoff for the duration of the marriage.[15] Parents take into account the effects of the transfers, so that the value to a parent, from a married boy, and a married girl, respectively, are given by:

$$U^m = \frac{u_B + \rho - t}{i},$$

$$V^m = \frac{u_G + \rho + \xi(t)}{i}.$$

At any instant, there are stocks of unmarried boys and unmarried girls, of measures μ and $x\mu$ respectively, so that x denotes the sex ratio in the stocks. We shall assume that matches arrive according to a Poisson process, where the arrival rate is increasing in both stocks, differentiable and a symmetric function of its arguments. We also assume constant returns to scale so that the analysis may be conducted in terms of x, the sex ratio, without reference to absolute market size μ. Let $\alpha(x)$ (resp. $\beta(x)$) denote the arrival rate of matches for a girl (resp. boy), where $\beta(x) \equiv x\alpha(x)$. $\alpha(x)$ is strictly increasing in x, while $\beta(x)$ is strictly decreasing. Finally, we shall assume that matching becomes more efficient if the market is more balanced, i.e. the number of matches per unit population is single peaked, with a maximum at $x = 1$.The values of a single boy and a single girl depend upon the sex ratio x and upon the prevailing transfer t, and are

$$U(x,t) = \frac{u_B}{i} + \frac{\beta}{i(\beta + i)}(\rho - t).$$

[14] For simplicity, we assume that there is no idiosyncratic component to match value. Our analysis extends, at the cost of additional notational burden, to the where idiosyncratic component is small relative to search frictions. Our assumption that the payoff from marriage is the same for both parties is without loss of generality if there is perfect transferability of utility.

[15] The importance of commitment power has been emphasized by several authors, e.g. Lundberg and Pollak (2003). In the absence of commitment, the results will be similar to the model without transfers, unless parties are able to capitalize future transfers at the time of marriage, in the form of bride prices or dowries.

$$V(x,t) = \frac{u_G}{i} + \frac{\alpha}{i(\alpha+i)}(\rho + \xi(t)).$$

The transfer t, from the boy to the girl, is determined by Nash bargaining between the two parties. That is the equilibrium transfer t^* is given by the Nash bargaining solution where the outside options are given by the values to remaining single, $U(x,t)$ and $U(x,t)$.[16] Now, in an equilibrium, the negotiated transfer between the matched pair, t^*, must itself be equal to the prevailing transfer in the market. This allows us to solve for t^* as a function of x, and this is defined implicitly by the condition

$$\frac{\rho + \xi(t^*)}{\rho - t^*} = \frac{\alpha(x) + i}{\beta(x) + i}. \tag{4}$$

Let $\tilde{U}(x) = U(x, t^*(x))$, and $\tilde{V}(x) = V(x, t^*(x))$ denote the value of singles as a function of x alone, given that $t = t^*(x)$. We can now determine the equilibrium sex ratio in the stock, x^*. This must be such that difference in values between boys and girls at the time of birth equals the expected cost of selection:

$$\tilde{U}(x^*) - \tilde{V}(x^*) = 2c. \tag{5}$$

We now turn to the relation between the sex ratio in stocks and that in the flow of births. Assume that the flow of new births is exogenously given at g, let θ be the fraction of births that are girls, and let the instantaneous death rate be δ. In a steady state the sex ratio in the stock must be stationary, giving us the relation

$$\theta(x) = \frac{g + \delta\alpha(x)(x-1)}{2g}.$$

The equilibrium sex ratio in the flow of births is given by $\theta(x^*)$. Note that $\theta(x^*)$ equals 1 at $x^* = 1$ and is less than one if $x^* < 1$.

We show first that the equilibrium sex ratio x^* must be less than 1 if $u_B - u_G > 2ci$. For if this is the case, then at $x = 1$, $\tilde{U}(1) - \tilde{V}(1) = \frac{u_B - u_G}{i}$ (since the matching function is symmetric, $\alpha(x) = \beta(x)$ when $x = 1$) and thus it is optimal to try again on having a girl. However, the sex ratio will be less biased towards boys than in the absence of transfers. Furthermore, the sex ratio will be less biased the greater the degree of transferability of utility, i.e. the closer $\xi(t)$ is to being linear.

Consider now the implications of population growth and the age gap at marriage. We may

[16] Alternatively, we could assume that the outside options constrain the bargaining solution, but do not otherwise affect it. The specification we have chosen allows the maximal effect of the sex ratio upon the bride price. Alternative specifications would only make the equilibrium more inefficient.

model this by assuming that the proportion of the flow of girls, in the absence of selection, $\hat{\theta}$, is greater than one-half. In the absence of selection, the sex ratio in the stock will be $\hat{x} = \theta^{-1}(\hat{\theta}) > 1$. The corresponding equilibrium transfer, $t^*(\hat{x})$, is given by equation (4), and will be negative if $\hat{x} > 1$; thus the marriage squeeze results in positive groom prices or dowries. t^* is a decreasing function of $\hat{x}$ (see appendix), implying that if the marriage squeeze intensifies, this increases the level of dowries. This provides an explanation for the increase in dowries in the twentieth century in India, and their spread to parts of the country where they were not prevalent.[17] It is important to clarify that an increase in population growth will raise dowries in a continuous way in a frictional market since there has been some controversy in the literature. Siwan Anderson (2007)) argues that the marriage squeeze cannot cause dowry inflation, but considers only a one-off increase in population, which then returns to its stationary level – this cannot cause a permanent increase in dowries. Also, she assumes perfect matching and transferable utility, and in such a world, the effect of sustained population growth on dowries would be discontinuous – there is a jump increase when population growth becomes positive, and no further increase with further rises in population growth, since dowries are already at their maximal level.

If $\hat{x} > 1$, $\tilde{V}(\hat{x}) < \tilde{U}(\hat{x})$. If c is sufficiently small, it is optimal to select boys. Thus the equilibrium sex ratio x^* must satisfy indifference condition (5). Consider now the case where gender bias is mild or absent, i.e. $u_B - u_G > 2ci$. In equilibrium, the payoff from a boy must exceed the payoff from a girl, so that that $x^* > 1$. The sex ratio in the marriage market is therefore biased against girls. Here again, the sensitivity of intra-household allocations or dowries to the sex ratio implies less bias than in the absence of such transfers.

Turning to welfare, the expected welfare of the parent is given by

$$W(x) = (1 - \theta(x))\tilde{U}(x) + \theta(x)\tilde{V}(x) - (1 - 2\theta)c.$$

The derivative of welfare with respect to x equals

$$W'(x) = \left\{(1-\theta)\tilde{U}'(x) + \theta\tilde{V}'(x)\right\} + \left\{\theta'(x)[\tilde{V(x)} + 2c - \tilde{U}(x)]\right\}. \tag{6}$$

The first term in curly brackets is the "match efficiency effect" – how the (weighted) sum of the utilities of the two sexes responds to x. Match efficiency is concave in x and maximized at $x = 1$, i.e. when the market is balanced (see appendix). The second term in curly brackets is (a positive multiple of) the private benefit from accepting a girl as compared to trying

[17] Sociologists and demographers (e.g. Bhat and Halli (1999)) have argued that dowry payments from the parents of girls have spread to parts of India where they were not prevalent, and have also increased in magnitude. Since dowry payments are illegal in India, systematic evidence on the magnitude of dowries is difficult to find (for some partial evidence, see Vijayendra Rao (1993)).

again. Thus this term is strictly negative when $x > x^*$ and strictly positive if the inequality is reversed. This decomposition of equation (6) gives us two immediate results. Consider first the case of significant gender bias, so that $x^* < 1$. The equilibrium outcome is socially inefficient, with the sex ratio being too low, since at x^*, the second term is zero, and thus $W'(x)_{|x=x^*} > 0$. The social optimum x^{**} lies between x^* and 1, since at 1 the first term is zero and the second term is negative implying that $W'(x)_{|x=1} < 0$.We conclude therefore that welfare is increasing in x at x^*, i.e. the equilibrium proportion of girls is too low from a welfare point of view. Parental choice results in an inefficient outcome, with too many boys, since parents do not internalize the congestion externality in the marriage market.

In the case where there is little or no gender bias, and population growth so that $x^* > 1$, the social optimum x^{**} will be smaller than x^*, so that there is too little selection in equilibrium. Thus the main findings of our model of section 1 appear to be robust.

With frictional matching social optimality does not require $r = 1$. From equation (6), at $x = 1$ the match efficiency term is zero but the private benefit term is negative, so welfare is decreasing in x. The welfare optimal level of x lies between x^* and 1.[18]

Our results here are related to the literature on job creation in search models of unemployment, as in Dale T. Mortensen and Christopher A. Pissarides (1994). This literature finds that job creation is typically inefficient, although the direction of the inefficiency is ambiguous – there maybe too few or too many jobs. The difference is, in our context of parental choice, a child may enter on either side of the market – either as a boy or as a girl. The preference for boys over girls, coupled with the symmetry of the bargaining situation, permits an unambiguous conclusion – welfare increases by making the market more balanced. In particular, with large gender bias, the equilibrium has too many boys, relative to the welfare optimum. In the job creation literature, Arthur J. Hosios (1990) has shown that appropriate assignment of bargaining power between the two sides can ensure an efficient allocation. In the present context, when there is large gender bias, efficiency requires that women have greater bargaining power than men, even when marriage markets are balanced. This seems somewhat unlikely given the inferior status of women in traditional societies. In an illuminating study on India, Francis Bloch and Vijayendra Rao (2002) show that married men use domestic violence in order to extract additional payments from their in-laws. The irreversibility of marriage in traditional societies, in conjunction with the vulnerability of women within marriage, may move effective bargaining power towards men. Such an asym-

[18] This is the one qualitative finding of the basic model of section 1 that appears not to be robust. With frictionless matching, match efficiency is a non-differentiable function of the sex ratio, r, since the number of matches equals the number of individuals on the short side of the market. Thus the loss in match efficiency is first-order in $1 - r$. With frictions, the loss in match efficiency is of second order in the difference $(1 - r)$, implying that the optimal sex ratio is below 1.

metry would only aggravate the inefficiency that we find, resulting in a worse sex ratio, i.e. a lower equilibrium value of x.

We now examine the effects of technological progress, i.e. a reduction in c, upon equilibrium welfare, $W(x^*(c))$. Using the indifference condition, this can be written as

$$\begin{aligned}\frac{dW(x^*(c))}{dc} &= \left.\frac{\partial\tilde{V}}{\partial x}\right|_{x=x^*}\frac{dx^*}{dc}+1.\\ &= \frac{2\tilde{V}'(x)_{|x=x^*}}{\tilde{U}'(x)\,|_{x=x^*}-\tilde{V}'(x)\,|_{x=x^*}}+1. \qquad (7)\end{aligned}$$

The results here are exactly parallel with those in section 1. When $x^* < 1$, $\tilde{V}'(x)\,|_{x=x^*} < 0$ is smaller than $\tilde{U}'(x)\,|_{x=x^*}$ in absolute magnitude, due to the match efficiency effect. Thus the first term is negative but greater than -1, and thus equilibrium welfare is an increasing function of c, since a higher value of c increases x^*. Conversely, when $x^* > 1$, technological progress increases welfare. We summarize our results as follows:

Proposition 2 *Consider a marriage market with frictional matching, where match efficiency is maximized when the sex ratio is balanced. If $u_B - u_G > ci$, both the equilibrium sex ratio and the welfare optimal sex ratio are biased towards boys, and the equilibrium has excessive boys compared to the welfare optimum. Technological progress that reduces c reduces welfare. Conversely, if $u_B - u_G < ci$, and there is a natural excess supply of girls due to the marriage squeeze, the equilibrium sex ratio has an excessive number of girls.*

Our main result, that the equilibrium sex ratio is inefficient in the presence of gender bias, is quite general, and applies as long as intra-household allocations vary continuously with the sex ratio. That is, as long as $t(.)$ is a continuous function, equilibrium requires adjustment in quantities as well as prices. When the sex ratio affects intra-household allocation in a continuous way, this reduces the magnitude of gender imbalances due to gender biased preferences but does not eliminate them. Our qualitative conclusions, that selection that results in sex ratio imbalances is welfare reducing, are unaffected. That is, the congestion externalities identified in section 1 continue to play a key role in determining welfare. The policy implications, that governments should subsidize girls and tax boys if the sex ratio has an excess of boys, is also reinforced.

3 Heterogeneity

What are the implications of the population belonging to distinct groups, who are ex ante heterogeneous? This is relevant when the population consists of different classes, castes or linguistic groups. One may distinguish two distinct cases: horizontal differentiation and vertical differentiation. With vertical differentiation, groups are hierarchically ordered, and an individual prefers a partner of higher status to one of lower status, independent of the individual's own status. Class or caste are possible examples. Horizontal differentiation occurs when an individual prefers a partner of his/her own group — linguistic, regional or religious identity are cases in point. These two cases turn out to have very different implications.

To model horizontal heterogeneity, let there be two groups or regions, 1 and 2. Let ρ^H be the payoff to an individual from matching with someone from the same region, and ρ^L be the payoff from matching with someone from a different region. Suppose that gender preferences are the same across regions. The equilibrium sex ratio will be the same in both regions, and in a stable match, there will be no inter-regional marriages. Now suppose that region 1 has large gender bias, while region 2 has no gender bias. In the absence of inter-regional marriages, the sex ratio in region 1 will be $r_1^* < 1$. In the absence of population growth, the sex ratio in region 2 will be 1. A male of quality $\underline{\varepsilon_1} = F(1 - r_1^*)$ is available to any woman in region 2, and the woman with the greatest incentive to make this match is the one with the lowest quality, $\eta = 0$. Her payoff from making this match is $\underline{\varepsilon_1} + \rho^L$, while her payoff from matching within her own region is ρ^H. Thus the imbalance in region 1 must be large enough to offset the payoff difference $\rho^H - \rho^L$, before any inter-regional marriages take place.[19] If there is population growth, then there will be an excess supply of girls in region 2, and those of the lowest quality will marry the lowest quality boys from region 1. However, inter-regional marriages yield small gains in utility, since both parties to the marriage get a payoff of only ρ^L, and therefore, the effects of ex ante selection decisions will be small.

Vertical differentiation is qualitatively different, since inter-group marriages will have large utility consequences for one party. Let us assume that there are two classes (or castes), H and L, with measures μ and 1 respectively. Assume the value from being matched does not vary across boys and girls, but does depend upon the status of the partner. Let ρ^i be the value from being matched to a partner of status i, where $i \in \{L, H\}$. Assume also that the preference parameters are identical across the two classes.[20]

[19] This assumes non-transferable utility. With transferable utility, the condition for inter-regional marriage is more stringent – $\underline{\varepsilon}_1$ must be greater than $2(\rho^H - \rho^L)$.

[20] We may allow our utility parameters (u_B, u_G and c) to be indexed by class – the equations that follow also apply with the appropriate indexation. However, some of the qualitative results – the comparisions

Consider first the upper class. If a girl married to a high class person is preferable to a boy married to a low class person (i.e. if $u_B + \rho^L < u_G + \rho^H$), and if c is sufficiently small, the equilibrium sex ratio in the upper class, r_H^*, satisfies

$$u_B + r_H^* \rho^H + (1 - r_H^*)\rho^L - 2c = u_G + \rho^H. \tag{8}$$

The left hand side of the above expression shows the expected payoff from selecting a boy, while the right hand side shows the value of a girl. Clearly, $r_H^* < 1$ if $u_B - u_G > 2c$.

Now let us consider the lower class. A measure $\frac{1-r_H^*}{1+r_H^*}\mu$ of upper class boys are available, and if the sex ratio in the lower class is r_L, the measure of lower class girls is $\frac{r_L}{1+r_L}$. So each lower class girl has a probability $\frac{(1+r_L)(1-r_H^*)}{r_L(1+r_H^*)}\mu$ of marrying an upper class boy. This leaves a measure $\left[\frac{r_L}{1+r_L} - \frac{1-r_H^*}{1+r_H^*}\mu\right]$ of lower class girls who are matched with a measure $\frac{1}{1+r_L}$ of lower class boys. Consequently, if the ratio of the former to the latter is less than one, some lower class boys are left unmatched, while girls will be left unmatched if the ratio is greater than one. The payoff to lower class boys is therefore given by

$$U^L(r_L, r_H^*) = u_B + \min\left\{ r_L - \frac{(1+r_L)(1-r_H^*)}{1+r_H^*}\mu, 1 \right\} \rho^L. \tag{9}$$

The payoff to lower class girls is given by

$$\begin{aligned} V^L(r_L, r_H^*) &= u_G + \frac{(1+r_L)(1-r_H^*)}{r_L(1+r_H^*)}\mu\rho^H \\ &\quad + \min\left\{ \frac{1+r_H^*}{(1+r_H^*)\, r_L - (1+r_L)\,(1-r_H^*)\,\mu}, 1 \right\} \rho^L. \end{aligned} \tag{10}$$

The equilibrium sex ratio in the lower class, r_L^*, is determined as follows. If $\left|U^L(1, r_H^*) - V^L(1, r_H^*)\right| < 2c$, then $r_L^* = 1$. Otherwise, r_L^* is such that $\left|U^L(1, r_H^*) - V^L(1, r_H^*)\right| = 2c$.

This analysis implies the following. First, $r_L^* > r_H^*$, so that the sex ratio is more favorable to girls among the lower class than among the upper class. This arises since the imbalance in the sex ratio amongst the upper class increases the payoff to lower class girls (since they can marry up), while reducing the payoff to lower class boys (for any value of r_L, the probability that a lower class boy gets a partner increases with r_H^*). Indeed, it is possible that the sex ratio among the lower class is biased towards boys, if the measure of the upper class is sufficiently large. This is probably empirically less likely, but the absence of any bias against girls in outcomes is possible for a large range of parameters, even though lower class preferences are as male biased as upper class ones. This result is consistent with census data

across classes – depend on the parameters not being too different across classes.

from India – the sex ratio in the lowest castes (the scheduled castes and scheduled tribes) are more female friendly than in the rest of the population. They are also consistent with data from the 1931 Indian census, the last census for which detailed caste based sex ratios at all levels are available. Portner (2010) uses survey data on the fertility decisions of married women from India's National Family Health Surveys in order to estimate the hazard rate for sex selective abortions. He finds that selection is restricted to women with eight years of schooling. Since education is highly correlated with caste and economic status, this is consistent with our theoretical predictions, although education could also directly affect the access to selection technologies.

>From a welfare point of view, sex selection reduces ex ante expected utility in the upper class if $u_G - u_B + 2c + 2(\rho^H - \rho^L) > 0$. What is more interesting is the effect on the lower class, since selection in the upper class raises the payoffs to girls, while lowering the payoff to boys. A benchmark case is when $r_L^* = 1$, so that there is no selection in the lower class. Now if $\rho^H < 2\rho^L$, then the benefit to a girl who marries up is less than the cost to the consequent lower class boy who fails to find a partner. So sex selection reduces welfare also in the lower class. Suppose now that $r_L^* < 1$. In this case, negative welfare effects are aggravated, since selection in the lower class reduces welfare, as in the simple model. We conclude that sex selection reduces welfare also in the lower class, on the assumption that parameter values are such that there is no selection for girls in this class.[21]

The analysis presented here may be extended to an arbitrary finite number of classes – see the discussion paper version of the paper, where we solve recursively for the equilibrium, starting with the uppermost class. Our findings in this section are most closely related to those of Edlund (1999), who observed that upper class parents have more incentive to select than lower class ones.[22] She examines the consequence of sex selection in finite hierarchical society where every individual is strictly ordered by rank, and where children inherit rank perfectly. She finds that if sex selection is perfect, then the sex ratio will be balanced, with boys being chosen by high ranked individuals, and girls by lower ranked individuals. Our model produces a more nuanced finding, since some upper class individuals will choose to have girls, even if sex selection is perfect; however, the sex ratio in the upper class will be more biased than in the lower class. Aggregate sex ratios can be unbalanced even when selection is perfect and costless ($c = 0$), due to the fact that each class has a large number of

[21] If parameter values are such that there is selection of girls in the lower class, then sex selection may raise welfare in the lower class.

[22] This is also related to the famous hypothesis in evolutionary biology advanced by Robert L. Trivers and Dan E. Willard (1973). Since the variance in the number of offspring is greater for males than for females, they argue that high quality individuals have a greater incentive to have male offspring, while low quality individuals (i.e. those in poor health) are better off having females.

ex ante homogeneous agents. [23] Our welfare results also show that all classes can be worse off due to selection.

4 Societies without generalized gender bias

Our analysis may also be applied to societies without generalized gender bias, such as the UK or the US, where sex selection could be used for family balancing reasons. In the UK, the Human Fertilization and Embryology Authority recommended against allowing sex selection for "social reasons" (including family balancing).[24] The American Society of Reproductive Medicine is more positive : "If flow cyclometry or other methods of preconception gender selection are found to be safe and effective, physicians should be free to offer preconception gender selection in clinical settings to couples who are seeking gender variety in their offspring..." (statement of May 2001).

While there is unease in official circles with allowing sex selection, there is considerable evidence that many parents have a desire for gender balance within the family. US census data for 1980 and 1990 shows that women with two children are 6 percentage points more likely to have a third child if the children are of the same gender (Joshua Angrist and William N. Evans 1998). The probability of a third child is slightly greater (1-2 percentage points) if the two children are girls rather than boys. This suggests that gender balancing is a primary concern, but also that the sexes are not treated completely symmetrically. Gordon B. Dahl and Enrico Moretti (2008) present suggestive evidence that parents in the US, especially men, prefer boys to girls. [25]

To examine these issues, we adapt the model of gender preferences based on family composition. For expositional reasons, we make a number of simplifying assumptions. Let us assume that the number of children is fixed exogenously at two. We also assume that there is no idiosyncratic component to match value, and that the payoff from finding a partner does not differ across sexes. We also assume that all individuals are willing to select; our analysis applies, with obvious modifications, when only a part of society is willing to select.

Let u_{ij}, $i, j \in \{G, B\}$ denote the base payoff from having gender composition ij. To reflect preferences for gender balancing, assume that $u_{GB} > u_{BB}$ and $u_{GB} > u_{GG}$ (we assume

[23] Our results would also hold when agents are strictly ordered ex ante in terms of expected quality, provided that the rank of the offspring was not perfectly inherited.

[24] The UK allows sex selection when there is the risk of gender specific genetic disorders.

[25] They find that women with first born daughters are less likely to marry, and also more likely to divorce if married than women whose first born is a son. Interestingly, shot-gun marriage is more likely if the child *in utero* is a boy, and the mother has an ultrasound. They also find that if the first birth is a daughter, this increases the expected number of children. Jason Abrevaya (2009) finds evidence of biased sex ratios in Asian families in the US.

$u_{BG} = u_{GB}$, i.e. there are no order effects). We shall also assume that $u_{BB} > u_{GG}$, to allow for the possibility that preferences are not completely symmetric across genders, i.e. there is an element of bias (our analysis obviously applies, with minor modification, if the bias is reversed, so that $u_{BB} < u_{GG}$). Let us assume that $u_{GB} - u_{GG} > 2c$, so that the parents of one girl have an incentive to select – if this condition is not satisfied, it is clear that there must be no selection, either in equilibrium or at the social optimum. Note that asymmetries can also arise for technological reasons. Sperm separation techniques are currently more effective in selecting girls than boys, so that the effective cost of selection could differ across the sexes. Our analysis would also apply if there were differences in the costs of selection rather than differences in gender specific utilities.

Given our assumptions, the equilibrium sex ratio r will be less than or equal to one. Thus, a daughter will be sure to find a partner, while a son will find a partner with probability r. Let ρ_2 be the payoff to the parents when both children find a partner, and let ρ_1 be the payoff when one child finds a partner, where $0 < \rho_1 < \rho_2 < 2\rho_1$.

Suppose that $u_{GB} - u_{BB} > 2c$. In this case, there is an equilibrium where every parent exercises choice after having the first child and selects a child of the opposite gender. Thus every family is gender balanced, consisting of one boy and one girl, and the sex ratio is balanced. Indeed, this is the only equilibrium — $r < 1$ cannot be an equilibrium outcome, since a parent whose first child is a boy has a strict incentive to exercise choice.

Suppose now that $u_{GB} - u_{BB} < 2c$. In this case, one cannot have an equilibrium with a balanced sex ratio, where all parents select after the first child, irrespective of gender. Nor can there be a balanced equilibrium where no parent selects. So we consider the equations

$$u_{GB} - u_{GG} - (1 - r)[\rho_2 - \rho_1] = 2c. \tag{11}$$

$$u_{GB} - u_{BB} + r(1 - r)[\rho_2 - \rho_1] + (1 - r)^2\rho_1 = 2c. \tag{12}$$

Equation (11) is the indifference condition for a parent whose first child is a girl. Let r^*_G be the value of r that solves this equation. Equation (12) is the indifference condition for a parent whose first child is a boy; let r^*_B be the value of r that solves this equation. We shall assume that parameter values are such that $\max\{r^*_G, r^*_B\} \geq 3/5$ (3/5 is the minimal sex ratio that can be achieved by selection for the second child, conditional on the gender of the first).[26] This ensures that equilibrium sex ratio is given by $\max\{r^*_G, r^*_B\}$. That is, if $r^*_G > r^*_B$, the equilibrium sex ratio is r^*_G, where all parents whose first child is a boy strictly

[26] Since we are discussing societies without generalized gender bias, this is the plausible range of parameters — the equilibrium sex ratio is unlikely to be very distorted. For completeness, we note that if $\max\{r^*_G, r^*_B\} < 3/5$, then the equilibrium sex ratio will equal 3/5.

prefer not to exercise choice, while a fraction of those with girls exercise choice. On the other hand, if $r_G^* < r_B^*$, the equilibrium sex ratio is r_B^*. In this case, all parents whose first child is a girl strictly prefer to exercise choice, while a fraction of those with boys exercise choice.

Our welfare criterion is the ex ante expected utility of the representative parent. If the equilibrium sex ratio is r_G^*, then a parent who has a girl is indifferent between selecting a boy and not doing so. By not selecting, such a parent improves the sex ratio, so that in the aggregate, two individuals get partners, thereby raising social welfare. Similarly, if the sex ratio is r_B^*, a parent who has a boy is indifferent between selecting a girl and not doing so. In this case, by selecting, she exercises a positive externality on society. Thus, in either case the equilibrium is inefficient and social welfare can be increased by moving towards a more balanced sex ratio.

We now turn to a characterization of the global social optimum. Let us assume that $[u_{BG} - u_{GG} - 2c] - 2[\rho_2 - \rho_1] < 0$. This condition states that the net gain from selection for a parent whose first child is a girl is lower than the marriage market cost of leaving two boys unmatched, where these boys belong a family where one child finds a partner. In this case, the global optimum corresponds to a balanced sex ratio. This could either be due to ensuring that all parents exercise choice, if $(u_{BB} - u_{BG} - 2c) + (u_{GG} - u_{BG} - 2c) > 0$. This condition states that the sum of benefits of selection for a pair of parents, one of which has a girl and the other has a boy, is greater than the sum of costs. If this inequality is reversed, social optimality is attained with no selection. We summarize these results in the following proposition, which is proved in the appendix.

Proposition 3 *If* $u_{GB} - u_{BB} < 2c < u_{GB} - u_{GG}$, *the equilibrium sex ratio equals* $\max\{r_G^*, r_B^*\} < 1$, *where some but not all parents exercise choice after the first child. Such an equilibrium is inefficient and efficiency is improved by making the sex ratio more balanced. The welfare optimal allocation has a balanced sex ratio if* $[u_{BG} - u_{GG} - 2c] - 2[\rho_2 - \rho_1] < 0$. *If* $(u_{BB} - u_{BG} - 2c) + (u_{GG} - u_{BG} - 2c) > 0$, *the optimal allocation has every family exercising choice and being gender balanced; otherwise, the optimal allocation has no families exercising choice.*

To summarize, in societies without pronounced gender bias, sex selection for family balancing purposes may have no adverse consequences, as long as it is balanced at the aggregate level. However, if preferences are not completely symmetric, then aggregate imbalances may arise, and thus there may be a marriage market congestion externality. There are a number of caveats regarding this conclusion. First, if the proportion of the population that selects is small, the imbalance will be proportionally small. Second, if preference imbalances are relatively minor, then it may be relatively easy to provide incentives to address any imbalance that may arise.

5 Conclusions

This paper's main contribution is a model of the equilibrium sex ratio when parents can choose the gender of their child. This allows us to examine the welfare consequences of selection. If gender bias is large, parental choice results in too many boys, and reduces welfare. Conversely, if intrinsic gender bias is mild or absent, and the observed preference for boys is due to the excess supply of girls caused by the marriage squeeze, selection may increase welfare. We combine these theoretical results with empirical evidence to show that sex selection and the marriage squeeze have different effects in the two largest societies in the world, China and India. In China, our data show an acute shortage of men, while in many of India, except the North West and the South, the sex ratio is not so imbalanced and the marriage squeeze partially counteracts any imbalance. Thus sex selection is unambiguously welfare reducing in China, and North West India.

The model we have presented is simple, but its results are robust in many ways; they hold if household allocations or parental investments are influenced by the sex ratio, in a continuous way. They also hold if parental investment decisions in their children are influenced by marriage market conditions. We believe that the model provides a useful framework to examine a host of issues related to sex ratios, and indeed, in ongoing work, we have used it to examine the effects on parental investments, and the effect of fertility reductions upon the sex ratio.

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A Appendix

Proof of Proposition 1:We show that the global welfare optimum corresponds to $r = 1$ under assumption A1. At $r < 1$, the derivative of welfare has the same sign as

$$(u_G + \rho_G + 2c - u_B) + \gamma[\rho_B + \mathbf{E}(\eta)] + (1 - r - \frac{r^2}{\gamma})\mathbf{E}(\varepsilon|\varepsilon \geq \underline{\varepsilon}) + (r + \frac{r^2}{\gamma})\underline{\varepsilon}.$$

Since the first term in brackets is strictly positive, this expression is positive if the sum of the remaining terms is positive. Since $r < 1, \gamma \geq 1$ and $\underline{\varepsilon} > 0$, a sufficient condition for this is that $\rho_B + \mathbf{E}(\eta) \geq \mathbf{E}(\varepsilon|\varepsilon \geq \underline{\varepsilon})$. $\mathbf{E}(\varepsilon|\varepsilon \geq \underline{\varepsilon})$ is bounded above by $\bar{\varepsilon}$, and A1 ensures that $\rho_B + \mathbf{E}(\eta) > \bar{\varepsilon}$, so that welfare is increasing in r at $r < 1$.

At $r > 1$, the derivative of welfare has the same sign as

$$(u_G + 2c - u_B - \rho_B) - \frac{1}{\gamma}[\rho_G + \mathbf{E}(\varepsilon)] + \frac{\gamma}{r}\left(\mathbf{E}(\eta|\eta \geq \underline{\eta}) - \underline{\eta}\right).$$

If the costs of selection are small, as stated in A1, this implies that the first term in brackets is strictly negative. Since $\underline{\eta} > 0$ and $r \geq 1$, this expression is negative if $\rho_G + \mathbf{E}(\varepsilon) \geq \gamma^2\mathbf{E}(\eta|\eta \geq \underline{\eta})$, which follows from A1. Thus welfare is decreasing in r at $r > 1$.

Proofs relating to section 2 and proposition 2:

We show first that $t^*(x)$ is decreasing in x. Differentiating (4) we obtain

$$\frac{dt^*}{dx} = \frac{\alpha'(x)(\rho - t^*) - \beta'(x)(\rho + \xi(t^*)}{(\alpha + i) + (\beta + i)\xi'(t^*)} < 0,$$

since α is decreasing in x and β is increasing.

To show that the match efficiency term is maximized at $x = 1$, define

$$M'(x) \equiv (1-\theta)\tilde{U}'(x) + \theta\tilde{V}'(x).$$

Differentiating the expressions for $\tilde{U}$ and $\tilde{V}$ and using condition (4):

$$M'(x) = \frac{\theta\beta'(\alpha + i) + (1-\theta)\alpha'(\beta + i)}{(\alpha + i)(\beta + i)^2}(\rho - t^*) + \left(\frac{\alpha\theta}{i(\alpha + i)}\xi'(t^*) - \frac{\beta(1-\theta)}{i(\beta + i)}\right)t^{*\prime}(x).$$

At $x = 1$, $\beta' = -\alpha'$, $\beta = \alpha$ and $\theta = \frac{1}{2}$, so the first term equals zero. Since $\xi'(0) = 1$, the second term is also zero.

Proof of Proposition 3: If $r_G^* > r_B^*$, then at r_G^*, a parent whose first child is a girl is indifferent between selecting and not selecting, while a parent whose first child is a boy strictly prefers not to select, verifying that the associated behavior corresponds to an equilibrium. Similarly, if $r_G^* < r_B^*$, then at r_B^*, the associated behavior corresponds to an equilibrium.

Let us now turn to welfare, as a function of selection decisions. With probability one-half, the first child is a girl. Let λ_i denote the fraction of parents who exercise choice after having a having a first child of sex i, , $i \in \{G, B\}$. Let $\lambda = \lambda_G - \lambda_B$ be a measure of the imbalance in the sex ratio, where λ is related to r by the equation $r = \frac{4-\lambda}{4+\lambda}$. Welfare is given by

$$W(\lambda, \lambda_B) = \frac{1 - \lambda - \lambda_B}{4}V_{GG}(r) + \frac{1 - \lambda_B}{4}V_{BB}(r(\lambda)) + \frac{2 + \lambda + 2\lambda(B)}{4}V_{BG}(r(\lambda)) - \frac{2\lambda(B) + \lambda}{2}c,$$

where $V_{ij}(r)$ is the overall payoff from having family composition ij, as a function of r. We first show that the equilibrium outcome is inefficient as long as λ differs from zero.

$$\frac{\partial W}{\partial \lambda} = \frac{1}{4}[V_{BG} - V_{GG} - 2c] + \frac{1 - \lambda_B}{4}\frac{\partial V_{BB}}{\partial \lambda} + \frac{2 + \lambda + 2\lambda_B}{4}\frac{\partial V_{BG}}{\partial \lambda}.$$

Suppose the equilibrium sex ratio equals r_G^*. In this case, the term in square brackets equals zero, since the parents who first have a girl are indifferent between choosing a boy and accepting nature's lottery. Since V_{BB} and V_{BG} are both decreasing in λ when this is positive as long as $\rho_1 > 0$ and $\rho_2 - \rho_1 > 0$, the derivative of W with respect to λ is negative at this equilibrium.

To deal with the case where the equilibrium sex ratio equals r_B^*, we re-write welfare as a function of λ and $\lambda_G, \hat{W}(\lambda, \lambda_G)$. The derivative of welfare with respect to λ is now given by

$$\frac{\partial \hat{W}}{\partial \lambda} = \frac{1}{4}[V_{BG} - V_{GG} - 2c] + \frac{1 - \lambda_G + \lambda}{4} \frac{\partial V_{BB}}{\partial \lambda} + \frac{2 - \lambda + 2\lambda_G}{4} \frac{\partial V_{BG}}{\partial \lambda}.$$

Here again, the same argument applies: $V_{BG} - V_{GG} - 2c = 0$ when the equilibrium sex ratio is r_B^*, and so welfare is decreasing in λ.

We now turn to characterizing the welfare optimal allocation in society. We first investigate the conditions under which $\lambda = 0$ (i.e. having a balanced sex ratio) is welfare optimal. If $\lambda > 0$, then some parent with a girl is selecting a boy. By doing so, the expected direct utility gain is $[u_{BG} - u_{GG} - 2c]$. In consequence, two additional boys are left unmatched, and the cost of this is at least $2[\rho_2 - \rho_1]$. So under the condition of the proposition $([u_{BG} - u_{GG} - 2c] - 2[\rho_2 - \rho_1] < 0)$, it is socially optimal to have $\lambda = 0$. [27]

[27] Although the proposition does not deal with necessary conditions, we may note that this condition (with a weak inequality, rather than a strict one) is also necessary. At first sight it does not seem necessary – if $\lambda > 0$, then the cost of having an additional boy is greater than $2[\rho_2 - \rho_1]$, since there is some probability that two boys in the same family are left unmatched, so that the cost in this event is ρ_2, which is greater than $2[\rho_2 - \rho_1]$. However, as $\lambda \to 0$, the probability that two boys in the same family are left unmatched tends to zero at a rate that is proportional to λ^2, so that the sufficient condition on parameters is also necessary.