Parental Sex Selection and Gender Balance*

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Abstract

We consider a society where parents prefer boys to girls, but also value grandchildren. Parental sex selection results in a biased sex ratio that is socially inefficient, due to a congestion externality in the marriage market. Improvements in selection techniques aggravate the inefficiency. These results are robust to allowing prices in the marriage market, if the market is subject to frictions. We extend the model to consider gender preferences which depend upon family composition, allowing us to examine the possible sex ratio effects of China's one-child policy, and the implications of choice in societies where family balancing considerations are paramount.

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

JEL Categories: J12, J13, J16

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1 Introduction

In many parts of the world, parents exhibit *gender bias* — they prefer to have a boy child rather than a girl. 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. Indeed, the community of *hijras* (eunuchs), who traditionally make their living by extorting money on joyous occasions, demand substantially larger amounts when a boy is born as compared to when a girl is born. Gender bias is also reflected in male biased sex ratios, and the problem of "missing women" (Sen,1992), although the problem 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" — due to their practice of female infanticide. [1]

Modern medicine has aggravated the problem of unbalanced sex ratios by reducing the cost of choosing boys. The development and spread of amniocentesis and ultrasound screening in the early 1980s made foetal sex determination possible, permitting sex selective abortion.[2] Foetal sex determination for selective abortion is illegal in China and India, but the practice flourishes. Indeed, 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 (Chahnazarian, 1998). 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 (Bhaskar and Gupta, 2007). In the 2000 Chinese census, the sex ratio at birth was 116.9, with some regions reporting ratios of 130-135. [3] 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.

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

[2] Foetal blood tests now permit sex determination at six weeks.

[3] Oster (2005) argues that hepatitis B infection explains a part of the imbalance in the sex ratio, especially in China. However, there are large *increases* in the sex ratios in these countries across censuses, that are most plausibly due to the spread of sex selection techniques. For more direct evidence on the extent of sex selective abortions, see Arnold et al. (2002) and Jha et al. (2006).

The marriage market consequences of sex ratio imbalances of this magnitude are enormous. For example, it is estimated that 40-50 million Chinese men could 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 has also endowed them with a strong desire for grandchildren. Can such biased 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 in a society with widespread gender bias? The standard response, from government agencies, international institutions and non-governmental organizations, is to deplore sex selection. In this view, gender bias reflects discriminatory preferences, that are based on ignorance and backwardness. Rather than allowing choice based on discriminatory preferences, the state has a duty to educate away such preferences, and in the meantime, constrain how they are exercised. This view is squarely paternalistic, in the sense that policy is not based upon the preferences of the citizens, but rather on those of enlightened agencies.

An alternative view, that is heard less often, is that allowing parental choice may in fact improve the position of girls. As girls become scarcer, their value will rise, and this will reduce realized gender bias and improve their position in society. Dharma Kumar (1983) was an early and trenchant proponent of this position. Indeed, she asks whether selective abortions are any worse than the neglect and infanticide of girl children. She goes on to argue that market forces will alleviate problems arising from discriminatory preferences. However, this view does not take into account possible externalities or market failure.

This paper proposes a simple economic model of parental choice in order to address these issues. We show that an imbalance in the sex ratio is an equilibrium consequence of gender biased preferences. At such an equilibrium, realized gender bias – the payoff difference between having a boy as compared to a girl – will be lower than in the absence of choice. This is mainly done by reducing the payoff to having a boy, from reduced marriage market prospects, rather than raising the payoff to having a girl (although this may also happen to an extent). In consequence, parents who select for boys exert a congestion externality in the marriage market, so that parental sex selection reduces welfare, where welfare is evaluated in terms of the ex ante expected utility of the typical parent. Technological improvements in selection, such as ultrasound or *in vitro* fertilization, will worsen the sex ratio and reduce welfare.

These negative social consequences arise from the fact that marriage markets without appropriate prices do not ensure efficiency. If the marriage market clears via prices, where these prices are Walrasian, then a bride price system can support the efficient allocation, where the sex ratio is balanced. However, this requires strong assumptions. If the marriage market is subject to frictions, so that prices move continuously with the sex ratio, then a bride price does not ensure efficiency. A frictional marriage market with prices produces results that are qualitatively similar to those in our simple model without prices. In particular, the equilibrium sex ratio is excessively biased towards boys from a social welfare standpoint, and technological progress reduces welfare by aggravating the congestion externality. We also extend our simple model to consider a variety of issues. These include the effects of China's one-child policy on the sex ratio, the effect of exogenous changes in the sex ratio (due to hepatitis B infection (Oster, 2005)) when there is a behavioral response, and upon possible class differences in sex selection behavior.

Our model can also be extended to consider the implications of sex selection is societies without widespread gender bias, where family balancing is a primary consideration. Recent technological developments have made this possible, by allowing sex selection with low psychological costs. *In vitro* fertilization allows control over the sex of the embryo, thereby reducing the psychological and financial costs of sex selection – essentially, it comes for free for those undergoing fertility treatment. More experimental are the techniques for preconception gender selection, through the separation of X-bearing and Y-bearing sperm. While preconception gender selection is not yet established, it is very much on the horizon. Indeed, the American Society for Reproductive Medicine has argued that parents should be allowed these techniques, when feasible, for family balancing reasons. However, many developed countries such as the UK prohibit the use of gender selection for social reasons such as family balancing. Our model shows that while allowing sex selection for family balancing may improve individual utility, a congestion externality may similarly arise if preferences or not fully symmetric between the sexes (or if the costs of selection vary depending on the sex). Thus society must ensure that incentives are in place to produce outcomes that are gender balanced at the aggregate level.

The layout of the remainder of this paper is as follows. Section 2 sets out our basic model of parental choice with gender biased preferences. It also develops extensions of this model to consider heterogeneity, either due to random variation in offspring quality, or due to ex ante heterogeneity, due to class or social status. Section 3 allows for bride prices, in a Walrasian as well as frictional matching setting. Section 4 considers the implications of having more than one child. With gender biased preferences, it develops empirical implications on the pattern of selection, and on China's one-child policy. It also analyzes the implications of preferences for family balancing, in the absence of generalized gender bias. The final section concludes.

2 A Simple Model

The standard biological model of the sex ratio dates back R.A Fisher (1930), following on ideas in Darwin. Fisher's model is one where a parent is concerned only with maximizing reproductive fitness, and predicts an equilibrium sex ratio that is balanced. In addition, in equilibrium, there is no gender bias – parents are equally happy when a girl is born as when a boy is.

Human societies have been transformed enormously from the hunter-gatherer societies where evolutionary preferences have been shaped. Increased life expectancy means that 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. 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. 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. The reforms raised the returns to cash crops such as tea and orchard fruit. While tea uses mainly female labor, orchards are usually tended by men. 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 strictly 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. Without loss of generality, the von-Neumann Morgenstern utilities may be parametrized as follows. Let u_B be the base payoff to the parents from having a single boy, and let $u_B + \rho_B$ be the total payoff from having a boy who is successful in finding a partner. That is, ρ_B is the additional payoff from successful mating. Similarly, let u_G be the payoff to the parents from having a single girl and let ρ_G be the additional payoff in the event that this girl finds a partner. Our assumptions on preferences imply that $u_B > u_G$ and $u_B + \rho_B > u_G + \rho_G$. Furthermore, $u_B < u_G + \rho_G$, since we have assumed a married girl is preferable to a boy who remains single.

Let r be the ratio of girls to boys in the population. We shall assume that every member of the scarcer sex gets a partner, while every member of the more abundant sex has an equal chance of getting a partner. The expected payoff to the parents from having a boy is given by

$$U(r) = u_B + \min\{r, 1\}\, \rho_B. \tag{1}$$

While the payoff from having a girl is given by

$$V(r) = u_G + \min\left\{\frac{1}{r}, 1\right\} \rho_G. \tag{2}$$

Turning to parental choice, let us consider first the case of ex post selection, e.g. via sex selective abortions. On becoming pregnant, the sex of the foetus is either male or female, each with equal probability. On observing the sex of foetus, the parents can pay a cost c to have an abortion and conceive another child. In this event, they have an independent draw, where the probability of a boy is one-half. Once again, if they are unsatisfied with the outcome of the new draw, they can again pay a cost of c and try again, and so on. Suppose that the sex of the foetus is female, so that the value of this option is $V(r)$. 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, c. So aborting the foetus and trying again is optimal if

$$U(r)-V(r)\} \geq 2c, \tag{3}$$

while accepting the girl child is optimal if the above inequality is reversed.

In the case of *in vitro* fertilization, choice is exercised ex ante, before pregnancy. If the parents select for 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 $\frac{1}{2}\{U(r)+V(r)\}$. It is easy to see that 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.[4]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 also easily extended to the case of imperfect ex ante selection technologies, such as sperm selection. If the technology costs c and produces a boy with probability $p>0.5$, then the relevant cost is $\frac{2c}{2p-1}$ rather than $2c$ (as on the right hand side of equation (3)).

Turning now to equilibrium, if the cost c is sufficiently large, so that $2c \geq U(1)-V(1)$, then the equilibrium sex ratio r will be 1. To verify this, observe that at a balanced sex ratio, both sexes earn their reproductive value, since every individual is matched with probability one. Thus the expected gain in value for a parent who chooses to try again is $\frac{U(1)-V(1)}{2}$, which is less than c. Nor can there be any other equilibrium − if $r<1$, then the gain from having

[4] This equivalence follows from the assumed separability between gender specific payoffs and the cost of selection. Also, if there is an endowment effect, then this could make accepting the status quo (the girl child) more valuable in the case of ex post selection. These considerations are likely to be dwarfed by the difference in direct psychological costs associated with the two technologies.

a boy is even smaller, and thus exercising the option to try again cannot be optimal.

Let us now assume $2c < U(1) - V(1)$. In this case, it is clear that $r = 1$ cannot be an equilibrium, since the value of trying again is greater than the cost. At an interior equilibrium, where $r^* \in (0,1)$, it must be the case that a parent is indifferent between accepting a girl child and trying again, which gives us the basic indifference condition:

$$U(r^*) - V(r^*) = 2c. \tag{4}$$

The intuition for this condition is straightforward: by exercising choice when one has a girl, a parent gets a half chance of an improvement in value from $V(r^*)$ to $U(r^*)$. Indifference requires that this equals the cost c. By substituting for the values of $U(.)$ and $V(.)$, one gets the equilibrium sex ratio as

$$1 - r^* = \frac{(u_B + \rho_B) - (u_G + \rho_G) - 2c}{\rho_B}. \tag{5}$$

That is, if $2c < U(1) - V(1)$, the equilibrium sex ratio is biased against girls.

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".[5] 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?[6] Even if society is able to prevent sex selective abortions, it cannot ensure that the unwanted girls are loved and taken care of. In addition, we must note that the newer ex ante selection technologies are less open to these absolutist moral objections. In the present paper, we assume a non-paternalistic welfare evaluation, and consider the welfare of the individual parent. Since all parents are ex ante identical (before the realization of the sex of their child), we take as our welfare criterion the expected ex ante utility of a typical parent – this also equals the sum of realized utilities in this society. Thus welfare, as a function of the sex ratio r, is given by

[5] Gendericide is a neologism that refers to the mass killing of members of a specific sex.

[6] Sex selective abortions are illegal in India and China; however, since both ultrasound and abortion are legal, it is hard to see how such a law can be enforced.

$$W(r) = \frac{1}{1+r}U(r) + \frac{r}{1+r}V(r) - c\frac{1-r}{1+r}. \tag{6}$$

The first two terms are straightforward – a proportion $\frac{1}{1+r}$ of parents have boys, and get utility $U(r)$, while the remainder have girls and utility $V(r)$. To account for the total cost associated with trying again for a boy, suppose that a measure λ of those parents who have girls at the first attempt keep trying until they get a boy. The expected cost associated with such a policy is given by the infinite summation $c + \frac{c}{2} + \frac{c}{4} + ..$, yielding $2c$. λ must equal $\frac{1-r}{2(1+r)}$ in order to have the sex ratio r.

How does welfare change with r? This is best understood intuitively. Suppose that $r \leq 1$ and a measure λ of parents who have had girls decide to try again, possibly repeatedly, until they have a boy. Abstracting from marriage market concerns, the private (and social) effect on welfare is $u_B - u_G - 2c > 0$, since the value of a single boy exceeds that of a single girl plus the expected cost of getting a boy given that the first offspring is a girl. Now, let us consider the marriage market. The effect of this change implies that a measure 2λ of boys will be without a partner, i.e. two boys will be left unmatched for every girl who is "converted" into a boy. Thus the marriage market cost of the choice by an individual parent is $-(\rho_B + \rho_G)$, and the per-capita effect on welfare equals $u_B - u_G - 2c - \rho_B - \rho_G$, which is strictly negative since $u_B - u_G - \rho_G < 0$ (due to our assumption that the payoff from a married girl exceeds that of a single boy). Thus welfare is reduced by parental choice, the exercise of which moves the sex ratio towards imbalance. More formally, the derivative of social welfare with respect to r at any $r < 1$ is given by

$$\left.\frac{\partial W}{\partial r}\right|_{r<1} = \frac{V(r) - U(r) + 2c + (1+r)[U'(r) + rV'(r)]}{(1+r)^2}. \tag{7}$$

Since $V'(r) = 0$ and $U'(r) = \rho$ when $r < 1$,

$$\left.\frac{\partial W}{\partial r}\right|_{r<1} = \frac{u_G - u_B + \rho_B + \rho_G + 2c}{(1+r)^2} > 0. \tag{8}$$

Similarly, it may be verified that $\left.\frac{\partial W}{\partial r}\right|_{r>1} < 0$, so that the welfare optimal level of r is 1. Intuitively, at the equilibrium sex ratio, a parent is indifferent between having a girl and trying again. However, the decision not to exercise choice has a positive effect on the parents of two boys in the aggregate. That is, there is a congestion externality in the marriage market which is not taken into account by parents who exercise choice. Indeed, this argument applies not only at the equilibrium sex ratio, but an any sex ratio less than 1 – there is a social loss from exercising choice, but since the loss of $\rho_B + \rho_G$ is shared amongst all boys, and since each parent is small in the population, this is not taken into account.

We may note that our notion of efficiency, which is based on individual preferences, differs considerably from the biological one. In evolutionary biology, the efficient sex ratio is the one that maximizes the growth rate of the species. From this standpoint, the balanced sex ratio is inefficient since there are too many "useless" males.

We now consider the implications of changes in c upon welfare. Equation (5) shows that the equilibrium sex ratio, r^*, increases with c. Let $W^*(c)$ denote equilibrium welfare as a function of c, i.e.

$$W^*(c) = W(r^*(c)). \tag{9}$$

Since it is optimal at r^* for a parent to accept the child that nature deals her, without trying again, this can be written as

$$W^*(c) = 0.5\{U(r^*(c)) + V(r^*(c))\}. \tag{10}$$

From the indifference condition at r^*, that the difference between $U(.)$ and $V(.)$ equals $2c$, this can be re-written as

$$W^*(c) = V(r^*(c)) + c. \tag{11}$$

From equation (2) note that $V(r)$ is constant as long as $r \leq 1$. Thus equilibrium welfare increases linearly in c. Technological progress, that makes selective abortions easier, reduces welfare. Notice that first best welfare continues to be achieved at a balanced sex ratio where $r = 1$, independent of c.

At this point, one may ask, are recent increases in the sex ratio in East and South Asia equilibrium phenomena, or do they reflect incorrect expectations on the part of parents? After all, parents must make choices today based on the anticipated sex ratio in the future. While learning models suggest that societies will be able to learn rational expectations equilibria in stable environments, recent technological developments have been so rapid that one cannot assume that behavior necessarily reflects equilibrium. Two points can be made in this context. First, while the aggregate magnitude of the sex ratio imbalance in East/South Asia is enormous, the consequent change in sex ratios is more modest. There are large ratio imbalances in specific regions, but these regions can possibly "import" brides from less unbalanced regions. Second, if there are expectational errors that result in an over-reaction of the sex ratio, the adverse welfare effects of selection are aggravated. Our point has been to demonstrate that negative welfare effects arise even in perfect foresight equilibrium. We summarize the results of this section in the following proposition.

Proposition 1 *If $u_B - u_G > c$ and there are no prices in the marriage market, then the equilibrium sex ratio is biased towards boys. This is socially inefficient, and the welfare optimal sex ratio is one. Technological progress that reduces c reduces welfare.*

Sex selection has adverse social consequences, suggesting that current policy banning sex selective abortions (in China and India) may be well motivated. However, a ban seems unworkable, since it is impossible to verify that a sex selective abortion has indeed taken place. An alternative policy is to increase the value of girls while reducing that of boys, by possibly taxing boys and making transfers to girls. This could be implemented, for instance, via differential school fees.

We now turn to some implications of the model for several issues relating to the sex ratio and parental decisions.

2.1 Heterogeneity

We have assumed so far that individuals are differentiated only by gender, and are otherwise identical in terms of class, social standing or attractiveness. We now consider the implications of allowing for heterogeneity. Agents may be heterogeneous ex post even while being homogeneous ex ante – that is the quality of the offspring can be random. Alternatively, they could be heterogeneous ex ante, differentiated by class or social status. Ex ante heterogeneity differs considerably from ex post, since the former affects the incentives for sex selection.

2.1.1 Ex post heterogeneity

Suppose that the quality of the offspring on the marriage market is random, and equals $\rho + \varepsilon$, where ε has a continuous and strictly increasing cumulative distribution function $F(.)$, with support $[0, e]$. We assume that when a child is born, nature chooses the gender and quality independently. We also assume that quality cannot be observed at conception (although gender can), but only later, on the marriage market. Assume that when individual i marries j, the payoff to i equals the quality of j. This assumption is standard in the literature, see for example, Burdett and Coles (1997). Assume also that parents evaluate matches in the same way that their offspring do. Matching in the marriage market will be positively assortative. If there are too many boys, then the lowest quality boys will be left unmatched. If $r \leq 1$, the ex ante expected utility of having a boy, as function of the sex ratio, is given by

$$U(r) = u_B + r[\rho + \mathbf{E}(\varepsilon)]. \tag{12}$$

That is, a boy has probability r of finding a match, and ex ante, before his own quality is realized, the match quality of his partner is a random draw from the set of all girls. Similarly, the ex ante expected utility of having a girl is now given by

$$V(r) = u_G + \rho + \mathbf{E}(\varepsilon | \varepsilon \geq F^{-1}(1 - r)). \tag{13}$$

From an ex ante point of view, a girl gets a draw from the top r fraction of boys, and thus the expectation of ε conditional on ε being greater than $F^{-1}(1 - r)$. Thus as r increases, this model produces the realistic result that the payoff to girls, $V(r)$, decreases.

Nevertheless, the results of this model are essentially the same as before. The equilibrium sex ratio must satisfy the same indifference condition as before, and the sex ratio will be unbalanced. Furthermore, if $u_B - u_G - 2c < 2\rho$, then the welfare optimal level of r is one. Proposition 1 continues to apply when we have ex post heterogeneity. A proof of this is in the appendix.

2.1.2 Ex ante heterogeneity

We now consider the implications of ex-ante heterogeneity of status in the population. 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.[7]

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

$$u_B + r_H^* \rho^H + (1 - r_H^*)\rho^L - 2c = u_G + \rho^H. \tag{14}$$

The left hand side of the above expression shows the expected value of boy, less the expected cost of ensuring a girl; 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

$$U^L(r_L, r_H^*) = u_B + \min\left\{ r_L - \frac{(1+r_L)(1-r_H^*)}{1+r_H^*}\mu, 1 \right\} \rho^L. \tag{15}$$

The payoff to lower class girls is given by

$$\begin{aligned} V^L(r_L, r_H^*) &= u_G + \frac{(1+r_L)(1-r_H^*)}{r_L(1+r_H^*)}\mu\rho^H \\ &\quad + \min\left\{ \frac{1+r_H^*}{(1+r_H^*)\, r_L - (1+r_L)\,(1-r_H^*)\,\mu}, 1 \right\} \rho^L. \end{aligned} \tag{16}$$

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 $\left|U^L(1, r_H^*) - V^L(1, r_H^*)\right| = 2c$. The following observations are immediate from this analysis. $r_L^* > r_H^*$, that is the sex ratio is more favorable to girls among the

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

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.

The results here are relevant for empirical work, suggesting that one should observe more male biased sex ratios in the upper class as compared to the lower class. This is consistent with census data 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.

From a welfare point of view, note that parental sex selection reduces ex ante expected utility in the upper class, under similar assumptions as in our simple model (i.e. if $u_G - u_B + 2c + 2(\rho^H - \rho^L) > 0$). 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.[8]

These findings in this section are related to the famous Trivers-Willard (1971) hypothesis of evolutionary biology. This applies to animals where mating is non-monogamous, where high quality males are able to mate many times, while low quality males fail to mate. This implies that healthier mothers, who

[8] If parameter values are such that there is selection for girls, then it is possible for sex selection to be welfare increasing for the lower class.

can expect higher quality offspring, have an incentive to produce boys. On the other hand, less healthy mothers have an incentive to produce girls. Note that the mechanism here is quite different, and arises from the imbalance in the sex ratio, since mating is assumed to be monogamous. It is also related to Edlund (1999), who examines the consequence of sex selection in finite society where every individual is strictly ordered by rank, rank being endowed ex ante. She finds that if sex selection is perfect, then the sex ratio will be balanced, with boys being chosen by high ranked individuals. Imbalances in the sex ratio can only arise with noisy selection, where parents can only choose boys (or girls) with some probability $p \in (0.5, 1)$, and this imbalance increases with son preference. In contrast, we find that 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 ex ante homogeneous agents. [9] We are also able to analyze the welfare implications of selection, and unbalanced sex ratios in this context.

2.2 Hepatitis B and the sex ratio

A recent paper by Oster (2005) argues that male biased sex ratios may be partially explained by hepatitis B, since infection by the virus makes mothers more likely to bear boys. Her estimates indicate that hepatitis B is responsible for about 20% of the excess of boys in China, but only about 5% in the case of India. However, these estimates assume that there is no behavioral response by parents to the incidence of the virus (as Oster acknowledges). We now consider how implications of biased sex ratios, arising from hepatitis B infection, upon the equilibrium behavior of the sex ratio. Let us suppose that uninfected mothers have a probability p^u of having a boy, while infected mothers have a probability $p^h > p^u$. We may think that $p^u = 0.5$, although this is not necessary for what follows. Let λ be the fraction of infected mothers.

Consider first a society where there is no significant gender bias so that there are no sex selective abortions. That is, let us assume that $u_B \simeq u_G$, with c being large relative to $|u_B - u_G|$, so that a parent is content to accept a child irrespective of gender. Let us also assume that the incidence of hepatitis B infection, λ, is small. In this case, there is no behavioral response to the rate of

[9] We conjecture that our results would also hold when agents are strictly ordered ex ante in terms of expected quality, provided that there was an element of ex post heterogeneity which could produce different rankings with some probability.

hepatitis B infection (λ), and the observed proportion of boys in the population depends linearly on λ:

$$p(\lambda) = p^u + \lambda(p^h - p^u). \tag{17}$$

Thus an increase in the incidence of hepatitis B raises the proportion of boys at rate $p^h - p^u$. The sex ratio, $r(\lambda) = (1 - p(\lambda))/p(\lambda)$.

Now let us consider a society where there is gender bias that is large enough to induce sex selective abortions. In this case, the behavioral response offsets any change in hepatitis B infection. Our analysis depends on whether mothers know about the link between hepatitis B and the sex ratio at birth or not. Since the hypothesized link between hepatitis B and the sex ratio is relatively new, and unknown even to most medical professionals in these countries, the most plausible assumption is that mothers assume that the probability of having a boy is 0.5, regardless of hepatitis B status. This implies that the equilibrium condition, for a mother to be indifferent between having a girl and trying again is as before, i.e. $U(r^*) - V(r^*) = 2c$. Thus the equilibrium sex ratio is invariant with respect to λ, and the behavioral response *completely offsets* the direct effect of hepatitis B on the sex ratio.

This conclusion must be modified, but only somewhat if mothers are aware of the link between hepatitis B and the sex ratio. The analysis here depends upon whether an individual mother observes her hepatitis B status or not. Let us assume the former. At any sex ratio r, the expected payoff from trying again is greater for an infected mother than for an uninfected mother, since the infected mother has a higher probability of having a boy. This implies that if an infected mother is indifferent from having a girl and aborting the foetus and trying again, the uninfected mother strictly prefers to accept the girl. Conversely, if the uninfected mother is indifferent, the infected mother strictly prefers to continue trying till she has a boy. This has the straightforward implication that the *observed* difference in frequencies of boys between infected and uninfected mothers is greater than the difference $p^h - p^u$.[10] This result is robust, in the sense that it applies as long as infected mothers have some inkling of their infection (i.e. they assign higher probability to being infected than uninfected mothers).

[10] This applies as long as one has an interior equilibrium where some mothers accept girls and others try again.

Turning to equilibrium, the indifference condition depends upon which type is marginal, i.e. which type has some mothers trying again while others accept a girl. This in turn depends upon how large λ, the fraction of infected mothers, relative to the equilibrium proportion of boys. The indifference condition characterizing equilibrium may be written as

$$p^j U(r^*) + (1-p^j)V(r^*) - 2c = V(r^*), \tag{18}$$

where

$$p^j = \begin{cases} p^h \text{ if } \lambda + (1-\lambda)p^u \geq 1/(1+r^*) \\ p^u \text{ if } \lambda + (1-\lambda)p^u < 1/(1+r^*). \end{cases} \tag{19}$$

Note that the indifference condition (18) is constant in λ except at the point where $\lambda + (1-\lambda)p^u - 1/(1+r^*)$ changes sign. This implies that changes in λ will have no effect on the equilibrium sex ratio r^* unless these changes induce a "regime-change", where the indifferent mother switches type. That is, even if hepatitis B affects the proportion of boys directly, the behavioral response may well completely offset this effect.

The basic point here is that if the sex ratio imbalance reflects parental preferences, then exogenous changes in the sex ratio, due to factors such as hepatitis B, will be offset, at least in part, by the behavioral response of parents.

3 Bride Prices

We have assumed that there are no transfers possible in the marriage market. Suppose that the more abundant sex (boys) compete for the scarcer sex by making transfers, say a bride price. We analyze a bride price system under two possible situations. We first consider a frictionless market, and then go on to consider market frictions. Before proceeding to the analysis, it is worth relating our analysis to current institutional arrangements. Following Becker (1981), an imbalance in the marriage market implies that the scarcer sex – females in this case – will be able to command a bride price. However, it is dowries (we use the term to denote groom-prices) that are the norm in most parts of India. Indeed, there is some evidence that dowries have increased over the twentieth century, and have also been established in areas where they were not previously customary – see, for example, Rao (1993).[11] This appears to be the case for two reasons. First, dowries may partially be a pre-mortem bequest to girls (Botticini and Siow, 2003; Zhang and Chan, 1999) and this component would tend to rise with incomes and wealth. Second, rapid population growth in the twentieth century, in conjunction with the age-difference in marriage has given rise to the "marriage squeeze" – see e.g. Bhatt and Halli (1999). [12] The magnitude of excess supply of women implied has been quite large – to illustrate, if cohort size grows at 2% per annum, and the age-difference in marriage is five years, then a balanced sex ratio implies over 10% excess supply of women. In other words, it appears that increase in dowries over the twentieth century in India reflects supply-demand factors; in consequence, one should expect that recent and ongoing changes in the sex ratio will also be reflected in prices. We should note that in recent years, population growth in India has declined, so that the marriage squeeze is less important. This makes the imbalance in the sex ratio even more worrying.

3.1 Walrasian Markets

Assume that the ex-post marriage market is Walrasian. Our focus is on a rational expectations equilibrium, where parents make their initial choices (regarding gender) anticipating a bride price, that in turn equals the realized bride price. Let t denote the transfer from boys to girls, i.e. the bride price. In a Walrasian market, an 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 date 1 (the time the child is born) 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^*. We show first that the sex ratio cannot be unbalanced in a rational expectations equilibrium. Suppose that $r^* < 1$, so that $t^* = \rho_B$. In this case, any parent who has a girl strictly prefers not to exercise choice, since we have assumed that $u_B - u_G < \rho_B$. So r^* cannot be less than one. Similarly, one cannot have $r^* > 1$.

[11] Apart from the data from six villages used used by Rao, there is little systematic quantitative evidence on dowry payments in India. However, informal evidence suggests that dowry payments have increased in the long term.

[12] See Anderson (2003) for an alternative explanation for the persistence and spread of dowries with modernization.

We now show that there is a continuum of rational expectations prices that support a single allocation, the efficient one with a balanced sex ratio, where the equilibrium transfer t^* satisfies

$$\frac{(u_B - u_G) - 2c}{2} \leq t^* \leq \frac{(u_B - u_G) + 2c}{2}. \tag{20}$$

To verify that this is indeed an equilibrium, note that the bounds lie within the interval $[-\rho_G, \rho_B]$, so that the equilibrium price is Walrasian. Furthermore, if the inequality is satisfied, a parent who has a girl will not find it optimal to exercise choice, and the same is true for a parent who has a boy. Notice that a Walrasian equilibrium permits gender bias – t^* may be such that parents are better off with a boy or for that matter, a girl, since $c > 0$.

Our model so far is static, and assumes that the payoff from marriage (ρ_G or ρ_B as the case may be) accrues immediately as soon as the marriage is contracted. However, it is more plausible to think of the payoff from marriage as a flow payoff, in which case ρ_G or ρ_B represent the discounted present value of flow payoffs. Now suppose that agents are credit constrained, so that there exists an upper bound $\bar{t}$ such that $|t| \leq \bar{t}$. That is, the bride price (or dowry) that can be paid at the time of marriage cannot exceed $\bar{t}$. Furthermore, let us suppose that $\bar{t} < \frac{(u_B - u_G) - 2c}{2}$, the minimum bride price that is required to support the efficient allocation. This in itself does not create any complications, if no element of irreversibility in marriage – if marriage is completely flexible, and men are in excess supply, then the continuation of marriage can be made contingent upon the payment of a "flow" bride price. However, marriage has strong elements of irreversibility, particularly so in countries such as India or China, where divorce is relatively rare. This means that agents on the long side of the market, say men, will not be able to commit to the flow payments, since they have the incentive to renege once married. [13] The equilibrium sex ratio will therefore be given by

$$1 - r^*(\bar{t}) = \frac{(u_B - u_G) + (\rho_B - \rho_G) - 2\bar{t} - 2c}{\rho_B - \bar{t}}. \tag{21}$$

Thus credit constraints provide one explanation for why the equilibrium sex ratio might be unbalanced, even if there are prices in the marriage market.

[13] As Becker (1981) suggests, dowries are one off payments which necessary due to the limited transferability of utility within marriage.

3.2 Frictional Matching

The Walrasian model has an unattractive property that the equilibrium price moves discontinuously with the sex ratio. Marriage markets are hardly centrally organized, and idiosyncratic factors play an important role in partner choice. We therefore consider decentralized matching, with the bride-price being the outcome of bargaining. Let us now consider a frictional matching model, as in Rubinstein and Wolinsky (1985) or Mortensen and Pissarides (1994). Time is continuous, the time horizon is infinite, and agents discount the future at a common interest rate i. At any instant, there is a stock of unmarried boys, of measure μ, and a stock of unmarried girls of measure $x\mu$, so that x denotes the sex ratio in the stocks. Matches arrive according to a Poisson process, with arrival rate $m(x\mu, \mu)$. The matching function $m(.)$ is increasing in both arguments, differentiable, symmetric (i.e. $m(y, z) = m(z, y)$) and satisfies constant returns to scale. This last assumption implies that the analysis maybe conducted in terms of x, the sex ratio, without reference to absolute market size μ. Accordingly, let $\alpha(x) = m(x, 1)$ denote the arrival rate of matches for a girl, so that the arrival rate of matches for a boy is $x\alpha$. It follows that $\alpha(x)$ is increasing in x, while $x\alpha(x)$ is decreasing in x, i.e. the arrival rate for either sex rises if the share of the opposite sex is larger in the population. Finally, we shall assume that matching becomes more efficient if the market is more balanced. More precisely, we assume that the sum of arrival rates, $s(x) = \alpha(x) + x\alpha(x)$, increases as the market becomes more balanced, i.e. $s(x)$ is strictly increasing (resp. decreasing) in x if $x < 1$ (resp. $x > 1$).

Suppose that a boy and a girl are matched and negotiate a marriage. We assume that there are no credit constraints, so that the bride-price $\frac{t}{i}$ that is paid from the boy to a girl is freely negotiated. Given this bride price, the value of a married boy may be written as

$$U^m = \frac{u_B + \rho - t}{i}, \tag{22}$$

where u_B and ρ represent flow utilities. We have assumed that $\rho_G = \rho_B = \rho$ – this is without loss of generality given unrestricted transferability of utility.[14] Similarly, the value of a married girl can be written as

[14] If ρ_B differs from ρ_G, let $\rho = (\rho_B + \rho_G)/2$, and let the actual bride price $\hat{t} = t + \rho - \rho_G$. The analysis that follows applies with this translation.

$$V^m = \frac{u_G + \rho + t}{i}. \tag{23}$$

The value of a single boy, as a function of x and the "market" bride price t that he anticipates paying satisfies the asset pricing equation

$$iU(x,t) = u_B + x\alpha(x)(U^m - U). \tag{24}$$

This may be written as

$$U(x,t) = \frac{u_B}{i} + \frac{x\alpha}{i(x\alpha + i)}(\rho - t). \tag{25}$$

Similarly, the value of a single girl is given by

$$V(x,t) = \frac{u_G}{i} + \frac{\alpha}{i(\alpha + i)}(\rho + t). \tag{26}$$

We assume that the bride price is determined by Nash bargaining between the two parties. That is the equilibrium bride price t^* is given by the Nash bargaining solution where the outside options are given by $U(x,t)$ and $U(x,t)$.[15] Now, in a steady state equilibrium, the negotiated bride price between the matched pair, t^*, must itself be equal to the anticipated market price t. Thus we obtain the condition:

$$U^m(t^*) - U(x,t^*) = V^m(t^*) - V(x,t^*). \tag{27}$$

This allows us to solve for the market bride price as a function of x :

$$t^*(x) = \frac{\rho(1-x)\alpha(x)}{\alpha(x)(1+x) + 2i}. \tag{28}$$

We may now use the equilibrium bride price to compute the equilibrium value as a function of x alone. That is $\tilde{U}(x) = U(x, t^*(x))$ is given by

$$\tilde{U}(x) = \frac{u_B}{i} + \frac{2\rho x\alpha(x)}{[\alpha(x)(1+x) + 2i]i}. \tag{29}$$

$$\tilde{V}(x) = \frac{u_G}{i} + \frac{2\rho\alpha(x)}{[\alpha(x)(1+x) + 2i]i}. \tag{30}$$

[15] 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.

With parental choice, the equilibrium sex ratio (in stocks) x^* must be so that the difference in values equals twice the one time cost of trying again, c:

$$\tilde{U}(x^*) - \tilde{V}(x^*) = 2c. \tag{31}$$

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, $\alpha(x) = x\alpha(x)$ when $x = 1$) and thus it is optimal to try again on having a girl.

We now turn to the implications for the flow of births. Let us assume that the flow of new births is exogenously given at g,[16] and let θ be the fraction of births that are girls. Let μ be the measure of the stock of boys, and assume that the instantaneous death rate is δ. Thus the steady state flows must satisfy

$$\alpha x\mu + \delta\mu = (1 - \theta)g. \tag{32}$$

$$\alpha x\mu + \delta x\mu = \theta g. \tag{33}$$

Solving these equations, we get θ as

$$\theta(x) = \frac{g + \delta\alpha(x - 1)}{2g}. \tag{34}$$

That is, if x^* is the required sex ratio in the stock of the unmatched, the proportion of girls in the flow of births is given by $\theta(x^*)$.

Turning to welfare, let us consider the expected welfare of the parent as a function of $x, W(x)$. This is given by

$$W(x) = (1 - \theta(x))\tilde{U}(x) + \theta(x)\tilde{V}(x) - (1 - 2\theta)c. \tag{35}$$

$$W'(x) = \left\{(1 - \theta)\tilde{U}'(x) + \theta\tilde{V}'(x)\right\} + \left\{\theta'(x)[\tilde{V(x)} + 2c - \tilde{U}(x)]\right\}. \tag{36}$$

Let us call the first term in curly brackets the "match efficiency effect" – this is the derivative of the (weighted) sum of the utilities of the two sexes with respect to x. This is proportional to

[16] This is a simplification, since the flow of births depends on desired family size and upon the matching rate, both of which depend upon the sex ratio.

$$\theta(x)\alpha'(x) + (1-\theta(x))\{x\alpha'(x) + \alpha(x)\}. \tag{37}$$

Now since $s'(x) = \alpha'(x) + \{x\alpha'(x) + \alpha(x)\} \gtreqless 0$ as $x \lesseqgtr 1$, and since $\theta(x)$ is an increasing function of x that equals one-half at $x = 1$, the expression in (37) has the same properties, i.e. it is zero at $x = 1$, and strictly positive when $x < 1$, and strictly negative when $x > 1$. In other word, since the efficiency of matching is maximized when the market is balanced, the match efficiency effect contribution to welfare increases as the market becomes more balanced.

Turning to the second term in curly brackets, this is simply a positive multiple of the private benefit from accepting a girl as compared to trying again. Thus this term is strictly negative when $x > x^*$ and strictly positive if the inequality is reversed.

This decomposition of equation (36) gives us two immediate results. First, the equilibrium outcome is socially inefficient, with the sex ratio x^* being too low, since at x^*, the second term is zero, and thus $W'(x)_{|x=x^*} > 0$. Second, 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. Thus the main finding of our simple model without prices appears to be robust.

With frictional matching it is not the case that $x = 1$ is socially optimal. From equation (36), at $x = 1$ the match efficiency term is zero but the private benefit term is negative so that welfare is decreasing in x at $x = 1$. Thus the welfare optimal level of x lies between x^* and 1. The one finding of the simple model (in section 2) that appears not to be robust is the result that the optimal sex ratio is one. With frictionless matching, match efficiency is a non-differentiable function of the sex ratio, r, since the number of matches per unit measure of population is $\frac{r}{1+r}$ as long as $r < 1$ and $\frac{1}{1+r}$ if $r > 1$. 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.

Our results in this section are related to those obtained in the literature on the efficiency of job creation in search models of unemployment pioneered by Mortensen and 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, that the equilibrium has too many boys relative to the welfare optimum. In this context, the search literature has also noted that an appropriate assignment of bargaining power between the two sides can ensure an efficient allocation (Hosios, 1990). In the present context, efficiency requires that women have greater bargaining power than men. This seems somewhat unlikely – indeed, the inferior status of women in traditional societies would reduce their bargaining power relative to men. In an illuminating study on India, Bloch and 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 asymmetry 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. From the basic indifference condition (31), the effect of a change in c upon the equilibrium sex ratio is given by

$$\frac{dx^*}{dc} = \frac{2}{\tilde{U}'(x)\mid_{x=x^*} - \tilde{V}'(x)\mid_{x=x^*}}, \tag{38}$$

which is positive if $x^* < 1$ since the match efficiency effect implies that $U'(.) > V'(.)$. Thus, technological progress in sex selection has the effect of reducing sex ratio, as intuition suggests. To examine the effect on equilibrium welfare, define $W^*(c) = W\left(x^*(c)\right)$. In equilibrium, it is optimal for a parent to accept the lottery that nature deals in terms of the sex of child. Using this, and the fact that the difference in values between a boy and a girl equals $2c$, we may rewrite equilibrium welfare as

$$W^*(c) = \tilde{V}(x^*(c)) + c. \tag{39}$$

$$\frac{dW^*}{dc} = \left.\frac{\partial \tilde{V}}{\partial x}\right|_{x=x^*} \frac{dx^*}{dc} + 1. \tag{40}$$

$$= \frac{2\tilde{V}'(x)_{|x=x^*}}{\tilde{U}'(x)\mid_{x=x^*} - \tilde{V}'(x)\mid_{x=x^*}} + 1. \tag{41}$$

Now $\tilde{V}'(x)\mid_{x=x^*} < 0$ but is smaller than $\tilde{U}'(x)\mid_{x=x^*}$ in absolute magnitude, due to the match efficiency effect. Thus the first term is negative but greater than -1. Thus we conclude that welfare is an increasing function of c. Thus technological progress reduces welfare. Notice that welfare optimal level of x is also an increasing function of c: from equation (36), an increase in c increases the second (private benefit) term, thereby increasing x^{**}.

We summarize our results as follows:

Proposition 2 *Let $u_B - u_G > ci$, and let there be prices in a marriage market with frictional matching, where the match efficiency is maximized when the sex ratio is balanced. Both the equilibrium sex ratio and the welfare optimal sex ratio are biased towards boys, with the equilibrium having excessive boys compared to the welfare optimum. Technological progress that reduces c reduces welfare.*

Our analysis in this section has explored the role of marriage market prices in the context of parental choice. The essential insights of our simple model in section 2, without any prices, appear to be robust to allowing for bride prices, provided that this market is subject to frictions. Specifically, we find that the equilibrium sex ratio tends to be inefficiently low, so that there are two many boys relative to girls. We also find that technological progress aggravates the problem and reduces welfare.

In this context, we may return to the arguments of Kumar (1983), who suggested that the scarcity of women could play a positive role, by increasing their value. While this is true, it is also the case that markets require appropriate prices in order to work. Specifically, prices must be Walrasian in order to ensure efficiency. Markets without prices – as in the simple marriage market model of section 2 – or those where pricing is not Walrasian, do not necessarily ensure efficient allocations.

4 Family Balancing Considerations

We now extend our analysis to consider the implications of parents having more than one child. The simple model of section 2 continues to apply when parents have more than one child, as long as gender preferences are independent of family composition, and as long as marginal reproductive value is constant. However, it is plausible that parents' relative preferences between a boy and girl will, in general, depend upon the gender of the child that they already have. It is also likely that reproductive value displays an element of diminishing returns, at least in the context of current parental preferences.

For simplicity, let us focus on a family with two children.[17] Let us assume that a child provides value to the parent in two different ways: the direct value of a child, and the reproductive value. Assume that these enter the utility function in an additively separable way. Let u_{GG}, u_{BG}, u_{BB} denote the direct utility from various child combinations – we assume that there are no order effects so that $u_{GB} = u_{BG}$.Turning to the reproductive value of a child, let $\rho_1 > 0$ denote the value in the event that one child gets a partner, and let $\rho_2 > \rho_1$ denote the payoff when two children get a partner. It is plausible to assume that $\rho_2 < 2\rho_1$, so that there is diminishing marginal utility for grandchildren.

Our analysis in this section has two purposes. First, we shall explore the nature of selection decisions in societies with pronounced gender bias (such as those in South or East Asia). This will allow us to interpret the micro empirical evidence on sex ratios and selection decisions at family level. It will also shed light on the role of China's one-child policy upon gender imbalance. Second, we shall investigate the implications for policy societies without pronounced gender bias, such as the UK or the US, where the desire for selection is driven by family balancing considerations. Our analysis will be conducted assuming that there are no prices in the marriage market.

4.1 Gender biased societies

Consider a society where $u_{BB} > u_{BG} > u_{GG}$, so that parents always prefer that the next child is a boy irrespective of whether the first is a girl or a boy. Even

[17] Since we assume that family size is exogenous, we do not investigate the relation between sex selection and fertility behavior. This is an interesting question which we hope to address in future work.

so, it is plausible to assume that cardinal utilities (which embody preferences over lotteries) are such that $u_{BB} - u_{BG} < u_{BG} - u_{GG}$, so that the marginal utility of the additional boy is lower when the first child is a boy than when the first child is a girl. Let us focus attention on the relevant case where $r \leq 1$, so a girl always finds a partner with probability one. The total payoff from having two girls can be written as

$$V_{GG}(r) = u_{GG} + \rho_2. \tag{42}$$

We shall assume random matching so that any boy finds a partner with probability r. The payoff from having a boy and a girl can be written as:

$$V_{BG}(r) = u_{BG} + r\rho_2 + (1-r)\rho_1. \tag{43}$$

Suppose that c is sufficiently small that $u_{GG} - u_{BG} - 2c > 0$. Let r_G be the sex ratio such that a parent whose first child is a girl is indifferent between accepting a girl and trying again. This is given by

$$r_G = 1 - \frac{u_{BG} - u_{GG} - 2c}{\rho_2 - \rho_1}. \tag{44}$$

Thus if $r > r_G$, a parent whose first child is a girl will prefer to select for a

boy.

Consider next the case of a parent who first has a boy. If this parent has a girl, the overall payoff is given by V_{BG}, as defined in equation (43). If the parent has a second boy, we assume that the event that the first finds a partner is independent of the event that his brother does. The payoff from having two boys is given by

$$V_{BB}(r) = u_{BB} + r^2\rho_2 + 2r(1-r)\rho_1. \tag{45}$$

The sex ratio r_B that makes such a parent indifferent between accepting a girl and trying again, is given by the value of $r \in (0,1)$ that solves the quadratic equation

$$u_{BB} - u_{BG} - 2c - r(1-r)(\rho_2 - \rho_1) - (1-r)^2\rho_1 = 0. \tag{46}$$

Under our assumptions of decreasing marginal reproductive value $(\rho_2 < 2\rho_1$ and the decreasing marginal utility of boys $(u_{BB} - u_{BG} < u_{BG} - u_{GG})$, $r_G < r_B$.

Furthermore, $V_{BB}(r_G) - V_{BG}(r_G) < 2c$ so that at r_G, a parent who has a boy prefers to accept a girl.

We are now in a position to characterize equilibrium in the two child society. If parameters are such that the sex ratio r_G is feasible given that some fraction of parents who have girls as the first child select for boys, then the equilibrium sex ratio is r_G. That is, if $r_G \geq 3/5$, then the equilibrium sex ratio is r_G. However, if $r_G < 3/5$, then the equilibrium sex ratio must be $r_{B.}$

Our results can easily be extended to analyze the case of families with more than two children. They imply that incentives to select for boys will be greater in families where the first (or first few children) are girls than where the first child (or children) are boys. This theoretical prediction is consistent with the findings of the survey of ever-married women carried out in India in 1998, and analyzed by Jha et al. (2006). The survey of 1.1 million households found that the sex ratio is more biased against girls if the first or first two children are girls, than if the first or the first two children are boys.

Our analysis can be used to analyze the implications of the one-child policy in China. It has been argued that the one-child policy has aggravated sex selection in China – see, for example, Hesketh et al. (2006).[18] This argument is based purely on temporal and spatial coincidence between the policy and sex ratios. The policy was introduced in 1978, and the sex ratio has moved against girls since. However, this is about the time that new technologies for sex selection became available. Secondly, sex selection appears to be greater in urban areas, where the one-child policy is more rigorously enforced, than in rural areas, where enforcement is more lax. Here again, urban areas have superior medical facilities, so that selection may be easier than in rural areas. Furthermore, the urban areas are also richer than the poorer areas, and the ability of richer boys to marry down would imply that the incentive to select may be greater in urban areas, as our discussion in section 2.1.2 demonstrates. In consequence, it is hard to infer causality from these correlations.

[18] These arguments have been made mainly in medical journals, but more extreme versions of the same argument are very prevalent in the press. For example, Eric Baculinao of NBC News (Baculinao, 2004) writes: 'The age-old bias for boys, combined with China's draconian one-child policy imposed since 1980, has produced what Gu Baochang, a leading Chinese expert on family planning, described as "the largest, the highest, and the longest" gender imbalance in the world.'

Although the observed correlations cannot resolve the effect of the one-child policy upon the sex ratio, theory can shed some light. From our analysis in section 2, the equilibrium sex ratio in a one-child society is given by

$$r^* = 1 - \frac{u_B - u_G - 2c}{\rho_1}. \tag{47}$$

Let us compare this with equation (44), which gives the equilibrium sex ratio in a two child society, r_G, on the assumption that the indifferent type is a parent whose first child is a girl. Now, $\rho_2 - \rho_1 < \rho_1$ due to diminishing marginal reproductive value. Further, it is also likely that $u_{BG} - u_{GG} > u_B - u_G$, since the intensity of gender preference for a boy over a girl is likely to be greater when one already has one girl than when one does not have any child. This implies that $r_G < r^*$, so that the equilibrium sex ratio will be more unbalanced in a two-child society as compared to a one-child society. Intuitively, when parents have two children, and the first is a girl, the incentive to select for a boy is stronger than when they can have only one child, due to diminishing "marginal utility" for girls, and since a grandchild is assured. Thus, it is far from clear that China's one-child policy has been responsible for the adverse movement in the sex ratio.

4.2 Societies without generalized gender bias

We now turn to the analysis in the case of 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). [19] The American Society of Reproductive Medicine has taken a more positive position : "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..." (May 2001).

While there is unease in official circles with allowing sex selection, this contrasts with considerable evidence that parents have concerns for gender balancing within the family. Angrist and Evans (1998) use US census data and find

[19] The UK allows sex selection for genetic reasons, when there is the risk of gender specific genetic disorders.

that parents with two children of the same gender are 6% more likely to have a third child than parents who have two children of the same gender. While this data suggests that gender balancing may be a primary concern, there is also evidence that the sexes are not treated completely symmetrically. The data reported by Angrist and Evans shows that the probability of a third child is slightly (1-2%) greater for parents with two girls than for parents with two boys. [20] Dahl and Moretti (2007) also present suggestive evidence that parents in the US, especially men, prefer boys to girls. [21]

Table 1: Prob. of having 3rd child

1st two children	1980	1990
GB	0.372	0.344
BB or GG	0.432	0.407
Difference	0.060	0.063
GG	0.441	0.412
BB	0.423	0.401
Difference	0.018	0.011

Source: US census, Angrist and Evans (1998).

We now examine equilibrium in such a society. To reflect preferences for gender balancing, we shall assume that $u_{GB} > u_{BB}$ and $u_{GB} > u_{GG}$. 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 for selecting for 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.

[20] The interpretation of this fertility evidence is not straightforward; in particular, it does not necessarily demonstrate son preference — see Bhaskar (forthcoming).

[21] 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.

The overall payoffs to families of different compositions are given by equations (42), (43) and (45) in section 4.1. 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 has 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

$$u_{GB} - u_{GG} - (1-r)[\rho_2 - \rho_1] = 2c. \tag{48}$$

$$u_{GB} - u_{BB} + r(1-r)[\rho_2 - \rho_1] + (1-r)^2\rho_1 = 2c. \tag{49}$$

Equation (48) is the indifference condition for a parent whose first child is a girl, i.e. the requirement that $V_{BG} - V_{GG} = 2c$; let r_G^* be the value of r that solves this equation. Equation (49) is the indifference condition for a parent whose first child is a boy, $V_{BG} - V_{BB} = 2c$; 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).[22] 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 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 for a boy and not doing so. By not selecting, such a parent improves the sex ratio, so that in the aggregate two individuals

[22] 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.

get partners, thereby raising social welfare. Similarly, if the sex ratio is r_B^*, a parent who has a boy is indifferent between selecting for 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. It will be satisfied, for example, if the parent does not wish to select if he knows that the selected boy will not find a partner (but is weaker than this condition). In this case, the global optimum corresponds to the 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. Alternatively, 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 family exercising choice.*

5 Conclusions

The main contribution of this paper is to set out a simple model of parental choice regarding the sex of their child. In gender biased societies, where boys may be valued more than girls, parental choice results in too many boys, and reduces welfare. Although bride prices can improve efficiency, they will not result in an efficient outcome since the marriage market is likely to be subject to frictions. We have extended the simple model in a number of directions. These include an analysis of class differences in sex selection and of the effects of exogenous changes in the sex ratio, e.g. due to hepatitis B. The model can also be used to analyze choice when family balancing considerations become important. This allows us to shed light on the effects of the one-child policy in China, and suggests that while the one-child may be illiberal, it is unlikely to have been responsible for the adverse movement in the sex ratio in China.

We have also used this model to examine the possible effects of parental sex selection in advanced economies, where widespread gender bias is absent. If preferences (or the technology of selection) are not completely symmetric between the sexes, our model suggests that there may be concern regarding the aggregate sex ratio consequences of individual choice. The exact nature of gender preferences in developed societies remains an open question.

Our model throws up more questions than we have tried to answer. One important omission is the effect of sex selection upon fertility decisions – we have assumed family size to be exogenous throughout the paper. This is important in developed societies, where the link between family gender composition and fertility is well established. It is no less important in the two most populous countries in the world, China and India, where sex selection will no doubt continue in the years to come.

6 Appendix

We first show that the welfare results in proposition 1 continue to apply when we have ex post heterogeneity in quality, i.e. welfare is maximized at $r = 1$. For $r \leq 1$, welfare is given by

$$W(r) = \frac{1}{1+r}\left[u_B + r(\rho + \mathbf{E}(\varepsilon))\right](r) + \frac{r}{1+r}\left[u_G + \rho + \mathbf{E}(\varepsilon|\varepsilon \geq F^{-1}(1-r))\right] - c\frac{1-r}{1+r}. \tag{50}$$

Writing out this expression for $r = 1$, and taking differences,

$$W(1) - W(r) = \frac{1-r}{2(1+r)}\left\{u_G + 2c - u_B + 2\rho + 2\mathbf{E}(\varepsilon) - 2r\mathbf{E}(\varepsilon|\varepsilon \geq F^{-1}(1-r))\right\}. \tag{51}$$

Since

$$\mathbf{E}(\varepsilon) - r\mathbf{E}(\varepsilon|\varepsilon \geq F^{-1}(1-r)) = \int_0^e \varepsilon dF - \int_{F^{-1}(1-r)}^e \varepsilon dF \geq 0, \tag{52}$$

$W(1) - W(r) > 0$ as long as $u_G + 2c - u_B + 2\rho > 0$ and $r < 1$. Similarly, it is easy to verify that $W(1) - W(r) > 0$ for $r > 1$.

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 $r = \frac{4-\lambda}{4+\lambda}$. The expression for welfare is given by

$$W(\lambda, \lambda_B) = \frac{1-\lambda-\lambda_B}{4} V_{GG} + \frac{1-\lambda_B}{4} V_{BB}(r(\lambda)) + \frac{2+\lambda+2\lambda(B)}{4} V_{BG}(r(\lambda)) - \frac{2\lambda(B)+\lambda}{2} c. \tag{53}$$

We first show that the equilibrium outcome is inefficient as long as λ differs from zero.

$$\frac{\partial W}{\partial \lambda} = \frac{1}{4}[V_{BG} - V_{GG} - 2c] + \frac{1-\lambda_B}{4} \frac{\partial V_{BB}}{\partial \lambda} + \frac{2+\lambda+2\lambda_B}{4} \frac{\partial V_{BG}}{\partial \lambda}. \tag{54}$$

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

$$\frac{\partial \hat{W}}{\partial \lambda} = \frac{1}{4}[V_{BG} - V_{GG} - 2c] + \frac{1 - \lambda_G + \lambda}{4}\frac{\partial V_{BB}}{\partial \lambda} + \frac{2 - \lambda + 2\lambda_G}{4}\frac{\partial V_{BG}}{\partial \lambda}. \quad (55)$$

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 for 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 $\lambda = 0$. [23]

Given that $\lambda = 0$ is welfare optimal, $\lambda_G = \lambda_B$. It is routine to verify that if $(u_{BB} - u_{BG} - 2c) + (u_{GG} - u_{BG} - 2c) > 0$, then optimality requires everyone exercising choice, while no one must exercise choice if the inequality is reversed.

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[23] 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 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.

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