Population Dynamics and Marriage Payments: An Analysis of the Long Run Equilibrium in India

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Abstract

Why do scarce Indian women pay dowry to secure grooms even as the sex-ratio of offspring is manipulated by parents? We develop a dynamic general equilibrium model of demographic and marriage market outcomes with endogenous gender preference. We find, that under a calibration of parameters suggested by Indian marriage market indicators, any long run steady state equilibrium must have both dowry and a masculine sex ratio. The key assumption that generates this result is the asymmetric marital preferences of men and women regarding own and spouse's ideal age at marriage.

Keywords: dowry, marriage squeeze, dynamic general equilibrium model, steady state

1. Introduction

Why do dowries exist? Several theories have been propounded by social scientists, invoking the role of inheritance laws, kinship and class structure and the economic contribution of women (Goody and Tambiah (1973); Boserup (1970); Epstein (1973); Dalmia and Lawrence (2005); Billig (1991)). One prominent economic theory, advanced by Botticini and Siow (2003), argues that dowries serve as an early inheritance to solve a free-riding problem. Another set of economic theories emphasizes the price motive, whereby dowries are payments that clear the marriage market (Becker (1981); Rao (1993a, 1993b); Tertilt (2005)). Other applications of the price motive invoke practices like caste hypergamy to explain the persistence of dowries in India (Anderson (2003)).

If marriage payments do have a 'price' component (as suggested by Arunachalam and Logan (2006); Anderson (2004); Dalmia (2004)), then India presents a puzzle.

India has experienced a persistent 'dowry problem' in the last century, despite numerous attempts to curb the custom: grooms' families demand and receive exorbitant dowry payments from brides' families, a practice that is linked increasingly with incidents of domestic violence and even bride-murder (Rao (1993a, 1993b); Bloch and Rao (2002)). At the same time, India is notorious for its 'missing women' (Sen (1992); Hutter et al (1996); Sudha and Rajan (1999); Arnold et al (2002)). If dowries are prices that clear the marriage market, then the scarce party (here women) would be expected to receive a bride price rather than disburse a payment in order to find a match in a monogamous setup; yet this does not seem to be happening. Meanwhile, high dowries are seen as an important reason for son preference and persistently skewed sex ratios (Sudha and Rajan (1999)).

In this paper, we construct a dynamic general equilibrium model connecting the (monogamous) marriage market (where marriage payments are determined) and population evolution (i.e. sex ratio and fertility). We adopt an overlapping generations framework where agents are identified by their gender ('man' or 'woman') and age ('young' or 'old'). Men and women are identical in every respect except for their preferences regarding age of marriage

– thus women prefer to marry young and prefer to marry older grooms; men prefer to marry when older and prefer younger brides. All agents face a (same) high social cost of being unable to find a partner in their lifetime.

In any period, parents choose the ideal sex ratio of their offspring based on expectations of marriage payments to be paid/received in future. This sex ratio (and exogenous fertility levels) determine how many men and women are born in the next generation. This in turn generates the relative numbers of potential brides and grooms in the future, and hence determines whether marriage payments will be dowry or bride price. We examine the properties of steady state general equilibria, defined as a state in which marriage payments, the (endogenous) sex ratio and the population growth rate are the same over time.

With a few exceptions (such as Edlund (1999); Bhaskar (2008)), most of the previous literature does not ask what will happen if parents can choose the sex of their child. This is an especially relevant question today, since the increasing availability of early-sex-detection technology and cheap abortions has made it easier to select the sex composition of offspring. Furthermore, the model presented here differs from this previous research (Edlund (1999); Bhaskar (2008)) in that son preference is not exogenously assumed. Instead, gender preference is endogenously generated through expectations of the relative marriage market returns of boys versus girls – a feature made possible by a dynamic general equilibrium approach to demographics and marriage markets.

We show, under calibrations of parameters consistent with Indian marriage market indicators, that *any* steady state equilibrium must be characterized by dowry payments and a sex ratio skewed in favor of men. In addition, we show that a *low* cost of sex ratio choice (for instance, low moral costs of infanticide or the ease of accessing modern sex selection techniques) is a sufficient condition for this result to hold. The result thus provides a remarkably accurate description of marriage market conditions in India in the last century.

The intuition of the finding follows from men's and women's asymmetric preferences regarding age of marriage. Recall that we assume that women prefer to marry when young and prefer to marry older grooms, while men prefer to marry when old, and prefer to marry younger brides (assume 'young' refers to ages 10-25 years and 'old' refers to ages 25-40 years). The motivation for this assumption is that women suffer declining fertility as they age while men do not; hence, to the extent that child-bearing is desirable to both genders, women prefer to marry when young and men prefer young brides. On the other side, men become more desirable as they grow older, potentially due to having acquired greater education, wealth and status than their younger counterparts; hence women prefer older grooms and men themselves prefer to marry when old. But the nature of this asymmetry in marital preferences ensures that men can out-wait women in the search for a partner, even when they face a high cost of being single for life (which is the same as that faced by women). Thus, for men, waiting for a partner generates unambiguously higher returns from marriage because (a) their ideal own age of marriage is late and (b) they become more desirable to their preferred partners, i.e. young women, if they wait. But for women, waiting is costly because (a) their ideal own age of marriage is young and (b) they become less desirable to their partners as they age; hence the possibility of never finding a partner becomes very likely.

Thus dowries – payments from brides to grooms – are generated by the fact that women enter the marriage market early and then need to find a partner as soon as they can. If they wait, women reduce their desirability to men and also find themselves facing a high social cost due to single status if they fail to match. Men can and do choose to wait and in doing so are assured of good returns from marriage. Thus there is essentially an excess supply of young women who are keen to match immediately, resulting in a loss of their bargaining power in the marriage market. This manifests itself in dowry payments.

If dowry is expected to persist, why don't parents choose more sons than daughters, generating an excess supply of men paying bride price? Indeed, this is the central question of the paper motivated by the coexistence of dowry payments and masculine sex ratios in India over the last century.

In the model we construct, expected dowry payments lead to (endogenous) son preference, so parents do indeed choose more sons than daughters. However, the sex ratio is not skewed enough to generate bride price in future periods. This occurs because the excess of young boys (relative to young girls) that are produced in every period do not enter the marriage market immediately. By the time these boys do enter the market, there is a fresh generation of young girls that appear in the marriage market in addition to the unmatched women from the previous generation. Therefore, in every period, there is an excess supply of girls (eager to marry as soon as possible), despite the masculine sex ratio at birth. Hence, dowry payments can and do persist despite a skewed sex ratio favoring boys.

Bride price cannot be sustained in a steady state equilibrium because it leads to parents skewing the sex ratio in favor of women. This exacerbates the excess supply of women who are keen to match immediately (as described above) leading to a switch in payments to dowry.

It is important to understand the context in which our model is to be interpreted. First, the model has been set up to describe marriage markets in a developing country where life expectancy is low, child marriage (especially for women) is accepted if not prevalent and fertility treatments that allow older women to bear children are prohibitively expensive or unavailable. These factors indicate that 'young' agents in the model are fairly young, say between 10-25 years of age. Similarly, 'old' agents refer to individuals between, say, 25-40 years of age. Hence, when we speak of 'old' men being more desirable to women, we are talking of men aged 25-40 years as compared with men of 10-25 years of age.

Second, the developing country scenario is captured also in the assumption that 'old' women are able to bear some children, albeit fewer than born to young women. In other words, agents do not live beyond their fertile years due to low life expectancy[1]. Within the fertile period of women, young women are able to have more children because they conceive

[1] This marks our departure from other papers that incorporate the limited fertility of women, viz. Siow (1998) where women in the old generation are assumed to be infertile, thereby generating an excess supply of men (who are fertile when young as well as when old). In that scenario, women are assumed to live beyond their fertile life cycle (i.e. life expectancy is sufficiently high).

with a higher probability and also have more time to produce additional children if infant deaths occur.

The results of this paper have some interesting implications for the effect of progress in medical technology on the bargaining power of women. First among these is the finding that easy access to modern sex-selective abortion technology (implying lower costs of sex ratio choice than, say, infanticide) is sufficient to guarantee dowry payments and a masculine sex ratio (viz. a compromise in women's bargaining power).

To understand a second implication of the main result, consider, for instance, a primitive world with a very low life expectancy. In such an economy, both men and women live for one period during which their top priority is to match and produce children. It is easy to show that in such a (single period) scenario there would be multiple equilibria in payments, with some (communities) paying dowry and others paying bride price such that the expected payment is zero. Suppose now that life expectancy increases – to two periods – and there is a possibility of agents spending the first period of their life acquiring human and physical capital. Given declining fertility, women face a trade-off between marrying and investing in human capital – if they marry young (when they are desirable) they give up the possibility of investment in their own human capital, or if they choose to invest in human capital, they postpone marriage forgoing marriage market returns due to diminished desirability among men. For men, there is no such tradeoff – it makes sense to delay marriage and invest in their own human capital since their returns from marriage are unambiguously better if they wait. Thus an increase in life expectancy – due to progress in medical technology – could lead to asymmetric preferences regarding age of marriage in men and women, and hence a loss in bargaining power for women (as demonstrated by the result of this paper)[2]. Further progress in medical technology (such as procedures to extend the fertile life of women) could again change marital age preferences allowing women to marry later. If preferences changed so that both men and women preferred to marry late and marry older partners, the situation of long

[2]This implication is consistent with Anderson and Ray's (2010) finding that developed countries like the USA have had historically skewed sex ratios in favor of men, which eased later in the demographic transition.

run dowry could disappear and men and women would have the same bargaining power in the long run. In this case, there would, yet again be mutiple equilibria in marriage payments with expected payments equal to zero. Symmetric preferences regarding the age of marriage are therefore, key to gender equality in terms of long run marriage-market bargaining power.

The formal model is presented in Section 2. Results are discussed in Sections 3-4.

2. The Model

Consider a dynamic general equilibrium model in an overlapping generations framework. The model has three components – a model of matching and price determination in the marriage market, a model of population evolution, and a model of sex-ratio choice. An assignment game (Shapley and Shubik (1972); Roth and Sotomayor (1990)) is used to model matching and the determination of marriage payments. The model of population evolution is derived with some modifications from Pollak (1987). The model of sex ratio choice draws from the literature on differential investment in children's health (Siow and Zhu (2002)), and allows parents to choose the gender composition of their offspring but subject to a cost of attempting to do so. The overall assumptions of the composite model are stated below and the individual components are presented in Sections 2.1-2.3.

General Assumptions There are two groups of monogamous agents in the economy, males and females. Each agent lives (in the marriage market) for two periods. The age of 'young' agents is '0' and that of 'old' agents is '1'. Agents of the same age and sex are identical. All agents earn the same income w in every period. w is perishable and high.

Marriage Market Assumptions In every period, the marriage market consists of a continuum of eligible men and a continuum of eligible women, who can be 'young' or 'old'. All single, never-married agents are eligible for marriage in each period. Remarriage is not permitted. Parents are responsible for arranging their offsprings' marriage and receive a (social) utility from securing the ideal match for their offspring. Parental preferences are common knowledge and the notion of the ideal match is based on the ages of the bride and groom to be paired. The marriage payment associated with a match is a transfer from the parents of one partner to the parents of the other in the period of marriage. Let D_i^j denote the marriage payment made when the age of the bride is i and the age of the groom is j. By convention, $D_i^j > 0$ represents dowry and $D_i^j < 0$ represents bride price.

Matching Assumptions Parents of eligible agents are price-takers in the marriage market. Given a price for a groom (or bride) of a certain type, parents decide whether or not to offer their daughter (or son) for marriage at that payment. The (competitive) equilibrium occurs at the market-clearing price.

Fertility Assumptions After marriage, couples choose the ratio of male and female offspring based on their total fertility level (or maximum possible children) and the value they place on girls versus boys. The total fertility of a couple is exogenously given and depends only on the age of the woman. Young women are more fecund and have a higher total fertility level (ρ_0) than old women (ρ_1). Parents care about the marriage market success of their offspring; hence, the value placed on a child of a particular gender depends on parental expectation of the marriage market surplus generated by an agent of that gender. The value of offspring accrues to both parents, i.e. children are public goods in the household. Rearing children is costless but there is a cost of trying to skew the sex ratio in favor of any gender. All children are born in the first period of marriage of the couple.

2.1 The Marriage Market

2.1.1 Preferences

Parents are socially responsible for arranging appropriate matches for their offspring[3]. They do so based on the following preferences. Let U^s denote the period utility to parents of a single agent and h denote the agent's age, $h = 0$ (young), 1 (old). Then,

$$U^s(c,h) = \begin{Bmatrix} c, if\ h = 0 \\ c - s,\ if\ h = 1 \end{Bmatrix} \tag{1}$$

where c is the offspring's consumption in the current period and s (> 0) is the cost (to the parent) of the offspring's being single in old age[4]. (1) indicates that parents of old, but not young, agents suffer this cost from social pressure and anticipated loneliness, if unable to find a match for their offspring in the current period. Let U^p denote the period utility accruing to parents of agents if married. The specific form of the period marital utility function is:

$$U^p(c,i,j) = c + K - (i-0)^2 - (j-1)^2 \tag{2}$$

where i denotes the bride's age at the time of marriage, j denotes the groom's age at the time of marriage, c denotes the married offspring's consumption in the current period and K (> 0) denotes the social utility parents receive for arranging their offspring's marriage[5].

The marital utility functions U^p in equation (2) indicate that in every period of marriage, parents receive social utility from marrying off the offspring $(K > 0)$ and from her (his) consumption (c) in that period. However, parents of female agents receive a higher period utility if their daughters marry young (at the age of $i = 0$) and marry an older man (of age $j = 1$) whereas parents of male agents receive a higher marital period utility if their sons

[3]See Dasgupta and Mukherjee (2003), Raman (1981).

[4]s can be attributed to the social pressure that parents face to find a partner for their offspring by a certain age and apprehension that their children may be lonely in old age if unmarried.

[5]K could represent the parental belief that a married child will be happy but stems also from the social network effects of an extended family by marriage.

marry late (at age $j = 1$) and marry a young woman (of age $i = 0$)[6].

Future outcomes are discounted by β; $0 < \beta < 1$. If agents are married young, their parents receive a lifetime (social) utility of $[U^p(c_0, i, j) + \beta U^p(c_1, i, j)]$, regardless of whether the spouse of the agent is living or dead in the second period of marriage. In other words, there are no costs associated with offspring being widowed, as having married off their children entitles parents to the social network effects of an extended family even when the daughter-in-law (or son-in-law) is not living[7] [8].

2.1.2 Budget constraint

The marriage payment associated with a match is a transfer from the parents of one partner to the parents of the other in the period of marriage. Let D_i^j denote the marriage payment made when the age of the bride is i and the age of the groom is j. By convention, $D_i^j > 0$ represents dowry and $D_i^j < 0$ represents bride price. The parental budget constraints in the period of marriage are then given by:

$$c = \begin{Bmatrix} w - D_i^j, \ for\ bride\ i\ marrying\ groom\ j \\ w + D_i^j, \ for\ groom\ j\ marrying\ bride\ i \end{Bmatrix} \tag{3}$$

where w is the income earned by all agents in each period[9]. By assumption, w is perishable and high so constraints (3) are satisfied in every period (see General Assumptions). In all other periods, the budget constraints are

[6] Similar marital utility functions are used in Anderson (2007) and Bergstrom and Lam (1991).

[7] There are several reasons why (2) may be considered to be an appropriate description of marital preferences, especially in a largely patrilocal society such as India. The preference for young brides could follow from their greater potential to adapt to the ways of the groom's family (Epstein (1973)). Similarly, preference for older grooms could result from seeking to maintain a desired age difference between spouses as this helps to maintain a favorable balance of power in the relationship (Jensen and Thornton (2003)). Older men could also be preferred because of their higher social and economic standing (also a possible reason why men themselves may prefer to postpone marriage in a social setting where they are the primary wage earners).

[8] Qualitative results are the same if marital returns last only one period for all agents.

[9] Think of offspring as being the property of parents as long as they are single. Thus the incomes w that children earn are also the property of parents as long as the former are unmarried. When arranging a marriage, parents commit to transfer (or receive) a part of the incomes (w) earned by children as marriage payment on their behalf.

$$c = w, \; for \;\; all \;\; agents \tag{4}$$

2.1.3 Marriage surplus

Let (i, j) refer to a match in which the woman is of age i and the man is of age j. Let $v_i^{j,t}$ denote the marriage surplus in period t to the parents of the bride in match (i, j). Let $V_i^{j,t}$ denote the marriage surplus in period t to the parents of the groom in match (i, j)[10]. The surplus is computed before marriage payments are transferred from one set of parents to the other.

For parents of old agents, the marriage surplus can be derived as follows using (1) and (2), :

$$v_1^{j,t} = U^p(w, 1, j) - U^s(w, 1) = K + s - 1 - (j - 1)^2 \tag{5}$$

$$V_i^{1,t} = U^p(w, i, 1) - U^s(w, 1) = K + s - (i - 0)^2 \tag{6}$$

For parents of young agents, the marriage surplus can be derived as:

$$v_0^{j,t} = U^p(w, 0, j)(1 + \beta) - [U^s(w, 0) + \beta X^{f,t+1}] = (w + K - (j - 1)^2)(1 + \beta) - [w + \beta X^{f,t+1}] \tag{7}$$

$$V_i^{0,t} = U^p(w, i, 0)(1 + \beta) - [U^s(w, 0) + \beta X^{m,t+1}] = (w + K - 1 + (i - 0)^2)(1 + \beta) - [w + \beta X^{m,t+1}] \tag{8}$$

where $X^{g,t+1}$ denotes expectations of the future marriage returns of an agent of gender

[10] A mnemonic for remembering notation: bigger/higher ≡ older. Thus, 'big V' denotes the surplus of the (ideally) older spouse, viz. men. 'Small v' denotes the surplus of the (ideally) younger spouse, viz. women. Similarly, the superscript denotes the age of the older spouse (men), and the subscript denotes the age of the younger spouse (women).

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In general, $X^{g,t+1}$ can be written (using (1) – (4)) as

$$X^{f,t+1} = E_t[p_1^{1,t+1}(w + K - 1 - D_1^{1,t+1}) + p_1^{0,t+1}(w + K - 2 - D_1^{0,t+1}) + (1 - p_1^{1,t+1} - p_1^{0,t+1})(w - s)] \quad (9)$$

$$X^{m,t+1} = E_t[q_1^{1,t+1}(w + K - 1 + D_1^{1,t+1}) + q_0^{1,t+1}(w + K + D_0^{1,t+1}) + (1 - q_1^{1,t+1} - q_0^{1,t+1})(w - s)] \quad (10)$$

where $E_t[.]$ denotes the expectation function based on information in period t, $p_1^{j,t+1}$ ($q_i^{1,t+1}$) denotes the probability of an old woman (old man) being matched with a man of age j (woman of age i) in the next period $(t+1)$ and $D_i^{j,t+1}$ denotes the payment in period $(t+1)$ for marriage (i,j). Note that the matching probabilities – which are proportions of brides and grooms available for marriage in period $(t+1)$ – are unknown in period t; hence they feature inside the expectations operator in (9) – (10)[11].

Definition 1. The value of a match, $\alpha_i^{j,t}$, between a woman of age i and a man of age j in period t is the sum of surpluses of the matched agents, i.e. $\alpha_i^{j,t} = v_i^{j,t} + V_i^{j,t}$.

2.1.4 Marriage payments

A marriage payment ($D_i^{j,t}$) associated with a match (i,j) is a transfer from the parents of one partner to the parents of the other in the period of marriage (t).

The following points summarize the relationship between marriage surplus (defined in Section 2.1.3) and marriage payments in any period t:

[11] Note, also, that for young agents, expected payments in $(t+1)$ are a part of the outside option of marriage in period t, since these payments must be made if they marry in period $(t+1)$. Hence, (expectations of) the $(t+1)-$payments feature in the definition of young agents' marriage surplus. Old agents do not live till $(t+1)$, hence there are no expected $(t+1)-$payments in old agents' surplus. There are no period-t payments in either young or old agents' surplus since the surplus is measured before any payments are made or received in period t.

1. In marriage (i,j), the (post-payment) marital return to the woman is given by $(v_i^{j,t} - D_i^{j,t})$ and the marital return to the man is given by $(V_i^{j,t} + D_i^{j,t})$. (Recall, $D_i^{j,t}$ denotes a dowry if positive and bride price if negative.)

2. Woman i (man j) will marry man j (woman i) if and only if $v_i^{j,t} - D_i^{j,t} \geqslant 0$ ($V_i^{j,t} + D_i^{j,t} \geqslant 0$). Failure of this condition to hold makes agents better off by choosing the outside option (viz. staying single in that period).

3. Woman i (man j) is *indifferent* between marrying man j (woman i) and her (his) outside option when $v_i^{j,t} - D_i^{j,t} = 0$ ($V_i^{j,t} + D_i^{j,t} = 0$). In other words, agents are indifferent between marrying and the outside option when the (post-payment) marital return is zero.

4. The *maximum* payment that woman i will make in marriage (i,j) is equal to her entire surplus $v_i^{j,t}$. Similarly, the maximum possible bride price in match (i,j) is man $j's$ entire surplus $(-V_i^{j,t})$. Paying the entire marriage surplus to the partner reduces one's marital return to zero, which is also the condition for indifference between marrying and the outside option.

5. Woman i is indifferent between marrying man j and j' if $v_i^{j,t} - D_i^{j,t} = v_i^{j',t} - D_i^{j',t}$. Similarly man j is indifferent between marrying woman i and i' if $V_i^{j,t} + D_i^{j,t} = V_{i'}^{j,t} + D_{i'}^{j,t}$. In other words, agents are indifferent to two potential partners if her/his (post-payment) marital return is the same for both.

6. It follows from the above that a necessary condition for a period$-t$ match (i,j) to occur is: $\alpha_i^{j,t} = v_i^{j,t} + V_i^{j,t} \geq 0$.

2.1.5 Matching

In every period, the marriage market consists of a continuum M of eligible men and a continuum F of eligible women, who can be 'young' (age 0) or 'old' (age 1). Let m_t (f_t)

denote the measure of eligible men (women) of age h ($h = 0, 1$) in period t.

Definition 2. A match is a function $\mu^* : M \times F \to M \times F$ such that (i) $x \in M \Rightarrow \mu^*(x) \in F \times \{x\}$; (ii) $x \in F \Rightarrow \mu^*(x) \in M \times \{x\}$ and (iii) $\mu^*(\mu^*(x)) = x$. A match is 'successful' if $x \in M \Leftrightarrow \mu^*(x) \in F$ or if $x \in F \Leftrightarrow \mu^*(x) \in M$. Let $\mu_i^{j,t}$ denote the measure of successful period$-t$ matches between women of age i and men of j.

Since unions are monogamous, the marriage market clears when successful matches satisfy the following conditions:

$$\mu_i^{0,t} + \mu_i^{1,t} = f_i^t \tag{11}$$

$$\mu_0^{j,t} + \mu_1^{j,t} = m_j^t \tag{12}$$

for all $i, j = 0, 1$.

Matching probabilities in any period t can be derived as follows:

$$p_i^{j,t} = \frac{\mu_i^{j,t}}{f_i^t};\ \overline{p}_i^t = p_i^{0,t} + p_i^{1,t} \tag{13}$$

$$q_i^{j,t} = \frac{\mu_i^{j,t}}{m_j^t};\ \overline{q}_j^t = q_0^{j,t} + q_1^{j,t} \tag{14}$$

where $p_i^{j,t}$ ($q_i^{j,t}$) denotes the probability that a woman of age i will marry a man of age j (man of age j will marry a woman of age i), for all $i, j = 0, 1$ and $\overline{p}_i^t$ $\left(\overline{q}_j^t\right)$ denotes the probability that a woman of age i (man of age j) will find a match in period t.

The next section presents the second component of the dynamic general equilibrium model, viz. the model of population evolution (Pollak (1987)).

2.2 Population Dynamics

Given a matrix of female births to couples of each type (i,j), a male-to-female sex ratio at birth σ, and a 'matching rule' that specifies the measure of matches μ_i^j of each type (i,j), it is possible to express the evolution of the population over time as a mapping ϕ (Pollack (1987)):

$$(F_0^t, F_1^t, M_0^t, M_1^t, u_{old}^t) = \phi(F_0^{t-1}, F_1^{t-1}, M_0^{t-1}, M_1^{t-1}, u_{old}^{t-1}) \tag{15}$$

where F_i^t (M_j^t) denotes the measure of females of age i (males of age j) in the total population in time t and u_{old}^t (the 'old unions' vector) denotes the vector of already-married agents in the population at the *beginning* of period t. Note that the successful matches or assignments $\{\mu_i^{j,t}; i,j = 0,1\}$ obtained from the marriage market (Section 2.1) performs the the role of the 'matching rule' since it specifies the measure of successful matches of each type (i,j) in each period t.

Let f_i^t (m_j^t) denote the measure of eligible (i.e. previously unmatched) women of age i (men of age j) in the marriage market in period t. All young members of the total population must also be eligible to marry; hence, $f_0^t = F_0^t$ and $m_0^t = M_0^t$. However, older members of the total population are eligible to marry only if they were unmatched in the previous period; hence, $f_1^t = (1-\overline{p}_0^{t-1})F_0^{t-1}$ and $m_1^t = (1-\overline{q}_o^{t-1})M_0^{t-1}$. Thus the set of marriage market participants can be expressed in terms of total population members who evolve as in (15). Specifically, the set of difference equations that govern the evolution of marriage market participants $(f_0^t, f_1^t, m_0^t, m_1^t)$ over time is given by:

$$f_0^{t+1} = b_{f1}^t(\mu_1^{1,t} + \mu_1^{0,t}) + b_{f0}^t(\mu_0^{1,t} + \mu_0^{0,t}) \tag{16}$$

$$m_0^{t+1} = b_{m1}^t(\mu_1^{1,t} + \mu_1^{0,t}) + b_{mo}^t(\mu_0^{1,t} + \mu_0^{0,t}) \tag{17}$$

$$f_1^{t+1} = Max[0, f_0^t - \mu_0^{1,t} - \mu_0^{0,t}] \tag{18}$$

$$m_1^{t+1} = Max[0, m_0^t - \mu_0^{0,t} - \mu_1^{0,t}] \tag{19}$$

where b_{fi}^t (b_{mi}^t) denotes the measure of female (male) children born to a woman of age i in period t and $\mu_i^{j,t}$ denotes the marriage market assignment (or matching rule) in period t $(i, j = 0, 1)$.

Equations $(16 - 19)$ simply state that the measure of young females (males) in any period is the sum of female (male) births to old and young women matched in the previous period. Similarly, the measure of old men (women) in the marriage market in any period is the measure of unmatched young men (women) in the market in the previous period.

So far the maternal age-specific birth rates (b_{fi}^t, b_{mi}^t) and hence the sex ratio $(\frac{b_{mi}^t}{b_{fi}^t})$have been assumed to be exogenously given $(i = 0, 1)$. In the next section, birth rates and the sex ratio are allowed to be determined endogenously by expected marriage market outcomes. This is the third component of the dynamic general equilibrium model.

2.3 Choice of Sex Ratio

The assumptions relevant for this section are summarized under Fertility Assumptions (see Section 2). The utility function of a just-married agent in period t is given by:

$$U^{marr,t} = c^t + E_f^{t+1} b_f^t + E_m^{t+1} b_m^t - (b_f^t - b_m^t)^2 \tag{20}$$

where b_g^t is the measure of offspring of gender g born in period t, E_g^{t+1} denotes the expected marriage market surplus from an offspring of gender g born in period t when he or she attains marriageable age in period $(t+1)$ and c_t is consumption in period t[12].

Equation (20) asserts that married agents care about the gender composition of offspring because they care about the marriage market returns generated by the child when he or she reaches marriageable age. These returns could be very different for boys versus girls, generating incentives for gender-selection by parents[13]. (20) indicates that a married agent

[12] Siow and Zhu (2002) use a quadratic cost of parental investment in offsprings' health (which affects their survival probabilities). The idea here is similar except that parents can directly and instantaneously choose the sex ratio of offspring at the time of childbirth, viz. in the period of marriage.

[13] The following quote from Sudha and Rajan (1999) demonstrates the rationale behind the assumption:

receives utility from her own consumption as well as from the measure of boys (b_m^t) and girls $\left(b_f^t\right)$ born to the couple, where the benefit of having a child of gender g is the expected marriage market surplus $\left(E_g^{t+1}; g = f, m\right)$ expected from an agent of that gender when he or she attains marriageable age.

Notice that while couples may choose the measure of male and female offspring, there is a cost, $\left(b_f^t - b_m^t\right)^2$, of skewing the sex ratio of offspring to anything other than 1. This reflects the cost of accessing technology such as amniocentesis and sex-selective abortion, or the psychological cost of infanticide or neglect, or social stigma from being observed to skew the sex ratio. Parents will refrain from attempting to skew the sex ratio when the cost of doing so is infinitely high – this constitutes the (benchmark) case of exogenous sex ratios. Section 3.2 discusses the role of the cost of skewing the sex ratio in greater detail.

Notice also that agents do not have an exogenous sex preference for offspring in this model. The cost of sex-ratio choice is symmetric to gender – viz. the same cost applies whether a boy or a girl is actively selected – and the choice depends purely on the incentives generated in the marriage market as captured in the expected marriage market returns $E_g^{t+1}(g = f,\ m)$[14].

Finally note that the assumption of arranged marriage separates marriage decisions and sex ratio choice in any period, since these decisions are made by different sets of agents. Hence, c_t is not a decision variable for married agents but is determined by the perishable income w and the terms of marriage formalized by their parents $[(3) - (4)]$.

Formally, E_g^{t+1} is defined as the utility that a child of gender g is expected to generate for her parents over her lifetime by marrying (or not), less the amount parents expect to

"... the now infamous slogan: Better Rs. 500 today than Rs. 500,000 tomorrow... was widely used in the early 1980s to advertise sex determination clinics until protests from women's groups put a stop to it. The slogan may no longer be used, but the underlying logic that an expenditure now (on the test) will save many multiples of the sum later (on dowry, if the foetus is a girl) still holds".

[14]Two alternative forms of U^{marr} may be used in place of (20) : (1) $U^{marr} = c + E_f b_f + E_m b_m - 2(b_f - \theta_f)^2 - 2(b_m - \theta_m)^2$ where θ_g represents the number of children of gender g that are born to a couple naturally. Since $\theta_f = \theta_m$ in the aggregate, using this form of U^{marr} does not change the results of the paper; (2) $U^{marr} = c + \beta E_f b_f + \beta E_m b_m - 2(b_f - b_m)^2$ where E_g indicates that offsprings' marital returns E_g are realized one period after their conception and birth. Using this form of U^{marr} does not change the qualitative results of the paper either.

earn if he or she is unable to find a partner in her lifetime. Hence, E_g^{t+1} will depend on the parameters which determine marital utility (K, s, β), expected marriage payments and probabilities of finding a match in each period of the offspring's life[15].

In particular, we can show that

$$E_f^{t+1} = E_t[\overline{p}_0^{t+1}\{K(1+\beta) + \beta s - D_0^{1,t+1}\} + \beta(1-\overline{p}_0^{t+1})\overline{p}_1^{t+2}\{K + s - 1 - D_1^{1,t+2}\}] \tag{21}$$

$$E_m^{t+1} = E_t[\overline{q}_0^{t+1}\{(K-2)(1+\beta) + \beta s - D_1^{0,t+1}\} + \beta(1-\overline{q}_0^{t+1})\overline{q}_1^{t+2}\{K + s - 1 + D_1^{1,t+2}\}] \tag{22}$$

where $E_t[.]$ denotes the expectation function based on information in period t, $\overline{p}_i^{t+k}$ $\left(\overline{q}_j^{t+k}\right)$ represents the probability that a woman of age i (man of age j) will find a match in period $(t+k)$ and $D_i^{j,t+k}$ denotes the payment in a period$-(t+k)$ marriage (i, j).

Note that since parents' choice of sex ratio depends on the expected marriage market *surplus* of offspring $\left(E_g^{t+1}; g = f, m\right)$, the optimization behavior of agents will ensure that $E_f^{t+1} \geq 0,\ E_m^{t+1} \geq 0$[16].

The assumption that couples have all their children in the first period of marriage reduces sex-ratio choice to a static problem. For a period$-t$ couple with a woman of age i, the optimal sex ratio is determined as follows:

$$\underset{b_f^t, b_m^t}{Max}\ [c^t + E_f^{t+1}b_f^t + E_m^{t+1}b_m^t - (b_f^t - b_m^t)^2] \tag{23}$$

subject to the constraints,

[15] Edlund (1999) exploits a similar idea, albeit in a different setup – assuming that parents care about whether their offspring can find a partner. The difference lies in Edlund's assumption that parents prefer sons over daughters. Here parents do not have an exogenous sex preference; instead, gender preference and (hence) the optimal sex ratio depends entirely on marriage market incentives.

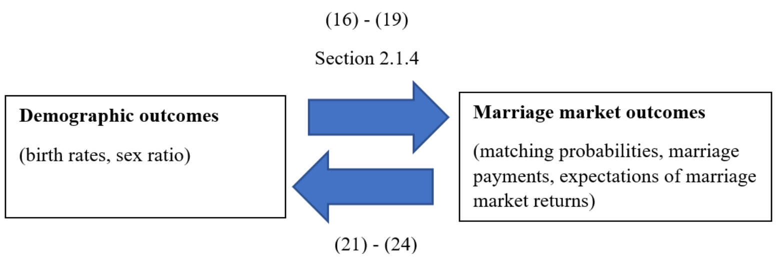
[16] Recall that, if unmarried, sons and daughters yield the same return $[w + \beta(w - s)]$. E_g^{t+1} indicates the additional return (or 'surplus') that an offspring of gender g is expected to earn in the marriage market. Assuming that parents' sex ratio choice depends on expected *total* utility from sons versus daughters (instead of surpluses) does not change results.

$$b_f^t + b_m^t \leq \rho_i;\ b_f^t \geq 0;\ b_m^t \geq 0 \tag{24}$$

2.4 Equilibrium

The composite model presented in Sections 2.1-2.3 establishes a two-way link between demographic and marriage market outcomes – this is summarized in Figure 1 below.

Figure 1: The dynamic general equilibrium model (Sections 2.1-2.3)



Demographic outcomes $\{b_m^t, b_f^t\}$ affect marriage market outcomes by governing the evolution of the population and eligible marriage market participants $[(16)-(19)]$. This feeds marriage market outcomes by determining matching probabilities and marriage payments (Section 2.1.4), which in turn, determine the expected marriage market returns of women and men in future E_g^{t+1} $(g = f, m)$. But the optimal birth rates in period t are themselves derived $[(23)-(24)]$ as functions of the expected marriage market returns, E_f^{t+1} and $E_m^{t+1}[(21)-(22)]$. Hence, endogenizing the sex ratio allows a feedback mechanism from marriage market outcomes to demographic outcomes.

Definition 3. A steady state general equilibrium in the composite model is obtained when the following conditions are true:

1. the total population and the eligible marriage market population are in stable population equilibrium (see Definitions 4-5 below)

2. the marriage market is in a steady state equilibrium (see Definitions 6-7 below)

3. birth rates $\{b_{mi}, b_{fi};\ i = 0, 1\}$ and sex ratios $\{\sigma_i = \frac{b_{mi}}{b_{fi}};\ i = 0, 1\}$ are unchanging over time $[(23) - (24)]$.

   A steady state state general equilibrium is non-trivial when the size of the population is non-zero.

Items (1)-(3) in Definition 3 are further explained below. First, following Pollak (1987), we define stable population equilibria as follows.

Definition 4. A stable population equilibrium is a vector $(\widehat{F_0}, \widehat{F_1}, \widehat{M_0}, \widehat{M_1}, \widehat{u_{old}})$ and a scalar $\widehat{r}$ such that $[(1+\widehat{r})\widehat{F_0}, (1+\widehat{r})\widehat{F_1}, (1+\widehat{r})\widehat{M_0}, (1+\widehat{r})\widehat{M_1}, (1+r)\widehat{u}_{old}] = \phi(\widehat{F_0}, \widehat{F_1}, \widehat{M_0}, \widehat{M_1}, \widehat{u_{old}})$. In keeping with standard demographic nomenclature, the population is stable since its age-sex structure is unchanging. A stable population equilibrium is non-trivial when its size is not zero.

Definition 5. A stable population equilibrium of eligible marriage market participants $(f_0^t, f_1^t, m_0^t, m_1^t)$ occurs when in each period, this vector replicates itself by a common factor.

Pollak (1987) shows that stable population equilibria exist if the matching rule used to generate the mapping ϕ in (15) satisfies certain properties[17]. It is easy to show that the marriage market assignment $\{\mu_i^{j,t}; i, j = 0, 1\}$ does indeed satisfy these properties. In addition, it is straightforward to show that when the total population $(F_0^t, F_1^t, M_0^t, M_1^t)$ is in a stable population equilibrium growing at the rate $(1 + \widehat{r})$, the eligible population in the marriage market $(f_0^t, f_1^t, m_0^t, m_1^t)$ must also be in a stable (population) equilibrium growing at the same rate[18]. In other words, in a stable total population equilibrium, $(\widehat{F_0}, \widehat{F_1}, \widehat{M_0}, \widehat{M_1})$, the age-sex composition of eligible marriage market participants $(f_0^t, f_1^t, m_0^t, m_1^t)$ is constant over time. It follows then that matching probabilities – which are simply ratios of eligible

[17]The required properties for the matching rule are: (1) Non-Negativity (the measure of matches is non-negative); (2) Adding-Up (the measure of agents in any age-sex category is greater than or equal to the measure of matched agents in that demographic category, in each period); (3) Universal Scope (the matching rule is defined for all non-zero populations); (4) Continuity; and (5) Homogeneity of degree one.

[18]Follows from: $f_0^t = F_0^t,\ m_0^t = M_0^t,\ f_1^t = (1 - \overline{p}_0^{t-1})F_0^{t-1},\ m_1^t = (1 - \overline{q}_0^{t-1})M_0^{t-1}$.

men and women in different age groups – are also constant over time in a stable population equilibrium.

Second, we define steady state equilibrium in the marriage market (item (2) of Definition 3).

Definition 6. In any period t, a competitive equilibrium in the marriage market is a set of successful matches of measure $\mu_i^{j,t}$ $(i, j = 0, 1)$ and corresponding marriage payments $D_i^{j,t}$ such that all price-taking agents (choose a match and payment-offer in order to) maximize their post-payment marriage surplus, and the market for all types of agents clears. An equilibrium assignment $\{\mu_i^{j,t}; i, j = 0, 1\}$ can involve random matches among identical agents.

Definition 7. The marriage market is in a steady state equilibrium when marriage payments D_i^j and matching probabilities p_i^j and q_i^j are constant over time $(i, j = 0, 1)$. When there are multiple possible equilibria in marriage payments, the marriage market is in a steady state equilibrium when the expected values of payments ED_i^j are constant over time. A steady state equilibrium assignment $\{\mu_i^{j,t}; i, j = 0, 1\}$ replicates by a constant factor every period and may involve random matches among identical agents.

Finally, Lemma 8 outlines the relationship between the equilibrium sex ratio and expected marriage market outcomes in a steady state general equilibrium[19].

Lemma 8. A non-trivial steady state general equilibrium (or equilibria) may exist only when $|E_f - E_m| < 4\rho_0$ and has the following properties:

1. Mothers choose to have as many offspring as their total fertility (ρ_i) allows, viz. $b_{fi} + b_{mi} = \rho_i$ $(i = 0, 1)$

2. Maternal-age (i) −specific sex ratios $\sigma_i (= \frac{b_{mi}}{b_{fi}})$ are determined as follows:

[19]Time subscripts are dropped in the statement of Lemma 8 to denote steady state values, i.e. $b_{gi}^{t+1} = b_{gi}^t = b_{gi}$; $E_g^{t+1} = E_g^t = E_g$ $(g = f, m;\ i = 0, 1)$.

$$\sigma_0 = \frac{4\rho_0 - (E_f - E_m)}{4\rho_0 + (E_f - E_m)} \in (0, \infty) \tag{25}$$

$$\sigma_1 = \left\{ \begin{array}{c} \frac{4\rho_0 - (E_f - E_m)}{4\rho_0 + (E_f - E_m)} \; if \; |E_f - E_m| < 4\rho_1 < 4\rho_0 \\ 0 \; if \; 4\rho_1 < |E_f - E_m| < 4\rho_0 \; and \; E_m < E_f \\ \infty \; if \; 4\rho_1 < |E_f - E_m| < 4\rho_0 \; and \; E_m > E_f \end{array} \right\} \tag{26}$$

The proof of Lemma 8 is provided in Appendix A[20].

2.5 Calibration of marriage market parameters

We calibrate the marriage market parameters (K, s, β) based on two observations about the Indian marriage market. The first is the observation that parental search for offsprings' partners begins earlier for women than for men. This is true even to the extent that sons are expected to postpone marriage till their younger sisters have been matched (Jensen and Thornton (2003); Caldwell et al (1983); Epstein (1973)). This suggests that (a) men enter the marriage market later than women, and, hence, (b) the cost of marrying at a non-ideal age (e.g. age 'young' for men) exceeds the benefits from doing so.

The second observation about the Indian marriage market is the universality of marriage throughout the last century (Goyal (1988)), viz. that all agents have been able to find a partner in their lifetime (or, the proportion of never-married agents is close to 0). For this to be true, older agents must be matched before their younger counterparts (or else they would be left single for life). An efficient matching mechanism would pair agents with the highest value of marriage $\left(\alpha_i^j\right)$ first. Hence, we calibrate parameters to ensure that the older agents are the high-surplus agents, viz. that matches with older agents have higher value. It is easy

[20]Notice, at the interior solutions in (25) – (26) above, that σ_i increases (decreases) with declines in total fertility ρ_i if $(E_f - E_m) < 0$ $(E_f - E_m > 0)$. In other words, a reduction in fertility skews the sex ratio in favor of offspring with higher expected marriage market returns. This relationship between fertility and the sex ratio is consistent with empirical observations from India (Das Gupta and Bhat (1997)) and has been cited as evidence of 'son preference' therein.

to show that this calibration reduces to assuming a sufficiently high cost (s) of being unable to marry off one's offspring during their lifetime – also identified frequently as a well-known feature of the Indian marriage market (Rao (1993b))[21].

The specific calibrations imposed on the parameters are stated below.

Condition 9. The following restrictions are placed on marriage market parameters (K, s, β).

1. $K < 1$

2. $\frac{\beta+2}{1-\beta} < s < \frac{\beta+2}{1-\beta} + \frac{2(1-K)(1-\beta)}{1-\beta}$

Restriction (1) states that the benefit parents receive from marrying off their children (K) is less than the cost of doing so at a non-ideal age. Restriction (2) states that parents receive a sufficiently high cost s (defined by the lower bound) of failing to marry off their offspring in their lifetime. Note that removing the upper bound on s in restriction (2) does not change the qualitative results of the paper; its imposition, however, allows us to focus on the key mechanisms that drive the result.

2.5.1 Marriage values/matching under the calibration

Lemma 10 shows the relationship between values of matches when Condition 9 above is imposed[22].

Lemma 10. Suppose Condition 9 is true. Then the following must be true in any period t:

$$\alpha_0^{0,t} < 0 \tag{27}$$

$$\alpha_1^{1,t} > \alpha_0^{1,t} > 0 \tag{28}$$

$$\alpha_1^{1,t} > \alpha_1^{0,t} \tag{29}$$

[21]High s is the reason that older women – who have passed their ideal age of marriage – are still in the marriage market searching for a partner. If s were not high, older women would choose to remain single for life, violating universality of female marriage.

[22]Proof in Appendix B.

where $\alpha_i^{j,t}$ is the value of the marriage between a woman of age i and a man of age j in period t.

In addition, if in the next period $(t+1)$, the marriage market structure is expected to satisfy $f_1^{t+1} > m_1^{t+1}$, then the following must be true in period t:

$$\alpha_1^{0,t} < 0 \tag{30}$$

Lemma 10 states, in essence, that when the calibration in Condition 9 is imposed, young men postpone marriage and older agents are the high surplus agents (hence matched first by an efficient matching mechanism)[23]. In the remainder of the paper we will assume Condition 9 and Lemma 10 are true.

Using Lemma 10, we can derive the equilibrium assignment $\{\mu_i^{j,t}; i,j = 0,1\}$ in any period t as follows, given a marriage market structure $(f_0^t, f_1^t, m_0^t, m_1^t)$:

$$\mu_1^{1,t} = Min(f_1^t, m_1^t) \tag{31}$$

$$\mu_0^{1,t} = Min[f_0^t,\ \{m_1^t - Min(f_1^t, m_1^t)\}] \tag{32}$$

$$\mu_1^{0,t} = \begin{Bmatrix} Min[m_0^t,\ \{f_1^t - Min(f_1^t, m_1^t)\}]\ if\ \alpha_1^{0,t} > 0 \\ 0,\ otherwise \end{Bmatrix} \tag{33}$$

$$\mu_0^{0,t} = 0 \tag{34}$$

where $\mu_i^{j,t}$ (the equilibrium assignment) represents the measure of successful matches (i,j) in period t. Equilibrium matching probabilities in period t are easily computed using $(31)-(34)$ and $(13)-(14)$.

[23] Recall that for a match (i,j) to occur, $\alpha_i^{j,t} \geq 0$ is necessary. Notice also, that young men refuse matches with young women whatever be the expected marriage market structure. They will refuse to marry older women if the expected marriage market structure in the next period $\left(f_1^{t+1} > m_1^{t+1}\right)$ ensures that they are guaranteed to find a match and receive a high payment (from older women who are in excess supply in the next period). But in steady state, – the focus of this paper – $(f_1^t > m_1^t)$ is the only configuration in the current period where young men may be called upon to match with older women. Hence, for the purpose of understanding steady state equilibria, is is sufficient to assume that young men choose to postpone marriage, regardless of the age of the partner available in the current period.

2.5.2 Marriage market structure under the calibration

It is straightforward to infer the exhaustive set of demographic configurations that may be sustained in steady state equilibrium when Condition 9 and Lemma 10 are true. These configurations are outlined in Conclusion 11 below.

Conclusion 11. Suppose Condition 9 is true. Then there are five possible demographic configurations consistent with a non-trivial steady state equilibrium. These are

$$f_1^t > m_1^t \tag{35}$$

$$f_1^t = m_1^t < f_1^t + f_0^t \tag{36}$$

$$f_1^t < f_1^t + f_0^t = m_1^t \tag{37}$$

$$f_1^t < f_1^t + f_0^t < m_1^t \tag{38}$$

$$f_1^t < m_1^t < f_1^t + f_0^t \tag{39}$$

In a steady state general equilibrium, the cohorts of eligible brides and grooms replicate by a constant factor every period; hence, p_i^j, q_i^j, D_i^j (for all $i, j = 0, 1$) – and therefore, E_m and E_f – are the same over time. This also ensures that the birth rates and sex ratios chosen by couples are the same over time[24].

The next section presents results.

[24] Recall, by definition, $E_t[D_i^{j,t+1}] = D_i^{j,t} = D_i^j$ in a steady state equilibrium when payments are unique $(i, j = 0, 1)$. If there are multiple equilibria in payments, $D_i^{j,t} \in [\underline{D}_i^{j,t}, \overline{D}_i^{j,t}]$, we assume that the distribution is uniform, $D_i^{j,t} \sim U[\underline{D}_i^{j,t}, \overline{D}_i^{j,t}]$; hence in steady state $E_t[D_i^{j,t+1}] = \frac{[\underline{D}_i^{j,t}+\overline{D}_i^{j,t}]}{2} = \frac{[\underline{D}_i^{j}+\overline{D}_i^{j}]}{2}$. Also, in steady state, $E_t[\overline{p}_i^{t+1}] = \overline{p}_i^t = \overline{p}_i$ and $E_t[\overline{q}_j^{t+1}] = \overline{q}_j^t = \overline{q}_j$ $(i, j = 0, 1)$.

3. Results

3.1 Main findings

Propositions 12 and 13 below, state the properties of long run (steady state) equilibria when the sex ratio is exogenous (the benchmark case) and when it is endogenous (Section 2.3), respectively.

Proposition 12. Suppose Condition 9 is true but that the sex ratio σ is exogenously given. Then there is dowry in steady state equilibrium when $\sigma < (1+\widehat{r}) + (1-\overline{p}_0)$ and bride price when $\sigma \geq (1+\widehat{r}) + (1-\overline{p}_0)$, where σ denotes the aggregate (exogenous) male-to-female sex ratio, $(1+\widehat{r})$ denotes the equilibrium growth rate of the population and $\overline{p}_0$ denotes the proportion of young women who find a partner in every period.

Notice that Proposition 12 establishes that unbalanced, masculine sex ratios ($\sigma > 1$) *may well* coexist with dowry payments in the long run, viz. when $\sigma < (1+\widehat{r}) + (1-\overline{p}_0)$ and $\sigma > 1$. Such an equilibrium is possible, for instance, when the population is growing at a high rate so that $(1+\widehat{r})$ is positive and high.

The intuition of Proposition 12 follows from the supply of and demand for agents in the marriage market. To see this, note that in steady state, the three terms – σ, $(1+\widehat{r})$ and $(1-\overline{p}_0)$ – govern the number of (old) men, young women and old women in the marriage market, respectively. Since each of these groups of agents receives a positive (pre-payment) surplus from marrying (i.e. $v_0^1 > 0$, $v_1^1 > 0$, $V_0^1 > 0$, $V_1^1 > 0$), when $\sigma < (1+\widehat{r}) + (1-\overline{p}_0)$ there is an excess supply of women in the marriage market, and hence the marriage payment is dowry. Likewise, when $\sigma \geq (1+\widehat{r}) + (1-\overline{p}_0)$, there is an excess supply of men, hence the payment is bride price.

To understand why the terms – σ, $(1+\widehat{r})$ and $(1-\overline{p}_0)$ – represent the different cohorts in the marriage market, consider the following. We know that in steady state, each of these terms is constant over time. The growth rate of the population $(1+\widehat{r})$ – which depends on exogenous fertility levels – governs the size of the young cohorts in the population; the higher the growth rate (for instance), the larger will be the size of the younger cohorts relative to older cohorts in a population. Since young men do not marry, $(1+\widehat{r})$ governs the number of young women in the population who are seeking a partner. Given the number of young women, σ pins down the number of young men in the current period, who enter the marriage market in the next period as old men. Thus σ governs the number of eligible (old) men in the marriage market in steady state. $(1-\overline{p}_0)$ is simply the proportion of young women who do not find a partner in the current period – hence it governs the number of old women in the marriage market in any period. It is straightforward to algebraically manipulate demographic configurations (35) , (36) and (39) to show that $\sigma < (1+\widehat{r}) + (1-\overline{p}_0)$ is true in these cases, hence these configurations are associated with dowry. Similarly, configurations (37) – (38) correspond to $\sigma \geq (1+\widehat{r}) + (1-\overline{p}_0)$; therefore (37) – (38) are associated with bride price[25].

To summarize, Proposition 12 states that when σ is exogenously given, there may be dowry or bride price in equilibrium depending on the relative magnitudes of σ and $[(1+\widehat{r}) + (1-\overline{p}_0)]$. Since a high fertility (or birth) rate leads to a high rate of population growth $(1+\widehat{r})$, it is likely to favor an excess supply of women and be associated with dowry payments in the long run. This phenomenon is referred to, in the demographic literature, as a "marriage squeeze against women" (Caldwell et al (1982, 1983); Rao (1993a, b)). Conversely, low birth rates and population decline are likely to support an excess supply of eligible men and (potentially) bride price in the long run.

Proposition 13 below applies to when the sex ratio σ is endogenously chosen.

Proposition 13. Suppose Condition 9 is true and that parents choose the sex ratio of their offspring as in (23) – (24) . Then:

(a) the only demographic configuration that is consistent with a non-trivial steady state general equilibrium is (39) regardless of the fertility level. In this equilibrium, the marriage

[25] Recall that $\overline{p}_0 = 0$ in (35) – (36), $\overline{p}_0 = 1$ in (37) – (38) and $\overline{p}_0 \in (0,1)$ in (39) .

payment is dowry and the aggregate male-to-female sex ratio (σ) is greater than 1.

(b) At any non-trivial steady-state general-equilibrium with configuration (39), $\sigma < (1 + \widehat{r}) + (1 - \overline{p}_0)$ must be true (as in Proposition 12).

To understand Proposition 13, let us focus on a steady state general equilibrium that can exist, viz. one with demographic configuration (39) : $f_1 < m_1 < f_0 + f_1$. Consider the marriage payments associated with this configuration.

Under Condition 9, old men and women match first. Since $f_1 < m_1$, all old women are able to find a partner but some old men need to marry young women. Furthermore, since $m_1 < f_0 + f_1$, not all young women will be able to find a partner in this period. Hence, the marriage payments must be such that (a) (old) men are indifferent to the age of their partner, and (b) young women are indifferent between marrying now versus later. Criteria (a) and (b) can be expressed mathematically as (40) and (41), respectively (see Section 2.1.4):

$$V_1^1 + D_1^1 = V_0^1 + D_0^1 \tag{40}$$

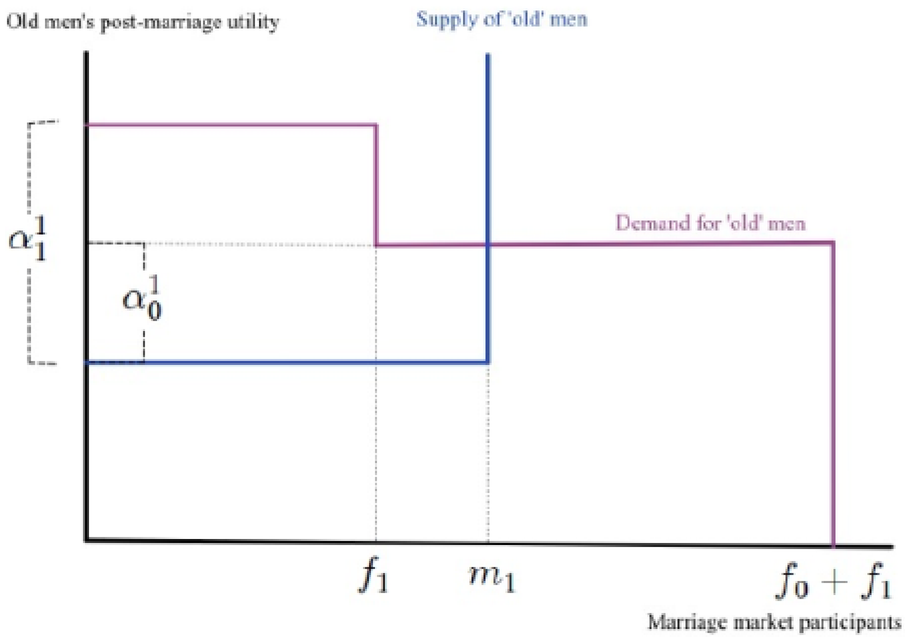
$$v_0^1 - D_0^1 = 0 \tag{41}$$

where v_i^j (V_i^j) denotes the marriage surplus to a woman of i (man of age j) upon marriage to a man of age j (woman of age i).

(41) states that young women must pay their entire positive surplus from marrying old men $(D_0^1 = v_0^1 > 0)$, so as to be indifferent between marrying now versus later; hence their payment is a dowry. Furthermore, since men prefer young to old women, the latter must pay more than the dowry offered by young women (so as to make men indifferent to the age of their partner). Hence, old women must pay a dowry as well. It is straightforward to solve (40) – (41) to show that equilibrium marriage payments for demographic configuration (39) are given by:

$$D_0^1 = \frac{K + 2\beta}{1 - \beta}; \; D_1^1 = \frac{K + 1 + \beta}{1 - \beta} \tag{42}$$

Figure 2 below illustrates the above argument in terms of the demand for and supply of eligible marriage market participants under configuration (39) .



Since dowry is expected in equilibrium, parents anticipate a higher return to begetting sons than daughters ($E_m > E_f$), hence the (endogenous) sex ratio is skewed in favor of men ($\sigma > 1$; see (25) − (26)). However, in order for demographic configuration (39) to persist, the chosen σ must be less than $(1+\widehat{r})+(1-\overline{p}_0)$ (Proposition 12)[26]. The following numerical example demonstrates the existence of a case where $\sigma < (1+\widehat{r})+(1-\overline{p}_0)$ persists along with dowry (42) and a masculine sex ratio, so that configuration (39) can be sustained in steady state.

Example 14. Consider the following parameter values: $\rho_0 = 3, \; \rho_1 = 2, \; K = 0.2, \; s = 4, \; \beta = 0.25$ (where ρ_i is the total fertility of a woman of age i). Note that Condition 9 is satisfied by these parameter values.

[26] A growing population – or high fertility rates – assists the satisfaction of this condition but is not a necessary condition for existence of equilibria such as (39) . Existence can be shown numerically for declining populations as well.

A non-trivial steady state equilibrium exists (corresponding to configuration (39)) and has the following characteristics:

- In each period, the structure of the marriage market is given by: $f_1^t < m_1^t < f_1^t + f_0^t$ [as in (39)]
- The probabilities of matching for men (denoted $\overline{q}_j$) and women (denoted $\overline{p}_i$) are given by: $\overline{q}_0 = 0$; $\overline{q}_1 = 1$; $\overline{p}_0 = 0.787$; $\overline{p}_1 = 1$. The corresponding (steady state) equilibrium assignment is given by: $\mu_0^{1,t} = 0.787 f_0^t$; $\mu_1^{1,t} = f_1^{1,t}$; $\mu_0^{0,t} = \mu_1^{0,t} = 0$. That is, in every period, all old men and women are matched, 78.7% of young women are matched and all young men are unmatched.
- The equilibrium marriage payments are $D_0^1 = \frac{K+2\beta}{1-\beta} = 0.93$; $D_1^1 = \frac{K+1+\beta}{1-\beta} = 1.93$.
- The stable population grows at the rate: $(1+\widehat{r}) = 1.237$, at the optimal birth rates and sex ratios chosen (see below).
- The optimal maternal-age-specific birth rates and sex ratios are: $b_{f0} = 1.38$; $b_{m0} = 1.62$; $\sigma_0 = 1.17$; $b_{f1} = 0.88$; $b_{m1} = 1.12$; $\sigma_1 = 1.27$.

Hence, equilibria of the form (39) exist[27].

Let us now discuss why the other configurations (35) – (38) cannot be sustained in a steady state general equilibrium. It is easy to see that in configuration (35) – ($f_1^t > m_1^t$) – all old men and some old women are matched in every period while none of the young agents are matched. Hence, we must have $f_1^t = f_0^{t-1}$ and $m_1^t = m_0^{t-1}$. Since aggregate $\sigma^t = \frac{m_0^t}{f_0^t} = \frac{m_1^{t-1}}{f_1^{t-1}} = \sigma$ is constant in steady state, configuration ($f_1^t > m_1^t$) can persist if and only if $\dot{\sigma} < 1$. But marriage payments resulting from (35) do not support $\sigma < 1$. Since

[27] Recall that the main result (Proposition 13) is *not* driven by an assumption that having an unmarried daughter is worse than having an unmarried son, since, by assumption, both sons and daughters receive $[w + \beta(w-s)]$ if unmarried. It can be shown, however, that having an unmarried *young* daughter is worse than having an unmarried *young* son in the long run equilibrium (39) because of the dowry expected to be paid (or received) in the next period. The latter fact is an outcome of the model – constituting endogenous son preference – and not an assumption.

some old women stay unmatched in every period, they must be indifferent between marrying or not, hence they bid away their entire (high) surplus (v_1^1) as dowry. Since high dowry payments are expected to persist, parents choose more boys than girls, i.e. $\sigma > 1$. This is a contradiction; hence (35) cannot persist in a steady state general equilibrium. A similar reasoning can be used to show that (36) may not persist in equilibrium either.

Consider (37): $f_1^t < f_1^t + f_0^t < m_1^t$. In this equilibrium, we must have $f_1^t = 0$, since all young women are matched in every period; hence (37) can be represented as: $f_0^t < m_1^t$. In order for (37) to be sustained, therefore, the chosen aggregate σ (that governs m_1^t) must exceed $(1 + \widehat{r})$ (which governs f_0^t). What are the marriage payments in this case? Since some old men are unmatched they are left indifferent between marrying or not, by bidding away their entire surplus (V_0^1) as bride price. Since daughters are expected to earn a bride price, parents choose more daughters than sons. It may be shown, however, that when $f_0^t < m_1^t$, the returns from having a daughter (E_f) so far exceeds the returns from having a son ($E_m = 0$) that parents have an incentive to overproduce girls. This renders the male-female sex ratio σ too low, violating $\sigma > (1 + r)$ in the future. The reason for E_f being so high in this case is that under configuration (37), daughters are expected to find a match with certainty at their ideal age and earn a very high bride price equal to (the high-surplus) old men's entire marital surplus. A similar reasoning also shows that configuration (38) may not be sustained in equilibrium either.

In summary, therefore, Proposition 13 states that bride price cannot be sustained in steady state because it leads to an overproduction of girls. This overturns the situation of excess demand for women which led to the payment of bride price in the first place. This argument is true also for equilibria with very high dowry (e.g. (35) – (36)) – where overproduction of sons will prevent the persistence of the high dowry.

However, there does exist one and only one demographic configuration – (39) – with dowry payments, where the incentive to produce more sons does not prevent their advantage in the marriage market from being sustained. There are two main reasons for this. First, in equilibrium (39) , men are not able to extract the entire marital surplus of high-surplus (old) women as dowry, and this fact imposes an upper bound on the excess returns from producing sons $(E_m - E_f)$. Thus while parents do produce more sons than daughters, the former are not "overproduced". The second reason is that the excess boys produced in each period do not enter the marriage market immediately, since young men do not marry. This allows men to wait for a new generation of women to become available for marriage, in addition to those left unmatched from the previous period. The ability of men to "out-wait" women works to "alleviate" the effect of a masculine sex ratio in generating an excess supply of men in the marriage market. Hence, (39) can be – and is, indeed, the only demographic configuration that may be – sustained in steady state. These findings provide a remarkably accurate description of the Indian marriage market in the last century, as outlined in Table 1 below[28].

Table 1: Model prediction vs. Indian evidence from the 20th century

Variable	Model prediction	Indian evidence
Marriage payments	Dowry	Dowry
Sex ratio	Masculine	Masculine
% women married by age 45-49	100	99.5
% men married by age 45-49	100	97.6
Average spousal age gap (Man - Woman)	Positive	Positive

3.2 Corollary: Variable cost of sex-ratio choice

Will a low cost of sex ratio choice overturn the above result by making parents overproduce sons under (39)? This question is pertinent because the advent of sex-selective abortion techniques in India in the 1980's may have lowered the costs of manipulating the sex ratio by making it easily accessible and eliminating the psychological costs associated with infanticide. Corollary 15 states that a low cost of sex ratio choice is a *sufficient* condition for Proposition 13's results.

[28]The data in Table 1 are obtained from Tertilt (2004) and Goyal (1988).

COROLLARY 15. Suppose, instead of (20) , that the post-marriage utility function of couples in period t is given by

$$U^{marr,t} = c^t + E_f^{t+1} b_f^t + E_m^{t+1} b_m^t - \tau (b_f^t - b_m^t)^2 \qquad (43)$$

where τ (> 0) indicates the cost to parents of manipulating the sex ratio. Suppose parents maximize (43) subject to constraints (24). If $\tau < (1 + \beta)$, then the only demographic configuration that is consistent with steady state equilibrium is (39) regardless of the fertility level. The steady state equilibrium payment is dowry and the aggregate sex ratio at birth is skewed in favor of men.

The intuition of Corollary 15 is straightforward. A low cost of sex-ratio choice (τ) does not alter the set of feasible demographic configurations – (35) – (39) – that may persist in steady state, or the payments and magnitudes of $(E_f - E_m)$ consistent with each of these configurations. Thus, a lower τ makes parents *more* likely to over-produce girls, which prevents a bride price equilibrium from being sustained in the long run. However, in a dowry equilibrium such as under (39) , men's parents are unable to extract the entire marital surplus from the (high-surplus) old women's parents. At the relatively low levels of dowry associated with such as equilibrium, boys are not overproduced even at low τ; thus an equilibrium such as (39) may be sustained in steady state.

3.3 What drives the main findings? Asymmetric preferences

Corollary 15 demonstrates the importance of marriage market outcomes – viz. those that affect $(E_f - E_m)$ – in driving the result of Proposition 13. For instance, it is harder, in steady state, to sustain payments that extract the entire surplus of high-surplus partners. The high expected payments in these cases (and correspondingly high values of $|E_f - E_m|$) leads to an overproduction of the paid agents in the market (either sons or daughters) in the next period. Hence, configurations (35) – (38) cannot hold in steady state.

A fundamental determinant of $(E_f - E_m)$ are the asymmetries in men's and women's preferences regarding age at marriage. Consider, for instance, a different scenario (than the one examined in Sections 2-3) where women prefer to marry when old. All other assumptions and preferences are the same – i.e. women prefer old men, men prefer to marry old and prefer young women – and parameter values are calibrated as in Condition 9. Consider the demographic configuration (39). When women prefer to marry old, young women's marital surplus (v_0^1) becomes negative. Hence, they must now be paid a bride price to make them indifferent between marrying now versus later. Men will choose to pay this amount to young women, because otherwise some of them will remain unmatched (since $f_1^t < m_1^t$). Old women's payments must be such that old men are indifferent between marrying old or young women. It is easy to show (employing (40) and (41)) that the payment associated with matches including old women may be dowry or bride price depending on whether $K \gtrless \dot{\beta}$. This makes intuitive sense, since K represents the immediate benefit of marrying and β is the discount factor denoting how much future returns are valued. When β exceeds K, women have greater bargaining power because men have to make marriage profitable for women by offering them bride price.

Under the above preferences, is it possible to have a sustainable steady state equilibrium with (endogenous) sex ratio skewed in favor of women? Yes, it is possible to show the existence of such equilibria using numerical examples[29]. It is also straightforward to show (employing (25) – (26)) that a feminine sex ratio can occur only if $(1 + \beta) > 2K$ – pointing once again to the fact that when the discount factor is high relative to immediate benefits from marriage, women receive greater bargaining power in the marriage market. This is true to the extent that an endogenous preference for *daughters* is generated and the chosen sex ratio is skewed in favor of women[30].

Finally, consider a situation of symmetric preferences of men and women – viz. that

[29] Claims on marital preferences other than (2) are based on numerical findings.

[30] Note that when $(1 + \beta) > 2K$ and $K < \beta$,all women receive bride price and the sex ratio is feminine. Such equilibria do exist in steady state. Alternatively, when $(1 + \beta) > 2K$ but $K > \beta$, only young women receive bride price (old women pay dowry) but the sex ratio is still feminine.

both men and women prefer to marry old and prefer an old partner. In this case, the calibration that makes young men prefer to postpone marriage must apply for young women as well. Thus, in this case both men and women enter the marriage market when old. The only steady state equilibrium that can persist is the one in which $\sigma = 1$,which generates $f_1^t = m_1^t$ in each period. This leads to multiple equilibria in payments (assumed to follow a uniform distribution):

$$D_1^1 \sim U[-V_1^1, v_1^1] \tag{44}$$

where $V_1^1 = v_1^1 = (K + s)$. Hence, payments may be negative (bride price) in some cases or positive (dowry) in others, but the expected dowry, $ED_1^1 = 0$, which in turn supports the parental decision to choose $\sigma = 1$ (or not engage in sex selection at all).

4. Conclusion: Broader implications of the findings

The primary motivation of this paper is to explain why scarce women in India pay dowry to secure a groom, and whether being able to choose the sex ratio of offspring will overturn this result in the long run. We show that when (i) men can out-wait women to find a partner (i.e. asymmetric marital preferences), (ii) the social cost of remaining single for life is high, (iii) the benefit of marriage is too low for young men to want to marry young, and (iv) sex-ratio choice is endogenous, any long-run steady state equilibrium must have dowry and a sex ratio skewed in favor of men. The prediction of this model provides a remarkably accurate description of and intuition for the coexistence of dowry and masculine sex ratios in India in the past century.

What are the model's implications for ways out of the long-run equilibrium in which women's bargaining power is so limited?

The most direct way would be to increase the cost of sex-ratio choice so as to return to the benchmark case of exogenous sex ratios (Proposition 12). Prevention of sex selection among parents could be accomplished through education programs and the prohibition of sex tests of fetuses. Exogenous sex ratios combined with low birth rates could bring about an improvement in women's bargaining power by allowing bride price equilibria to be sustainable. Note, however, that if we assume the exogenous sex ratio to be 1 in the absence of any sex selection, a necessary condition for bride price equilibria to exist would be a declining population (since $1 = \sigma > (1 + \widehat{r}) + (1 - \overline{p}_0)$; $\overline{p}_0 = 1$ in any bride price equilibrium, (37) – (38)).

A more permanent way of improving women's bargaining power – irrespective of the fertility level – would require altering the marital preferences of both men and women. We can show that if women preferred to marry late (instead of young) there is an improvement in payments – viz. bride price for young women, and also for old women if they value the future highly enough relative to the present return from marriage (high β relative to K). Furthermore, the male advantage in the long-run marriage market dissipates completely when they too prefer to marry older women, making marital preferences identical for men and women. Thus, making the future more valuable for women, not by lowering the outside option (the role played by s), but by improving the benefit that directly accrues to them in the later period, serves to improve their long-run bargaining power. This points to the importance of reproductive health technology – such as the availability of contraception, safe abortion of early pregnancies, fertility treatments etc – in facilitating postponement of female marriage to a later age[31]. The availability of fertility treatments for older women could serve also to alter men's ideal age of partner (e.g. by making older women more able to bear the desired number of children), as would a sufficient reduction in the gender gap in wages, or removal of the 'glass ceiling'. Several of these goals – e.g. better access to reproductive health technology, elimination of the gender wage gap – are already recognized as noble objectives grounded in the realm of human rights and social justice. Our model demonstrates the existence of a deeper economic connection between such health advancements and the long-

[31]Consequently, prohibiting or limiting access to such reproductive health technology serves to limit the bargaining power of women in the long-run.

run disadvantage faced by women in the marriage market. When marital preferences are identical for men and women, their bargaining power in the marriage market is matched and unaffected by overall fertility levels. There remains no incentive for choosing more sons or daughters, hence sex ratios are as good as exogenous in this scenario.

While the dynamic general equilibrium model used in this paper has been developed specifically to explore the Indian scenario in the last century, we feel that the theoretical framework developed here may be used to throw light on why women suffer a general disadvantage in the marriage market even in other countries. It is beyond the scope of this paper to explore the emergence and persistence of long-run gender inequality across time and countries. It is hoped, however, that future research will examine this topic and its various aspects, and that the framework demonstrated in this paper will be useful for the purpose.

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