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

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ABSTRACT

Why do scarce women in India pay dowries to find grooms? And will growing sex-selection against females lead to the emergence of a bride price regime therein? These are important questions since the widespread availability of early-sex-detection technology and cheap abortions has led to an increasingly skewed sex ratio in India. My paper develops a dynamic general equilibrium model of population dynamics and marriage markets, where parents can *choose* the sex-ratio of their offspring based on expected marriage market returns. Son preference is not exogenously assumed. I outline three conditions (arguably reasonable descriptors of the Indian marriage market) under which scarce women will pay dowry in steady state. More importantly, I show that under these same conditions, *any* steady state equilibrium must be characterized by scarce women (an endogenous, masculine sex ratio) paying dowry. The result provides valuable insights on the economic foundation of son preference and dowry in India.



Keywords: dowry; sex ratio; son preference; population growth

JEL classifications: D90; D91; J13; J16; O10

## 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); Rao (1993b); Anderson (2003)). Keeping with the marriage price interpretation, some authors have argued that a preference for younger brides together with high population growth leads to a dowry regime (Caldwell et al. (1982); Caldwell et al. (1983); Rao (1993a); Rao (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 in 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); Rao (1993b); Bloch and Rao (2002))[1]. 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, I attempt to resolve the Indian puzzle using a dynamic general equilibrium model with overlapping ('young' and 'old') generations. I investigate the economic foundation of the relationship between population dynamics (sex ratios and population growth rates) and marriage market outcomes (payments and matching probabilities) when the sex ratio is *endogenous*, i.e. chosen by parents in anticipation of their offspring's expected marriage market returns.

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 ever easier to select the sex composition of offspring. Here I address this gap in the literature and ask, in addition, if the current 'anomaly' will dissolve in the long run through the emergence of a bride price regime.

The model proposed here further differs from previous research (Edlund (1999); Bhaskar

[1] It has been argued that the Indian pratice is more aptly described as 'groom price' than 'dowry' per se.

(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.

In the framework presented here, population structure determines marriage payments by a straightforward competitive demand-supply mechanism: the side of the market (brides or grooms) in excess supply pays for a partner (dowry or bride price). There are two channels through which population dynamics may impact the marriage market – (1) the sex ratio, which determines the relative number of men and women in the population (and hence in the marriage market), and (2) the population growth (or decline) rate, which affects the relative sizes of 'young' and 'old' cohorts. If older men marry younger women, then the differential impact on cohort size will impact the relative numbers of eligible brides and grooms (Caldwell et al. (1982); Caldwell et al. (1983); Rao (1993a); Rao (1993b); Tertilt (2005)).

But population structure is itself determined by marriage market conditions. Expectations of the future availability of eligible brides and grooms and the resulting future marriage payments determine the sex ratio of offspring that parents consider optimal. There is, therefore, a *feedback* from marriage market outcomes (payments and matching probabilities) to population dynamics (sex ratios and growth rates). The key innovation of our model is to explicitly incorporate this feedback effect, enabling an endogenization of son preference.

I show that three conditions are sufficient to explain the Indian puzzle, namely, the coexistence of a dowry regime and an endogenous sex ratio skewed in favour of men. More importantly, I show that under these three conditions, any steady state equilibrium *must* be characterized by dowry payments and a masculine sex ratio. This result, while seemingly counterintuitive, seems to describe the Indian marriage market very well.

The three conditions sufficient to generate the above result are stated below. In Section 2.1.1.1, I discuss why these conditions are reasonable descriptors of Indian society.

The first condition is a standard theoretical assumption about asymmetric preferences regarding the ideal ages of marriage of men versus women. In the current framework of arranged marriages, I assume that the parental notion of an 'ideal' marriage for a daughter corresponds to her being married 'young' to a groom who is 'old'. However, the 'ideal' marriage for a son occurs when he is 'old' and his bride is 'young'. Such preferences clearly affect the parents of sons and daughters asymmetrically by driving (among other things) *when* they find it optimal to start the search for a daughter-in-law versus a son-in-law; they also constitute the channel through which population growth (or decline) can impact marriage payments by altering the cohort sizes of eligible brides and grooms. Such preferences form a standard assumption in the theoretical literature modelling the impact of population dynamics on marriage markets (Anderson (2007); Bergstrom and Lam (1991)).

The second and third conditions (stated jointly as Condition (1) in Section 2.1.1) represent two parametric restrictions motivated by marriage norms prevalent in Indian society. These conditions require that (1) the social benefit that parents receive from arranging their offspring's marriage is less than the cost they face if the bride or groom is not of the 'ideal' marriageable age; and (2) the social cost to parents of having an 'old' child who fails to find a match is reasonably high.

Why can bride price not be sustained in a long-run equilibrium when the sex ratio is endogenously determined and the above parametric restrictions are imposed? I show that whenever bride price payments are expected, parents overproduce girls relative to boys. This tips the balance against women in future periods, ensuring that bride price cannot persist in the long run. The key factor that drives this finding is that bride price payments, when they occur, must be high in magnitude. This is because the bride price offered in equilibrium reflects the surplus that sons' parents get from marrying off their sons. Since the cost of marrying off 'young' sons exceeds the social benefits of doing so (restriction 1), the search for a daughter-in-law effectively begins only when the son is 'old'. However, there is also a considerable social pressure to find a match for the 'old' son within the current period, failing which parents will have to face the high social cost of having a son who is single for life (restriction 2). The high marital surplus of sons (generated by the low outside option of marriage for 'old' sons) which also drives the high magnitude of the equilibrium bride price cannot, therefore, be sustained in steady state.

Why then do parents not overproduce boys in the dowry equilibrium, even when they choose to have more sons than daughters? I show that in any long-run equilibrium, the magnitude of the dowry is not so large as to cause parents to overproduce sons. Thus, even though the sex ratio is biased in favor of men (since they are expected to earn a dowry), it is not so skewed as to overturn the dowry equilibrium. Once again the intuition follows from the surpluses of the agents who offer the dowry – the parents of 'young' and 'old' women. I show that in any long-run equilibrium, men are able to extract the entire surplus from the parents of 'young' women but not from parents of 'old' women. Note that the former is considerably lower than the latter since the high cost of having a single 'old' daughter (restriction 2) greatly reduces the outside option for parents of 'old' women. This implies that the equilibrium dowry – reflecting the surplus to parents of 'young' women – is also relatively low. Thus, even though the expectation of dowry makes parents produce more sons than daughters, the sex ratio is not so skewed as to overturn the dowry equilibrium[2].

Hence, dowry can be sustained in a long-run equilibrium even though bride price cannot.

In an extension of the analysis described above, I ask if a lower cost of sex ratio choice will make parents overproduce boys when dowries are expected, thereby altering the main result of this paper. This question is motivated by the advent of modern ultrasound and sex-selective abortion technology in India, which is expected to have made sex ratio choice easier for parents (Das Gupta and Shuzhuo (1999)).

I show that a low cost of sex ratio choice is a *sufficient* condition for the main result to hold. The reason is that the low cost does not alter the size of marriage payments in equilibrium. Hence, equilibrium dowry payments remain relatively low, ensuring that

[2] In fact, I also show that there cannot exist a dowry equilibrium in which the entire high surplus of the parents of 'old' women is extracted as payment. Such a dowry would be too high and the corresponding optimal sex ratio too skewed for the dowry equilibrium to be sustainable over time.

sons are not overproduced in equilibrium. But the magnitude of the equibrium bride price payments, which remain high, makes parents facing a low cost of sex-ratio choice even more likely to overproduce daughters, rendering a bride price equilibrium unsustainable. This finding strengthens the main result of the paper, viz. that when the sex ratio is endogenous (or equivalently, when the cost of sex ratio choice is low), any long run equilibrium will feature dowry payments, regardless of the population growth rate (or fertility level).

The paper is organized as follows: Section 2 outlines the model in detail; Section 3 presents the main results and intuition; Section 4 concludes the paper.

## 2. The Model

Consider a dynamic general equilibrium model in an overlapping generations framework[3]. 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[4]. 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 offspring's 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.

[3]Tertilt (2005) uses a general equilibrium model in an overlapping generations framework to analyze the effect of bride price on savings decisions. The sex ratio is exogenous in her analysis, unlike in the present paper.

[4]In the current (Indian) context, it is useful to think of 'young' agents as being between 13-26 years of age and 'old' agents as being between 27-40 years of age.

**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 ($\rho_0$) than old women ($\rho_1$). 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 (Dasgupta and Mukherjee (2003); Raman (1981)). They do so based on the following preferences.

Let $U^s$ denote the period utility to parents of a *single* agent, where $h$ denotes the agent's age, $h = 0$ (young), 1 (old). Then,

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

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. $s$ 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. Equations (1) indicate 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.

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 marrying off their offspring; this utility 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[5].

The marital utility functions $U^p$ in equation (2) demonstrate parental preferences for their offspring's and her (his) spouse's age at marriage. The equations indicate that in every period of marriage, parents receive social utility from marrying off the offspring ($K$) 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 marry late (at age $j = 1$) and marry a young woman (of age $i = 0$).

Future outcomes are discounted by $\beta$; $0 < \beta < 1$. 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[6].

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).

**Parametric restrictions** Recall, from the previous section: $K > 0,\ s > 0,\ 0 < \beta < 1$. In the following analysis, two additional restrictions are imposed on the parameters $(K, s, \beta)$ of the model.

**Condition 1.** *The following two restrictions are imposed on model parameters* $(K, s, \beta)$*:*

(*i*) $K < 1$

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

Restriction (*i*) requires that the social benefit that parents receive from marrying off their offspring is less than the cost they face if the bride or groom is not of the 'ideal'

[5] Anderson (2007) uses similar marital utility functions to model the short-run effect of population growth on marriage payments. Bergstrom and Lam (1991) also use a similar utility function to demonstrate how an excess supply of brides or grooms may be absorbed by changing age differentials of spouses. Their utility formulation includes an ideal (own) age of marriage for men and women with the former being higher than the latter.

[6] Relaxing this assumption and allowing parents a utility of $c$ when the offspring's spouse is not alive does not change the qualitative results of the paper.

age[7]. Restriction $(ii)$ requires that parents face a sufficiently high cost (defined by the lower bound) of being unable to marry off their offspring by a certain age ('old'). Note that removing the upper bound of $s$ in $(ii)$ does not change the qualitative results of the paper; its imposition, however, allows us to focus on the key mechanisms that drive the result.

The prevalence of arranged marriages in India has been well-documented (Dasgupta and Mukherjee (2003); Raman (1981)). There is evidence also that social factors are very important in driving notions of the 'ideal' match for one's offspring, including (among other things) the age at which an 'ideal' marriage must occur, and the manner in which the wedding must be celebrated[8]. In the light of existing marriage norms in India, therefore, I argue that the imposed restrictions are reasonable descriptors of Indian marital preferences.

For instance, various anthropological and sociological studies have pointed out that in India parental search for offsprings' partners begins at a much earlier age for daughters than for sons (Caldwell et al. (1983); Epstein (1973)). Furthermore, sons are expected to postpone their search for a partner till their younger sisters have found a match (Caldwell et al. (1983); Jensen and Thornton (2003); Epstein (1973)). This norm provides the motivation for restriction $(i)$, which states that while there is social gratification from marrying off an offspring ($K > 0$), there is a pressure to do so at the socially accepted 'ideal' age and with an ideal partner. In the Indian environment where fertility treatments are prohibitively expensive for the population at large, the shorter biological clock of women could be a possible source of the urgency to marry daughters young (Díaz-Giménez and Giolito (2008)) relative to sons.

Restriction $(ii)$ is motivated by the oft-repeated observation that Indian parents face considerable social pressure to find a match for their offspring by a certain age. As Rao (1993b) points out: "(there are) strong social and economic pressures for women to be married within an 'acceptable' age range... due both to a lack of job-market opportunities for women, as well as to an extreme drop in social status associated with having (or being) an older unmarried daughter" (Rao (1993b): 285). This suggests that $s$ – the social cost of having an unmarried 'old' offspring – is reasonably high, i.e. it has a lower bound. However, trends in modernization such as better education and labor market opportunities and the relaxing of stringent social sanctions against late marriages also suggest that $s$ may not be unbounded above. Hence an upper bound for $s$ is also a plausible restriction, although, as mentioned before, removing the upper bound does not change the qualitative results of the paper.

### 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

[7]Recall, from the quadratic costs in (2), that the cost to parents is 1 if either spouse is of the non-ideal age.

[8]Recall repeated references to the importance of social norms in Indian marriages in popular literature (e.g. Seth (1993)) and 'Bollywood' films (e.g. "Monsoon Wedding").

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:

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

where $w$ is the income earned by all agents in each period (see General Assumptions)[9].

In all other periods, the budget constraints are:

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

### 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 woman in match $(i, j)$. Let $V_i^{j,t}$ denote the marriage surplus in period $t$ to the parents of the man in match $(i, j)$. 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 comes from the utility from marrying an agent of a particular type (age) less the utility from remaining single at the end of the period. Using (1) and (2), I derive the parental marriage surplus of old agents to be,

$$\begin{aligned} v_1^{j,t} &= U^p(w,1,j) - U^s(w,1) = K + s - 1 - (j-1)^2 \\ V_i^{1,t} &= U^p(w,i,1) - U^s(w,1) = K + s - (i-0)^2 \end{aligned} \tag{5}$$

For parents of young agents, the marriage surplus comes from the lifetime utility from marrying an agent of a particular type less the expected return from postponing marriage to the next period. The latter includes the utility from remaining single now as well as the expectation of marriage returns in the next period (discounted by $\beta$). I shall denote agents' expectations of future marriage returns by $X^{g,t+1}$, where $g$ denotes the gender of the agent. Hence, the marriage surplus to parents of young agents can be written as

$$\begin{aligned} v_0^{j,t} &= U^p(w,0,j)(1+\beta) - [U^s(w,0)+\beta X^{f,t+1}] = (w+K-(j-1)^2)(1+\beta) - [w+\beta X^{f,t+1}] \\ V_i^{0,t} &= U^p(w,i,0)(1+\beta) - [U^s(w,0)+\beta X^{m,t+1}] = (w+K-1-(i-0)^2)(1+\beta) - [w+\beta X^{m,t+1}] \end{aligned} \tag{6}$$

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

$$\begin{aligned} X^{f,t+1} &= E_t[p_1^{1,t+1}(w+K-1-D_1^{1,t+1}) + p_1^{0,t+1}(w+K-2-D_1^{0,t+1}) \\ &\quad +(1-p_1^{1,t+1}-p_1^{0,t+1})(w-s)] \\ X^{m,t+1} &= E_t[q_1^{1,t+1}(w+K-1+D_1^{1,t+1}) + q_0^{1,t+1}(w+K+D_0^{1,t+1}) \\ &\quad +(1-q_1^{1,t+1}-q_0^{1,t+1})(w-s)] \end{aligned} \tag{6'}$$

[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 $w$ (earned by the children) as marriage payment on their behalf.

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 a marriage between a woman of age $i$ and man of age $j$ $(i, j = 0, 1)$[10].

**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 the surpluses of the matched agents:* $\alpha_i^{j,t} = v_i^{j,t} + V_i^{j,t}$. *A match between a woman of age* $i$ *and a man of age* $j$ *may occur in period* $t$ *only if* $\alpha_i^{j,t} \geq 0$.

### 2.1.4. Marriage Payments

Recall that a 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. Whether a particular payment is feasible or not for the parents of an agent depends on the associated surplus from the marriage:

**Definition 2.** *A payment* $D_i^{j,t}$ *made in a period*$-t$ *marriage between a woman of age* $i$ *and a man of age* $j$ $(i, j = 0, 1)$ *is* ***feasible*** *when* $D_i^{j,t} \leq v_i^{j,t}$ *and* $-V_i^{j,t} \leq D_i^{j,t}$. *Henceforth, I shall refer to these inequalities as feasibility constraints. Feasibility requires that the parents of each agent earn at least as much from the marriage as the reservation utility.*

Recall the budget constraints (3) and (4) outlined in Section 2.1.2. Note that $w$ (the income earned by agents in each period) is high by assumption, ensuring that the maximum feasible payments for all matches are affordable to both men and women.

### 2.1.5. Matching and Equilibrium

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

**Definition 3.** *A match is a function* $\mu^* : M \times F \rightarrow M \times F$ *such that (i)* $x \in M \Rightarrow \mu^*(x) \in F \cup \{x\}$*; (ii)* $x \in F \Rightarrow \mu^*(x) \in M \cup \{x\}$ *and (iii)* $\mu^*(\mu^*(x)) = x$. *A match is 'successful' if* $x \in M \Leftrightarrow \mu^*(x) \in F$ *or if* $x \in F \Leftrightarrow \mu^*(x) \in M$.

**Definition 4.** *Let* $\mu_i^{*j,t}$ *denote the measure of matches and* $\mu_i^{j,t}$ *denote the measure of successful matches between women of age* $i$ *and men of age* $j$ *in period* $t$. *The marriage market clears when*

$$\begin{aligned} \mu_0^{*j,t} + \mu_1^{*j,t} &= m_j^t \; (j = 0, 1) \\ \mu_i^{*0,t} + \mu_i^{*1,t} &= f_i^t \; (i = 0, 1) \end{aligned}$$

[10] See equation $\left(7'\right)$ for a derivation of $p_1^{j,t+1}$ and $q_i^{1,t+1}$ $(i, j = 0, 1)$.

*Moreover, the following is true of successful matches in any period, since unions are monogamous:*

$$\begin{aligned} \mu_0^{j,t} + \mu_1^{j,t} &\leq m_j^t \ (j = 0, 1) \\ \mu_i^{0,t} + \mu_i^{1,t} &\leq f_i^t \ (i = 0, 1) \end{aligned}$$

**Definition 5.** *A competitive equilibrium is a set of successful matches of measure $\mu_i^{j,t}$ $(i, j = 0, 1)$ and corresponding feasible marriage payments $D_i^{j,t}$ such that all price-taking agents maximize their 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.*

Lemma 1 follows from imposing the restrictions in Condition (1)[11].

**Lemma 1.** *Suppose Condition (1) is true. Then, the following must be true in any period $t$:*

$$\begin{aligned} \alpha_0^{0,t} &< 0 \\ \alpha_1^{1,t} &> \alpha_0^{1,t} > 0 \\ \alpha_1^{1,t} &> \alpha_1^{0}, t \end{aligned} \qquad (*)$$

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

Note that while the precise magnitudes of $\alpha_i^{j,t}$ $(i, j = 0, 1)$ are time-dependent (since marital surpluses depend on expectations of matching outcomes and payments in the next period), Lemma 1 states that the rankings in $(*)$ must be true *in any period* whenever Condition (1) holds. The intuition of $(*)$ is easily explained using the parametric restrictions in Condition (1).

Focus first on $\alpha_0^{0,t}$, the value of marriage of a young man and young woman. Recall that the value of marriage is the sum of the parental surpluses of each member of the couple. Two considerations drive the surplus to young agent's parents: (1) the social utility that parents get from marrying off their offspring in period $t$ (depends on $K$), appropriated over two periods of married life: $t$ and $(t+1)$; and (2) the utility that parents expect to appropriate if they postponed their offspring's marriage to period $(t+1)$. Since 'young' is the non-ideal age of marriage for a man $(K < 1)$, the social utility in period $t$ is negative for both sets of parents of young agents. Note that the period$-(t+1)$ social utility to parents of young agents matched in $t$ must be the same as the utility to parents of old agents matched in $(t+1)$ (prior to payments being made in $(t+1)$). This is true because in period $(t+1)$, there is no difference between couple $(0, 0)$ who were matched in $t$ and couple $(1, 1)$ who are matched in $(t+1)$. Hence, in computing the *surplus* to parents of young agents in $t$, the social utility of the period$-t$ marriage in the second period of life $(t+1)$ cancels out with the expectations of marital utility in period $(t+1)$ if marriage is postponed (component 2). Hence, the surplus to each set of (young) parents is reduced

[11] See proof in Appendix A.

to the negative social utility in period $t$ of marrying their offsprings combined with the payments expected to be made in $(t+1)$. Since expected payments in $(t+1)$ are pure transfers, they cancel out in the *sum* of surpluses (or the value of marriage). Thus, the value of marriage is negative ($\alpha_0^{0,t} < 0$ for all $t$) implying that there will never be a match between a young man and a young woman.

The inequality – $\alpha_1^{1,t} > \alpha_0^{1,t} > 0$ – asserts that the value of a marriage between an old man and an old woman exceeds the value of a marriage between an old man and a young woman. This is easy to see since Condition (1) ensures that $s$ is sufficiently high (greater than the lower bound), and parents of all old agents (both men and women) stand to face this high social pressure if unable to find a match for their offspring by the end of the period. Since both parties (old men and old women) have a low outside option of marriage, the sum of their marital surpluses, $\alpha_1^{1,t}$, is high. Young women have one more period to search for a mate, hence their parents do not face the imminent social pressure $s$, ensuring that $\alpha_1^{1,t} > \alpha_0^{1,t}$. Parents of young women do, however, have a clear incentive to offer their daughters for marriage in the market since 'young' is considered to be the ideal age for a bride by both men and women. Hence, $\alpha_0^{1,t} > 0$.

The inequality – $\alpha_1^{1,t} > \alpha_1^{0,t}$ – follows again from the fact that the parents of both old men and old women face a high social cost $s$ of being unable to find a match by the end of the period, ensuring a high magnitude of $\alpha_1^{1,t}$. The value of a marriage between a young man and an old woman – both of non-ideal age – is less in magnitude because one party (the young man's parents) do not face the imminent social pressure $s$ and both parties suffer the costs of a non-ideal marriage ($K < 1$).

To understand the process of matching and payments-determination under $(*)$, consider the following example.

**Example 1.** *Competitive Equilibrium*

*Suppose* $(*)$ *is true in the period* $t$ *and that the marriage market structure in period* $t$ *is given by* $f_1^t < m_1^t < m_1^t + m_0^t < f_0^t + f_1^t$.

*Figure 1 represents the demand for and supply of men in period* $t$*, along with the equilibrium assignment and payments in competitive equilibrium.*

*In the current example, eligible women outnumber eligible men in period* $t$*; hence women will have to bid for their partners in equilibrium. Since* $\alpha_0^{0,t} < 0$*, young men do not match with young women. Also, since old women are the 'high-surplus' female agents* ($\alpha_1^{1,t} > \alpha_0^{1,t}$ *and* $\alpha_1^{0,t} > \alpha_0^{0,t}$)*, they can outbid younger women for a match. Hence, the older women will be matched before young women in a competitive equilibrium. Similarly, since old men are the 'high-surplus' male agents* ($\alpha_1^{1,t} > \alpha_1^{0,t}$ *and* $\alpha_0^{1,t} > \alpha_0^{0,t}$)*, older men will be matched before young men in a competitive equilibrium.*

*What are the period–*$t$ *marriage payments in the competitive equilibrium? There are not enough men in the market for all women, but sufficient men for the older women who are matched first* ($f_1^t < m_1^t$)*. Hence, in the competitive equilibrium, some young women will fail to find a match. So young women bid their entire surplus away as dowry, making them indifferent between marrying or not. Older women are guaranteed a match as long as the (older) men are indifferent between young and older brides. To ensure this indifference, older women offer a higher dowry than young women (recall men's preferences* *in (2)). Since older women are the high-surplus agents, this higher dowry is feasible for them to pay.*

*The equilibrium assignment matches all old men and women, and some young women. No young man finds a match.*

*In summary, (old) men are able to capture the entire marital surplus of young women thereby retaining the entire value $\alpha_0^{1,t}$ of the marriage. However, they are unable to capture the entire higher value $\alpha_1^{1,t}$ of the marriage with older women. This outcome follows from the (assumed) configuration of the marriage market: $f_1^t < m_1^t$.*

It is easy to see (e.g. from Figure 1) that whenever $(*)$ is true, the process of matching must embody the following properties (regardless of the explicit marriage market structure): (1) young men do not marry young women; (2) young men marry old women only if the expected marriage market returns in the next period are such that $\alpha_1^{0,t} > 0$; and (3) old women (old men) are matched before young women (young men). Hence, in any period $t$, when the marriage market structure is represented by $(f_0^t, f_1^t, m_0^t, m_1^t)$, the equilibrium assignment $\{\mu_0^{1,t}, \mu_0^{0,t}, \mu_1^{1,t}, \mu_1^{0,t}\}$ must be given by the following functions:

$$\begin{aligned}
\mu_1^{1,t} &= Min(f_1^t, m_1^t) \\
\mu_0^{1,t} &= Min[f_0^t, \{m_1^t - Min(f_1^t, m_1^t)\}] \\
\mu_1^{0,t} &= \begin{cases} Min[m_0^t, \{f_1^t - Min(f_1^t, m_1^t\}] & \text{only if } \alpha_1^{0,t} > 0, \\ 0 & \text{otherwise.} \end{cases} \\
\mu_0^{0,t} &= 0
\end{aligned} \tag{7}$$

where $\mu_i^{j,t}$ (the equilibrium assignment) represents the measure of successful matches between women of age $i$ and men of age $j$ $(i, j = 0, 1)$ in period $t$.

Using (7), it is straightforward to compute agents' matching probabilities in any period $t$ as follows:

$$\begin{aligned}
p_i^{j,t} &= \frac{\mu_i^{j,t}}{f_i^t} \\
q_i^{j,t} &= \frac{\mu_i^{j,t}}{m_j^t}
\end{aligned} \tag{7'}$$

where $p_i^{j,t}$ $\left(q_i^{j,t}\right)$ represents the probability that a woman of age $i$ (man of age $j$) will match with a man of age $j$ (woman of age $i$) in period $t$ $(i, j = 0, 1)$.

Condition (1) is assumed to be true throughout the analysis. This is sufficient to generate the ranking of $\alpha_i^{j,t'}s$ in $(*)$ in every period, and hence, equilibrium assignments (matching probabilities) as in $(7)-(7')$ in every period. The next section demonstrates how the marriage market structure $(f_0^t, f_1^t, m_0^t, m_1^t)$ evolves with the population as matching and births occur in each period.

## 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 $\sigma$, and a 'matching rule' that specifies the measure of matches $\mu_{ij}$ of each type

$(i, j)$ in each period, it is possible to express the evolution of the population vector over time as a mapping $\phi$ (Pollak (1987)):

$$(F_0^t, F_1^t, M_0^t, M_1^t, u_{old}^t) = \phi(F_0^{t-1}, F_1^{t-1}, M_0^{t-1}, M_1^{t-1}, u_{old}^{t-1}) \tag{8}$$

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 $t$. Recall that the equilibrium assignment derived in (7) performs the the role of the 'matching rule' since it specifies the measure of successful matches $\mu_i^j$ of each type $(i, j)$ in each period, given the values of the exogenous parameters (Condition (1)) and the marriage market structure[12].

Following Pollak (1987), I define stable population equilibria as follows.

**Definition 6.** *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* $[(1+\widehat{r})\widehat{F}_0,\ (1+\widehat{r})\widehat{F}_1,\ (1+\widehat{r})\widehat{M}_0,\ (1+\widehat{r})\widehat{M}_1,\ (1+\widehat{r})\widehat{u}_{old}] = \phi(\widehat{F}_0, \widehat{F}_1, \widehat{M}_0, \widehat{M}_1, \widehat{u}_{old})$. *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.*

Pollak (1987) shows that stable population equilibria exist if the matching rule used to generate the mapping in (8) above satisfies certain properties. It is easy to show that the equilibrium assignment (7) satisfies these properties[13]. Note that Pollak focuses on the existence of stable 'total' population equilibrium $(F_0^t, F_1^t, M_0^t, M_1^t)$. But here the focus is on the path of marriage market participants $(f_0^t, f_1^t, m_0^t, m_1^t)$. In the following definition and proposition, I establish the link between the two in the long run[14].

**Definition 7.** *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 upto a constant factor.*

**Proposition 1.** *: When the total population is in a stable population equilibrium growing at the rate* $(1 + \widehat{r})$*, the eligible population in the marriage market must also be in a stable (population) equilibrium growing at the same rate.*

Proposition 1 asserts that 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 – from (7) and (7′) – that matching probabilities $\{p_i^j; i, j = 0, 1\}$ and $\{q_i^j; i, j = 0, 1\}$ are also constant over time in a stable population equilibrium.

[12] See Appendix B.1 for a derivation of $\phi$ under the assumptions of the current model.

[13] 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.

[14] See proof of Proposition 1 in Appendix B.2.

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 provided in equation (9) below:

$$\begin{aligned} f_0^{t+1} &= b_{f1}^t(\mu_1^{1,t} + \mu_1^{0,t}) + b_{f0}^t \mu_0^{1,t} \\ m_0^{t+1} &= b_{m1}^t(\mu_1^{1,t} + \mu_1^{0,t}) + b_{m0}^t \mu_0^{1,t} \\ f_1^{t+1} &= f_0^t - \mu_0^{1,t} \\ m_1^{t+1} &= m_0^t - \mu_1^{0,t} \end{aligned} \tag{9}$$

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 equilibrium assignment (matching rule) in period $t$ as derived in equations (7) $(i, j = 0, 1)$.

Equations (9) 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. 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.

I now define a steady state equilibrium in the marriage market.

**Definition 8.** *The marriage market is in a* ***steady state equilibrium*** *when equilibrium 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.*

Lemma 2 outlines the properties of steady-state demographic configurations $(f_0^t, f_1^t, m_0^t, m_1^t)$, when Condition (1) is true[15].

**Lemma 2.** *Suppose Condition (1) is true and the sex ratio is exogenously given. Then, in any non-trivial steady state equilibrium $(f_0^t, f_1^t, m_0^t, m_1^t)$, the following must be true:*

$$f_1^t \geq m_1^t \Rightarrow \alpha_1^0 < 0$$

We know from Lemma 1, that young men will never match with young women $\left(\alpha_0^{0,t} < 0\ \forall\ t\right)$. Lemma 2 asserts that in any *steady state equilibrium*, young men will not match with old women either. This follows because whenever there are old women available for young men to marry (after old men have been matched, i.e. $f_1^t \geq m_1^t$) the associated expectations from postponing marriage are such that young men are unwilling to marry old women $(\alpha_1^0 < 0)$. Conversely, when young men *are* willing to marry old women $(\alpha_1^0 > 0)$ there are no old women available for them to marry (after old men have been matched, i.e. $f_1^t < m_1^t$).

The intuition is straightforward. Recall that in any period $t$, the value of marriage $\left(\alpha_1^{0,t}\right)$ between a young man and an old woman is the sum of the surpluses accruing to

[15] See proof in Appendix C.1.

the young man's parents and the old woman's parents. In a steady state equilibrium, the value, $\alpha_i^j$, is the same in every period[16].

Consider the surplus $\left(v_1^{0,t}\right)$ to parents of old women in any period $t$. Parents of old women receive a negative utility from marrying them off to young men because both bride and groom are of the non-ideal age. However, if the cost $s$ of never finding a partner is very high, old women might still be willing to match with young men and even pay a price for it. Condition (1), however, imposes an upper limit on the magnitude of $s$, which prevents situations in which parents of old women might 'buy out' young men, convincing them to marry. Thus Condition (1) ensures that $v_1^{0,t}$ is low in magnitude.

Now consider the surplus $\left(V_1^{0,t}\right)$ in period $t$ to parents of young men. They too receive a negative utility from marrying off their young sons to old women, since both parties are of non-ideal age. Moreover, young men have another period to look for a partner, in which they mature into the ideal age of marriage for men. Hence, the expectation of marital returns in the next period plays an important role in determining the magnitude of the surplus $V_1^{0,t}$ that accrues to parents of young men.

What are the expected returns to young men from postponing marriage? This depends on the demographic configuration in the next period. Suppose $f_1^t \geq m_1^t$ in a steady state equilibrium. This means that there are old women available for young men to marry after the old men have been matched (recall (7)). But, in such a steady state equilibrium all old men are guaranteed to find a match and will be paid a dowry by old women (who are in excess supply). Being guaranteed a match with dowry at the ideal age means that postponing marriage assures a very good marriage market outcome for young men; which ensures, in turn, that their steady-state surplus ($V_1^0$) from marrying now is low. Hence, $V_1^0$ is highly negative, ensuring $\alpha_1^0 < 0$.

Conversely, suppose $\alpha_1^0 > 0$ in steady state, so young men are willing to match with old women. This happens when young men's expectations of returns from postponing marriage is low. Recall that low expectations from postponing marriage follow from a positive probability of not finding a match (and paying bride price), which corresponds to a configuration of the type: $f_0^t + f_1^t < m_1^t$. But the relative scarcity of women that leads to this situation ($f_0^t + f_1^t < m_1^t \Rightarrow f_1^t < m_1^t$) also ensures that there *are* no old women available for young men to marry now.

Combined together, the results of Lemma 1 and Lemma 2 establish the following properties of any steady state equilibrium: (1) young men do not participate in marriage; hence the marriage market consists of only one type (old) of men and two types (old and young) of women; (2) old men and old women are matched before old men and young women (see (7)). Keeping this in mind, it is possible to outline the exhaustive set of demographic configurations that may be sustained in steady state: Corollary 1[17].

**Corollary 1.** *Suppose Condition (1) is true and the sex ratio is exogenously given. Then, there are five possible demographic configurations consistent with a non-trivial steady*

[16] Dropped time superscripts denote values that are constant over time in steady state.

[17] See proof in Appendix C.2.

*state equilibrium. These are:*

$$\begin{array}{lcl} (a)\ f_1^t & > & m_1^t > 0 \\ (b)\ f_1^t & = & m_1^t < f_1^t + f_0^t \\ (c)\ f_1^t & < & f_1^t + f_0^t = m_1^t \\ (d)\ f_1^t & < & f_1^t + f_0^t < m_1^t \\ (e)\ f_1^t & < & m_1^t < f_1^t + f_0^t \end{array} \qquad (**)$$

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, I allow the birth rates and sex ratio to be endogenously determined by expected marriage market outcomes.

### 2.3. Choice of Sex Ratio

The assumptions relevant for this section are summarized under Fertility Assumptions. The utility function of a just–married agent in period $t$ is given by:

$$U^{marr,t} = c^t + E_f^{t+1} b_f^t + E_m^{t+1} b_m^t - (b_f^t - b_m^t)^2 \qquad (10)$$

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 $t$[18].

Equation (10) 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 in parents[19]. (10) indicates that a married agent receives utility from her own consumption as well as from the measure of boys $(b_m^t)$ and girls $(b_f^t)$ born to the couple, where the benefit of having a child of gender $g$ is the expected marriage market surplus $(E_g^{t+1}, g = f, m)$ 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 of choosing to skew the sex ratio $(\frac{b_m^t}{b_f^t})$ 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

[18] Siow and Zhu (2002) use a quadratic cost of parental investment in offspring's 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.

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

the cost of doing so is infinitely high. This would constitute 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 – 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 $(E_g^{t+1})$[20].

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, $E_g^{t+1}$ – or the expected marriage surplus from an offspring of gender $g$ – 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 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 $(K, s, \beta)$, expected marriage payments (which are also functions of $K, s, \beta$ in equilibrium) and probabilities of finding a match in each period of the offspring's life[21]. In particular, it is is easy to show that

$$\begin{aligned} E_f^{t+1} &= E_t[\overline{p}_0^{t+1}\{K(1+\beta)+\beta s - D_0^{1,t+1}\} + \beta(1-\overline{p}_0^{t+1})\overline{p}_1^{t+2}\{K+s-1-D_1^{1,t+2}\}] \quad (11) \\ E_m^{t+1} &= E_t[\overline{q}_0^{t+1}\{(K-2)(1+\beta)+\beta s + D_1^{0,t+1}\} + \beta(1-\overline{q}_0^{t+1})\overline{q}_1^{t+2}\{K+s-1+D_1^{1,t+2}\}] \end{aligned}$$

where $E_t[.]$ denotes the expectation function based on information in period $t$, $\overline{p}_i^{t+k}$ $(\overline{q}_j^{t+k})$ 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 between a woman of age $i$ and a man of age $j$[22]. Matching probabilities $\overline{p}_i^{t+k}$ and $\overline{q}_j^{t+k}$ are derived directly from $(7')$ as $\overline{p}_i^{t+k} = p_i^{0,t+k} + p_i^{1,t+k}$ and $\overline{q}_j^{t+k} = q_0^{j,t+k} + q_1^{j,t+k}$ $(i, j = 0, 1)$.

Note that parents are assumed to base their sex ratio decision on the marriage market *surplus* from offspring $(E_g^{t+1})$, rather than the *total* utility they expect to receive. This is because they are guaranteed a return of $[w + \beta(w - s)]$ from offspring regardless of their gender; hence parents care only about the additional returns that their children will earn in the marriage market. However, the results of this paper do not change even if total utilities are used to define parental preferences instead of $E_g^{t+1}$. Since $E_g^{t+1}$ represent marriage *surpluses*, the optimization behavior of agents will ensure that $E_f^{t+1} \geq 0$, $E_m^{t+1} \geq 0$.

[20] Two alternative forms of $U^{marr}$ may be used in place of (10): (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 $\theta_g$ 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 $(\beta E_g)$ 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.

[21] Edlund (1999) exploits a similar idea, albeit in a different modeling 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 have no exogenous sex preference; instead, gender preference and hence the optimal sex ratio depends entirely on marriage market incentives.

[22] (11) has been explicitly derived in Appendix D.1.

The assumption that couples have all their children in their 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:

$$\underset{b_f^t, b_m^t}{Max}\ [c^t + E_f^{t+1} b_f^t + E_m^{t+1} b_m^t - (b_f^t - b_m^t)^2] \tag{12}$$

subject to the constraints,

$$b_f^t + b_m^t \leq \rho_i;\ b_f^t \geq 0;\ b_m^t \geq 0 \tag{13}$$

I shall now define a steady state general equilibrium.

**Definition 9.** *A* ***steady state general equilibrium*** *is obtained when the following conditions are true:*

*i. the total population and the eligible marriage market population are in stable population equilibrium (Definitions 6, 7),*

*ii. the marriage market is in a steady state equilibrium (Definition 8), and*

*iii. 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.*

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

The following proposition is then true[23].

**Proposition 2.** *There is no non-trivial steady state general equilibrium compatible with the condition* $|E_f - E_m| \geq 4\rho_0$. *When* $|E_f - E_m| < 4\rho_0$, *any non-trivial steady state general equilibria has the following properties:*

*1. Mothers choose to have as many offspring as their total fertility* ($\rho_i;\ i = 0, 1$) *allows:*

$$b_{fi} + b_{mi} = \rho_i$$

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

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

$$\sigma_1 = \begin{cases} \frac{4\rho_1 - (E_f - E_m)}{4\rho_1 + (E_f^t - E_m^t)}\ \epsilon\ (0, \infty) & \text{if } |E_f - E_m| < 4\rho_1 < 4\rho_0 \\ 0 & \text{if } 4\rho_1 < |E_f - E_m| < 4\rho_0 \text{ and } E_m < E_f \\ \infty & \text{if } 4\rho_1 < |E_f - E_m| < 4\rho_0 \text{ and } E_m > E_f \end{cases}$$

[23] See proof in Appendix D.2.

The proof and intuition of Proposition 2 is provided in Appendix D. Notice, at the interior solutions in statement (2) above, that $\sigma_i$ increases (decreases) with declines in total fertility $\rho_i$ 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.

Having now presented all three components of the dynamic general equilibrium model, it is important to underline the links between the models of sex-ratio choice (Section 2.3), the marriage market (Section 2.1) and population evolution (Section 2.2).

The solution to the problem of sex-ratio choice in period $t$ [(12) – (13)] yields the optimal sex ratio ($\frac{b_m^t}{b_f^t}$) as a function of $E_f^{t+1}$ and $E_m^{t+1}$ [Proposition 2]. But the values of $E_f^{t+1}$ and $E_m^{t+1}$ [(11)] are derived from marriage market outcomes, viz. expected marriage payments $\{D_i^{j,t+k}\}$, and matching probabilities $\{\overline{p}_i^{t+k}, \overline{q}_j^{t+k}\}$ in the future ($k = 1, 2$). Moreover, the endogenous birth rates $\{b_m^t, b_f^t\}$ themselves govern the evolution of the population [(9)]. Endogenization of the sex ratio therefore allows a feedback mechanism from marriage market outcomes to demographic outcomes. The evolution of the population, in turn, feeds the expectations of marriage market outcomes by determining matching probabilities [(7)] and payments in the future (recall that payments are determined competitively based on the relative numbers of available brides and grooms).

In a steady state general equilibrium, the cohorts of eligible brides and grooms replicate by a constant factor every period [Proposition 1]; hence $\overline{p}_i, \overline{q}_j, D_i^j$ (for all $i, j = 0, 1$) – and therefore, $E_f$ and $E_m$ – 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 following section provide numerical illustrations of how the composite model described above functions.

### 2.4. How the Model Works: Numerical Illustrations

**Example 2.** *Steady State Equilibrium*

*Assume that the cost of skewing the sex ratio is infinitely high; hence sex ratios and birth rates are exogenous. For concreteness, suppose $\sigma = 2$, $b_0 = 1$ and $b_1 = 0.67$, where $b_i$ is the measure of female children born to mothers of age $i$ and $\sigma$ is the (male/female) sex ratio at birth. Also suppose $K = 0.75$, $s = 5.25$ and $\beta = 0.5$. Note that the parameter values satisfy Condition (1); hence Lemmas 1 and 2 are true.*

*It is easy to show that $f_1^t = 0$ and $f_0^t = 0.5m_1^t$ will define a stable population equilibrium of marriage market participants, with a growth rate of $(1 + \widehat{r}) = 1$[25]. (Notice that*

[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 $E_t[\overline{q}_i^{t+1}] = \overline{q}_i^t = \overline{q}_i$ ($i, j = 0, 1$).

[25] Note that $F_0^t = f_0^t$, $M_0^t = m_0^t$, $F_1^t = f_0^{t-1}$, $M_1^t = m_0^{t-1}$. Hence, the stable population equilibrium structure of the *total* population is the same as that of marriage market participants.

*this equilibrium corresponds to configuration* $(d)$ *stated in* $(**)$*).*

*To see why, suppose that in period* $T$ *the demographic structure of the marriage market is as follows (consistent with* $f_1^t = 0,\ f_0^t = 0.5m_1^t,\ \sigma = 2$*):*

$$f_0^T = x;\ f_1^T = 0;\ m_0^T = 2x;\ m_1^T = 2x\ for\ some\ x > 0$$

*Using the equilibrium assignment (or matching rule)* $(7)$ *for the above marriage market structure, we see that* $\mu_1^{1,T} = 0,\ \mu_0^{1,T} = x,\ \mu_1^{0,T} = 0,\ \mu_0^{0,T} = 0$*. Now applying the population evolution equations* $(9)$*, we get*

$$f_0^{T+1} = x,\ m_0^{T+1} = 2x,\ f_1^{T+1} = 0,\ m_1^{T+1} = 2x$$

*Hence, the marriage market structure of period* $T$ *is replicated in period* $(T+1)$*. This satisfies the definition of a stable population equilibrium with growth rate* $(1+\widehat{r}) = 1$*.*

*Given the above marriage market structure, the (steady state) equilibrium marriage payments and surplus-distribution are determined by the model of marriage markets presented in Figure 2. Since* $(*)$ *is true, young men do not marry young women and old women are matched first. But there are no unmatched old women in the marriage market and the old men outnumber the young women in each period. Hence, old men bid their entire marriage surplus* $(V_0^1)$ *as bride price, ensuring that young women appropriate the entire marital surplus* $\alpha_0^1$ *in their marriage to older men (see Figure 2). This corresponds to young women receiving a bride price of* $(K+s) = 6$*. The equilibrium assignment pairs young women with older men. All the women find a partner whereas some older men and all young men remain unmatched.*

Now consider an example where $\sigma$ is endogenous.

**Example 3.** *Steady State General Equilibrium*

*Consider, for concreteness, the following parameter values:* $\rho_0 = 3,\ \rho_1 = 2,\ K = 0.2,\ s = 4,\ \beta = 0.25$ *(where* $\rho_i$ *is the total fertility of a woman of age* $i$*). Note that Condition (1) is satisfied, hence Lemmas 1 and 2 are true.*

*Then a non-trivial steady state general equilibrium exists (corresponding to configuration* $(e)$ *stated in* $(**)$*) and has the following characteristics* [26]*:*

$(a)$ *In the stable population equilibrium, the structure of the marriage market in each period is given by:* $f_1^t < m_1^t < f_1^t + f_0^t$*. 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:* $\mu_1^{1,t} = f_1^t;\ \mu_0^{1,t} = 0.787 f_0^t;\ \mu_0^{0,t} = \mu_1^{0,t} = 0$*. That is, in every period, young men are not matched and all old men are matched. All old women are married while only some (78.7%) young women find partners. The stable population grows at the rate* $(1+\widehat{r}) = 1.237$*. The above is true at the optimal birth rates and sex ratios derived in* $(c)$ *below.*

[26] See Appendix E for a detailed derivation.

($b$) *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 (positive) equilibrium payments are dowries.*

($c$) *The optimal maternal-age-specific birth rates and sex ratios are:* $b_{f0} = 1.38, \ b_{m0} = 1.62, \ \sigma_0 = 1.17, \ b_{f1} = 0.88, \ b_{m1} = 1.12, \ \sigma_1 = 1.27.$

*The intuition for why dowry is paid in equilibrium is exactly similar to that presented in Example 1 (Section 2.1.5) where the marriage market structure is assumed to be* $f_1^t < m_1^t < f_1^t + f_0^t$. *Here, this same recurring structure of the marriage market is generated by the male and female births* chosen *by parents in each period. Recall also, from Example 1 and* $(*)$, *that in the competitive equilibrium men are not able to capture the entire value of marriage with old women* $(\alpha_1^1)$, *but only the lower value of marriage with young women* $(\alpha_0^1)$. *This ensures that the magnitude of the equilibrium dowry is relatively low.*

*The expectation of dowry induces parents to express (endogenous) son preference by choosing more sons than daughters* $(\sigma_i > 1, \ i = 0, 1)$; *but the relatively low magnitude of expected dowry ensures that parents do not* overproduce *sons relative to daughters. The dowry equilibrium is, thus, sustained in the long run because the endogenous sex ratio is not so skewed as to generate an over-supply of grooms in future periods.*

*Formally, the matching probabilities and dowries stated in* ($a$) *and* ($b$) *determine* $E_f$ *and* $E_m$ *[(11)] and hence determine the sex ratio (or birth rates) chosen by parents [Proposition 2]. These sex ratios then determine the population and marriage market structure in the next period [(9)], which in turn yield equilibrium matching probabilities [(7)] and dowries such as in* ($a$) *and* ($b$).

# 3. Results

## 3.1. The Long-Run Equilibrium

Recall the exhaustive list of demographic configurations that may be sustained in a steady state equilibrium (see $(**)$, Corollary 1). Propositions 3 and 4 state the properties of long run equilibria when the sex ratio is exogenous (the benchmark case) and endogenous, respectively[27].

**Proposition 3.** *Suppose Condition (1) is true and that* ***the sex ratio 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* $\sigma$ *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.*

**Proposition 4.** *Suppose Condition (1) is true and that* ***parents choose the sex ratio*** *of offspring as in* $(12) - (13)$. *Then,*

[27] See proofs in Appendices F and G.

1. *the only demographic configuration that is consistent with a non-trivial steady state general equilibrium is $(e)$ (see $(**)$), and the equilibrium marriage payment is a dowry. The aggregate male-to-female sex ratio at birth $(\sigma)$ in this equilibrium is greater than 1.*

2. *at the non-trivial steady state general equilibrium,*

$$\sigma < (1 + \widehat{r}) + (1 - \overline{p}_0)$$

*where $\sigma$ denotes the equilibrium aggregate 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.*

### 3.1.1. Discussion: Intuition of the Results

Propositions 3 and 4 constitute the key result of this paper. Taken together, they imply that population growth rates (or fertility levels) matter for long-run marriage payments only in the benchmark case where the sex ratio $\sigma$ is exogenous[28]. However, when $\sigma$ is endogenously chosen based on the expected marriage market returns of boys and girls, any long run equilibrium must be characterized by dowry, regardless of the fertility level. The intuition of the results are discussed below.

The intuition of Proposition 3 follows from the law of supply and demand. The male-to-female sex ratio, $\sigma$, governs the measure of men in the marriage market, all of whom belong to the older cohort since young men do not participate in the marriage market (Lemma 2). But the women in the market can belong to both younger and older cohorts. The growth rate $(1 + \widehat{r})$ governs the size of the young cohort whereas $(1 - \overline{p}_0)$ – the proportion of young women who fail to find a partner when young – governs the size of the older cohort of unmarried women. Therefore, when $\sigma < (1 + \widehat{r}) + (1 - \overline{p}_0)$, there is an excess supply of women and hence dowry payments in steady state. The reverse inequality marks an excess supply of men and is associated with bride price[29]. Therefore, in the benchmark case where $\sigma$ is exogenously given, the inequality can hold either way depending on the fertility level (population growth rate), and hence both dowry and bride price regimes can potentially occur.

However, when $\sigma$ is *endogenous* (Proposition 4), it *must* be less than $(1+\widehat{r})+(1-\overline{p}_0)$ in equilibrium, whatever be the level of fertility. Hence any long-run equilibrium must have dowry payments. Furthermore, any long run equilibrium must be of the type $(e)$ (see $(**)$). To see the intuition of the finding, refer to Figures 1-3 and consider, individually, the cases $(a)$– $(d)$ in $(**)$.

Suppose $(a)$ is true in a steady state general equilibrium, i.e. $f_1^t > m_1^t > 0$ (Figure 3). This is possible only if the sex ratio at birth $\sigma$ is less than 1, viz. there are more women than men in any generation. This is because, if old women are paired first and they exceed the measure of eligible men $(f_1^t > m_1^t)$ then none of the young women can find

[28] Exogenous sex ratios occur when the cost – technical, psychological or social – of attempting to skew the sex ratio is infinitely high. Section 3.2 discusses the role of the cost of skewing the sex ratio.

[29] Example 2 in Section 2.4 demonstrates the existence of a steady state equilibrium with bride price.

a match in any period. This implies $f_1^t = F_0^{t-1}$. Also, if young men postpone marriage, then $m_1^t = M_0^{t-1}$. Hence, $(a)$ implies $\sigma^{t-1} = \frac{M_0^{t-1}}{F_0^{t-1}} = \frac{m_1^t}{f_1^t} < 1$ and since $\sigma^{t-1} = \sigma^t = \sigma$ in a steady state equilibrium, $(a)$ can be sustained only when the equilibrium sex ratio $\sigma < 1$.

Will parents choose a sex ratio $\sigma < 1$ in the steady state equilibrium? As demonstrated in Figure 3, when configuration $(a)$ prevails older men appropriate the entire value $\alpha_1^1$ of marriage with older women. Moreover all men are certain to find a match in their lifetime. Hence expected surplus from a son's marriage $(E_m)$ is high. Women, on the other hand, face the possibility of never finding a partner and bid away their entire marital surplus as dowry if they do find a match. Hence expected surplus from a daughter's marriage $(E_f)$ is zero. But $E_m > E_f$ implies that parents will choose more sons than daughter, resulting in $\sigma > 1$. This is a contradiction. Hence $(a)$ cannot be sustained in a steady state equilibrium.

An argument similar to the one above will reveal that $(b)$ cannot be sustained in a long run equilibrium either.

Suppose now that $(d)$ were true in steady state equilibrium (i.e. $f_1^t < f_1^t + f_0^t < m_1^t$, Figure 2). This implies $f_1^t = 0$ (because all women are matched when young) and $f_0^t + f_1^t = f_0^t < m_1^t$. Such a demographic structure may be replicated in every period only if the sex ratio $\sigma$ is *greater* than the equilibrium growth rate of the population, $(1+\widehat{r})$[30]. Since the male-female ratio $\sigma$ has to be sufficiently large to sustain an equilibrium like $(d)$ there must be an upper limit on the excess marriage market returns of women $(E_f - E_m)$ in equilibrium, because $\sigma$ varies inversely with it (Proposition 2). It may be shown, however (see Appendix G), that at the equilibrium marriage payments and surplus distribution implied by $(d)$, $(E_f - E_m)$ will be higher than this upper limit and $\sigma$ will be lower than that which can sustain an equilibrium like $(d)$. This is true because at an equilibrium of the form $(d)$, parents of old men will pay their entire marital surplus as bride price to parents of young women. Since the surplus to parents of old men is high (due to intense impending social pressures $s$ if their sons do not find a match), the magnitude of the bride price is high. Moreover, the high bride price is received by the parents of women who are at their ideal age of marriage, viz. 'young'. Since girls expect to find an ideal partner and earn a high bride price at their ideal age of marriage, the expected excess marriage surplus from girls $(E_f - E_m)$ is high and parents overproduce girls relative to boys. This prevents an equilibrium of type $(d)$ from being sustained in the long run.

A similar argument ensures that $(c)$ also cannot hold in a long-run equilibrium.

Hence $(e)$ $(f_1^t < m_1^t < f_1^t + f_0^t)$ is the only demographic configuration possible in equilibrium. Example 3 in Section 2.4 demonstrates numerically that a steady state equilibrium of the form $(e)$ exists under parameterizations consistent with Condition (1). I show in Appendix G that in an equilibrium of the form $(e)$, $\sigma$ is greater than 1 but less than $(1+\widehat{r}) + (1-\overline{p}_0)$, and the equilibrium marriage payment is a dowry. To see why, consider Figure 1, and the following argument.

First, in the configuration $(e)$, there are more eligible women than men in the marriage

[30] To see why, recall that the number of young women $(f_0^t)$ is governed by the growth rate $(1+\widehat{r})$ and the number of old men $(m_1^t)$ is governed by the sex ratio $\sigma$. Hence $(d)$ – which implies $f_0^t < m_1^t$ – implies $(1+\widehat{r}) < \sigma$.

market in each period. Second, parents of young women stand to gain a positive surplus ($v_0^1$) from marriage because 'young' is the ideal age of marriage for women. In equilibrium, there are enough men for all the old women (who are matched first), but not for all the young women. Thus parents of young women bid away their total surplus ($v_0^1$) enabling old men's parents to appropriate the entire marital surplus $\alpha_0^1$ ($= v_0^1 + V_0^1$) from marrying young women. Since the marital surplus of young women ($v_0^1$) is positive, the payment is a dowry.

Parents of old women must match the offer of young women to make men's parents indifferent to the age of the bride (i.e. ensure that men's parents receive a total surplus of $\alpha_0^1$ regardless of the bride's age). Since young brides are preferred to older brides, parents of the latter must offer a higher payment than young women in order to achieve men's indifference to the age of the bride. Hence, older women pay dowry too. This structure of payments and matching probabilities ensure that the marriage market returns of men exceed that of women ($E_m > E_f$), so parents choose more sons than daughters in equilibrium ($\sigma > 1$).

Notice that in a steady state equilibrium of type ($e$), women are assured of finding a partner in their lifetime. Moreover, the entire high surplus $\alpha_1^1$ of parents of old women is not extracted as payment, ensuring that women's parents expect to receive a positive surplus from their daughters' marriage. This implies that the expected marital surplus from daughters $E_f$ is strictly positive, which serves to lower the magnitude of the excess marriage market returns of men ($E_m - E_f$). Thus, the equilibrium male-female ratio, while skewed to be greater than 1, is not skewed so high that an excess supply of men results. This allows the dowry equilibrium to persist in steady state.

The discussion above demonstrates that while a bride price equilibrium cannot be sustained in the long-run, there exists a dowry equilibrium that can. The former is true because parents overproduce girls whenever they are expected to earn bride price. However, the dowry equilibrium in ($e$) can be sustained because boys are *not* overproduced despite the sex ratio being skewed in favor of males.

The next section asks if the above prediction would break down if the cost of sex-ratio choice is low, inducing parents to overproduce boys when dowry is expected.

### 3.2. Extension: Varying the cost of sex-ratio choice

With the widespread availability of sex-selective abortion techniques since the 1980s, the cost of biasing the sex ratio is expected to have fallen, making sex-ratio choice easier for parents. Will this skew the sex ratio sufficiently in favor of men to reverse the dowry equilibrium ($e$) (and the result of Proposition 4)? In this section I show that a low cost of skewing the sex ratio is a *sufficient* condition for the main result of this paper to hold.

Let $\tau$ be a cost parameter in the post-marriage period$-t$ utility function,

$$U^{marr,t} = c^t + E_f^{t+1} b_f^t + E_m^{t+1} b_m^t - \tau (b_f^t - b_m^t)^2, \qquad \tau > 0 \tag{14}$$

Suppose parents maximize (14) subject to constraints (13). Then it is easy to show that a reduction in the cost of sex-ratio choice ($\tau$) skews the optimal sex ratio in favor of offspring with the higher expected marriage surplus, i.e. the male-to-female ratio

$\sigma_i^t$ increases (decreases) with declines in $\tau$ if $E_f^{t+1} - E_m^{t+1} < 0$ ($E_f^{t+1} - E_m^{t+1} > 0$)[31]. This appears to suggest that a low value of $\tau$ may lead to an over-production of boys when dowry is expected (i.e. $E_f^{t+1} - E_m^{t+1} < 0$), thereby invalidating the result of Proposition 4. However, the following proposition asserts that this is not the case[32].

**Proposition 5.** *Suppose Condition (1) is true and that* ***parents choose the sex ratio*** *of offspring subject to the constraints* (13). *Suppose that the post-marriage utility function is given by* (14) *where* $\tau$ $(> 0)$ *represents the cost to parents of choosing to skew the sex ratio of offspring. If* $\tau < (1 + \beta)$, *then the only demographic configuration that is consistent with a steady state general equilibrium is* $(e)$ *(see* $(**)$*) and the equilibrium marriage payment is a dowry. The aggregate male-to-female sex ratio at birth* $(\sigma)$ *in this equilibrium is greater than 1.*

The intuition of Proposition 5 is as follows. A low cost of sex ratio choice ($\tau$) does not alter the set of feasible marriage market structures $(a) - (e)$ (in $(**)$), or the magnitudes of payments and $(E_f - E_m)$ associated with each of these structures. So, as before, bride price can only occur when the high surplus of older men's parents is extracted, resulting in a high magnitude of bride price and high $(E_f - E_m)$. A low $\tau$ then makes parents *more likely* to over-produce girls, which prevents the bride price equilibrium from being sustained in the long run. However, in a dowry equilibrium such as $(e)$, men's parents are unable to extract the entire marital surplus from high-surplus (older) women's parents. At the relatively low levels of dowry associated with such an equilibrium boys are not overproduced even at low $\tau$; hence such an equilibrium can persist in the long run[33].

Infinitely high values of $\tau$ correspond to the benchmark case of exogenous sex ratios, where population growth rates can play a role in determining the payment regime, viz. bride price or dowry (Proposition 3). Proposition 5 strengthens the finding that when sex ratios are endogenous ($\tau$ is low), population growth rates do not matter for determining long-run marriage payments; these payments must be dowries regardless of the fertility level. Proposition 5 also has an interesting corollary: it suggests that a high $\tau$ is a *necessary* condition for bride price to be sustained in equilibrium.

### 3.3. Model versus evidence

The table below compares the predictions of the model (Propostions 4 and 5) with current evidence on Indian marriage markets, where dowry has coexisted with active sex selection against girls. The match is noteworthy. Notice, especially, that the prediction appears to match the empirical evidence not only for variables of immediate focus, such as dowry and the sex ratio, but also for more general marriage market indicators such as universality of female and male marriage[34].

[31] See Lemma 3 in Appendix H.1.

[32] See Appendix H.2 for proof.

[33] Note that for a non-trivial equilibrium to exist, $\tau$ must be non-zero, else all parents will choose only boys or only girls according as $E_f \lesseqgtr E_m$.

[34] The data in the table are obtained from Tertilt (2004) and Goyal (1988).

| 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 |

Another test of the explanatory power of the mechanisms exploited in this paper is a check for consistency of the model's predictions with the recent history of marriage payments in India. The central result of the paper predicts that dowry and masculine sex-ratios constitute the only sustainable (monogamous) regime in the long run (Proposition 4). But bride price regimes were known to exist in certain monogamous regions in southern India in the early part of the twentieth century. Can the mechanisms of the model explain this phenomenon?

In the context of the model, there are two essential (exogenous) differences in Indian demography in the earlier and latter parts of the twentieth century. In the earlier part of the century, population growth rates were low (the Indian demographic transition began only in the 1930's) but the cost of sex-ratio choice was high (corresponding to crude methods such as infanticide). In the latter part of the century, population growth rates increased (and then fell) but the cost of sex-ratio choice declined unambiguously as modern 'easier' methods of sex-selection became available.

Note also that North India has been notorious for the widespread use of active sex-selection across the century. This includes evidence of rampant infanticide in the early years, now replaced increasingly by sex-selective abortion (Sudha and Rajan (1999)). Broadly speaking, therefore, North India could be classified as having a greater immunity to the pyschological costs of infanticide – or, in other words, an effectively lower cost of sex-selection – than South India, throughout the century[35].

If the cost of infanticide was very high in South India, it is reasonable to expect that the sex ratio was exogenous in the early years of the century when the only available technology for sex-selection was infanticide. Combined with a low population growth rate, Proposition 3 predicts that a bride price regime would prevail there in the early part of the century. This is indeed the case.

Since the cost of sex-selection was arguably low in the North throughout the century, Propositions 4 and 5 predict a dowry regime there throughout that time, regardless of the population growth rate. This is also consistent with evidence of payments from the North.

Finally, to the extent that the cost of sex-selection has decreased over time, the South too may have actively started to engage in sex selection in recent years. Proposition 4 then predicts that only a dowry regime can persist in these regions in the later years.

[35] The North is widely accepted in the literature as having a greater 'son preference' than the South across time (Bhatia (1978); Basu (1992)). Here we need only articulate a difference in the cost of sex-ratio choice in the North and the South. This is quite different from assuming greater 'son preference' in the North since the cost is symmetric – the same regardless of whether a boy or a girl is actively chosen.

Indeed, there is evidence that the bride-price-paying regions of the South have switched to paying dowry in more recent periods (Epstein (1973)).

Thus the predictions of the model align well with the recent history of payments' regimes in India. This suggests also that varying costs of sex-ratio choice could be a potential source of regional differences in payments' regimes and explain the recent switch to dowry documented in certain areas.

## 4. Summary and Conclusion

How can there be both dowries and 'missing women' in India? And will growing infanticide and sex selective abortion against females lead to the emergence of a bride price regime therein? These are important questions since India has a well-known and persistent "dowry problem" despite a multitude of efforts to curb the practice. At the same time, there are rising concerns about the widespread use of sex selective abortion against females that has led to an increasingly skewed sex ratio. The literature on marriage payments has largely ignored the two-way connection between such *endogenous* sex ratios and marriage market outcomes. This paper makes a contribution to this literature by providing an economic foundation for this connection, without assuming an exogenously given son preference.

Using an overlapping-generations dynamic general equilibrium framework, I outline three conditions – arguably reasonable descriptors of Indian society – under which dowry payments can persist in the long run even as active sex selection against girls is practiced. More importantly, I show that under these conditions, the *only* possible steady state equilibria are characterized by dowry payments and a masculine sex ratio. Moreover, a low cost of skewing the sex ratio is sufficient to generate this result: an important finding since with the advent and spread of sex-selective abortion techniques in India, sex-ratio choice is suspected to have become considerably easier for parents. Fertility levels matter for payment regimes only when sex ratios are exogenous, i.e. when the cost – technical, psychological or social – of sex ratio choice is infinitely high.

The analysis presented here focuses on a fundamental aspect of marriage markets – the relative numbers of brides and grooms – which is key in determining marriage payments in a competitive equilibrium. The innovation lies in explicitly allowing the incentives generated within the marriage market to impact the relative numbers of marriage market participants. The resulting model provides valuable insights on the interplay between marriage decisions and marriage-market-dynamics in India and makes a contribution to the literature in an area that has not been traversed before. In particular, it generates a remarkably accurate prediction that explains why women may have to pay for a groom even in the face of long-practised sex-selection against their favor.

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Figure 1: Demand-supply graphs (when $(*)$ is true): $f_1^t < m_1^t < f_1^t + f_0^t$

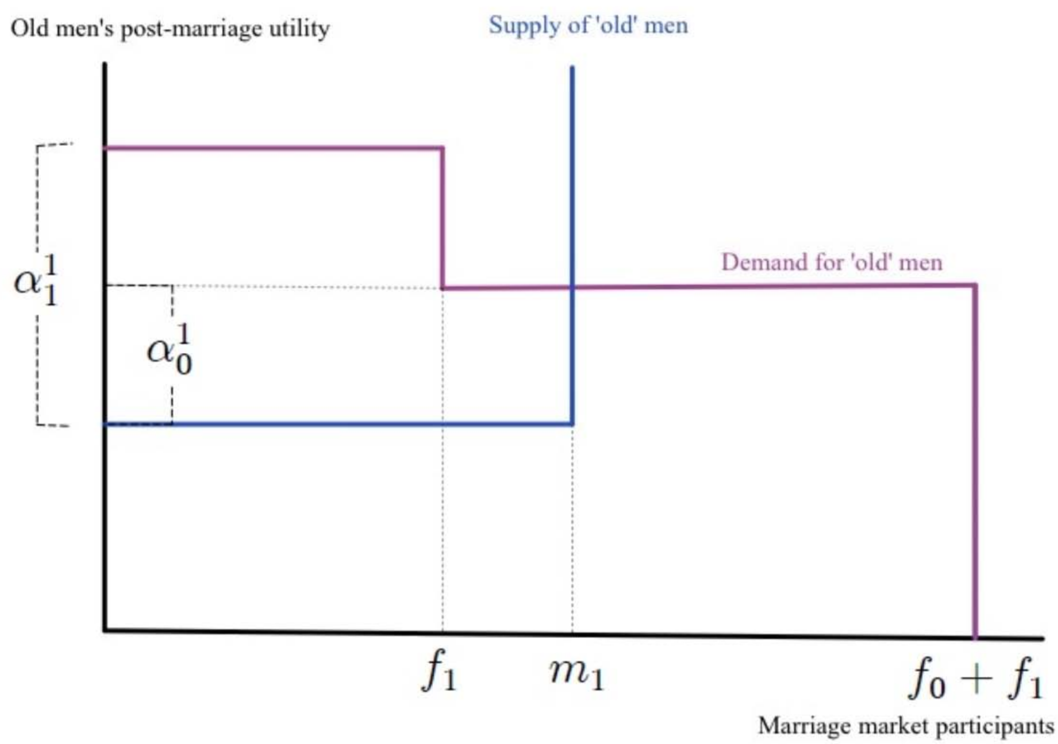

Figure 2: Demand-supply graphs (when $(*)$ is true): $f_0^t < m_1^t$ ($f_1^t = 0$)

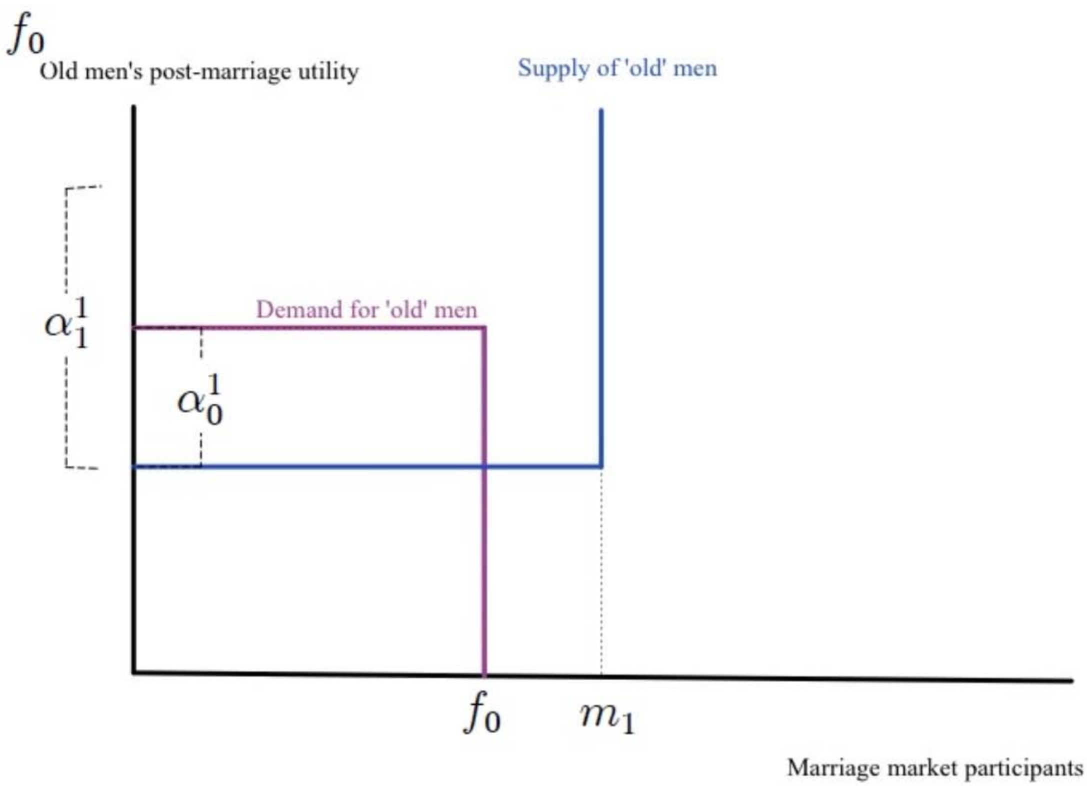

Figure 3: Demand-supply graphs (when $(*)$ is true): $f_1^t > m_1^t$