Population Growth and Rising Dowries: The Long-Run Mechanism of a Marriage Squeeze*

Sudeshna Maitra

Department of Economics

York University

1118 Vari Hall

4700 Keele Street

Toronto, ON M3J 1P3

Email: smaitra@econ.yorku.ca

Phone: 416-736-2100 Ext. 33233

Fax: 416-736-5987

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ABSTRACT

India has experienced a much-documented dowry inflation since the 1950s, which has been attributed to a spurt in population growth post-World War II. Will recent declines in fertility lead to a reversal of this trend and a regime of bride price? My paper develops a dynamic general equilibrium model of marriage markets, sex-ratio choice and population growth that is used to characterize the long-run relationship between population dynamics and marriage payments in India. I show that in the absence of exogenous sex preferences for offspring, and with no asymmetries between men and women except in desired ages of marriage (of self and spouse), *any* long run equilibrium will be characterized by an excess supply of brides, dowry payments and a masculine sex ratio. The result holds for parameters consistent with marriage market indicators in India.

Keywords: Dowry; Marriage squeeze; Population growth

JEL classifications: J11; J12; J16; D10

1. Introduction

Many traditional societies follow the practice of making transfers at the time of marriage. When the transfer is made from the bride to the groom, it is called a dowry, whereas the reverse transaction – from groom to bride – is called bride price. Both practices of dowry and bride price have been known to coexist in India (Epstein (1973), Billig (1991, 1992), Rao (1993), Dalmia and Lawrence (2005)). Typically areas in north India have followed the practice of dowry whereas regions of the south observed bride price. In the latter half of the last century, however, a real inflation of dowries has been observed throughout the country (Epstein (1973), Billig (1991, 1992), Rao (1993)). This has involved an increase in the real value of dowries in the regions where it was practiced as well as a switch to dowries in areas that used to pay bride price.

A popular explanation for the Indian dowry inflation is the marriage squeeze hypothesis (Caldwell et al (1982, 1983), Billig (1991, 1992), Rao (1993), Bhat and Halli (1999)), which attributes the rise in dowries to population growth. The argument runs as follows. Higher rates of population growth lead to larger numbers of younger relative to older cohorts in the population. When older men marry younger women, as is the case in India, this causes an excess supply of brides in the marriage market – or a marriage squeeze against women – causing a bidding up of the price of grooms. Hence dowry inflation occurs. The Indian population started to grow in the 1930s (see Table and Figure 1) and the dowry inflation was documented since the 1950s when babies of the population 'boom' would have reached marriageable age. Hence the marriage squeeze hypothesis appears to be a plausible explanation for the dowry inflation in India (Maitra (2006), Rao (1993))[1].

Recent trends in Indian demographics, however, suggest a de-intensification of the marriage squeeze against women. Fertility levels and crude birth rates have both been declining since the 1980s (see Table and Figure 2). Moreover, the sex ratio – which has always been skewed in favor of men (Sen (1992)) – has become even more masculine over the 1980s (see Table and Figure 3), the decade in

[1] The overall sex ratio in India has been skewed in favor of men throughout the past century. However, the correct indicator of a marriage squeeze is not the overall sex ratio but the ratio of men and women of marriageable age. Caldwell et al (1983) attempt to measure this ratio and conclude that a deficit of 4 million women in the marriage market in 1931 was replaced by a surplus of the same magnitude by 1971. Clearly, population growth in the last century has outweighed the initial bias in the sex ratio ensuring that the 'missing women' were not sufficient in number to ease the squeeze against women.

which ultrasound technology and sex-selective abortion techniques became widely available in India (Hutter et al (1996), Sudha and Rajan (1999)).

The recent decline in fertility levels and the widespread practice of sex-selective abortion against women lead naturally to the question – will the marriage squeeze against women reverse in the long run (Bhat and Halli (1999), Das Gupta and Shuzhuo (1999))? Will bride price then emerge as the dominant form of marriage payments in India?

The answers to these questions are of interest for at least three reasons. First, it is a well-documented fact that brides in India have been victims of domestic violence and even murder if unable to pay the exorbitant dowries demanded by their husbands (Bloch and Rao (2002)). Second, fear of high dowries leads parents to kill their daughters through either infanticide or sex-selective abortion methods (Sudha and Rajan (1999), Arnold, Kishor and Roy(2002)). Lastly, there is a substantial literature that suggests that an improvement in female bargaining power may lead to better outcomes in intra-household allocations (Thomas (1990), Hoddinot and Haddad (1995), Duflo (2003), Pitt et al (2003), Case and Ardington (2005)). Hence the question of the future of female bargaining power in the Indian marriage market is one that is worthy of investigation. Here I attempt to provide an answer.

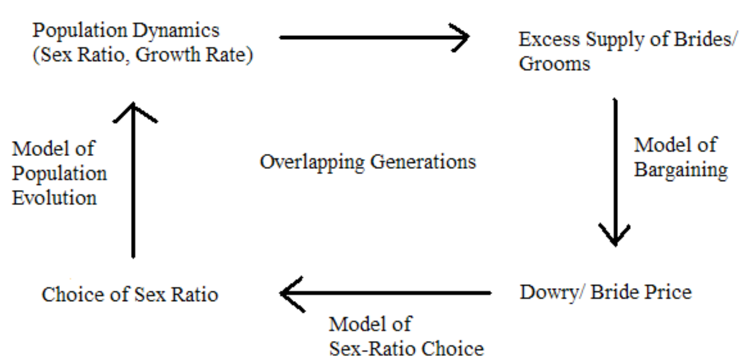
I show that when parents actively choose the sex ratio of offspring based on expectations of their marriage market outcomes in future, any long-run steady state equilibrium will be characterized by a marriage squeeze against women, the existence of dowry payments and a sex ratio that is skewed in favor of men. The result – which holds for parameter values consistent with Indian marriage market indicators – provides a remarkably accurate description of current marriage market conditions in India. In particular, it explains why dowry payments can persist even in the face of long-practised infanticide and feticide against women.

The result described above follows from a dynamic general equilibrium model (in an overlapping generations framework) that explicitly captures the two-way link between population dynamics and marriage market outcomes. Population dynamics can impact marriage payments by influencing the structure of the marriage market, viz. whether there is an excess supply of brides/grooms of the ideal marriageable ages[2]. This is the first link from population dynamics to the marriage market. However, expectations of future marriage market outcomes also play a

[2]The only asymmetry between men and women in the model lies in their 'ideal' age of marriage. Specifically, women prefer to marry young and prefer older men. Men prefer to marry when older and prefer younger women.

role in determining the optimal sex ratio of offspring that parents choose. For example, if dowries are expected to persist in the future, parents are likely to choose more sons than daughters, thereby skewing the sex ratio against women. This comprises the second link from marriage payments to population dynamics, since the sex ratio thus chosen determines the population structure (and hence marriage payments) in future periods. Figure A provides a diagrammatic representation of the two-way link and the composite model used in this paper.

Figure A: The Model



A long-run (steady state) general equilibrium occurs when population dynamics – the growth rate and the sex ratio – and marriage payments are the same over time.

I find that when the sex ratio is exogenous, the intuition of the marriage squeeze hypothesis is valid even in the long run. That is, there exist long-run equilibria with bride price when the fertility level is low, just as there exist dowry equilibria when the fertility level is high. To see how, consider an overlapping generations framework where agents can be young (age '0') or old (age '1'). When men marry later than women, the marriage market comprises men of age '1' and women of ages '0' and '1'. The number of men in the market is then governed by the male-to-female sex ratio σ. The number of young women (age '0') is governed by the growth rate of the population $(1+\widehat{r})$ and the number of old women (age '1') is driven by the proportion of young women who do not find a partner when young, $(1-\overline{p}_0)$.[3] There will be bride price in a long-run equilibrium if the number

[3] $\overline{p}_0$ is the proportion of young women who do find a partner when young (i.e. at age '0').

of men exceeds the number of women in the market (an excess supply of men), i.e. if $\sigma > (1+\widehat{r}) + (1-\overline{p}_0)$. This could occur when the fertility level and hence the growth rate $(1+\widehat{r})$ is low. Similarly, dowry payments will occur in a long-run equilibrium when $\sigma < (1+\widehat{r}) + (1-\overline{p}_0)$ (an excess supply of women) which may hold when the fertility level and hence $(1+\widehat{r})$ is high.

However, I show that when the sex ratio σ is endogenously determined based on expectations of future marriage market outcomes then $\sigma < (1+\widehat{r}) + (1-p_0)$, whatever be the level of fertility. In other words, any long-run equilibrium will be characterized by dowry payments, even at a low level of fertility. Since dowry is expected in future, parents wish to beget more sons than daughters and hence the equilibrium sex ratio σ is skewed in favor of men.

Why can bride price not be sustained in a long-run equilibrium when the sex ratio is endogenously determined by marriage market expectations? I show that whenever bride price is expected, parents overproduce girls relative to boys. This tips the balance against women in future periods, ensuring that bride price cannot persist in equilibrium.

Why then do parents not overproduce boys in the dowry equilibrium even when they choose to have more sons than daughters? The answer to this question lies in the relative lifetime returns from marriage of men and women.

Recall that since men marry late they receive only a single period return from marriage that is discounted because it occurs late. This imposes an upper limit on the expected marriage market returns of men – and hence the 'value' of a son – even when he is expected to earn a dowry at the time of marriage. But the upper limit on the value of a son imposes, in turn, an upper limit on the male-to-female sex ratio, σ, chosen by parents. This ensures that parents do not overproduce sons even when they choose more sons than daughters. Hence, dowry can be sustained in a long-run equilibrium even though bride price cannot.

With the advent of modern ultrasound and sex-selective abortion technology in India, sex ratio choice is expected to have become easier for parents (Das Gupta and Shuzhuo (1999)). Will the ease of sex-ratio selection – or a low cost of sex ratio choice – make parents overproduce boys when dowries are expected, thereby altering the result obtained above?

I show that low costs of sex ratio choice are a sufficient condition for the main result to hold. The reason is that the low cost does not alter the fact that men marry relatively late and get limited lifetime returns from marriage. This

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Hence, $(1-\overline{p}_0)$ is the proportion of women who return to the marriage market at age '1' to look for a spouse.

guarantees that there is an upper limit on the sex ratio σ and ensures that sons are not overproduced in the dowry equilibrium. However, bride price is even less sustainable at low costs of sex ratio choice since parents are more likely to overproduce daughters if bride price is expected!

The primary focus of the literature on the Indian dowry inflation has been to investigate if population growth may indeed have been responsible for the rise in dowries in the last century (Rao (1993, 2000), Edlund (2000), Dalmia and Lawrence (2005), Anderson (2005), Maitra (2006)). The emphasis has therefore been on the short run impact of a demographic marriage squeeze. This paper differs from the rest of the literature in that it focuses on the long run implications of population dynamics on marriage payments, specifically when marriage market outcomes also have an impact on demographics through sex-ratio selection. As the analysis demonstrates, using a general equilibrium framework is the key to the main prediction, which explains why dowries can persist even in the face of long-practised infanticide and feticide against women, as is widely observed in India.

The rest of the paper is organized as follows. In the next section, I outline the dynamic general equilibrium model described in Figure A. Section 3 discusses a suitable calibration of parameters that matches Indian marriage market indicators, and presents the main result pertaining to Indian marriage markets. In Section 4, I extend the analysis to allow a low cost of sex ratio choice. Section 5 summarizes and concludes the paper.

2. The Model

The dynamic general equilibrium model described in Figure A has three components – a model of marriage market bargaining and determination of marriage payments, a model of population growth, and a model of sex-ratio choice – which I shall present in order in the subsections that follow. I use an overlapping generations framework to analyze the marriage market and sex-ratio choices of agents, and Pollak's (1987) Two-Sex Birth-Matrix Mating-Rule Model with Persistent Unions to link the marriage market to population growth[4].

There are two groups of agents in the economy, males and females. Each agent lives for two periods. Agents of the same age and sex are identical. All single,

[4] 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.

never-married agents are in the marriage market in each period. Remarriage is not permitted. Parents are responsible for arranging their offspring's marriage[5]. In each period, therefore, parents of single (never-married) agents observe the number of potential spouses of each type (age) in the market and submit their offers of marriage payments and post-payments preferences for partners to a matchmaker. The matchmaker then matches agents based on these post-marriage-payments preferences and a matching rule that will be described below. After marriage, couples 'choose' the number of male and female offspring based on the expected surpluses that their offspring will earn in the marriage market in future.

In the following subsections, I describe the model of marriage market bargaining and determination of payments.

2.1. Marriage Market

2.1.1. Preferences

Preferences are common knowledge to all agents. Since parents arrange the marriages of their offspring, these may be interpreted as the utility from marriage ascribed to agents by their parents.

Let U_i denote the period utility of agents of age i when single, where $i = 0\ (young), 1\ (old)$. Then,

$$\begin{aligned} U_0(c) &= c \\ U_1(c) &= c - s \end{aligned} \qquad (M1)$$

where c is consumption in the current period and s is the cost of being single in old age. s can be attributed to social pressures to be married and loneliness in old age.

Let U_i^g denote the period utility from marriage of an agent of sex g and age i. The specific form of the marital utility function is[6]:

$$\begin{aligned} U_i^f(c,i,a) &= c + K - (i-0)^2 - (a-1)^2 \\ U_i^m(c,i,a) &= c + K - (i-1)^2 - (a-0)^2 \end{aligned} \qquad (M2)$$

[5] The norm of arranged marriages is widely prevalent and accepted in India (Dasgupta and Mukherjee (2003), Raman (1981)).

[6] Anderson (2005) uses similar marital utility functions to model the short-run mechanism of a marriage squeeze. Bergstrom and Lam (1991) also use a similar utility function to demonstrate how a marriage squeeze 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.

where $i = 0$ (*young*), 1 (*old*), a denotes the age of the spouse at the time of marriage, c denotes consumption in the current period and K (> 0) denotes the utility from marriage, viz. companionship and the social network effects of an extended family. If married young, agents receive a lifetime utility of $[U_0^g(c_0, i, a) + \beta U_0^g(c_1, i, a)]$ (where β is the discount factor and c_t denotes the consumption chosen in period t) regardless of whether the spouse is living or dead in the second period of marriage. In other words, having been married entitles agents to the social network effects of an extended family even when the spouse is not living.[7]

Each agent earns a wealth w in each period. In order to detract from issues of saving and borrowing, I assume that w is perishable and high. The budget constraint is derived in Section 2.1.2, after an exposition of the structure of marriage payments.

The marital utility functions U_i^g demonstrate agents' preferences for own and spouse's age at marriage. Other things equal, men prefer to marry at age 1 and women at age 0. Also, men prefer to marry younger women whereas women prefer to marry older men. Possible reasons for women preferring to marry young and men preferring young women could be the higher fertility of the latter, and, in a largely patrilocal society such as India, their greater potential to adapt to the ways of the groom's family (Epstein (1973)). Men could prefer to marry later because they seek to maintain a desired age difference between themselves and their spouse as this helps to maintain a favorable balance of power in the relationship (Jensen and Thornton (2003)). Women could prefer to marry older men because of the latter's 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. In this model, however, I make the simplifying assumption that all agents earn the same wealth in every period, hence I justify women's preference for older men to be a result of the latter's higher standing in society (compared with younger men).

2.1.2. Marriage Payments

Marriage payments D are made in the period of marriage and may not be jointly consumed by both spouses . By convention, let $D > 0$ denote a dowry paid by the bride to the groom and $D < 0$ denote a bride price paid by the groom to the

[7] Relaxing this assumption and allowing agents a utility of c when the spouse is not alive does not change the qualitative results of the paper.

bride. Then the budget constraints in the period of marriage are:

$$\begin{aligned} c &= w - D, \ for\ the\ bride \\ c &= w + D, \ for\ the\ groom \end{aligned} \tag{M3.1}$$

In all other periods, the budget constraints are:

$$c = w, \ for\ all\ agents \tag{M3.2}$$

Let v_i^j denote the pre-payments marriage surplus of a woman of age i married to a man of age j and V_i^j denote the pre-payments marriage surplus of a man of age j married to a woman of age i. For old agents, this is the utility from marrying an agent of a particular type (age) less the utility of remaining single at the end of the period. Using $(M1)$, $(M2)$ and $(M3)$, I derive,

$$\begin{aligned} v_1^j &= U_1^f(w,1,j) - U_1 = K + s - 1 - (j-1)^2 \\ V_i^1 &= U_1^m(w,1,i) - U_1 = K + s - (i-0)^2 \end{aligned} \tag{M4.1}$$

For young agents, the pre-payments surplus is 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 β). I shall denote agents' expectations of future marriage returns by X^g, where g denotes the gender of the agent. The specific form of X^g depends on demographic structure.[8] Hence,

$$\begin{aligned} v_0^j = U_0^f(w,0,j)(1+\beta) - [U_0 + \beta X^f] = (w + K - (j-1)^2)(1+\beta) - [w + \beta X^f] \\ V_i^0 = U_0^m(w,0,i)(1+\beta) - [U_0 + \beta X^m] = (w + K - 1 - (i-0)^2)(1+\beta) - [w + \beta X^m] \end{aligned} \tag{M4.2}$$

Definition 1. *A payment made in a marriage of a woman of age i and a man of age j $(i, j = 0, 1)$ is feasible when $D_i^j \leq v_i^j$ and $-V_i^j \leq D_i^j$. Henceforth, I shall refer to these inequalities as feasibility constraints. Feasibility requires that each agent earns at least as much as her/his reservation utility upon marriage.*

Definition 2. *An agent is eligible to marry if she is single and has never been married before.*

Definition 3. *A marriage market participant is an eligible agent whose feasibility constraints are satisfied at the offered payments.*

[8] See equations $(D.1)$ and $(D.2)$ in Appendix D for a derivation of X^g in equilibrium, for a specific demographic case.

2.1.3. Search for Partners and the Matching Rule

Let us focus on a social planner's matching outcome, viz. a matching rule that maximizes the total marital surplus of married agents in each period. In the framework described below, I shall use a specific matching rule that achieves the social planner's matching outcome in equilibrium. The results obtained will be true for all matching rules that generate the same equilibrium outcome, viz. that maximize the total marital surplus of married agents.

In each period, parents of eligible agents observe the number of potential partners in the market and submit their schedule of marriage payments along with their post-payments preferences for partners to the matchmaker. The latter then matches agents according to a rule that is specified below and is common knowledge to all agents.

In agents' (post-marriage-payments) ranking of preferences for potential partners, let '1' denote the first preference, '2' denote the second preference and so on. In case of indifference between potential partners who would have taken ranks $\kappa, (\kappa+1), ..., (\kappa+n)$ in the preference ordering, let each of these agents receive a rank of $[\frac{\kappa+(\kappa+1)+...+(\kappa+n)}{n+1}]$. Let $F(x,y)$ denote the rank of male y in female x's preferences and $M(x,y)$ denote the rank of female x in male y's preferences. Also, let (x,y) denote a match between a woman x and a man y.[9] Then, the matching rule is as follows:

i. Matchings (x,y) occur in increasing order of $r(x,y) = F(x,y) + M(x,y)$, i.e. the (x,y) with the minimum $r(x,y)$ is matched first and then the rest in increasing order of magnitude.

ii. In case of equal $r(x,y)$, matches with the highest total (pre-payments) surplus from marriage occur first. [10]

iii. In case of identical total surplus from marriage, matching is random.

[9] Note that in this model, the actions of agents x and y are completely identified by their ages. I refrain from labeling x and y as ages, however, to demonstrate the applicability of the matching rule even when agents behave sub-optimally (e.g. if some agents choose to behave differently from others of the same sex and age).

[10] The total marriage surplus in a marriage of a woman x and a man y is the sum of the (pre-payments) marriage surplus that accrues to x from marrying y and that which goes to y from marrying x. Since marriage surpluses depend only on sex and age in this model, if x is of age i and y is of age j, then the total marriage surplus when they marry is $S_i^j = (v_i^j + V_i^j)$.

The above rule specifies the order in which the matchmaker pairs agents. Agents who express 'strict' preferences for partners (as represented by $r(x, y)$) are paired first. When agents are indifferent to the type of spouse, groups with higher (pre-payments) marital surpluses are matched first. Among individuals with the same marital surplus, matching occurs at random.

Note that the above matching rule is exhaustive, i.e. it does not leave marriage market participants of both sexes unmatched.

I now define an equilibrium of marriage payments as follows.

Definition 4. *An equilibrium (Nash) of marriage payments is a vector of feasible marriage payments $\{D_i^j\}$ from which no agent has an incentive to deviate. Each agent of the same age and sex is identical and hence offers to pay/receive the same marriage payments in equilibrium.*

Definition 5. *An* equilibrium matching rule *is a rule that specifies the order in which agents are matched when the latter offer (Nash) equilibrium marriage payments. This rule typically involves random matches among identical individuals.*

The following propositions are then true:[11]

Proposition 1. *Let m and f denote the number of eligible men and women in the marriage market in any period. Suppose the following demographic conditions are true:*

(a) *$m \neq f$, i.e. there are some agents in the market who are* not *guaranteed a match that meets the reservation utility*

(b) *The numbers of men and women with the highest (pre-payments) marriage surpluses are not equal to each other or to the total number of prospective partners in the market.*

Then agents whose types are matched in equilibrium with both types of the opposite sex must offer (receive) payments that make them indifferent to the type of their spouses. Further, if the matching rule leaves some young agents matched and some unmatched, then the former's marriage payments must be such that make them indifferent between marrying now and marrying later.

[11] A discussion of Propositions 1 and 2 is provided in Appendix A.

Proposition 2. *When conditions (a) and (b) above are true, the equilibrium in marriage payments is unique and so is the equilibrium matching rule. When condition (a) or (b) is violated, there may be multiple equilibria in marriage payments but the equilibrium matching rule is unique. In both cases, the unique matching rule matches high (pre-payments) surplus agents before low surplus agents thereby obtaining the social planner's matching outcome in which the total marital surplus of all agents is maximized.*

Note that the equilibrium matching rule satisfies the following axioms:

1. Non-negativity: The number of matches is non-negative.
2. Adding-Up: The total number of agents in any age-sex category is greater than or equal to the number 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: The equilibrium matching rule pairs high-surplus agents first and is continuous when the categories of high-surplus agents do not change over time.
5. Homogeneity: The equilibrium matching rule is homogeneous of degree one, when the categories of high-surplus agents do not change over time.

Pollak (1987) assumes the above properties of the matching rule in establishing the existence of stable population equilibria in the Birth-Matrix-Mating-Rule Model described in Section 2.2.

2.1.4. Example 1: Determination of Marriage Payments

Consider a simple static model in which the discount factor $\beta = 0$. Also suppose, for concreteness, that parameters s and K are in the range: $0 < s < 1$, $K > 2$.

In this static model, the pre-payments marriage surpluses of women can be derived from $(M4.1)$ and $(M4.2)$ as:

$$\begin{aligned} v_0^0 &= K - 1 \qquad (E1.1) \\ v_0^1 &= K \\ v_1^0 &= K + s - 2 \\ v_1^1 &= K + s - 1 \end{aligned}$$

From $(M4.1)$ and $(M4.2)$, the pre-payments marriage surpluses of men are:

$$\begin{aligned} V_0^0 &= K-1 \\ V_0^1 &= K+s \\ V_1^0 &= K-2 \\ V_1^1 &= K+s-1 \end{aligned} \tag{E1.2}$$

Since $0 < s < 1$, $K > 2$, we can show

$$\begin{aligned} v_0^1 &> v_1^1 > v_0^0 > v_1^0 > 0, \\ V_0^1 &> V_1^1 > V_0^0 > V_1^0 > 0, \\ S_0^1 &> S_1^1 > S_0^0 > S_1^0 \end{aligned} \tag{E1.3.1}$$

where $S_i^j = v_i^j + V_i^j$ is the total marriage surplus of a match (i, j).

The ordering of S_i^j in $(E1.3.1)$ ensures that the matchmaker pairs old men before young men and young women before old women, when agents are indifferent to the age of their spouse.

Let f_i (m_j) denote the number of eligible women of age i (men of age j) in the marriage market $(i, j = 0, 1)$. Let (i, j) denote a match between a woman of age i and a man of age j.

Consider the case where $f_0 < m_1 < m_1 + m_0 < f_0 + f_1$. This is an example where the total number of eligible women in the marriage market exceeds the total number of eligible men, so women have to bid for men in equilibrium. What are the marriage payments in equilibrium?

The matching rule indicated by $(E1.3.1)$ implies that the equilibrium marriage payments will be:

$$\begin{aligned} D_0^0 &= K+s-3 \;\; (\textit{no } (0,0) \textit{ matches in equilibrium}) \\ D_0^1 &= K+s-2 > 0 \\ D_1^0 &= K+s-2 > 0 \\ D_1^1 &= K+s-1 > 0 \end{aligned}$$

Discussion: In this example, the total number of eligible women exceeds the total number of eligible men, hence women will have to bid for their partners in equilibrium. Also, since young women are the 'high-surplus' female agents (see $(E1.3.1)$), they can outbid older women for a match. But recall, from the specification of the matching rule, that high-surplus women are paired first when men are indifferent to the age of women. Therefore, young women need only offer the amounts of dowry that make potential spouses indifferent to the age of their brides, i.e. $D_0^j = D_1^j - 1$. How much do older women offer? Since older women are low-surplus agents, they are matched *after* young women when the latter bid to make men indifferent to the age of their brides. This does not leave enough men in the market for all older women (since $m_1 + m_0 - f_0 < f_1$). Hence older women bid away their entire marriage surplus, v_1^j, as dowry.

Notice that there are two types of competition among agents in excess supply, here women. In this example, *within-group competition* among older women makes them give away their entire marital surplus as dowry. This happens because the parameter values, matching rule and marriage market demographics ensure that there are not enough men for all the older women in the market. The high-surplus young women do not engage in within-group competition since the matching rule ensures that they are matched first (when they offer enough to make men indifferent to the age of women) and that there are enough men for all women of age 0 ($f_0 < m_1 + m_0$). However, *between-group competition* implies that they have to match the offers made by older women, which is why younger women also pay a positive dowry in equilibrium.

It is easy to see that at the equilibrium payments the matching rule will indeed pair high surplus agents first. This is because at these payments all agents are indifferent to the age of their spouses. Thus the post-marriage-payments preference rankings submitted to the matchmaker look like:

$F(i,j)$	0	1
0	1.5	1.5
1	1.5	1.5

$M(i,j)$	0	1
0	1.5	1.5
1	1.5	1.5

So, $r(0,0) = r(0,1) = r(1,0) = r(1,1) = 3$

In equilibrium, therefore, the high-surplus agents (older men and younger women) are matched before others and matching among identical agents (of the same age and sex) is random. This ensures that all men and all young women are matched but some older women are left unmatched at the end of the period.

2.2. Population Dynamics

I use Pollak's (1987) Birth-Matrix Mating-Rule (BMMR) Model with Persistent Unions, to model the evolution of the population and connect it to marriage market decisions modeled in the previous section. As Pollak (1986, 1987, 1990) demonstrates, the existence, uniqueness and dynamic stability of population equilibria are often hard to establish analytically. I show in this paper that under certain (realistic) parametric calibrations, it is possible to narrow down the characteristics of dynamic steady state equilibria quite effectively.

The main constructs of Pollak's (1987) model are a matrix of female births to couples of each type (i, j), a (male/female) sex ratio at birth σ and a mating rule that specifies the number of matches μ_{ij} of each type (i, j) in each period. Using these, he shows that the evolution of the population vector and the 'old unions' vector (defined below) over time can be expressed as a mapping[12],

$$(F_0^t, F_1^t, M_0^t, M_1^t, u_{old}^t) = \phi(F_0^{t-1}, F_1^{t-1}, M_0^{t-1}, M_1^{t-1}, u_{old}^{t-1}) \qquad (P1)$$

where F_i^t (M_j^t) denotes the number of females of age i (males of age j) in the population in time t and u_{old}^t (the 'old unions' vector) denotes the vector of married agents in the population at the *beginning* of period t.[13]

Definition 6. *A stable population equilibrium in the above model 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.*

Definition 7. *Eligible marriage market participants* $(f_0^t, f_1^t, m_0^t, m_1^t)$ *are in a stable population equilibrium when in each period, this vector replicates itself upto a constant factor.*

I make the following assumptions to link Pollak's BMMR model to the model of marriage markets derived in the previous section. I assume that maximum total fertilities of couples are exogenously given and that all children are born in the first period of marriage of the couple. Pollak's (1987) original model allows remarriage – I redefine the mapping ϕ to incorporate the assumption of no remarriage made in a previous section.

Note that the assumption of instant birth of offspring has to be true for all other than $(0, 0)$ matches since one or the other spouse dies at the end of the first period of marriage. Hence this assumption really applies to $(0, 0)$ couples and states that they are impatient to conceive their children and partake of their benefits.

[12] See Appendix B.1 for a derivation of ϕ in the context of this model.

[13] Agents in the 'old unions' vector are not in the pool of eligible marriage market participants in period t. Matches that occur in period t enter the old unions vector in $(t + 1)$.

The analysis in this section assumes that birth rates and the sex ratio at birth σ are constant over time. These assumptions will be relaxed later.

The following proposition is then true[14].

Proposition 3. *: 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 3 implies that in a stable 'total' population equilibrium, the age-sex composition of eligible marriage market participants is also fixed over time. Hence agents' expectations of future matching probabilities will be constant over time too.

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

Definition 8. *The marriage market is in a steady state equilibrium when agents' Nash equilibrium choices of decision variables (e.g. marriage payments) are constant over time. When there are multiple possible equilibria in decision variables, the marriage market is in a steady state equilibrium when the expected values of the decision variables are constant over time.*

Population dynamics and marriage market outcomes interact in the following manner. In each period, old agents' choice of marriage payments is determined by their marriage market returns in the current period. Young agents determine their optimal marriage payments by looking at their current as well as expected future returns from the marriage market. All decisions are informed by a knowledge of the matching rule and expectations about the evolution of the state variables $(f_0^t, f_1^t, m_0^t, m_1^t)$ over time. The evolution of the state variables $(f_0^t, f_1^t, m_0^t, m_1^t)$ depends on the births in each period and the matching rule, which determines which couples are matched and, hence, which birth rates govern the evolution of the population (the rule also serves to remove eligible agents from the pool of marriage market participants in the next period). This determines the marriage market structure in each period and, through it, the marriage returns and payments offered by potential bride and grooms. The complete set of optimization problems and the evolution of the state variables are summarized in Appendix C.

In a steady state equilibrium of the marriage market, the optimal marriage payments and the age-sex structure of the population as determined by the above

[14]See proof in Appendix B.2

procedure must be constant over time. Example 2 provides a numerical illustration of such an equilibrium.

2.2.1. Example 2: Steady State Equilibrium

Assume that sex ratios and birth rates are exogenous and that the total fertility of a couple depends only on the age of the woman in the couple. For concreteness, suppose $\sigma = 2,\ b_0 = 1$ and $b_1 = 0.67$, where b_i is the number of female children born to mothers of age i and σ is the (male/female) sex ratio at birth. Also suppose $K = 2,\ s = 3$ and $\beta = 0.5$.

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 $(1 + \widehat{r}) = 1$[15]. In the equilibrium, older agents have a higher marital surplus and will be matched first[16].

To see why ($f_1^t = 0;\ f_0^t = 0.5m_1^t$) is a stable population equilibrium, suppose that in period T the demographic structure of the marriage market is as follows:

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

Note that this structure is consistent with the claimed stable population equilibrium structure (recall that $m_0^t = \sigma f_0^t$, by definition). I will now argue, using the mapping ϕ, that this marriage market structure is replicated in period $(T + 1)$.

Recall that, in equilibrium, the matching rule will pair older men first. Since there are more older men than young women, all young women (x) find a match and each produces 1 female birth ($b_0 = 1$) and 2 male births ($\sigma b_0 = 2$) in T. But this means that in period $(T+1)$ the number of young women is x and the number of young men is $2x$. Also, the number of older women in the market in $(T + 1)$ is 0 since all young women in time T find a partner. Since none of the young men ($2x$) in period T find a partner, they comprise the cohort of older men in the market in $(T + 1)$. Notice that the marriage market demographics of period T is replicated in period $(T + 1)$. This satisfies the definition of a stable population equilibrium with growth rate $(1 + \widehat{r}) = 1$.

What do marriage payments look like in the steady state equilibrium? Since the older men outnumber the women in each period, the former engage in within group competition and bid their entire marriage surplus as bride price. Young

[15] 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.

[16] See Appendix D for proof.

men are not able to compete with this payment since the bride price offered by high-surplus older men exceeds the former's lower marriage surplus (and hence, the maximum bride price that young men are willing to pay). Hence, at the equilibrium payments offered, young women strictly prefer older men to young men. The matching rule, therefore, pairs young women with older men. All the women find a partner whereas some older men and all young men remain unmatched.

2.3. Choice of Sex Ratio

This section presents the model of sex-ratio choice. The sex ratio of offspring chosen by parents is informed by demographics and expectations of marriage market returns, and feeds back into population dynamics via the BMMR Model described in the previous section.

Here I make the following assumptions.

Parents are responsible for arranging their offspring's marriage. After marriage, paired agents may choose the sex composition of offspring based on their total fertility level as well as the 'value' they place on girls versus boys.

The maximum total fertility of a married couple is exogenous and depends only on the age of the woman. Let ρ_i be the maximum total fertility of a couple with a woman of age i. Then $\rho_0 > \rho_1$, i.e. younger women are more fecund. Also, as assumed before, couples have all their children in their first period of marriage.

The 'value' of offspring accrues to both parents, i.e. children are 'public goods' in the household. Rearing children is costless. The utility function of each married agent is given by:

$$U^{marr} = c + E_f b_f + E_m b_m - (b_f - b_m)^2 \qquad (F0.1)$$

where E_g is the expected marriage market surplus of an offspring of gender g, b_g is the number of offspring of gender g and c is consumption[17].

Notice that there is a cost of choosing to skew the sex ratio of offspring to anything other than 1[18]. This reflects the cost of accessing technology such as

[17] 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.

[18] An alternative form of U^{marr} may be used: $U^{marr} = c + E_f b_f + E_m b_m - 2(b_f - \theta_f)^2 - 2(b_m - \theta_m)^2$ where θ_g represents the number of children of gender g that are born to a couple

amniocentesis and sex-selective abortion or the psychological cost of infanticide or neglect. Notice also that agents do not have an exogenous sex preference in this model. The choice of sex ratio depends purely on the incentives generated in the marriage market.

Finally, note that the assumption of arranged marriage separates marriage decisions and sex ratio choice in every period, since these decisions are made by different sets of agents. Hence, c is not a decision variable for married agents but is determined by the perishable wealth w and the terms of marriage formalized by their parents[19].

E_f and E_m are determined by agents' expectations of the relative numbers of marriage market participants in the future, and the marriage payments that will have to be paid at that time. In a steady state marriage market equilibrium, E_f and E_m will be the same over time ensuring that couple (c)-specific birth rates b_{gc} ($g = f, m$) and sex ratios $\frac{b_{mc}}{b_{fc}}$ are also constant over time.[20]

Formally, E_g ($g = f, m$) is defined as follows:

Denote the *total* utility that a woman expects to receive over her lifetime by $\widetilde{E}_f$.Then,

$$\begin{aligned} \widetilde{E}_f &= \overline{p}_0[(w+K)(1+\beta) - ED_0^1] + (1-\overline{p}_0)\overline{p}_1[w + \beta\{w + K - 1 - ED_1^1\} \\ &\quad +\{1 - \overline{p}_0 - (1-\overline{p}_0)\overline{p}_1\}[w + \beta(w - s)] \end{aligned}$$

where $\overline{p}_i$ is the probability that a woman of age i finds a partner[21].

If a woman cannot find a partner in her lifetime, she gets $w + \beta(w - s)$. Hence the total *surplus* that a daughter is expected to receive over her lifetime is

$$E_f = \widetilde{E}_f - [w+\beta(w-s)] = \overline{p}_0[K(1+\beta)+\beta s - ED_0^1] + \beta(1-\overline{p}_0)\overline{p}_1[K+s-1-ED_1^1] \tag{F0.2}$$

'naturally' (i.e. without intervention). Since $\theta_f = \theta_m$ in the aggregate, using this form of U^{marr} will not change the results of the paper.

[19] 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.

[20] Birth rates and sex ratios will depend on the total fertility of the couple. A steady state is characterized by constancy of couple-specific values of the same over time.

[21] Note that I do not break $\overline{p}_i$ into the probabilities of matching with different types in equilibrium. This is not necessary since when agents are matched with more than one type in equilibrium, they must be indifferent between them (see Proposition 1). When matched with only one type in equilibrium, $\widetilde{E}_g$ must contain the probability of matching with this type and the returns from this marriage.

By a similar derivation,

$$E_m = \overline{q}_0[(K-1)(1+\beta) + \beta s + ED_0^0] + \beta(1-\overline{q}_0)\overline{q}_1[K + s + ED_0^1] \qquad (F0.3)$$

where $\overline{q}_j$ is the probability that a man of age j finds a partner.

Notice that optimization behavior of agents will ensure that $E_f \geq 0,\ E_m \geq 0$.

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

$$\underset{b_f, b_m}{Max}\ c + E_f b_f + E_m b_m - (b_f - b_m)^2 \qquad (F1.1)$$

subject to the constraints,

$$\begin{aligned} b_f + b_m &\leq \rho_i \\ b_f &\geq 0 \\ b_m &\geq 0 \end{aligned} \qquad (F1.2)$$

Consider the following proposition[22].

Proposition 4. *In all non-trivial equilibria couples choose to have as many offspring as their total fertility allows, ensuring that young mothers have more offspring than old mothers. Maternal-age (i)-specific sex ratios σ_i (male/female) of offspring are determined as follows:*

when $|E_f - E_m| < 4\rho_1$,

$$\sigma_i = \frac{4\rho_i - (E_f - E_m)}{4\rho_i + (E_f - E_m)}\ \epsilon\ (0, \infty)\ for\ i = 0, 1 \qquad (F6)$$

when $4\rho_1 < |E_f - E_m| < 4\rho_0$,

$$\sigma_0 = \frac{4\rho_0 - (E_f - E_m)}{4\rho_0 + (E_f - E_m)}\ \epsilon\ (0, \infty) \qquad (F7.1)$$

$$\begin{aligned} \sigma_1 &= 0\ if\ E_m < E_f \\ \sigma_1 &= \infty\ if\ E_m > E_f \end{aligned} \qquad (F7.2)$$

Further, there is no non-trivial steady state equilibrium compatible with the condition $|E_f - E_m| > 4\rho_0$.

[22] See proof in Appendix E.

Notice that at the interior solutions $(F6)$ and $(F7.1)$, σ_i increases (decreases) with decline 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)).

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, and

ii. the marriage market is in a steady state equilibrium, viz. marriage payments and sex-ratios are unchanging over time.

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

Example 3 demonstrates the existence of a steady state general equilibrium as defined above.

2.3.1. Example 3: Steady State General Equilibrium

Consider, for concreteness, the following parameter values: $\varphi_0 = 3,\ \varphi_1 = 2,\ K = 0.2,\ s = 5,\ \beta = 0.25$

Then a non-trivial steady state general equilibrium exists and has the following characteristics[23]:

1. Young men are not willing to marry at the offered marriage payments because K is too small $(K < 1)$.

2. The equilibrium matching rule matches old men and old women first when agents are indifferent to the age of their spouse.

3. In the stable population equilibrium, $\overline{q}_0 = 0,\ \overline{q}_1 = 1,\ \overline{p}_0 = 0.787,\ \overline{p}_1 = 1$. That is, in every period, young men refrain from marrying and old men are matched with all old women and some young women. Also, the stable population grows at the rate $(1 + \widehat{r}) = 1.237$, so $\widehat{r} = 0.237$. This is true at the optimal birth rates and sex ratios derived in (5) below.

[23] See Appendix F for a detailed derivation.

4. The equilibrium marriage payments are $D_0^1 = \frac{K+2\beta}{1-\beta} = 0.93,\ D_1^1 = \frac{K+1+\beta}{1-\beta} = 1.93$. Hence the equilibrium payments are dowries.

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

3. The Indian Scenario

Since high-surplus agents are matched first in equilibrium, the matching rule associated with a steady state general equilibrium will be determined by the pre-payments marriage surpluses of agents. These depend on model parameters $(K,\ s,\ \beta)$ and the age-sex composition of the marriage market in equilibrium. What parameter values and matching rule are appropriate for the Indian case? One way to determine the answer is by looking at data on marriage market indicators in India and ascertaining the parameter values in the model that generate predictions consistent with these.

One of these indicators is the universality of female marriage in India. Table 4, from Goyal (1988) lists estimates of the percentage of single females in different age groups by birth cohort. The proportion of single females in the age-group 35-39 is 0.5% for cohorts 1931-36 to 1946-51. Since the Indian population started growing from the 1930s these are the cohorts that would be the first to experience the demographic squeeze. Yet we see that most women in these cohorts find partners during their lifetime. This suggests, in my model, that the matching rule is such that *older* women are matched first when men are indifferent to the age of their spouses. It is easy to see why – if young women exceed the number of men in the marriage market (due to population growth), there will clearly be some women who do not find a match when young.[24] If in the next period young women again exceed the number of men in the marriage market and are matched before old women, then it must be the case that none of the old women in the market in this period find a match in their lifetime. Since this has not been observed empirically, it seems reasonable to assume that parameter values are such that the matching rule matches old women before young women.

[24] Since the overall sex ratio in India has been masculine throughout the last century, these young women would have all found a match if young men were willing to marry them. But then, the age at which men marry should have declined over time. This has not been observed in India. The ages at marriage of both men and women have been rising with a narrowing of the age gap at marriage (Mensch et al (2005), Bhat and Halli (1999)).

Another useful set of indicators are overall and juvenile sex ratios and their behavior over time. Figure 3, from Mayer (1999) and Hutter et al (1996) shows that the sex ratio (female/male) in India has been steadily falling throughout the twentieth century. Bhat and Halli (1999) estimate juvenile sex ratios in 1911 and 1981 and find that these have become more 'masculine' over the period too. Sudha and Rajan (1999) also find sex ratios at birth to have become more masculine in the period 1981-91 and report a worsening female mortality disadvantage during this time. In the context of my model, women would not be in surplus in the marriage market if the juvenile sex ratio (male/female) were greater than one and men were willing to marry young. The latter phenomenon could generate a demographic marriage squeeze against men and result in bride price instead of dowry, violating the evidence on rising dowries in India in the latter half of the twentieth century. Further, the minimum age of first marriage for men in India has been persistently higher than that of women despite an increasing trend of delayed marriage for both sexes over the last century (Mensch et al (2005)). These indicators suggest that parameter values may be such that young men in India choose to postpone marriage at the offered marriage payments. In the analysis that follows, I assume this to be the case.

Despite the inherent difficulties of analytically deriving the properties of population equilibria in Pollak's (1987) model, it is possible to characterize steady state equilibria in the general equilibrium model presented here, under the parametric restrictions imposed by the above.

There are five possible demographic configurations that may be obtained in a non-trivial steady state general equilibrium. These are:

$$\begin{aligned}
(a)\ f_1^t &> m_1^t > 0 \\
(b)\ f_1^t &= m_1^t < f_1^t + f_0^t \\
(c)\ f_1^t &< f_1^t + f_0^t = m_1^t \\
(d)\ f_1^t &< f_1^t + f_0^t < m_1^t \\
(e)\ f_1^t &< m_1^t < f_1^t + f_0^t
\end{aligned} \tag{I1}$$

Proposition 5 states the properties of steady state general equilibria when the sex ratio is exogenous[25].

Proposition 5. *Suppose parameter values are such that young men postpone marriage at the offered payments, and old women are matched before young*

[25] See proof in Appendix G.

women. Assume 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 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 in the steady state equilibrium.*

The intuition of Proposition 5 follows from the law of supply and demand. It states that there is dowry in the steady state equilibrium when there is an excess supply of women and bride price when there is an excess supply of men. The male-to-female sex ratio, σ, governs the number of men in the marriage market, all of whom must belong to the older cohort since young men postpone marriage. But the women in the market can belong to both younger and older cohorts. The growth rate $(1+\widehat{r})$ governs 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, whereas the reverse inequality is associated with bride price[26].

The result of Proposition 5 reinstates the intuition of the marriage squeeze hypothesis in the long run. When the population growth rate is high relative to the (male-to-female) sex ratio, dowry payments are observed whereas a relatively low population growth rate is associated with bride price. Example 2 demonstrates the existence of a steady state equilibrium with bride price. However, Proposition 5 (and Example 2) assumes that the sex ratio is exogenous, and hence incorporates only a one-way link from population dynamics to the marriage market. Proposition 6 incorporates the effect of the two-way link between population dynamics and marriage market outcomes by allowing endogenous sex ratios[27].

Proposition 6. *Suppose parameter values are such that young men postpone marriage at the offered payments, and old women are matched before young women. Assume that* ***parents choose the sex ratio*** *of offspring as in $(F1)$. Then,*

[26] A subsequent discussion (see the discussion of Proposition 6) will demonstrate that when $\sigma = (1+\widehat{r}) + (1-\overline{p}_0)$, there will be multiple equilibria in marriage payments. In this case – case (c) – individual payments may be dowry or bride price but under the assumptions made, the *expected* payment will be a bride price.

[27] See Appendix H for proof of Proposition 6.

1. *the only demographic configuration that is consistent with a non-trivial steady state general equilibrium is* (e) *(see* $(I1)$*) and the equilibrium marriage payment is a dowry. The aggregate male-to-female sex ratio at birth* (σ) *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 σ *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 in the steady state equilibrium.*

Point (2) in Proposition 6 highlights the difference in the characteristics of long-run equilibrium for endogenous versus exogenously given sex ratios. Recall, from Proposition 5, that when σ is exogenous there could be dowry or bride price in long-run equilibrium depending on whether $\sigma \lesseqgtr (1 + \widehat{r}) + (1 - \overline{p}_0)$. Point (2) in Proposition 6 states, that when σ is *endogenous,* it will 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.

To see the intuition of point (1) in Proposition 6, consider, individually, each of the cases $(a) - (d)$ in $(I1)$.

Suppose (a) is true in a steady state general equilibrium. This is possible only if the overall sex ratio σ is less than 1, viz. more women than men in any generation. This is because, if old women are paired first by the matchmaker, then $f_1^t > m_1^t$ implies $f_1^t = F_0^{t-1}$ (since none of the young women can find a match in any period). 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 $\sigma < 1$.

Now consider the marriage payments consistent with an equilibrium of the form (a). Within-group competition among old (high-surplus) females would lead to the payment of a dowry that is equal to the latter's entire surplus from marriage. At these high payments and the expected probabilities of matching consistent with (a), the expected returns from marriage are higher for men $(E_m > E_f)$, so it is *not* worthwhile for parents to have more daughters than sons. Hence, a σ *greater* than 1 is generated in all non-trivial equilibria, demonstrating that (a) cannot be sustained in a steady state equilibrium.

By an argument similar to the one presented above, (b) would be true in a steady state equilibrium only if $\sigma = 1$. However, when the demographic structure is of the form (b), there are multiple equilibria in marriage payments since the high-surplus agents (old men and old women) are equal in number, implying that neither group has a credible threat point in marriage market bargaining. The lower limit of payments, D_1^1, is the dowry that makes old men indifferent to the age of their spouse (recall that there are young women in the marriage market also) and the upper limit is the payment that reduces the surplus of old women to zero. I assume that in such circumstances, the matchmaker draws the actual payments associated with each match from a uniform distribution over the feasible range. The average payment, ED_0^1, is then a dowry. At this payment, however, sons have a higher expected return from the marriage market, so parents prefer to have more sons than daughters and $\sigma > 1$. This shows that (b) cannot be sustained in a steady state equilibrium either.

If (c) were true in a steady state equilibrium, the resulting marriage market demographics would be $f_1^t = 0$ (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 equilibrium growth rate of the population, $(1 + \widehat{r})$, is exactly equal to the sex ratio, σ.[28] Note also that since women must bear children in the first period of marriage and since there are no old women among eligible marriage market participants, the equilibrium growth rate of the population must be equal to the number of girls born to young women. These observations imply that $\sigma = \frac{b_{m0}}{b_{f0}} = (1 + \widehat{r}) = b_{f0}$ which further implies $b_{f0}^2 = b_{m0}$.

I show in Appendix H that at the expected marriage payments implied by (c), ($b_{f0}^2 = b_{m0}$) cannot be satisfied for a set of parameters in the relevant range, viz. $K > 0$, $s > 0$, $\beta \epsilon (0, 1)$ and that satisfy the matching rule. The intuition of this result is as follows. If (c) is true in equilibrium, there will be multiple equilibria in marriage payments since the number of potential brides and grooms are exactly equal. The upper limit of payments, D_0^1, is a dowry equal to young women's pre-payments marital surplus and the lower limit is the bride price equal to old men's pre-payments surplus. If old agents are the high-surplus agents who

[28] To see why, suppose that the population is growing in equilibrium so that $(1 + \widehat{r}) > 1$. This will lead to more younger women in the population than older men, if $\sigma \leq 1$. The numbers of old men and young women will be equal in each period if and only if there are more men born in each period than women ($\sigma > 1$) and by the exact magnitude of population growth. Hence $(1 + \widehat{r}) = \sigma$.

are matched first, then it must be the case that the (absolute value of the) lower limit exceeds the upper limit. This yields an average payment of bride price.[29] Also, for older agents to be the high-surplus agents β has to be sufficiently low or else the surpluses of young agents driven by their two-period marital returns would be higher. Since men get married only in the last period of their life – with returns discounted by a low β – and expect to pay a bride price at that stage, it is not worthwhile for parents to have as many sons per daughter as ensures $\sigma = (1 + \widehat{r})$.Therefore, the marriage market outcomes corresponding to (c) indicate a lower σ than that required to sustain (c) in a steady state general equilibrium.

Suppose (d) were true in steady state equilibrium. 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 equilibrium growth rate of the population, $(1 + \widehat{r})$, is *less* than the sex ratio, σ. Since σ has to be sufficiently large to sustain an equilibrium like (d) there must be an upper limit on $(E_f - E_m)$ in equilibrium, because σ varies inversely with it (see Proposition 4, $(F6)$, $(F7.1)$). It may be shown, however, that at the equilibrium marriage payments implied by (d), $(E_f - E_m)$ will be higher than this upper limit and σ will be lower than that which can sustain an equilibrium like (d). This is true because at an equilibrium of the form (d), old men will pay their entire pre-payments marital surplus as bride price to young women. If old men and old women are the high surplus agents, then this bride price will be too large for parents to want as many sons per daughter as is required to sustain (d).

Hence (e) is the only demographic configuration possible in equilibrium. Example 3 demonstrates numerically that a steady state equilibrium of the form (e) exists. I show in Appendix H that in an equilibrium of the form (e), σ is greater than 1 and the equilibrium marriage payment is a dowry. This is due to the following reasons.

First, there are more eligible women than men in the marriage market since young men postpone marriage. Second, young women stand to gain a positive surplus from marriage. This is because they value marriage sufficiently to want to marry young *and* reap this value over two periods. In equilibrium, there are enough men for all the old women (who are matched first), but not for all the young women. Thus within-group competition makes young women bid away their entire surplus which, being positive, is a dowry. Old women engage in between-

[29] Once again assuming that the matchmaker draws the actual payments from a uniform distribution over the feasible range.

group competition and match this offer to make men indifferent to the age of their spouse. Hence, they 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 ($\sigma > 1$).

However, recall that the marriage market returns of men are single-period returns that are discounted by β because they occur late. Also, if old agents are the high-surplus agents, then β must be sufficiently small or else the two-period gains of young agents would exceed that of their older counterparts (see proof in Appendix H). Moreover, since the high-surplus older women do not engage in *within*-group competition for a spouse, the dowry paid in equilibrium is less than the total surplus of old women. Since the entire surplus of old women is not extracted the equilibrium dowry is relatively small. All these factors impose an upper limit of the excess marriage market returns of men, ensuring that the equilibrium σ is not skewed (high) enough to reverse the marriage squeeze against women.

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 in future. However, the dowry equilibrium in (e) can be sustained because the upper limit imposed on men's marriage market returns ensures that boys are not overproduced despite the sex ratio being skewed in favor of males. The prediction is noteworthy for its remarkable accuracy in describing current conditions in the Indian marriage market, as outlined in the following table.[30] It also provides an explanation for why dowries can persist over time even in the face of long-practised female infanticide and foeticide.

Variable	Model	Evidence
Marriage Payments	Dowry	Dowry
Sex Ratio	Masculine	Masculine
% Men Married by Age 45-49	100	97.6

4. Extension: Introducing a Cost Parameter in 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. Will this be

[30] The datum on percentage of men married by age 45-49 is from Tertilt (2004).

instrumental in skewing the sex ratio sufficiently in favor of men to reverse the marriage squeeze against women (and the result of Proposition 6)? This section introduces a cost parameter in sex ratio choice. 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 τ be a cost parameter in the post-marriage utility function,

$$U^{marr} = c + E_f b_f + E_m b_m - \tau(b_f - b_m)^2, \qquad \tau > 0 \qquad (F0.1a)$$

Note that in the model presented in the previous sections, $\tau = 1$.

Proposition 7 outlines the optimal sex-ratio choice of agents when the post-marriage utility function is of the form $(F0.1a)$. It reinstates the results of Proposition 4 (where $\tau = 1$)[31].

Proposition 7. *Suppose that the post-marriage utility function of agents is given by* $(F0.1a)$*. In all non-trivial equilibria, couples choose to have as many offspring as their total fertility allows, ensuring that young mothers have more offspring than old mothers. Maternal-age* (i)*-specific sex ratios* σ_i *(male/female) of offspring are determined as follows:*

when $|E_f - E_m| < 4\tau\rho_1$,

$$\sigma_i = \frac{4\tau\rho_i - (E_f - E_m)}{4\tau\rho_i + (E_f - E_m)} \ \epsilon \ (0, \infty) \ for \ i = 0, 1 \qquad (F6a)$$

when $4\tau\rho_1 < |E_f - E_m| < 4\tau\rho_0$,

$$\sigma_0 = \frac{4\tau\rho_0 - (E_f - E_m)}{4\tau\rho_0 + (E_f - E_m)} \ \epsilon \ (0, \infty) \qquad (F7.1a)$$

$$\begin{aligned} \sigma_1 &= 0 \ if \ E_m < E_f \qquad (F7.2a) \\ \sigma_1 &= \infty \ if \ E_m > E_f \end{aligned}$$

Further, there is no non-trivial steady state equilibrium compatible with the condition $|E_f - E_m| > 4\tau\rho_0$.

The results in Proposition 7 are used to derive Proposition 8, which summarizes the characteristics of a steady state general equilibrium when the post-marriage utility function is of the form $(F0.1a)$[32].

[31] See Appendix I.1 for proof of Proposition 7.

[32] See Appendix I.2 for proof of Proposition 8.

Proposition 8. *Suppose parameter values are such that young men postpone marriage at the offered payments, and old women are matched before young women. Suppose that the post marriage utility function is given by* $(F0.1a)$ *where* τ (> 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* $(I1)$*) and the equilibrium marriage payment is a dowry. The aggregate male-to-female sex ratio at birth* (σ) *in this equilibrium is greater than 1.*

The intuition of Proposition 8 is as follows. Notice in $(F6a)$ and $(F7.1a)$ that τ has the same effect on sex ratios as fertility ρ_i. In other words, a decline in τ skews the sex ratio in favor of the offspring with the higher expected surplus in the marriage market. This suggests that a low value of τ may lead to an over-production of boys when dowry is expected, thereby invalidating the result of Proposition 6. This is not true, however, because a low cost of sex ratio choice does not alter the fact that men marry late and receive a single-period discounted return from marriage whereas women expect to receive two periods of marital gains. Thus the upper limits on $(E_m - E_f)$ and σ continue to hold and parents do not over-produce boys in the equilibrium (e), allowing dowry to be sustained in the long run. However, low τ makes a bride price equilibrium even less likely because it makes parents more inclined to over-produce *girls* when bride price is expected. A high τ is, therefore, a *necessary* condition for a bride price to be sustained in equilibrium because this precludes agents from 'over-responding' to the associated high excess returns of girls $(E_f - E_m > 0)$.

Propositions 6 and 8 demonstrate that at the given parameters and preference structure E_f is more 'sensitive' to marriage market conditions than E_m. This is because women are willing to marry young and when they do so, reap the (high) benefits of marriage in both periods of life. Men, on the other hand, marry only when old whereupon their returns are discounted by β (which has to be low to justify the matching rule). Further, the different ages at marriage for men and women imply that a dollar of dowry is valued less in the calculation of E_m – because it is received late and is discounted – than a dollar of bride price in the calculation of E_f. The resulting 'excess' sensitivity of E_f ensures that a female advantage in the marriage market cannot be sustained in the long run because girls are overproduced whenever bride price is expected. The limited sensitivity of E_m, however, guarantees that there exists an equilibrium, viz. (e), where the chosen σ is low enough to sustain the male advantage in the marriage market.

5. Summary and Conclusion

The dowry inflation that has been observed in India since the 1950s has been attributed to a marriage squeeze against women caused by population growth. In this paper, I ask if declining fertility levels and widespread sex-selective abortion against women will lead to a reversal of the squeeze and a regime of bride price in the long run.

I show, using an overlapping-generations dynamic general equilibrium framework, that at parameter values consistent with marriage market indicators in India the only possible steady state equilibria are characterized by dowry payments, a marriage squeeze against women and a masculine sex ratio. I show, moreover, that this result is true at low costs of skewing the sex ratio, which with the advent of sex-selective abortion techniques in India, is suspected to be the case.

The above result stems from an analysis that focuses purely on the incentives of the marriage market. It provides valuable insights on the interplay between marriage decisions and population dynamics and makes a contribution to the literature in an area that has not been traversed before. In particular, it generates a prediction that explains why women may have to pay for a groom even in the face of long-practised female infanticide and feticide.

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Table 1: Population (millions) and Population Growth of India, 1891-1991

Year	Population (millions)	Absolute Growth (millions)	Decadal Growth (%)	Average Annual Exponential Growth Rate (%)
1891	235.9			
1901	238.4	2.5	1.1	0.11
1911	252.1	13.7	5.7	0.56
1921	251.3	-0.8	-0.3	-0.03
1931	279.0	27.7	11.0	1.04
1941	318.7	39.7	14.2	1.33
1951	361.1	42.4	13.3	1.25
1961	439.2	78.1	21.5	1.96
1971	548.2	109.0	24.8	2.20
1981*	683.3	135.1	24.7	2.20
1991**	846.3	163.0	23.6	2.14

Source: Registrar General of India, Census

*Including Assam: population estimated to be 18.04 million
**Including Jammu and Kashmir: population estimated to be 7.72 million

Reproduced from Hutter et al (1996), pp.9

Table 2: Crude Birth Rate (CBR) and Crude Death Rate (CDR) in India, 1891-1981

Year	CBR*	CDR**
1891-1901	48	48
1901-11	49	43
1911-21	49	49
1921-31	47	37
1931-41	45	33
1941-51	43	31
1951-61	44	26
1961-71	42	20
1971-81	37	15

Source: Registrar General of India, Census

Table 2 (contd.): Crude Birth Rate (CBR) and Crude Death Rate (CDR) in India, 1980-1992

Year	CBR*			CDR**		
	Rural	Urban	Combined	Rural	Urban	Combined
1980-82	35.4	27.6	33.8	13.6	7.7	12.3
1981-83	35.4	27.8	33.8	13.3	7.7	12.1
1982-84	35.3	28.6	33.8	13.3	8.0	12.1
1983-85	35.0	28.6	33.6	13.3	8.1	12.1
1984-86	34.6	28.2	33.2	13.0	8.0	11.8
1985-87	34.1	27.5	32.6	12.4	7.6	11.3
1986-88	33.6	26.9	32.1	12.0	7.6	11.0
1987-89	33.0	26.3	31.5	11.7	7.4	10.7
1988-90	32.3	25.4	30.8	11.2	7.2	10.3
1989-91	31.6	24.7	30.1	10.7	7.1	9.9
1992	30.7	23.1	29.0	10.8	7.0	10.0

Source: Registrar General of India, Sample Registration System (SRS)

*CBR: Births per 1000 population
**CDR: Deaths per 1000 population

Reproduced from Hutter et al (1996), pp. 11

Fig 1: Population of India (millions), 1891-1991

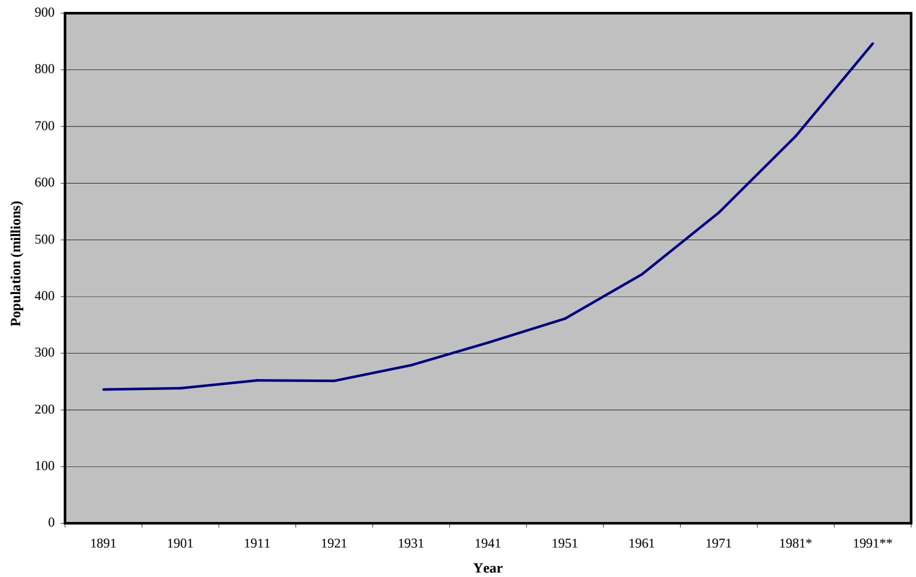

Fig 2: Demographic Transition in India, 1891-1991

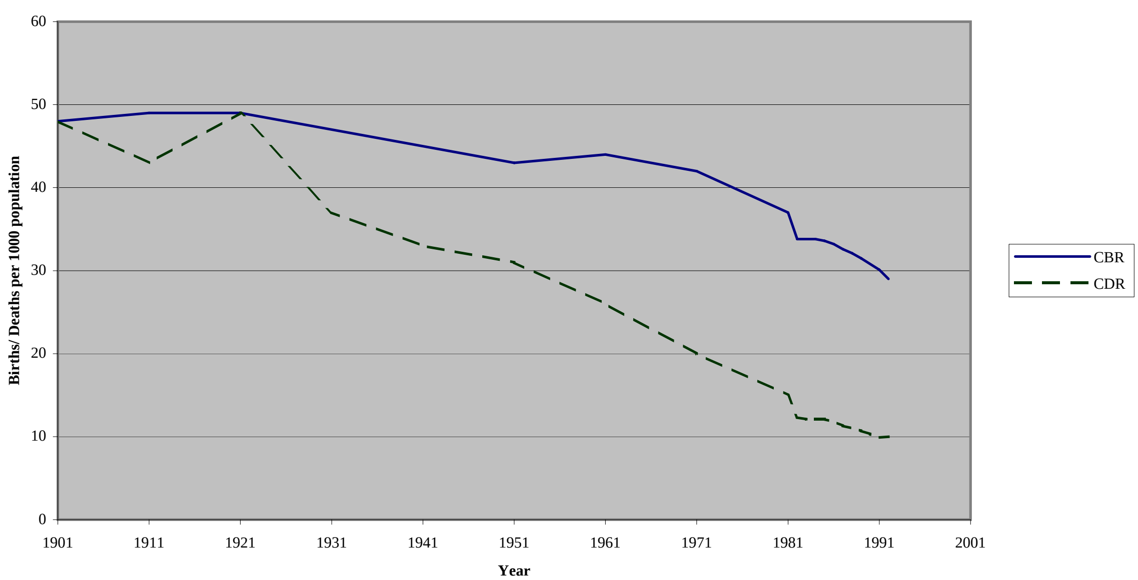

Table 3: Sex Ratio in India, 1901-1991

Year	Sex Ratio*
1901	972
1911	964
1921	955
1931	950
1941	945
1951	946
1961	941
1971	930
1981	934
1991	927

Source: Registrar General of India, Census

*Females per 1000 males

Reproduced from Hutter et al (1996), pp. 14

Fig 3: Sex Ratio in India, 1901-91

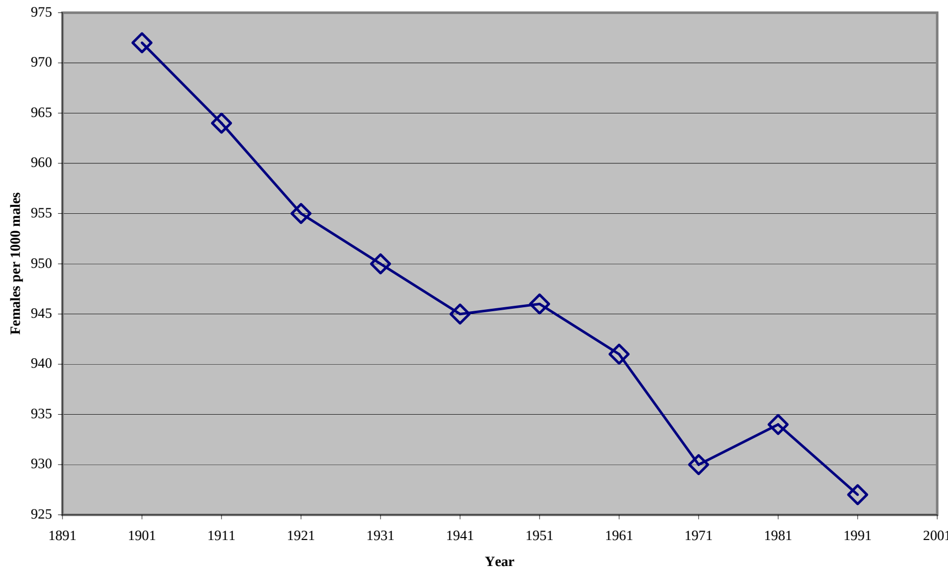

Table 4: Percentage of Single Females in Different Age Groups, and Mean and Median Ages at Marriage by Birth Cohorts: India, 1886-91 to 1946-51

Birth Cohorts	Percentage of Single in Age Group								Age at Marriage	
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	Mean	Median
1886-91	98.6	88.1	54.3	15.9	4.4	2.4	1.9	1.3	13.05	13.05
1891-96	98.6	88.9	54.9	16.3	4.8	2.5	1.6	1.1	13.17	13.13
1896-01	98.5	88.9	55.5	17.6	5.2	2.1	1.3	1.0	13.25	13.22
1901-06	98.5	89.0	57.8	18.8	4.7	1.8	1.1	0.9	13.36	13.49
1906-11	98.5	89.9	60.1	17.7	4.2	1.6	1.2	0.9	13.38	13.69
1911-16	98.7	90.7	54.7	16.6	4.2	1.4	1.3	1.2	13.12	13.11
1916-21	98.8	88.3	49.3	20.9	4.1	2.5	2.1	1.1	13.13	12.37
1921-26	98.2	85.8	62.4	25.2	4.6	3.6	1.5	0.7	13.93	14.16
1926-31	97.6	88.8	75.5	26.7	5.2	2.8	1.0	0.6	14.75	15.11
1931-36	98.1	91.9	75.6	28.1	5.6	1.9	0.9	0.5	15.00	15.19
1936-41	98.6	92.5	75.8	28.6	6.0	1.9	0.8	0.5	15.11	15.23
1941-46	98.6	93.2	78.2	29.2	7.5	2.0	0.8	0.5	15.38	15.38
1946-51	98.6	96.6	80.5	36.1	9.1	2.1	0.8	0.5	16.12	15.93

Source: C.R. Malaker, Study of Indian Nuptiality, Ph.D dissertation, 1978. Indian Statistical Institute, pp. 85-86

Reproduced from Goyal (1988), pp. 17