Can Population Growth Impact Marriage Payments? Theory and the Indian Evidence*

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ABSTRACT

The empirical evidence on the relationship between population growth and dowries in India has been contradictory, suggesting that demographics may have no role to play in determining marriage payments. In this paper, I reconcile the contradictory empirical evidence under a unified theoretical framework. I employ Anderson's (2007) theoretical model of population growth and dowry payments, to yield a novel prediction for the evolution of dowries over time. In particular, I show that the time-path of dowries may be non-monotonic, with an eventual decline (as predicted by Anderson (2007)) being preceded by a spike – a feature that has not previously been highlighted in the literature. I further demonstrate that such a non-monotonic dowry path can successfully generate all of the apparently contradictory findings in the empirical literature. Finally, I show that either a wide ideal spousal age gap or a low outside option of marriage for women are sufficient conditions for such a non-monotonic dowry path to prevail. Both of these conditions are well-documented features of the Indian marriage market. Thus, while other factors cannot be ruled out, demographic change could suffice to explain the evolution of dowries observed in twentieth-century India.

Keywords: Dowry; Population growth
JEL classifications: J11; J12; J16; D10

INTRODUCTION

Why do dowries exist? Anthropologists have highlighted the role of inheritance laws, kinship and class structure, and the economic contribution of women to explain the existence of marriage payments (Goody and Tambiah 1973, Boserup 1970, Epstein 1973, Dalmia and Lawrence 2005, Billig 1991). Economists have argued that dowries could serve as a mechanism for early inheritance, to solve a free-rider problem (Botticini and Siow 2003). Another set of economic theories argues that marriage payments are prices that serve to clear the marriage market (Becker 1991, Anderson 2003, Rao 1993, Tertilt 2005).

In the price view of marriage payments, the size and direction of dowry payments depend on the supply and demand of marriage market participants (brides and grooms). Various factors have been proposed that may affect this supply and demand. For instance, if lower caste women marry upper caste men (caste hypergamy), the supply of eligible brides may outnumber that of grooms, resulting in dowries (Anderson 2003, Billig 1991). Alternatively, if men have multiple wives (polygyny), the supply of eligible grooms could outnumber that of brides, resulting in bride price (Tertilt 2005). Finally, *demographic change* may play a role in determining marriage payments. If men and women marry at different ages, then the relative supply of grooms and brides (who belong to younger cohorts) will depend on population growth rates, leading again to various payment structures (Rao 1993, Edlund 2000, 2006, Dalmia and Lawrence 2005, Anderson 2007).

The relationship between population growth and marriage payments is especially interesting in the context of India, which underwent its demographic transition in the early twentieth century and which is also known to have a long-standing institution of dowry payments (Caldwell et al 1982, 1983, Rao 1993, Bhat and Halli 1999, Hutter 1996). Several papers have attempted to investigate this relationship empirically (Rao 1993, Edlund 2000, 2006, Dalmia and Lawrence 2005). However, these studies have yielded contradictory results, suggesting that demographic change may not be a relevant factor in the determination of marriage payments in India.

For instance, Rao (1993) finds a positive but insignificant association between dowries and year of marriage, for the period between the 1920s and the 1970s. Edlund (2000) replicates this finding using the same data as Rao (1993). But Dalmia and Lawrence (2005) conduct a similar analysis using a different dataset, and they find a significant negative association between dowries and year of marriage, for the period between the 1950s and the 1990s. Finally, Edlund (2006) uses the same data as Edlund (2000) to show that there is evidence of an increase in net dowries only prior to the 1950s but not after.

In addition to studying the evolution of dowries tracking the demographic transition, researchers have investigated the relationship between dowries and a direct measure of marriage market supply-demand, namely, the ratio of women to men of marriageable age. Here too the results are mixed. Rao (1993) finds a significant positive association between dowries and this gender ratio. Edlund (2000) and Dalmia and Lawrence (2005) both find a positive but insignificant association. And Edlund (2006) finds a negative association between dowries and this gender ratio.

The evidence on Indian dowries is therefore puzzling, and casts doubt on the hypothesis that demographic factors help determine marriage payments via the pricing mechanism.

In this paper, I show that a simple non-monotonic path for the evolution of dowries can resolve this puzzle and explain all of the apparently contradictory evidence on Indian dowries obtained in the literature. More importantly, I argue that there is a strong theoretical basis for the existence of such a non-monotonic path.

What could generate a non-monotonic path for dowries? The answer is suggested in a recent theoretical paper by Anderson (2007). Anderson (2007) formulates a model of marriage payments in which the only shock to the marriage market comes from population growth. Here I use Anderson's (2007) framework to outline the time-path of dowries in response to a population-growth shock. In particular, I show that dowry payments respond to the demographic shock by registering a sharp rise followed by a protracted decline – a non-monotonic path. Anderson (2007) provides a robust argument for the decline in dowries that must occur after a population-growth shock. Here I show that dowries may register a rise before the decline begins, a finding that has not, to my knowledge, been highlighted in the literature.

For ease of exposition, I construct a specific numerical example of dowries within Anderson's framework to demonstrate a non-monotonic dowry path such as that described above.

I then simulate dowry data based on this numerical example, and run OLS regressions akin to those used in previous empirical studies (Rao 1993, Edlund 2000, Dalmia and Lawrence 2005 and Edlund 2006). I show that my regression results correctly match the varying (and apparently contradictory) signs of coefficients found in the empirical literature. I demonstrate, moreover, that if population growth affects different districts at different times, the empirical results will depend on how the data has been drawn.

I thus show that the seemingly puzzling empirical findings on Indian dowries are perfectly consistent with the predictions of a theoretical model of population growth (a la Anderson (2007)).

Finally, I show that a low outside option of marriage of women or a high ideal spousal age gap are *sufficient conditions* to generate a non-monotonic dowry path such as in the numerical example above. I argue, citing evidence, that these conditions very accurately describe Indian marriage markets. Hence the numerical example used in my exposition is not a rare case driven by 'cherry-picked' numbers, but a highly probable description of the Indian scenario.

Recall that the simulated data originate from a theoretical example where the *only* shock to the marriage market is population growth (as in Anderson (2007)). Within the framework of this example, I am able to replicate the seemingly contradictory empirical results on the evolution of dowries in India (Rao 1993, Edlund 2000, Dalmia and Lawrence 2005, and Edlund 2006). This suggests that, while other causes cannot be ruled out, a demographic shock such as a rise in the population growth rate could suffice to explain the evolution of dowries in India in the twentieth century.

The contribution of this paper is, therefore, twofold. First, the theoretical framework in Anderson (2007) is employed to yield a novel prediction about the impact of population growth on the dowry path, viz. that the path may be non-monotonic with first a spike in dowry payments followed by a protracted decline. That dowries will eventually decline has been proven robustly in Anderson (2007), but the preceding spike in payments is a finding that has not, to the best of my knowledge, been highlighted in the literature. Second, the prediction of such non-monotonicity successfully resolves, in a unified theoretical setting, the puzzle posed by mixed empirical results on the evolution of dowries in India. Taken together, this demonstrates that while other factors cannot be ruled out, demographic factors may plausibly be a driver of marriage payments, as observed in India. The analysis underlines the importance of using a theoretical framework to interpret empirical findings.

THE MODEL

This section outlines Anderson's theoretical structure. It is a brief reproduction of Section 2 in Anderson (2007).

Time is discrete. An equal number, N, of males and females are born in each period. Women prefer to marry at age b and men at age g, where $b < g$. Agents marry either at the desirable ages (b, g) or later. Let a_b (a_g) denote the number of years beyond the ideal age of marriage that the bride (groom) actually marries. The costs associated with delaying marriage beyond the ideal age are represented by $c(a_b)$ and $k(a_g)$, which are increasing and convex. Marriages are monogamous and there is full information and costless search in the marriage market. Dowry payments, d, are made from the bride to the groom – these are derived endogenously and vary by agents' respective ages at marriage, a_b and a_g, and potentially also by the time period of marriage. Let the dowry payment made in period t by a woman of age a_b to a man of age a_g be represented by $d(a_b, a_g, t)$.

Assume, for simplicity, that all benefits and costs of marriage occur in one period only and that individuals do not discount the future. Consider the following quasilinear specification of utility of a bride:

$$U(a_b, a_g, t) = -d(a_b, a_g, t) - m(a_g) - c(a_b) \qquad (u1)$$

where the disutility from marrying an older groom is represented by $m(a_g)$. This cost is also increasing and convex. Costs are normalized so that $m(0) = c(0) = 0$.

Similarly, a groom's utility from marrying is

$$V(a_b, a_g, t) = d(a_b, a_g, t) - k(a_g) - q(a_b) \qquad (u2)$$

where the disutility from marrying an older bride is represented by $q(a_b)$ which is also convex. Here too, costs are normalized such that $k(0) = q(0) = 0$.

If unable to find a partner, women obtain a utility of $\overline{U}$ and men, $\overline{V}$. These are the outside options of marriage to women and men, respectively.[1]

Marriage Market

Marriage market equilibrium requires the satisfaction of three conditions:

1. Feasibility of a match (a_b^*, a_g^*) :[2]

$$-d(a_b^*, a_g^*, t) - m(a_g^*) - c(a_b^*) \geq \overline{U} \ for \ brides \qquad (m1.1)$$

[1] Note the distinction between 'reservation utility' and 'outside option of marriage'. The former is the lifetime utility that agents are guaranteed if they do not marry at a certain age, say x. The outside option is the utility obtained from never marrying. The two are equal only when agents may not find a partner upon postponing marriage beyond age x. The marital surplus refers to the difference between marital utility and the *outside option* of marriage (see footnote 2).

[2] The marital surplus of women is, therefore, $[-d(a_b^*, a_g^*, t) - m(a_g^*) - c(a_b^*) - \overline{U}]$ and of men, $[d(a_b^*, a_g^*, t) - k(a_g^*) - q(a_b^*) - \overline{V}]$.

$$d(a_b^*, a_g^*, t) - k(a_g^*) - q(a_b^*) \geq \overline{V} \ for \ grooms \tag{m1.2}$$

$for \ a_b^* \geq 0, \ a_g^* \geq 0, \ -\infty < t < \infty$

2. Stability of a match (a_b^*, a_g^*) :

$$-d(a_b^*, a_g^*, t) - m(a_g^*) - c(a_b^*) \geq -d(a_b, a_g, t + a_b - a_b^*) - m(a_g) - c(a_b), \tag{m2.1}$$

$$for \ brides$$

$$d(a_b^*, a_g^*, t) - k(a_g^*) - q(a_b^*) \geq d(a_b, a_g, t + a_g - a_g^*) - k(a_g) - q(a_b), \tag{m2.2}$$

$$for \ grooms$$

$for \ a_b \neq a_b^*, \ a_g \neq a_g^*, \ where \ a_b^* \geq 0, \ a_g^* \geq 0, a_b \geq 0, a_g \geq 0, \ -\infty < t < \infty$

3. Market Clearing:

$$S(a_g^*, t) = S(a_b^*, t) \tag{m3}$$

$for \ a_b^* \geq 0, \ a_g^* \geq 0, \ -\infty < t < \infty$, where $S(a_m, t)$ denotes the supply of individuals of age a_m $(m = b, g)$ in the marriage market in period t.

Population Growth

Assume that there is a one-shot population growth in period 0 in which γN males and females are born $(1 < \gamma < 2)$. From period 1 onwards the birth rate reverts to N boys and girls in each period. (Allowing for continuous population growth does not alter the qualitative results of this paper; indeed it makes the sufficient conditions of the penultimate section easier to satisfy. All theoretical results are therefore presented for one-shot population growth.)

In period b, there will be more women (γN) than men (N) in the marriage market, hence some women of the ideal age b must postpone marriage. If all these women eventually find a partner – i.e. if there is continuing universality of marriage – then the spousal age gap will narrow over time. Alternatively, the age gap will remain the same but the number of single women in the population will be observed to rise. This paper shall focus on the former case of universal marriage and a narrowing spousal age gap, since this fits the empirical evidence on India in the twentieth century (Anderson 2007, Bhat and Halli 1999, Caldwell et al 1983, Rao 1993, Goyal 1988).

Eligible brides will continue to outnumber eligible grooms until period g, when the boys belonging to the 'boom' generation reach ideal marriageable age. In the following analysis, I shall denote these periods of excess brides by the symbol $\widetilde{t}$.

EXAMPLE: POPULATION GROWTH AND THE DOWRY PATH

This section provides a numerical example in which population growth leads to a non-monotonic dowry path – a spike in dowries followed by a decline – accompanied by a narrowing of the spousal age gap. A subsequent section will derive sufficient conditions under which such dowry paths will occur.

Consider the following functional forms consistent with the model assumptions made above:

$$\begin{aligned} m(a_m) &= 34a_m^4 \\ k(a_m) &= 34a_m^4 \\ c(a_m) &= 3a_m^4 \\ q(a_m) &= 3a_m^4 \\ \overline{U} &= -50 \\ \overline{V} &= -17 \\ g &= b+2 \end{aligned} \tag{A}$$

Since we are interested in the empirically observed case where all agents eventually marry and the spousal age gap narrows over time, I shall assume that older women are matched first when men are indifferent to the age of spouse. Also, when there are multiple equilibria in payments, I shall assume that each of these payments is equally likely. That is, dowries follow a uniform distribution, $d(a_b, a_g, t) \sim U[l, u]$, where l and u denote the lower and upper limits of the dowry payments, determined by the reservation utilities of agents. Finally, I shall assume that agents are informed of population dynamics only through their observation of the marriage market. For example, if there is a one-shot population growth in period t, agents learn of it in period $(t+b)$ when its impact on the marriage market is first manifested.

The following claims are true for the numerical example cited above. Proofs are provided in Appendix A.

Claim 1. *Grooms must marry at age $a_g = 0$. Brides may marry at age $a_b = 0$ or 1.*

Claim 1 follows from the the fact that the participation constraints of *both* brides and grooms are not satisfied except at $a_g = 0$ and $a_b = 0$ or 1. Henceforth, I shall refer to women of age $a_b = 0$ as 'young' and those of age $a_b = 1$ as 'older' women. Clearly, the ideal age of marriage for women is 'young'.

Claim 2. *Suppose the population and marriage market are in a steady state equilibrium with zero population growth (N boys and girls are born in every period) and identical expected dowry payments over time ($Ed(a_b, a_g, t) = Ed(a_b, a_g, t + 1)$). Then women prefer marriage at age $a_b = 0$ to marriage at age $a_b = 1$.*

Claim 2 follows from two facts. First, women value marriage more, ceteris paribus, when they marry at the ideal age. Second, when age-specific (expected) dowry payments are the same over time, women expect to pay a higher dowry if they postpone marriage beyond the ideal age, since men prefer young to older brides. Hence, in a steady state equilibrium with no population growth and constant dowries, women (and men) marry at the ideal age.

Claim 3. *Suppose that the population is initially in a steady state equilibrium with zero population growth (N boys and girls are born in every period) and constant expected dowries ($Ed(a_b, a_g, t) = Ed(a_b, a_g, t+1)$). Let a one-time population growth occur in period 0 (i.e. γN boys and girls are born in period 0 ($1 < \gamma < 2$) and N boys and girls are born in periods $t > 0$). Then there is a glut of eligible brides in periods $\widetilde{t} \in [b, g-1]$. Moreover, dowry payments will follow a non-monotonic path; that is, dowries will be higher in period b than in periods $t < b$ and will decline over the periods $\widetilde{t} \in [b, g-1]$.*

To understand the intuition of Claim 3, consider the composition of the marriage market in different periods, when all agents find a partner in their lifetime and the spousal age gap narrows over time. Let $f_i^t(m_j^t)$ denote the number of unmarried women (men) of age $a_b = i$ ($a_g = j$) in any period t. Then the marriage market structure in each period is as outlined in Table 1[3]. Note that in periods $\widetilde{t} \in [\, b,\, (g-1)]$ there are more eligible women than men in the market, since γN brides enter the market in period b but the number of grooms continue to be N till period g ($> b$).

What are the equilibrium marriage payments corresponding to the marriage market structure described in Table 1? In the steady state equilibrium with zero population growth ($t < b$), the number of ideal brides and grooms is exactly equal. Since there is one groom for every bride there may be multiple payments consistent with such an equilibrium, but women will extract a positive surplus from marriage even at the maximum feasible dowry payment. This is because at the maximum dowry that women are willing to pay, they receive the expected utility from postponing marriage to the next period. The women in the market, being of the ideal age b, know that they can find a partner if they postpone marriage by a period[4]. Hence even at the maximum dowry, they are not reduced to their outside option of

[3]Recall that older women are matched first when men are indifferent to the age of spouse. The marriage market structure in Table 1 has been formulated assuming that this is true.

[4]Note that women of age $(b+1)$ (or $a_b = 1$) must be able to find partners (at appropriate payments), else universality of female marriage and a narrowing of the spousal age gap would not be observed. These outcomes are ensured by the assumption that older women are matched first when men are indifferent to

never finding a partner and appropriate a positive post-payments marital surplus.

A backward induction approach demonstrates how equilibrium payments are determined in the periods $\widetilde{t} \in [b, (g-1)]$. Notice that in period g, the number of women and men in the market are exactly equal. Hence there will again be multiple payments in this period, with the limits determined by the reservation utilities of agents. Since there are both young and older women in the marriage market in this period, they may both be reduced to their reservation utility. Moreover, since older women may not find a match in the next period of their lives, their reservation utility is equal to the outside option of marriage.

Consider the marriage market in the previous period $(g-1)$. Competition for a spouse in this period will ensure that the marital utility of young women is equal to the expected utility of older women in period g. In other words, young women in period $(g-1)$ must bid up dowries to the point that they receive the expected marital utility of older women in period g.

Compare now the expected marital utilities of young women in period $(g-1)$ and of those in periods $t < b$. In the steady state equilibrium $(t < b)$, young women were guaranteed a marital utility greater than the outside option, even at the maximum feasible dowry payments. Note also that the maximum feasible payments – hence, the minimum marital utility of young women – were driven by the disutility of postponing marriage to age $a_b = 1$, viz. -3 (see $(u1)$ and (A)). In period $(g-1)$, however, young women foresee the possibility of being compelled to postpone marriage and be reduced to the outside option in the next period. Since the outside option of marriage is far less than the (dis)utility of marrying at $a_b = 1$, (recall $\overline{U} = -50$), the expected utility of young women in $(g-1)$ is lower and they pay a higher dowry than do women in the steady state equilibrium[5].

the age of the bride.

[5] When there are multiple equilibria, the lower limit of payments is determined by the outside option of grooms, since they may only marry at the age $a_g = 0$. Therefore the expected dowry (and hence, the expected marital utility of women) depends on the upper limit of payments, determined by the reservation utility of the bride. Thus the expected dowry is higher (expected marital utility of women is lower) when

Figure 1 plots the values of equilibrium dowries for this example in particular. Notice that dowries decline over the horizon $\widetilde{t} \in [b, (g-1)]$ (as in Anderson (2007)), but after an initial jump in the first period b. The time-path of dowry payments is therefore non-monotonic[6].

The above example demonstrates the effect of population growth on dowry payments, when there is a narrowing of the spousal age gap and continuing universality of female marriage. This is the empirically relevant case for India, where the spousal age gap has been falling over time and where universality of female marriage has been a noteworthy feature of marriage markets throughout the last century (Anderson 2007, Bhat and Halli 1999, Caldwell et al 1983, Rao 1993, Goyal 1988).

Does this theoretical prediction of a non-monotonic dowry path fit the empirical evidence? I address this question in the next section.

THEORY VERSUS EMPIRICAL EVIDENCE

In this section, I test if data simulated from a theoretical model can replicate the puzzling findings reported in the empirical literature.

The ensuing analysis continues to make all the assumptions presented in the previous section but differs in two respects. First, I assume continuous population growth for four periods instead of a one-shot population growth. The dowry path for continuous population growth is derived in Appendix D and presented in Figure 2. Continuous population growth allows for a more realistic replication of the empirical literature, while ensuring that the theoretical results of the previous sections remain unchanged. Second, I assume the existence of three districts that are identical in all respects (such as preferences and ideal marriage ages) but which experience population growth at different times. Each district is a closed marriage market, so that men and women do not marry outside their own district[7]. Data is

the reservation utility of the bride is lower.

[6] Appendix D derives the dowry path that would be obtained if the population continued to grow for $(k+1)$ periods instead of only one period. Qualitative results are unchanged.

[7] This is an implicit assumption made in the empirical literature, in which the district sex ratio of men and

drawn from the dowry paths experienced by the three districts and used to run regressions akin to those analyzed in the empirical literature (Rao 1993, Edlund 2000, Edlund 2006 and Dalmia and Lawrence 2005).

As before, I assume that initially N boys and girls are born in each period. Suppose that population growth starts in period t_0 (which may differ by district) and continues upto period $(t_0 + 3)$. Consistent with Anderson (2007), let the number of births in any period t $(t_0 \leq t \leq t_0{+}3)$ be given by $\gamma_t N$ $(1 < \gamma_t < 2$ for $t = t_0, ...t_0{+}3)$. From period $(t_0{+}4)$ onwards the number of births reverts to N. For concreteness, let $\gamma_{t_0} = 1.1,\ \gamma_{t_0+1} = 1.2, \gamma_{t_0+2} = 1.65$ and $\gamma_{t_0+3} = 1.95$. Also, let population growth begin (t_0) in period $-b$ in district 1, in period $(-b + 1)$ in district 2 and in period $(-b + 2)$ in district 3.

Table 2 presents the marriage market composition and dowry path in each district (also see Figure 2). Notice that district 1 experiences a glut of marriageable women in periods $(\widetilde{t})$ 0 to 4, district 2 in periods 1 to 5, and district 3 in periods 2 to 6.

I now draw data from these 3 districts starting from period -5 up to period 8. The data are presented in Table 3. The marriage market composition presented in Table 2 and the assumed birth rates (γ_t) yield the ratio of women to men at ideal age in each period. In the empirical literature, this ratio has been used to measure the availability of brides relative to grooms in a district.

I use the data in Table 3 – simulated from the numerical example described above – to run OLS regressions of dowry payments on the bride-availability indicator and year of marriage. I run separate regressions for early periods $(t < 5)$, middle periods $(0 < t < 4)$, late periods $(t > 3)$, and all periods taken together, so as to correspond with various empirical analyses. Henceforth, I shall refer to these regressions (that use simulated data) as 'theoretical' regressions.

Note that the Indian population started to grow in the early 1930s (Caldwell et al 1983, Rao 1993, Hutter 1996). If women marry around the age of twenty, therefore, the initial

women of ideal marriagable age is routinely used to measure the relative availability of brides and grooms.

dowry spike(s) would occur roughly around the year 1950. Hence, the early periods' theoretical regression is akin to those run by Rao (1993) and Edlund (2000), in whose samples the year of marriage dates from the 1920s to the 1970s. The theoretical regression using late years is akin to that of Dalmia and Lawrence (2005), whose data run from the 1950s to the 1990s. Finally, Edlund (2006) uses the same dataset as Edlund (2000) but drops observations on year of marriage prior to 1940. She also drops the last two survey years. Hence, the theoretical regression using the middle years is comparable to Edlund (2006).

The theoretical regressions are presented in Tables 4 and 6 (panel 1) and the comparable results from the empirical literature are reported in Tables 5 and 6 (panel 2). The signs of the regression coefficients are perfectly matched in the two, as is summarized in the following table.

Study	Reported from Study: Coef. [Yr., $\frac{\#\ Ideal\ Brides}{\#\ Ideal\ Grooms}$]	Predicted by Theoretical Reg.: Coef. [Yr., $\frac{\#\ Ideal\ Brides}{\#\ Ideal\ Grooms}$]
Rao 1993	[+, +]	[+, +]
Edlund 2000	[+, +]	[+, +]
Dalmia et al 2005	[–, +]	[– , +]
Edlund 2006	[+, –]	[+, –]
Edlund 2006 (dummies for pre/post 1950)	[+ ($\leq$ 1950), – (> 1950), –]	[+ (early yrs), – (later yrs), –]

How does the non-monotonic path predicted by economic theory explain the regression results reported in the literature?

The relationship between dowries and year of marriage is easily explained using Figure 2. Focusing on the non-monotonic dowry path in any district, it is clear that if a linear trend is fitted using only the early years – that is, the years before the dowry spike occurs to just after (as in Rao (1993) or Edlund (2000)) – a positive association will be obtained. Likewise, if a linear trend is fitted to the years after the spike has occurred (as in Dalmia and Lawrence (2005)), the association between dowry and year of marriage will be negative.

Finally, Edlund (2006) – the only analysis that allows for different trends in dowry payments before and after the 1950s – finds a stronger rise in net dowries prior to the 1950s than after this period. This too is consistent with the dowry paths in Figure 2.

The association between dowries and the ratio of brides to grooms is explained using Table 2. Table 2 shows that under the assumed population growth structure (in any district), the sex ratio of ideal women to men first rises, then falls and finally jumps again. This occurs simultaneously with the familiar non-monotonic dowry path comprising a spike followed by a decline. The ambiguous sign of the correlation between dowry and the sex ratio of marriageable men and women results from the fact that in any time period, data is drawn from different districts which may be at different points on the non-monotonic dowry path[8].

The above analysis demonstrates that the theoretical regressions can match the signs of coefficients in the regressions conducted in the empirical literature. In other words, the apparently contradictory evidence on Indian dowries is resolved if the time-path of dowries is non-monotonic as in Figures 1 and 2, as predicted by economic theory.

Recall that in the data used in the theoretical regressions, the *only* shock to the marriage market is population growth. Hence, the fact that the results obtained in the empirical literature can be replicated using this data clearly indicates that population growth *can* impact the dowry path, as it has been observed in India. Therefore, while other factors cannot be ruled out, demographic change constitutes a plausible explanation for the evolution of dowries in India in the twentieth century.

SUFFICIENT CONDITIONS FOR A NON-MONOTONIC DOWRY PATH

The empirical findings on dowries in India can be replicated by a non-monotonic dowry path in which dowries first rise before declining. The analysis in previous sections demonstrates

[8] The results may also be affected by the relative numbers of observations from each district. In the simulated data presented here, each district contributes the same number of observations to the dataset.

the existence of such a non-monotonic path, consistent with the predictions of economic theory. In this section, I derive sufficient conditions to generate such a non-monotonic path. I further argue that these conditions are accurate descriptors of the Indian marriage market.

All the assumptions of previous sections continue to apply, but we will now focus on a single district experiencing a one-shot population growth. The conditions derived herein become less stringent (i.e. more easily satisfied) if continuous population growth is permitted[9].

It is empirically observed in twentieth-century India that all women continue to find a partner in their lifetime and that the spousal age gap has narrowed over time (Anderson 2007, Bhat and Halli 1999, Caldwell et al 1983, Rao 1993, Goyal 1988). Lemma 1 provides a necessary condition to generate the same. The proof is provided in Appendix B.

Lemma 1. *Suppose that men may marry at age* $a_g = 0$ *and women at age* $a_b = 0$ *or* 1. *Consider a one-shot population growth in period* 0. *A necessary condition for the age gap to narrow and for all agents to secure a match in the periods* $\widetilde{t} \in [b, (g-1)]$, *is that*

$$d(0,0,b) = \frac{\overline{V} - \overline{U} + (2g - 2b - 1)[q(1) + c(1)]}{2} \leq -\overline{U} \qquad (p1)$$

This is the participation constraint of young women in the first period, b, *of mismatch in the numbers of brides and grooms.*

Lemma 1 follows from the fact that on any payments path that guarantees universality of marriage and a narrowing of the spousal age gap, the composition of the marriage market in each period must be as given in Table 1. The only payments path that is consistent with this composition of the marriage market is the one that is derived by backward induction using the equilibrium payments that must exist in period g. For this path to be feasible however, the highest possible dowry payment – in period b – must be feasible. Condition ($p1$) in Lemma 1 states the participation constraint of women – which ensures the feasibility of the equilibrium dowry payments – in period b.

[9] Proofs are available upon request.

Proposition 1 outlines sufficient conditions for a non-monotonic dowry path when a one-shot population growth (in period 0) is accompanied by a narrowing of spousal age gap and continuing universality of marriage. The proof is provided in Appendix C.

Proposition 1. *Suppose that men may marry at age $a_g = 0$ and women at age $a_b = 0$ or 1. Suppose that $(p1)$ holds. Let a one-shot rise in the population growth rate occur in period 0. Then, if $(p1)$ does not bind or if the ideal age gap at marriage is 2 or higher, a non-monotonic dowry path that can replicate the empirical findings is obtained. The non-monotonic dowry path is characterized by a spike in expected dowries in period b followed by a decline over periods $\widetilde{t} \in [b, (g-1)]$.*

Note that a low outside option of marriage for women $(\overline{U})$ is sufficient to ensure that $(p1)$ does not bind. Hence, by Proposition 1, a low outside option for women or a high ideal spousal age gap is sufficient to generate a dowry path that can replicate the empirical findings.

To see the intuition of this result, consider the necessary condition for universality of female marriage $(p1)$. Notice that a low value of $\overline{U}$ guarantees the satisfaction of this condition because a low outside option of marriage ensures that women are willing to pay a high dowry rather than remain single. But a low value of $\overline{U}$ also lowers the reservation utility of old women in period g, and hence, by backward induction, lowers the expected utilities of young women in previous periods $\widetilde{t}$. This causes young women to bid higher dowries in those earlier $\widetilde{t}$.

If the difference in ideal ages of marriage of men and women is high, then the horizon $\widetilde{t}$ stretches for a longer range of time. Since dowries must decline over the periods b to g and are derived by backward induction from period g, the longer the stretch $\widetilde{t}$ extends, the higher must be the equilibrium dowry in the first period, b.[10] Hence, a low outside option

[10]Recall that the equilibrium dowries in period g are determined by the reservation utilities of men and women. Hence the expected dowry in period g is independent of the length of the horizon $\widetilde{t}$ during which there are more eligible women than men in the market.

from marriage and a high ideal age gap of spouses ensure that dowries will spike in period b and decline over periods $\widetilde{t}$, if all agents are to eventually find a partner in their lifetime[11].

Therefore, the non-monotonic dowry path demonstrated above, which replicates the empirical finding, is not a numerical rarity but is *guaranteed* by a low outside option of marriage for women or a high ideal spousal age gap.

Observations on the Indian marriage market have been consistent with both the sufficient conditions outlined above. Rao (1993: 285) points out that "in the Indian marriage market there are strong social and economic pressures for women to be married within an 'acceptable' age range... This is 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." This suggests a low outside option of marriage of Indian women, i.e. a low $\overline{U}$. The age gap at marriage has also been relatively high in India compared with other countries. Bhat and Halli (1999) estimate the difference in singulate mean age of marriage of men and women in India to be 6.9 years in 1911; the gap declined to 5.4 years in 1951. Festy's (1973) estimation of the differences in mean age of marriage of men and women in Canada, USA, Australia and New Zealand in 1911-1915 are, respectively, 2.7, 2.8, 2.6 and 2.3 years. In 1936-1940, the estimates of the age gaps in these countries were, respectively, 2.5, 2.4, 3.6 and 3 years.

SUMMARY AND CONCLUSION

Empirical evidence on the role of population growth on Indian dowry payments has been contradictory, suggesting that demographics may have no role to play in determining mar-

[11] Allowing continuous population growth also expands the horizon $\widetilde{t}$, increasing the dowry spike in period b, and yielding the non-monotonic time-path required to replicate empirical findings. The sufficient condition for a non-monotonic dowry path under continuous growth is, therefore, less stringent: $(g-b) > 0$ can generate the required non-monotonic dowry path, whether or not $(p1)$ binds. (Proof available from the author upon request.)

riage payments. In this paper, I propose a resolution of the empirical puzzle using principles of economic theory. I employ Anderson's (2007) theoretical framework to model the impact of population growth on dowry payments. I show that the time-path of dowries may be non-monotonic – an eventual decline in dowries (as predicted by Anderson (2007)) preceded by a spike – a feature that has not previously been highlighted in the literature. I demonstrate, moreover, that such a non-monotonic dowry path can successfully generate all of the apparently contradictory findings in the empirical literature, in a unified theoretical setting. This suggests that while other factors cannot be ruled out, demographic change could suffice to explain the evolution of dowries observed in twentieth-century India.

APPENDICES

A. Example

A.1. Proof of Claim 1

Proof. For the participation constraint of brides and grooms (of age a_b and a_g respectively) to hold simultaneously, we require, (see $(m1.1)$ and $(m1.2)$)

$$k(a_g) + q(a_b) + \overline{V} \leq d(a_b, a_g, t) \leq -\overline{U} - m(a_g) - c(a_b)$$

a necessary condition for which is:

$$k(a_g) + m(a_g) + c(a_b) + q(a_b) \leq -(\overline{V} + \overline{U}) \tag{A.1}$$

where $a_m \geq 0$ $(m = b, g)$.

Notice that a necessary condition for $(A.1)$ is that it be true at $a_b = 0$, since $c(.)$ and $q(.)$ are minimized at $a_b = 0$.

Consider $a_g = 1, a_b = 0$. At this value, $(A.1)$ is not satisfied since the left hand side is 68 and the right hand side is 67. Since the left hand side is increasing in a_g for $a_g > 0$, this means that $(A.1)$ is not satisfied for all $a_g \geq 1, a_b \geq 0$.

At $a_g = 0, a_b = 0$, $(A.1)$ is satisfied.

Hence, men may only find a willing partner when they are of age $a_g = 0$.

Since grooms must marry at age 0 (see previous claim), let us now consider matches in which grooms are of age 0.

At $a_b = 1, a_g = 0$, $(A.1)$ is satisfied since the left hand side is 6 and the right hand side is 67. This means that $(A.1)$ is true for $a_b = 0, 1$ ($a_g = 0$) since the left hand side is increasing in a_b for $a_b \geq 0$.

At $a_b = 2, a_g = 0$, $(A.1)$ is not satisfied since the left hand side is 96 and the right hand side is 67. Hence $(A.1)$ is not true for $a_b \geq 2, a_g = 0$.

Hence women may marry at ages $a_b = 0$ or 1. ■

A.2. Proof of Claim 2

Proof.

$$\text{Expected lifetime utility from marrying at age } 0 = -Ed(0,0,t) - m(0) - c(0) \qquad (A.2)$$

$$\text{Expected lifetime utility from marrying at age } 1 = -Ed(1,0,t) - m(0) - c(1) \qquad (A.3)$$

where $Ed(.)$ denotes expected dowry payments.

Suppose that women prefer to marry at age 1 in period $(t+1)$ than at age 0 in period t. Then, from $(A.2)$ and $(A.3)$, we have:

$$-Ed(0,0,t) - m(0) - c(0) < -Ed(1,0,t+1) - m(0) - c(1) \qquad (A.4)$$

Also, men of age 0 must prefer to marry women of age 1 in $(t+1)$. This is true if:

$$-k(0) - q(0) + Ed(0,0,t+1) < -k(0) - q(1) + Ed(1,0,t+1) \qquad (A.5)$$

Adding $(A.4)$ and $(A.5)$, we get:

$$Ed(0,0,t+1) - Ed(0,0,t) < -q(1) - c(1) \qquad (A.5')$$

At the intitial steady state equilibrium, $Ed(0,0,t+1) = Ed(0,0,t)$. Hence $(A.5')$ implies:

$$0 < -q(1) - c(1)$$

which is clearly not satisfied since $q(1) = 3 > 0$, $c(1) = 3 > 0$.

Hence, at the initial steady state equilibrium, women prefer to marry at $a_b = 0$. Men have to marry at age $a_g = 0$, since they cannot find partners at ages higher than 0. ■

A.3. Proof of Claim 3

Proof. I shall demonstrate this claim by using backward induction to compute the equilibrium marriage payments in each period. The payments are determined by the marriage market structure in each period, outlined in Table 1. Note from Table 1 that there are more eligible brides in the market in periods $\widetilde{t} \in [b, (g-1)]$.

First, I shall solve for the steady state equilibrium payments in $t < 0$ and $t \geq g+1$. Note that in these periods the number of men and women in the marriage market are perfectly matched. Hence there will be multiple equilibria in marriage payments since neither party has a credible threat point for marriage.

The stability conditions of women (see $(m2.1)$) yields:

$$d(0,0,t) \leq Ed(1,0,t+1) + c(1)$$

Combined with the stability constraint of men $(m2.2)$, this becomes

$$d(0,0,t) \leq Ed(0,0,t+1) + q(1) + c(1) \tag{A.6}$$

From the participation constraint of men $(m1.2)$ we obtain

$$d(0,0,t) - k(0) - q(0) - \overline{V} \geq 0 \tag{A.7}$$

where $\overline{V} = -17$ is the outside option of marriage of men.

$(A.6)$ and $(A.7)$ yield the condition

$$\overline{V} \leq d(0,0,t) \leq Ed(0,0,t+1) + q(1) + c(1) \tag{A.8}$$

Note that since the number of men and women are exactly equal marriage payments may settle anywhere in this range. Suppose that each of these payments are equally likely, i.e. dowries follow a uniform distribution. Then we have

$$d(0,0,t) \sim U[\overline{V}, Ed(0,0,t+1) + q(1) + c(1)]$$

so the expected payments in each period t such that $t < b$ or $t \geq (g+1)$, are

$$Ed(0,0,t) = \frac{\overline{V} + Ed(0,0,t+1) + q(1) + c(1)}{2}$$

$$Ed(0,0,t) = Ed(0,0,t+1) = q(1) + c(1) + \overline{V} \qquad (A.9)$$

In the case of the present example, we have (using $(A.8)$ and $(A.9)$):

$$\begin{aligned} Ed(0,0,t) &= Ed(0,0,t+1) = -11 \qquad (A.10) \\ -17 &\leq d(0,0,t) \leq -5 \end{aligned}$$

in periods t, $t < b$ or $t \geq (g+1)$.

Next I will determine the equilibrium payments in period g. In this period too, there may be multiple equilibria in marriage payments since the total number of men and women in the marriage market are equal.

Using the above analysis once again, the equilibrium dowries paid by young women is obtained to be

$$Ed(0,0,g) = q(1) + c(1) + \overline{V} \qquad (A.11)$$

The participation constraint of older women $(m1.1)$ and that of men marrying older women $(m1.2)$ yield the condition,

$$\overline{V} + q(1) \leq d(1,0,g) \leq -c(1) - \overline{U}$$

Again, assuming $d(1,0,g) \sim U[\overline{V} + q(1),\ -c(1) - \overline{U}]$ we get

$$Ed(1,0,g) = \frac{q(1) - c(1) + \overline{V} - \overline{U}}{2} \tag{A.12}$$

In the present example, therefore, we have

$$\begin{aligned} Ed(0,0,g) &= -11 \\ -17 &\leq d(0,0,g) \leq -5 \\ Ed(1,0,g) &= 16.5 \\ -14 &\leq d(1,0,g) \leq 47 \end{aligned} \tag{A.13}$$

I shall now determine the equilibrium payments in period $(g-1) = (b+1)$.

Using the stability constraint of young women $(m2.1)$ and $(A.12)$, we get

$$d(0,0,g-1) = \frac{q(1) + c(1) + \overline{V} - \overline{U}}{2} \tag{A.14}$$

Older women's payments are then (in order to satisfy the stability constraint of men):

$$d(1,0,g-1) = \frac{q(1) + c(1) + \overline{V} - \overline{U}}{2} + q(1) \tag{A.15}$$

In the present example, we have

$$d(0,0,g-1) = 19.5 \qquad (A.16)$$

$$d(1,0,g-1) = 22.5$$

Finally, I determine the equilibrium payments in period b.

Using the stability constraint $(m2.1)$ and $(A.14)$, young women's payments are determined by (recall $g = b + 2$),

$$d(0,0,b) = \frac{3q(1) + 3c(1) + \overline{V} - \overline{U}}{2} \qquad (A.17)$$

In the present example this is

$$d(0,0,b) = 25.5 \qquad (A.18)$$

Using $(A.10), (A.13), (A.16)$ and $(A.18)$, I can outline the dowry path in the present example:

	$Ed(0,0,t)$	$Ed(1,0,t)$	$Min\ d(0,0,t)$	$Max\ d(0,0,t)$
$t \leq b-1$	-11	$*$	-17	-5
$t = b$	25.5	$*$	25.5	25.5
$t = b+1 = g-1$	19.5	22.5	19.5	19.5
$t = g$	-11	16.5	-17	-5
$t \geq g+1$	-11	$*$	-17	-5

where $*$ denotes that there are no unmarried women of age $a_b = 1$ in the market in this period.

Therefore, when there is a one-time growth in the population in period 0, average dowries paid by young women rise in period b and subsequently decline in the periods $\widetilde{t} \in [b, (g-1)]$, in which there are more eligible women than men in the market. This is represented diagrammatically in Figure 1.

Also, the dowry paid in each period $\widetilde{t} \in [b, (g-1)]$ is higher than the steady state dowry levels. ■

B. Proof of Lemma 1

Proof. Suppose that men marry at age $a_g = 0$ and women at $a_b = 0$ or 1. Consider a one-shot population growth in period 0 in which the birth rate rises from N to γN $(1 < \gamma < 2)$.

If the spousal age gap is to narrow and all women continue to marry, then it must be the case that older women $(a_b = 1)$ are matched first in each period. This implies a unique marriage market structure, viz. that presented in Table 1. The marriage payments on this path (derived by backward induction as in Appendix A) are given by:

$$d(0,0,g-k) = \frac{\overline{V} - \overline{U} + (2k-1)[q(1)+c(1)]}{2} \qquad (B.I)$$

where $0 < k \leq (g-b)$.

A necessary condition for this dowry path to be feasible, is that the highest dowry on this path (in period b) is feasible. This implies, from $(B.I)$ and $(m1.1)$,

$$d(0,0,b) = \frac{\overline{V} - \overline{U} + (2g-2b-1)[q(1)+c(1)]}{2} \leq -\overline{U} \qquad (p1)$$

(putting $k = g - b$ in $(B.I)$). ■

C. Proof of Proposition 1

Proposition 1 stated in the text is a summary of the more detailed statement (Proposition 2) presented below, outlining the role of parameters in generating a non-monotonic dowry path.

The following definition outlines three possible (non-monotonic) dowry paths based on how high is the spike in dowries before a decline sets in.

Definition 1. *Suppose that the population and marriage market are in a steady state equilibrium with zero population growth. Women's ideal age of marriage is b and men's ideal age of marriage is g ($b < g$). Consider a one-shot population growth in period 0. A non-monotonic dowry path – which entails a spike in dowries in period b followed by a decline over periods $\widetilde{t} \in [b, (g-1)]$ – can take the following forms:*

1. *Dowries in each period $\widetilde{t}$ are higher than the maximum dowry in the initial steady state equilibrium, i.e. $d(0,0,\widetilde{t}) > Max\ d(0,0,t < b)$ for all $\widetilde{t}$*

2. *The dowry in period b is higher than the maximum dowry in the initial steady state equilibrium, i.e. $d(0,0,b) > Max\ d(0,0,t < b)$*

3. *Dowries in each period $\widetilde{t} \in [b, (g-1)]$ are higher than the expected dowry in the initial steady state equilibrium, i.e. $d(0,0,\widetilde{t}) > Ed(0,0,t < b)$ for all $\widetilde{t}$*

Note that a dowry path of type 1 must necessarily satisfy the conditions for paths of types 2 and 3. Likewise, a type-2 path must necessarily satisfy the condition for a path of type 3. More importantly, when the sample size is large, a dowry path of type 3 is *sufficient* to generate results such as those obtained in the empirical literature. This is due to the fact that since regression coefficients measure averages, an increase in dowry payments relative to the average payment in the initial steady state equilibrium ($Ed(0,0,t<b)$), is all that is required to generate coefficients akin to those obtained in the empirical literature.

Proposition 2. *Suppose that men may marry at age $a_m = 0$ and women at age $a_b = 0$ or 1. Suppose that $(p1)$ holds. Let $\widetilde{t}$ denote the periods $(b \leq \widetilde{t} < g)$ when there are more eligible brides than grooms in the marriage market. Then the following statements are true*[1]*:*

1. *If the ideal age gap is greater than 2, the dowry in each period $\widetilde{t}$ is higher than the maximum dowry in the initial steady state equilibrium (type 1 dowry path). Thus $d(0,0,\widetilde{t}) > Max\ d(0,0,t<b)$ for all $\widetilde{t}$ if $(g-b) > 2$.*

2. *If the ideal age gap is 2, then the type of dowry path depends on whether $(p1)$ binds. In particular,*

    1. *if $(p1)$ does not bind, the dowry in each period t_s is higher than the maximum dowry in the initial steady state equilibrium (type 1 dowry path). Thus $d(0,0,\widetilde{t}) > Max\ d(0,0,t<b)$ for all t_s if $(g-b) = 2$ and $(p1)$ does not bind*

    2. *if $(p1)$ binds, then*

        1. *the dowry in each period $\widetilde{t}$ is higher than the expected dowry in the initial steady state equilibrium (type 3 dowry path). Thus $d(0,0,\widetilde{t}) > Ed(0,0,t<b)$*

[1] *Under continuous population growth, the sufficient conditions are less stringent. $(g-b) \geqslant 2$ guarantees that squeeze dowries exceed the maximum steady state dowry (type 1 dowry inflation) and $(g-b) = 1$ ensures that these are higher than the steady state average dowry, regardless of whether the condition $[d(0,0,b) < -\overline{U}]$ binds. Proofs are available from the author upon request.*

for all $\widetilde{t}$ if $(g-b)=2$ and $(p1)$ binds. Also,

2. *the dowry in the period b is higher than the maximum dowry in the initial steady state equilibrium (type 2 dowry inflation). Thus $d(0,0,b) > Max\ d(0,0,t<b)$ if $(g-b)=2$ and $(p1)$ binds.*

3. *If the ideal age gap is less than 2, then the form of dowry inflation depends on whether $(p1)$ binds. In particular,*

   1. *if $(p1)$ does not bind, then the dowry in each period $\widetilde{t}$ is higher than the expected dowry in the initial steady state equilibrium (type 3 dowry path). Thus $d(0,0,\widetilde{t}) > Ed(0,0,t<b)$ for all $\widetilde{t}$ if $0<(g-b)<2$ and $(p1)$ does not bind*

   2. *if $(p1)$ binds, the dowry in each period $\widetilde{t}$ is equal to the expected dowry in the initial steady state equilibrium. Thus $d(0,0,\widetilde{t}) = Ed(0,0,t<b)$ for all $\widetilde{t}$ if $0<(g-b)<2$ and $(p1)$ binds.*

Proof. Applying the method of analysis presented in Appendix A, the dowries in the initial steady state equilibrium may be derived to be:

$$\begin{aligned} Ed(0,0,t &< b) = Ed(0,0,t+1) = q(1)+c(1)+\overline{V} \qquad (C.19) \\ Min\ d(0,0,t &< b) = \overline{V} \\ Max\ d(0,0,t &< b) = 2q(1)+2c(1)+\overline{V} \end{aligned}$$

Also, $(B.I)$ in Appendix B derives the equilibrium dowry in each period $\widetilde{t} \in [b,(g-1)]$, in which there are more eligible women than men in the marriage market:

$$d(0,0,g-k) = \frac{\overline{V} - \overline{U} + (2k-1)[q(1)+c(1)]}{2} \tag{B.I}$$

where $0 < k \leq (g-b)$ corresponds to $\widetilde{t} \in [b, (g-1)]$.

Suppose that $(p1)$ holds. $(p1)$ simplifies to

$$[2(g-b)-1][q(1)+c(1)] \leq -(\overline{U}+\overline{V}), \tag{p1'}$$

which is a necessary condition for a dowry path on which the spousal age gap narrows and all women continue to find a partner.

Proposition 1 follows easily from proving the relation between $(C.19)$ (steady state dowries) and $(B.I)$ ('$\widetilde{t}$' dowries), implied by $(p1')$, for different ranges of $(g-b)$. ■

D. Continuous Population Growth

Proof. Consider the numerical example considered thus far. Suppose the population is in an initial steady state equilibrium, with N girls and boys being born in each period. Now suppose that population growth starts in period 0 and continues upto period k, where the number of births in any period t $(0 \leq t \leq k)$ is given by $\gamma_t N$ $(1 < \gamma_t < 2$ for $t = 0, 1, ..., k)$. From period $(k+1)$ the number of births returns to N[2]. The marriage market structure in each period can then be derived as follows, assuming that older women are matched first when men are indifferent to the age of bride (this ensures that all women are married in each

[2]This structure of population growth is similar to that used by Anderson.

period and that the age gap between grooms and brides narrows over time)[3].

Time (t)	f_0^t	f_1^t	m_0^t	$f_1^t - m_0^t$	$f_1^t + f_0^t - m_0^t$
$t < b$	N	0	N	–	0
$t = b$	$\gamma_0 N$	0	N	–	$(\gamma_0 - 1)N > 0$
$t = b + 1$	$\gamma_1 N$	$(\gamma_0 - 1)N$	N	$(\gamma_0 - 2)N < 0$	$(\gamma_0 + \gamma_1 - 2)N > 0$
$t = g = b + 2$	$\gamma_2 N$	$(\gamma_1 + \gamma_0 - 2)N$	$\gamma_0 N$	$(\gamma_1 - 2)N < 0$	$(\gamma_1 + \gamma_2 - 2)N > 0$
$t = g + 1$	$\gamma_3 N$	$(\gamma_1 + \gamma_2 - 2)N$	$\gamma_1 N$	$(\gamma_2 - 2)N < 0$	$(\gamma_2 + \gamma_3 - 2)N > 0$
...	...	...	...	...	...
$t = g + k - 2$	$\gamma_k N$	$(\gamma_{k-1} + \gamma_{k-2} - 2)N$	$\gamma_{k-2} N$	$(\gamma_{k-1} - 2)N < 0$	$(\gamma_{k-1} + \gamma_k - 2)N > 0$
$t = g + k - 1$	N	$(\gamma_{k-1} + \gamma_k - 2)N$	$\gamma_{k-1} N$	$(\gamma_k - 2)N < 0$	$(\gamma_k - 1)N > 0$
$t = g + k$	N	$(\gamma_k - 1)N$	$\gamma_k N$	$-N < 0$	0
$t \geq g + k + 1$	N	0	N	–	0

Using arguments similar to those in Appendix A (see proofs of Claims 1-3), the dowry path can then be calculated to be[4]:

[3] The earlier example of a one-shot population growth (that takes place in period 0) corresponds to $k = 0$.

[4] Note that the path outlined herein is feasible only if the highest dowry (in period b) satisfies the participation constraint of women. Any population growth structure can be accompanied by universality of marriage and a narrowing of the age gap, only if this condition is satisfied. For the values of model parameters assumed in the third section of the paper, a maximum of 5 periods of population growth ($k = 4$) can be accompanied by declining age gap and universality of marriage.

$Time\ (t)$	f_0^t/m_0^t	$Ed(0,0,t)$	$Ed(1,0,t)$
$t < b$	1	-11	$-$
$t = b$	γ_0	$19.5 + 6(k+1)$	$-$
$t = b + 1$	γ_1	$19.5 + 6k$	$22.5 + 6k$
$t = g = b + 2$	$\frac{\gamma_2}{\gamma_0}$	$19.5 + 6(k-1)$	$22.5 + 6(k-1)$
$t = g + 1 = b + 3$	$\frac{\gamma_3}{\gamma_1}$	$19.5 + 6(k-2)$	$22.5 + 6(k-2)$
...	...	...	...
$t = g + k - 2 = b + k$	$\frac{\gamma_k}{\gamma_{k-2}}$	25.5	28.5
$t = g + k - 1 = b + k + 1$	$\frac{1}{\gamma_{k-1}}$	19.5	22.5
$t = g + k = b + k + 2$	$\frac{1}{\gamma_k}$	-11	16.5
$t \geq g + k + 1 = b + k + 3$	1	-11	$-$

The above example shows that even with continuous population growth there is first a dowry spike followed by declining payments over time. Also, the dowry is higher in each period $\widetilde{t} \in [(b, (g + k - 1)]$ compared with previous periods.

For $k = 3$, $\gamma_0 = 1.1$, $\gamma_1 = 1.2, \gamma_2 = 1.65$ and $\gamma_3 = 1.95$ (as assumed in the fourth section of the paper), the dowry path and sex ratio of men and women at the ideal age of marriage is given by:

$Time\ (t)$	f_0^t/m_0^t	$Ed(0,0,t)$	$Min\ Ed(0,0,t)$	$Max\ Ed(0,0,t)$
$t < b$	1	-11	-17	-5
$t = b$	1.1	43.5	43.5	43.5
$t = b + 1$	1.2	37.5	37.5	37.5
$t = g = b + 2$	1.5	31.5	31.5	31.5
$t = g + 1 = b + 3$	1.625	25.5	25.5	25.5
$t = g + k - 1 = b + k + 1$	0.6061	19.5	19.5	19.5
$t = g + k = b + k + 2$	0.5128	-11	-17	-5
$t \geq g + k + 1 = b + k + 3$	1	-11	-17	-5

$\blacksquare$

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Table 1: Marriage Market Structure in Each Period, under a One-shot Population Growth

Time Period (t)	f_0^t	f_1^t	m_0^t	*Market Structure*
$t < b$	N	0	N	$f_0^t = m_0^t;\ f_1^t = 0$
b	γN	0	N	$f_0^t > m_0^t;\ f_1^t = 0$
$b + 1 = g - 1$	N	$\gamma N - N$	N	$f_1^t < m_0^t < f_1^t + f_0^t$
g	N	$\gamma N - N$	γN	$m_0^t = f_1^t + f_0^t$
$t \geq g + 1$	N	0	N	$f_0^t = m_0^t;\ f_1^t = 0$

Table 2: Marriage Market Composition and Dowry Path under 4-Period Population Growth

District 1: Population growth starts in period t_0 = -b and continues to period (t_0 + 3) = (-b + 3)

Time (t)	f_0^t	f_1^t	m_0^t	Ed(0,0,t)	$f_0^t + f_1^t > m_0^t$? (If more eligible women)	f_0^t/m_0^t (Women/Men of ideal age)
t < 0	N	0	N	-11	No	1
0	1.1N	0	N	43.5	Yes	1.1
1	1.2N	0.1N	N	37.5	Yes	1.2
2	1.65N	0.3N	1.1N	31.5	Yes	1.5
3	1.95N	0.85N	1.2N	25.5	Yes	1.625
4	N	1.6N	1.65N	19.5	Yes	0.6061
5	N	0.95N	1.95N	-11	No	0.5128
t > 5	N	0	N	-11	No	1

District 2: Population growth starts in period t_0 = (-b + 1) and continues to period (t_0 + 3) = (-b + 4)

Time (t)	f_0^t	f_1^t	m_0^t	Ed(0,0,t)	$f_0^t + f_1^t > m_0^t$? (If more eligible women)	f_0^t/m_0^t (Women/Men of ideal age)
t < 1	N	0	N	-11	No	1
1	1.1N	0	N	43.5	Yes	1.1
2	1.2N	0.1N	N	37.5	Yes	1.2
3	1.65N	0.3N	1.1N	31.5	Yes	1.5
4	1.95N	0.85N	1.2N	25.5	Yes	1.625
5	N	1.6N	1.65N	19.5	Yes	0.6061
6	N	0.95N	1.95N	-11	No	0.5128
t > 6	N	0	N	-11	No	1

District 3: Population growth starts in period t_0 = (-b + 2) and continues to period (t_0 + 3) = (-b + 5)

Time (t)	f_0^t	f_1^t	m_0^t	Ed(0,0,t)	$f_0^t + f_1^t > m_0^t$? (If more eligible women)	f_0^t/m_0^t (Women/Men of ideal age)
t < 2	N	0	N	-11	No	1
2	1.1N	0	N	43.5	Yes	1.1
3	1.2N	0.1N	N	37.5	Yes	1.2
4	1.65N	0.3N	1.1N	31.5	Yes	1.5
5	1.95N	0.85N	1.2N	25.5	Yes	1.625
6	N	1.6N	1.65N	19.5	Yes	0.6061
7	N	0.95N	1.95N	-11	No	0.5128
t > 7	N	0	N	-11	No	1

Note 1: The marriage market composition and dowry path are derived in Appendix D. Population growth is assumed to occur as follows: N boys and girls are born in each period before t_0. The population starts to grow in period t_0 and continues upto period (t_0 + 3), where the birth rate in period t ($t_0 \leq t \leq t_0 + 3$) is given by $\gamma_t N$. Assume $\gamma_{t0} = 1.1$, $\gamma_{t0+1} = 1.2$, $\gamma_{t0+2} = 1.65$ and $\gamma_{t0+3} = 1.95$.

Note 2: All assumptions other than the structure of population growth are the same as in the third section of the paper. The above path ensures that all women find a match in every period and that the age gap between grooms and brides narrows over time.

Table 3: Data for Theoretical Regressions in Table 4 (n = 42)

District	Period of Marriage (t)	Dowry[a]	(Women/Men) of Ideal Age
1	-5	-11	1
1	-4	-11	1
1	-3	-11	1
1	-2	-11	1
1	-1	-11	1
1	0	43.5	1.1
1	1	37.5	1.2
1	2	31.5	1.5
1	3	25.5	1.625
1	4	19.5	0.6061
1	5	-11	0.5128
1	6	-11	1
1	7	-11	1
1	8	-11	1
2	-5	-11	1
2	-4	-11	1
2	-3	-11	1
2	-2	-11	1
2	-1	-11	1
2	0	-11	1
2	1	43.5	1.1
2	2	37.5	1.2
2	3	31.5	1.5
2	4	25.5	1.625
2	5	19.5	0.6061
2	6	-11	0.5128
2	7	-11	1
2	8	-11	1
3	-5	-11	1
3	-4	-11	1
3	-3	-11	1
3	-2	-11	1
3	-1	-11	1
3	0	-11	1
3	1	-11	1
3	2	43.5	1.1
3	3	37.5	1.2
3	4	31.5	1.5
3	5	25.5	1.625
3	6	19.5	0.6061
3	7	-11	0.5128
3	8	-11	1

[a] These are expected dowries paid in marriages of men and women of the ideal age (see Table 2 and Figure 2).

Table 4: Theoretical Regressions using Simulated Data from Table 3
Dependent Variable: Dowry on the Equilibrium Path

	All t			Early t (t < 5)			Middle t (0 < t < 4)			Late t (t > 3)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Period of marriage (t)	1.137	-	1.340	5.998	-	5.153	4.083	-	31.715	-9.533	-	-9.004
(Women/Men) of ideal age (in district)	-	36.669	38.194	-	56.357	20.061	-	-0.910	-161.748		16.891	9.377
Constant	2.473	-33.915	-37.510	16.699	-50.076	-6.425	30.778	40.411	236.108	44.200	-25.085	34.316
Observations	42	42	42	30	30	30	9	9	9	15	15	15
R-squared	0.048	0.232	0.298	0.598	0.323	0.626	0.090	0.045	0.406	0.761	0.273	0.799

Note 1: Regressions control for district.

Note 2: Column (6): akin to Rao (1993), Edlund (2000).

Note 3: Column (9): akin to Edlund (2006).

Note 4: Column (12): akin to Dalmia and Lawrence (2005).

Table 5: Results from the Empirical Literature
Dependent Variable: Net Dowry Transfer[a]

	Early t (Mean ≈ 1954, SD ≈ 11)						Middle t (Mean ≈ 1956, SD ≈ 9)	Late t (Mean ≈ 1979, SD ≈ 9)
	Rao (1993)[b]		Edlund (2000)[c]		Edlund (2000)[d]		Edlund (2006)[e]	Dalmia & Lawrence (2005) All India [f]
Year of marriage (t)	-	281.16	-	288.33	-	552.65	0.731	-0.08
		(0.9)		(0.8)		(1.50)	(2.12)	(26.93)
(Women/Men) at ideal age	81,547.00	71,423.00	#######	#######	#######	7062.73	-25.738	0.16
	(2.5)	(2.1)	(1.5)	(0.8)	(1.1)	(0.3)	(1.25)	(0.56)
Observations	141	141	127	127	127	127	160	1037
R-squared	0.129	0.128	0.126	0.123	0.291	0.300	0.310	0.526

t statistics in parentheses.

[a] Rao (1993) and Edlund (2000, 2006) use net dowry transfer in constant 1984 rupees, Dalmia and Lawrence use net dowry transfer in constant 1994 rupees. All regressions have controls for characteristics of the bride, groom and their families. Other controls used are location, labor force participation ratio, distance of marriage migration etc. The exact set of controls differ by study.

[b] See Rao (1993), Table 3, p. 291.

[c] Replication of Rao's (1993) results, using difference in the bride's and the groom's traits as controls [see Edlund (2000), Table 4, p.1331].

[d] Traits of the bride and groom are included individually in the controls [see Edlund (2000), Table 5, p.1332-33].

[e] See Edlund (2006), Table, column (2), p. 547. Edlund (2006) uses the same data as Rao (1993) and Edlund (2000) but omits observations prior to the 1940s and the last two years of the survey (1970s). Rao's observations range from the 1920s to the 1970s.

[f] See Dalmia and Lawrence (2005), Table 3, col. 'India', p. 85

Table 6: Replication of Edlund's (2006) Non-Monotonic Dowry Path

Panel 1: Theoretical Regression[a]
(Dependent Variable: Dowry on the Equilibrium Path in Table 3)

	Middle t (0 < t < 4)
Period of marriage (t)	40.640
Period of marriage (t) * Indicator for t > 2	-6.281
(Women/Men) of ideal age	-158.842
Observations	9
R-squared	0.485

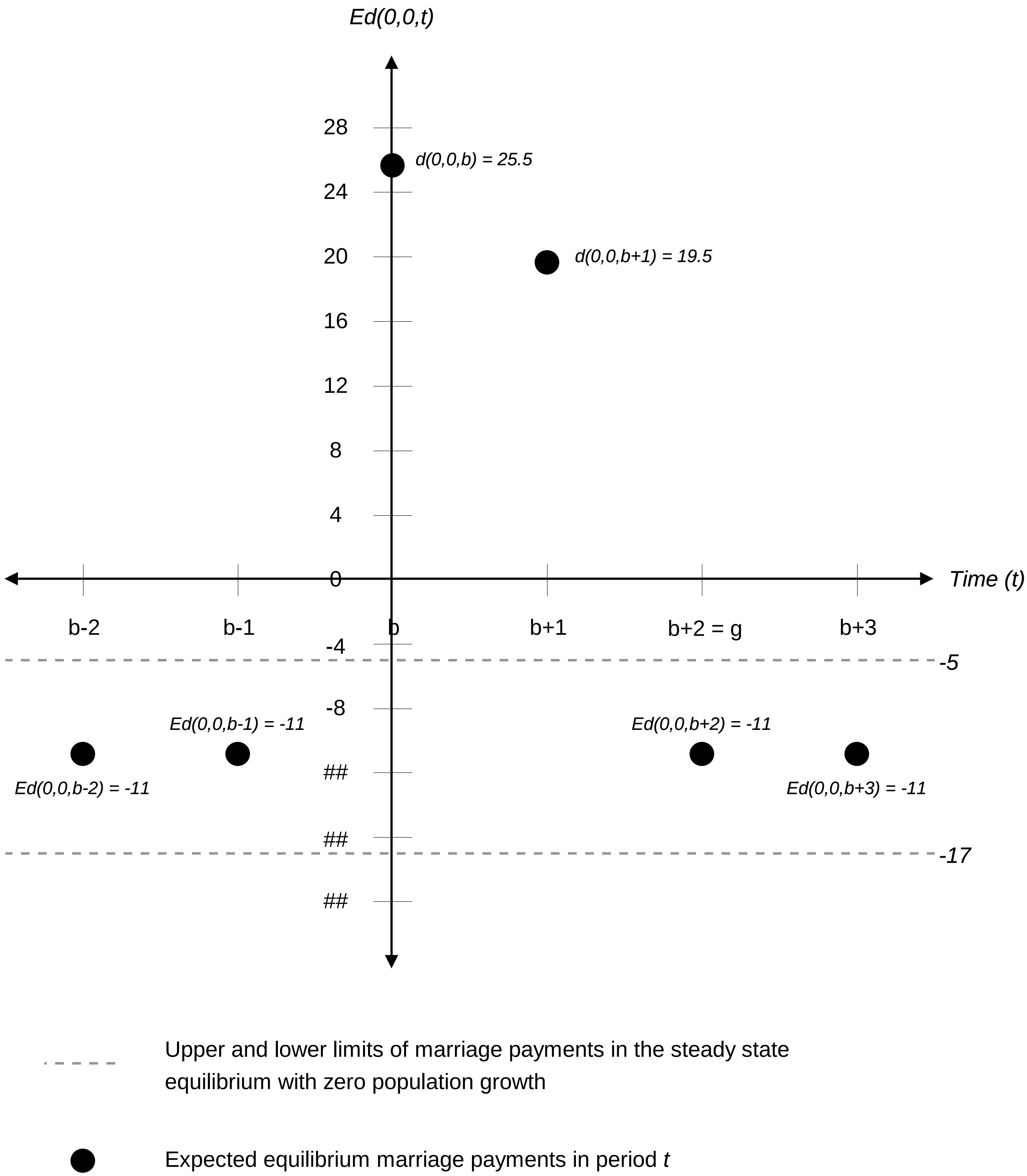
Panel 2: Edlund's (2006) Results[b]: Table 1, col. (7), p. 547
(Dependent Variable: Net Dowry Transfer in 1984 Rupees)

	Middle t (Mean ≈ 1956, SD ≈ 9)
Period of marriage (t)	0.825
	(1.24)
Period of marriage (t) * Indicator for post-1950	-0.140
	(0.795)
(Women/Men) of ideal age	-33.661
	(1.376)
Observations	160
R-squared	0.320

[a] Regression controls for district.

[b] t-statistics in parentheses.

Figure 1: Equilibrium Path of Expected Marriage Payments *Ed(0,0,t)* , under One-shot Population Growth[1]



[1]By assumption, dowry payments *d(0,0,t)* follow a uniform distribution *U[-17, -5]* when there may be multiple equilibrium payments, viz. in periods $t < b$ and $t > b+1$. The complete model specification is provided in the third section of the paper.

Figure 2: Equilibrium Path of Expected Marriage Payments Ed(0,0,t), under Continuous Population Growth