Sex Ratios and Long-Term Marriage Trends*

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Abstract

In this paper, we ask to what extent changes to the age and sex structure of the population account for the changes in the marriage behavior observed in the United States in the last century (from 1900 to 1980). The decrease in mortality, especially for women, and the changes in immigration patterns have increased the female to male ratio. With respect to marriage, there has been i) an increase in its incidence, ii) a reduction in the gender gap of the median age at first marriage, and iii) an increase in the divorce rate. We pose a model of marriage and divorce in which preferences over spouses depend on their age and on love (an idiosyncratic shock) and where search frictions make it difficult to get new partners. We estimate our model using marital and population patterns of the 1950-1959 birth cohort. Using the preference parameters estimated on the 1950s cohort and the age and sex structure of the 1870s cohort, we find our model can generate marriage patterns which are quite similar to those observed in the earlier period. By making divorce costly for the 1870s cohort, the resemblance is much stronger. In particular, we find that these features account for most of the changes in the marriage behavior observed in the last century; our model explains i) 94.5% of the increase in the incidence of marriage, and ii) 140.8% of the shrink the gender age gap in the median age at first marriage.

Keywords: Sex Ratio, Marriage, Search and Matching

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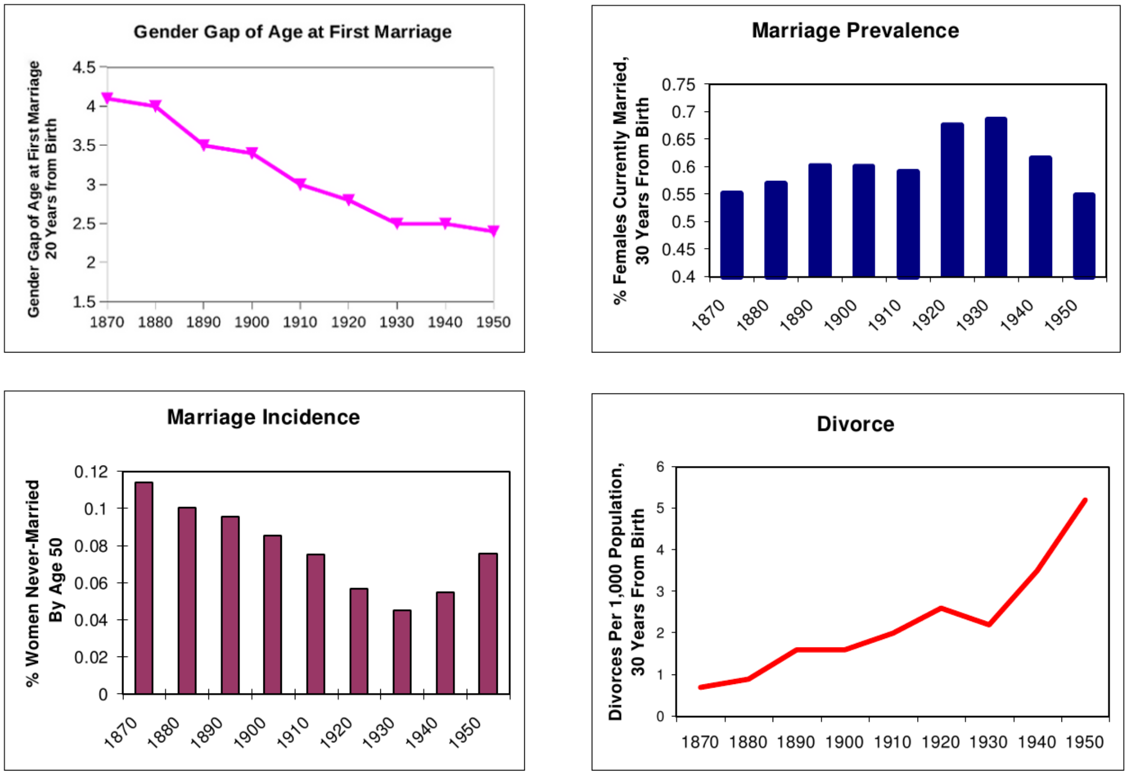

Figure 1: Trends in Marriage: 1870s to 1950s Birth Cohorts

1 Introduction

The last century has seen three important changes in the characteristics of marriage in the United States. First, there has been an increase in the incidence of marriage; the fraction of never married women by age 50 went from 0.102 in the 1870s birth cohort to 0.055 in the 1950s birth cohort. Second, there has been a reduction in the gender gap of the median age at first marriage (the gap between the medians of groom's age and bride's age); the gap was 4.0 in the 1870s cohort and 2.7 in 1950s cohort. Third, the divorce rate has increased; the number of divorce per 1,000 population at age 30 of the cohort was 0.7 in the 1870s cohort and 5.2 in the 1950s cohort. (See Figure 1.) Those features of the historical trends in marital statistics have been well documented in the literature.

Simultaneously, there have been significant changes in the sex structure of the population both in the relative number of men and women and in the age characteristics of each sex. (a) The ratio of males to females aged 15 years and older fell from 1.043 to 0.926. (b) The life expectancy of women went from 44.6 to 61.0 while for men went from 44.5 to 54.4. (See Table 1.)

Table 1: Demographic Transitions: : 1870s, 1930s, and 1950s Birth Cohorts

	Life Expectancy (at age 15)		Men Per 100 Women (aged 15 and above)
	Women	Men	
1870s	45.6	44.5	104.3
1930s	56.7	52.5	98.4
1950s	61.0	54.4	92.6

In this paper, we ask the extent to which changes in the structure of the population have contributed to shape the changes in the characteristics of marriages. We start by posing a search model of marital choice, where men and women differ in their numbers, and in their aging process. Every period, men and women meet (not all since there are different numbers of them) and may or may not choose to marry or to continue to be married. Those outcomes depend on preferences over spouse's age and on love shock (an idiosyncratic shock), whose structures we assume invariant over time.

We map the model to the born in the 1950s by using a method of moments estimator of the relevant model parameters (for preferences, meeting technology, and mechanisms to create and maintain marriages and demographic turnover). We find that the model is able to fit most of the marital statistics for the 1950s birth cohort. Then, we substitute the demographic turnover characteristics of the model for the 1950s cohort with those that generate the population structure of the 1870s. We keep preferences and the mating process as estimated for the 1950s birth cohort. The new predictions of the model are in the general direction of those in the data. Finally, we add a minimal change in the process to maintain marriages (a change in the cost of divorce parameter). We estimate this parameter alone using the other parameters at the values of the previous exercise to match the divorce rate of the 1870s cohort. This is a way to estimate the extent of the social changes that eased the divorce process. By making divorce costly for the 1870 cohort, we find that the model essentially matches all the other features of the data: (i) 94.5% of the increase in the incidence of marriage. (ii) 140.8% of the shrink the gender age gap in the median age at first marriage.

The intuition of the mechanism in our model is quite simple. As the population shifted from a high sex ratio/low life expectancy regime in the 1870s cohorts to a low sex ratio/high life expectancy regime in the 1950s cohort, the model predicts the earlier age at marriage for men because it became easier to find a wife, and the rise in marriage prevalence and incidence for women because there are larger average gains of marriage as their life expectancy has increased. In summary, the combination of increased longevity and a scarcity of men in the 1950s cohort serve to increase the incentives of men to get married early but couples participate in marriage to a greater extent in the 1950s cohort than in the 1870s cohort.

Features of the Model We use an overlapping generations model of marriage with stochastic aging, where agents are randomly matched with partners and draw a love shock to form and maintain marriages. Demographics play two roles in determining marital status: men and women age at different rates within the model, in essence capturing biological constraints that determine the gains to marriage and the sex imbalance in the population determines the rate at which men and women meet, where the sex in short supply meets partners at a relatively fast rate. Together, biological constraints and differential mortality rates across gender determine the timing and attractiveness of marriage.

Properties of Estimates Our parameter estimates suggest: (i) Men become attractive marriage partners later in life than women. (ii) Women lose their attractiveness in the marriage market earlier than men. (iii) Men are attractive for a longer portion of their lives than women.

Papers with Related Question Many theories have been advanced in an attempt to explain the delay in marriage and rise in divorce, which observed in the 1980s and 1990s. The most prominent explanations for the delay in marriage point to a fall in the gains to marriage. In Greenwood and Güner (2004), technological innovations in home production reduced the gains to specialization within marriage. Goldin and Katz (2002) suggest the introduction of the birth control pill reduced the gains to marriage as pre-marital sex became less costly. Both explanations are consistent with a decline in marriage and a rise in divorce. What existing theories cannot explain is a lesser known fact that changes considerably our understanding of the trends in marriage:

Papers with Related Models Our work builds on several strands of the literature on marriage. As in Siow (1998), biological constraints such as gender differences in fertility horizons play an important role in determining the timing of marriage. A large literature (see Becker (1981); Wilson and Neckerman (1986); Brien (1997); Angrist (2002); Seitz (2004)) studies the relationship between sex ratios, marriage and divorce. The model framework we adopt here is similar in spirit to recent equilibrium marriage models used to study marriage and divorce (Aiyagari, Greenwood, and Guner (2000)), single motherhood (Regalia, Ríos-Rull, and Short (2010)), and marital sorting (Fernandez, Güner, and Knowles (2004); Choo and Siow (2003)). Our work is also complementary to a recent literature on that examines the economic implications of the demographic transition (Nardi, Imrohoroglu, and Sargent

(1999); Attanasio and Violante (2005)).

Questions to Which Our Model and Findings Can Contribute to The remainder of the paper is structured as follows. We describe the model that we use to study marriage and divorce in Section 2. Section 3 outlines the estimation procedure and provides evidence on the performance of our baseline model for the 1950 cohort. In Section 4 we conduct model experiments to determine the extent to which the demographic transition and divorce liberalization can account for the trends in marriage and divorce. Section 5 concludes and discusses directions for future research.

2 The Model

The model has four main features: First, the model is an overlapping generations model with stochastic aging, where men and women have different life expectancies (a full description of demographics is contained in Section 2.1 and the aggregate state is described in Section 2.3). Second, agents match randomly, where the matching rate depends on the relative supplies of unmarried men and women (outlined in Section 2.4). Third, the quality of men and women as marriage partners changes as individuals age over time. Combined with the differential in life expectancies of men and women, this feature allows us to capture gender differences in the incentives to delay marriage and to divorce (preferences and individual's decisions are presented in Sections 2.5 and 2.6, respectively). Fourth, agents draw a love shock to form and maintain relationships. The marital decisions agents make are described in Section 2.7. A steady state is defined in Section 2.8.

2.1 Demographics

At each point in time there are many agents differing in sex (male and female), $g \in \{m, f\}$, and maturity (adolescent, young, and old), $i \in \{a, y, o\}$. While sex is a permanent fixture of agents, an individual's maturity is stochastic with transition probabilities $\Gamma^g_{i,i'}$. All agents begin their lives as adolescents. Agents of any maturity can make contacts in the marriage market, but only the young and the old can form matches. From the point of view of the model, death or leaving the matching environment are equivalent, and this happens to agents of different maturities with probability π^g_i. The fact that men and women die at different rates generates differences in the age and sex distribution of the population. We normalize the measure of females to 1, and we denote the total number of males by x^m. To keep the population stationary, each period there is an inflow of newborn females (n^f) that equal the outflow of women through death. The measure of newborn males is equal to that for females.

The measure of newborns is

$$n^f = n^m = \frac{\left[1 - \Gamma^f_{a,a}(1-\pi^f_a)\right]\left[1 - \Gamma^f_{y,y}(1-\pi^f_y)\right]}{1 - \Gamma^f_{y,y}(1-\pi^f_y) + \Gamma^f_{y,o}(1-\pi^f_y)\Gamma^f_{a,y}(1-\pi^f_a)}. \tag{1}$$

Male adolescent immigrants i_m also enter the market in every period. Immigration is introduced to allow us to account for exogenous changes in the aggregate stocks of men and women that we observe in the data but cannot attribute directly to mortality. Mortality and immigration determine both the age structure of the population and the sex imbalance in the model by determining the rate at which individuals exit the matching environment.

At the beginning of each period an agent can be in one of three marital states: single ($z = 0$), dating ($z = 1$) or married ($z = 2$). All couples must date for one period before becoming married.

2.2 Match Quality

In the first half of the period, each member of a couple draws match quality q. The match quality has two components, a Markov component and an i.i.d. component as $q = \mu + \epsilon$. A Markov component $\mu \in \{\mu_G, \mu_B\}$ has age-dependent transition probability Λ^i, and λ is the initial probability of $\mu = \mu_G$. ϵ is drawn from a normal distribution as $\epsilon \sim N(0, \sigma^2)$. We denote it's cumulative distribution function as $\Phi(\hat{\epsilon}) = Prob(\epsilon < \hat{\epsilon})$. Whether the pair becomes a marriage depends on the realization of each member's match quality (q^f, q^m).

2.3 Aggregates

We denote by $x^{g,i}(z, i^*, \mu, \mu^*)$ the measure of agents of gender g and maturity i that are paired in a type z relationship with a partner of maturity i^*. The state variables μ and μ^* are the current regimes of match quality for partners respectively. Since every paired male must be matched with a paired female, a feasibility constraint is

$$x^{f,i}(z, i^*, \mu, \mu^*) = x^{m,i^*}(z, i, \mu^*, \mu) \qquad \forall\ z, i, i^*, \tag{2}$$

where

$$x^g(z, i^*, \mu, \mu^*) = x^{g,a}(z, i^*, \mu, \mu^*) + x^{g,y}(z, i^*, \mu, \mu^*) + x^{g,o}(z, i^*, \mu, \mu^*) \tag{3}$$

and

$$x^g(0) = x^{g,a}(0) + x^{g,y}(0) + x^{g,o}(0). \tag{4}$$

2.4 Matching Technology

At the end of each period there is a measure of available males and a measure of available females, composed of those agents who were single, those who were dating but who did not marry in the previous period, and those who were married and subsequently separated. All these agents meet via a constant-returns-to-scale matching function described by:

$$\psi^f = \min\left\{1, \frac{x^m(0) + x^m(1,.)}{x^f(0) + x^f(1,.)}\right\} \tag{5}$$

for women, and

$$\psi^m = \min\left\{1, \frac{x^f(0) + x^f(1,.)}{x^m(0) + x^m(1,.)}\right\} \tag{6}$$

for men. The matching technology depends directly on the sex ratio of available agents, the ratio of potential spouses to potential competitors. In particular, the gender in short supply meets a potential spouse with certainty, while the opposite sex meets partners at a rate equal to the size of the sex imbalance in the population of available men and women. The measures of the single population $\{x^f(0), x^m(0)\}$ and the paired population $\{x^f(z, i^*, \mu, \mu^*), x^m(z, i^*, \mu, \mu^*)\}$ of women and men, respectively, refer to the situation after the meetings have occurred and we refer to this as the beginning of the period.

2.5 Preferences

Preferences differ by gender and current marital status. The utility function for a single or dating individual of gender g is described by $u^g(0)$. If married, preferences also depend on two other factors: *(i)* the maturity of the spouse and *(ii)* match quality as $u^g(i^*) = \alpha^g_{i^*} + q$.

2.6 Value Functions

In this section, we describe the problems faced by agents at different ages and in different marital states. In each instance, we denote by $V^g(i, z, i^*, \mu, \mu^*)$ the value of a gender g person of maturity i, with marital status z, that has a pairing with an agent of maturity i^*, where i^* is equal to zero for unpaired agents. The states μ and μ^* are the current regimes of match quality. The future is discounted at rate β. Note that we are implicitly assuming stationarity in the sense that agents assume meeting rates and the behavior of other agents to be time invariant.

2.6.1 Single Agents

The value for a single agents of gender g and age i is

$$\begin{aligned} V^{g,i}(0,0,0,0) \;&=\; u^g(0) \;+\beta\;(1-\pi^g)\;\sum_{i'}\Gamma^g_{i,i'}\Bigg\{\;(1-\psi^g)\;V^{g,i'}(0,0,0,0) \\ &+\psi^g \sum_{i^{*\prime},\mu,\mu^*}\frac{x^{g^*,i^{*\prime}}(1,.)}{x^{g^*}(0)+x^{g^*}(1,.)}\;\lambda(\mu)\lambda(\mu^*)\;V^{g,i'}(1,i^{*\prime},\mu,\mu^*)\Bigg\} \end{aligned} \tag{7}$$

for $i, i', i^{*\prime} \in \{a, y, o\}$, where g^* denotes the gender of the opposite sex. The first term is the period utility of being single. The second term, the expected value of entering the next period unmarried, is composed of two parts. The first is the value of being unpaired and the second is the value of dating, conditional on meeting a spouse of age i^*.

2.6.2 Paired Agents

The value functions for paired agents depend on the actions of both members of the couple. The couple is indexed by $\{z, i, i^*, \mu, \mu^*\}$: marital status (dating or married), the maturities of the female and her spouse, and the current regimes of match quality for the female and her spouse. The value of being a paired individual is given by:

$$\begin{aligned} V^{g,i}(z,i^*,\mu,\mu^*;\hat{\epsilon}_{g^*,i^*}) &= \max_{\hat{\epsilon}_{g,i}}\left\{V^{g,i}(0,0,0,0)-\omega 1_{[z=2]}\right\}\Phi(\hat{\epsilon}_{g,i})\;\Phi(\hat{\epsilon}_{g^*,i^*}) \\ &+\int_{\hat{\epsilon}_{g,i}}^{\infty}\int_{\hat{\epsilon}_{g^*,i^*}}^{\infty}\Bigg\{\alpha^g_{i^*}\;+\;\mu\;+\;\epsilon_g\;+ \\ &+\;\beta(1-\pi^g)\Big[(1-\pi^{g^*})\sum_{i',i^{*\prime},\mu',\mu^{*\prime}}\Gamma^g_{i,i'}\Gamma^{g^*}_{i^*,i^*}\Lambda^{i'}_{\mu,\mu'}\Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}}V^{g,i'}(2,i^{*\prime},\mu',\mu^{*\prime}) \\ &+\;\beta\pi^{g^*}\sum_{i'}\Gamma^g_{i,i'}V^{g,i'}(0,0,0,0)\Big]\Bigg\}\;d\Phi(\epsilon_g)\;d\Phi(\epsilon_{g^*}) \end{aligned} \tag{8}$$

for $i, i^* \in \{a, y, o\}$, where ω is the divorce cost for individuals.

In the above problem, a member of the couple with gender g and age i chooses the cutoff value $\hat{\epsilon}_{g,i}(z, i^*, \mu, \mu^*)$ for the realization of the i.i.d. component of match quality given his/her partner's cutoff value $\hat{\epsilon}_{g^*,i^*}(z, i, \mu^*, \mu)$: If the realized value of ϵ_g is greater than $\hat{\epsilon}_{g,i}(z, i^*, \mu, \mu^*)$, the individual accepts being married in the next period. The probability that the couple will break up in the next period is, then, $\Phi(\hat{\epsilon}_{g,i}) \times \Phi(\hat{\epsilon}_{g^*,i^*})$. The first term on the right hand side in the equation (8) is the utility the individual would get when breakingup with the current partner. With probability $1-\Phi(\hat{\epsilon}_{g,i})\times\Phi(\hat{\epsilon}_{g^*,i^*})$, the pair continues and the agents are married in the next period.

2.7 Cutoff Strategies

The decisions on the cutoff values are taken in pairwise meetings by agents that play Nash. A female member of each couple solves:

$$\begin{aligned}
\hat{\epsilon}_{f,i}(z,i^*,\mu,\mu^*,\hat{\epsilon}) = \arg\max_{\hat{\epsilon}_{f,i}} & \left\{V^{f,i}(0,0,0,0)-\omega 1_{[z=2]}\right\}\Phi(\hat{\epsilon}_{f,i})\ \Phi(\hat{\epsilon}) \\
& + \int_{\hat{\epsilon}_{f,i}}^{\infty}\int_{\hat{\epsilon}}^{\infty}\Bigg\{\alpha^f_{i^*}\ +\ \mu\ +\ \epsilon_f\ + \\
& +\ \beta(1-\pi^f)\Big[(1-\pi^m)\sum_{i',i^{*\prime},\mu',\mu^{*\prime}}\Gamma^f_{i,i'}\Gamma^m_{i^*,i^*}\Lambda^{i'}_{\mu,\mu'}\Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}}V^{f,i'}(2,i^{*\prime},\mu',\mu^{*\prime}) \\
& +\ \beta\pi^m\sum_{i'}\Gamma^f_{i,i'}V^{f,i'}(0,0,0,0)\Big]\Bigg\}\ d\Phi(\epsilon_f)\ d\Phi(\epsilon_m)
\end{aligned} \tag{9}$$

The male solves a similar problem that yields the solution $\hat{\epsilon}_{m,i^*}(z,i,\mu^*,\mu,\hat{\epsilon})$. A Nash equilibrium is a pair of values that are a fixed point denoted, as above with a slight abuse of notation, by $\hat{\epsilon}_{f,i}(z,i^*,\mu,\mu^*)$ and $\hat{\epsilon}_{m,i^*}(z,i,\mu^*,\mu)$ that satisfy

$$\begin{aligned}
\hat{\epsilon}_{f,i}(z,i^*,\mu,\mu^*) &= \hat{\epsilon}_{f,i}(z,i^*,\mu,\mu^*,\hat{\epsilon}_{m,i^*}(z,i,\mu^*,\mu,\hat{\epsilon}_{f,i})) \\
\hat{\epsilon}_{m,i^*}(z,i,\mu^*,\mu) &= \hat{\epsilon}_{m,i^*}(z,i,\mu^*,\mu,\hat{\epsilon}_{f,i}(z,i^*,\mu,\mu^*,\hat{\epsilon}_{m,i^*})).
\end{aligned} \tag{10}$$

2.8 Steady States

A steady state requires that agents maximize and that the allocation is stationary. Formally,

Definition 1. *A steady state is a distribution of the population across sex, maturity, marital status, and spousal maturity* $\{\tilde{x}^g(z,i^*,\mu,\mu^*),\tilde{x}^g(0)\}$*, a set of value functions* $\{\tilde{V}^{g,i}(z,i^*,\mu,\mu^*)\}$*, and a set of cutoff strategies* $\{\tilde{\epsilon}_{g^*,i^*}(z,i^*,\mu,\mu^*)\}$ *for* $g\in\{f,m\}$*,* $i,j\in\{a,y,o\}$*,* $z\in\{1,2\}$*, and* $\mu,\mu^*\in\{\mu_G,\mu_B\}$ *such that:*

1. *The value functions satisfy (7) and (8).*

2. *Agents play Nash (9) and (10).*

3. *Individual and aggregate behavior are consistent; agent's choices yield the stationary*

distribution which for single females is:

$$\widehat{x}^{f,i'}(0) = \Big[1 \; - \; \psi^f\Big]\Big\{ \sum_{i,\mu,\mu^*} \Gamma^f_{i,i'} \, \Lambda^{i'}_{\mu,\mu'} \Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}} \, (1-\pi^f) \, \Big\{ \widehat{x}^{f,i}(0)$$

$$+ \sum_{z,i^*} \pi^m \, \widehat{x}^{f,i}(z,i^*,\mu,\mu^*) + \sum_{z,i^*} (1-\pi^m) \, \Phi(\hat{\epsilon}_{g,i}) \, \Phi(\hat{\epsilon}_{g^*,i^*}) \;\; x^{f,i}(z,i^*,\mu,\mu^*) \Big\}\Big\}, \quad (11)$$

for dating mature and old females is

$$\widehat{x}^{f,i'}(1,i^{*\prime},\mu',\mu^{*\prime}) = \psi^f \Big\{ \sum_{i} \; \Gamma^f_{i,i'} \, \Lambda^{i'}_{\mu,\mu'} \Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}} \, (1-\pi^f) \, \Big\{ \widehat{x}^{f,i}(0)$$

$$+ \sum_{z,i^*} \pi^m \, \widehat{x}^{f,i}(z,i^*,\mu,\mu^*) + \sum_{z,i^*} (1-\pi^m) \, \Phi(\hat{\epsilon}_{g,i}) \, \Phi(\hat{\epsilon}_{g^*,i^*}) \;\; \widehat{x}^{f,i}(z,i^*,\mu,\mu^*) \Big\}\Big\}, \quad (12)$$

and for mature and old married females is

$$\widehat{x}^{f,i'}(2,i^{*\prime},\mu',\mu^{*\prime}) = (1-\pi^f) \, (1-\pi^m) \; \sum_{i,j,z} \Gamma^f_{i,i'} \; \Gamma^m_{i^*,i^{*\prime}} \; \Lambda^{i'}_{\mu,\mu'} \Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}}$$

$$\times \left[1 - \Phi(\hat{\epsilon}_{g,i}) \, \Phi(\hat{\epsilon}_{g^*,i^*})\right] \; \widehat{x}^{f,i}(z,i^*,\mu,\mu^*). \quad (13)$$

Similar conditions are required for males.

4. *The meeting probabilities ψ^g are consistent with the number of people that end a period single and with the meeting technology.*

2.9 Taking Stock

In the following section, we assess the extent to which our parsimonious model can account for the trends in marriage. Before proceeding to our quantitative analysis, it is worth discussing the role of the two main demographic mechanisms in shaping marital status in the model.

2.9.1 Mortality Rates

Mortality plays three roles in the analysis. First, a fall in mortality rates for the opposite sex implies an increase in the expected future value of marriage, as the probability of remaining married in the future increases. The second role of mortality is through its effect on the marriage opportunities for men versus women through the sex ratio. If mortality rates fall to a greater extent for women than for men, as we observe in the data, then men are predicted to experience an improvement in marriage market conditions. Thus, we expect the fall in mortality to benefit men more than women along two dimensions: the value of marriage increases because one's current spouse is more likely to survive and the value of being single increases as one's marriage market improves. Third, the age composition of the population is determined by mortality rates, where a fall in mortality rates is consistent with an increase in the average age in the population.

2.9.2 Immigration Rates

We model immigration as an inflow of young men into the marriage market in every period. This assumption, although restrictive, is consistent with the fact that men are more likely to immigrate than women and the young are more likely to immigrate than the old. An increase in the immigration rate serves two roles in the model, similar to the effect of a fall in the male mortality rate. First, marriage market conditions for women improve as immigration for men increases, as more potential husbands become available. Second, an increase in the immigration rate results in a decrease in the average age of men in the model.

3 Mapping the Model to the Data

In this section, we describe how to specify the model so that its equilibrium yields the demographic structure and marriage behavior for the cohort born in 1950, i.e. the calibration. We start by choosing the functional forms and listing the parameters that we need to calibrate in Section 3.1. In Section 3.2, we describe the set of targets we use to solve for the parameter values. We present and interpret the parameter values in Section 3.3. Evidence on the ability of the baseline model to match the targets and other features of the data is presented in Section 3.4

3.1 Parameters

In addition to the discount factor, which we set equal to 0.95, the model has 24 parameters. We divide the parameters into three groups: *(i)* demographic parameters (3), *(ii)* preference parameters (11), and *(iii)* parameters determining the match quality (10). Each set of parameters is discussed in turn below.

3.1.1 Demographics

Agents remain alive at rate π^g ($g \in \{f, m\}$). There is also a immigration parameter for men (i^m).

Table 2: Demographic targets

	1950's
Men per 100 women (aged 15 and above)	92.9
Life expectancy of women (at age 15)	61.0
Life expectancy of men (at age 15)	54.4

3.1.2 Preferences

The current period utility function takes the form: $u^g(j) = \alpha_j^g$ for paired men and women and $u^g(0) = 0$ for single agents. Preferences for a paired agent depend only on gender and on the age of the agent's spouse. We assume all men and women start out young and age stochastically over time. As a result, there are eight preference parameters to be determined $\{\alpha_a^f, \alpha_y^f, \alpha_o^f, \alpha_a^m, \alpha_y^m, \alpha_o^m, \Gamma_{a,y}^f, \Gamma_{y,o}^f, \Gamma_{a,y}^m, \Gamma_{y,o}^m\}$.

3.1.3 Match Quality

Agents decide whether they get married or not observing the realization of match quality. The parameters, which govern the initial distribution and the transition of match quality, are $\{\mu_G, \mu_B, \sigma, \lambda, \Lambda_{GG}^a, \Lambda_{GG}^y, \Lambda_{GG}^o, \Lambda_{BB}^a, \Lambda_{BB}^y, \Lambda_{BB}^o\}$.

3.2 Targets

We choose the parameters to match three sets of targets: *(i)* 3 demographic targets summarizing the age and sex structure of the population, *(ii)* 28 statistics summarizing detailed marriage behavior and divorce behavior by age.

3.2.1 Demographics

We want the model to match the age and sex structure of the population for the 1950s cohort. To this end, we set the demographic parameters so that they match the life expectancies for men and women and sex ratios for the population that is active in the matching environment. We target the life expectancy of men and women at age 15 (two targets) and the number of men per 100 women aged 15 and above (one target).[1] The values of the demographic targets are presented in Table 2.

[1] Sex ratios are computed from Table 094 of the International Data Base of the U.S. Bureau of the Census.

3.2.2 Marital Status

There are three sets of marital status statistics that we want the baseline model economy to match, resulting in a total of fourteen marital status targets. First, we want the model to capture the marriage rates for agents at different ages. For each sex, we therefore target the marriage rates, per 1,000 in the relevant unmarried population for six age groups and both genders for the 1950 birth cohort (twelve targets). Second, to match the incidence of marriage, we target the fraction of men and women that never marry by the age of 50 for each sex (two targets). The last sixteen targets we consider are the divorce rates per 1,000 married couples for six age groups (twelve targets), the first age at marriage (two targets), and the percent of the people aged 16 to 49 that are married, (two targets). The values for the marriage and divorce targets are presented in Table 3.

There are three features of the marriage data in particular that we want the model to replicate. First, marriage rates rise then fall with age, peaking between the ages of 25 to 29 for both men and women. Second, despite the fact that marriage rates for men and women peak during the same age range, marriage rates for men are low relative to those of women before the age of 35, and high relative to those of women after the age of 35. Both trends are consistent with the well documented fact that men tend to marry younger women. Both trends are reflected in the stocks through the higher fraction of women that are married prior to age 35 and the higher fraction of men that are married thereafter. Finally, as illustrated in Table 3, the data on marriage incidence and divorce indicate that men have both higher rates of entry into and exit from marriage.

3.3 Parameter Values

In this section, we briefly summarize the estimation results. We start with the parameters that describe the biological aging process in the model and the parameters that determine how the gains to marriage change as individuals age, presented in Table 4. The parameter estimates indicate that *(i)* there exists a peak age of attractiveness for men and women in the marriage market, *(ii)* women become attractive marriage partners at an earlier age than men, and that *(iii)* men remain attractive marriage partners for a longer period of time than women. All three features of the estimates are consistent with the biological differences across gender, where men mature more slowly than women and women become infertile earlier than men. In fact, the ages at which men and women transit from middle-aged to old in the model are strikingly consistent with the ages at which reproductive ability starts to fall: between the ages of 27 to 29 for women and after the age of 35 for men (Dunson,

Table 3: Marriage rates and divorce statistics by age

Age	Women	Men
Marriage rates by age, per 1,000 unmarried		
16-19 in 1965	22.8	29.6
20-24 in 1970	15.8	18.8
25-29 in 1975	15.1	14.5
30-34 in 1980	15.9	13.3
35-39 in 1985	16.6	13.0
40-44 in 1990	17.0	13.0
Divorce rates by age, per 1,000 married		
16-19 in 1965	19.9	29.8
20-24 in 1970	19.3	17.3
25-29 in 1975	18.1	16.4
30-34 in 1980	17.4	15.1
35-39 in 1985	15.5	13.0
40-44 in 1990	15.4	11.2
Marriage incidence		
% of women never-married by age 50 in 1990		5.5
% of men never-married by age 50 in 1990		6.4
Age at marriage		
Median first age at marriage for women		22.0
Median first age at marriage for men		24.7
Marriage prevalence		
% of Women aged 16 to 49 that are married		56.7
% of Women aged 16 to 49 that are married		52.8

Table 4: Estimated values of the preference and aging parameters in the baseline model

Parameter	Value
Female's preferences over adolescent spouse (α_a^f)	-14.08
Female's preferences over young spouse (α_y^f)	-2.29
Female's preferences over old spouse (α_o^f)	-3.50
Male's preferences over adolescent spouse (α_a^m)	-14.96
Male's preferences over young spouse (α_y^m)	11.15
Male's preferences over old spouse (α_o^m)	-1.71
Average age at which women become young	21.5
Average age at which women become old	25.3
Average age at which men become young	21.4
Average age at which men become old	27.7

Colombo, and Baird (2002)).

Table 5 presents the calibrated values of the parameters determining the ease with which agents enter and exit marriage. The estimates indicate that everyone starts with bad regime when dating. Also, the transition probability of switching to a good match (μ_G) from a bad match (μ_B) is higher for the adolescent and for the young. Furthermore, the estimates show that the Probability of switching to a bad match (μ_B) from a good match (μ_G) is higher for the young. These properties of the match quality captures the patterns of marriage and divorce in the data; both the marriage rate and the divorce rate are higher for the young.

3.4 Performance of the Baseline Model Economy

In this section we assess the extent to which the baseline model matches the statistics in the data. It is worth emphasizing that, in addition to the discount factor and demographic parameters, the benchmark model has 21 parameters and 29 targets; thus the model is over-identified. Overall, our parsimonious model is able to replicate the data very well. Table 6 shows the model is able to simultaneously match the divorce rates and the incident rates of marriage, including the fact that men have both higher exit and entry rates than women.

Turning to Table 6, the model is able to replicate two important features of the data on marriage rates: the hump-shaped marriage rate profiles by age and the peak ages of marriage for men and women. The model is also able to generate the high marriage rates of women relative to men before the age of 35 and the opposite trend at later ages.

Table 5: Estimated values of the match-quality parameters in the baseline model

Parameter	Value
Mean of match quality in good regime,μ_G	8.28
Mean of match quality in bad regime,μ_B	-20.5
Variance of match quality, σ	7.01
Initial dist. of good match, λ	0.000
Initial dist. of bad match, $1-\lambda$	1.000
Transition probability of regimes, $\Lambda^a_{G,G}$, for adolescent	0.996
Transition probability of regimes, $\Lambda^a_{B,B}$, for adolescent	0.066
Transition probability of regimes, $\Lambda^y_{G,G}$, for young	0.980
Transition probability of regimes, $\Lambda^y_{B,B}$, for young	0.011
Transition probability of regimes, $\Lambda^o_{G,G}$, for old	1.000
Transition probability of regimes, $\Lambda^o_{B,B}$, for old	0.647
Cost of divorce	2.36

3.5 Identification of the Parameters

To be completed.

Table 6: Model performance: Marriage and divorce Statistics

	Women		Men	
	Data	Model	Data	Model
Marriage Rates by Age, per 1,000 Unmarried				
16-19 in 1965	127.7	135.9	57.8	74.2
20-24 in 1970	220.6	206.1	184.4	167.7
25-29 in 1975	129.4	151.1	145.6	156.4
30-34 in 1980	105.6	95.5	124.1	120.4
35-40 in 1985	68.9	61.5	80.9	90.0
40-44 in 1990	60.1	43.8	75.3	69.7
Divorce Rates by Age, per 1,000 Married				
16-19 in 1965	19.9	22.8	29.8	29.6
20-24 in 1970	19.3	15.8	17.3	18.8
25-29 in 1975	18.1	15.1	16.4	14.5
30-34 in 1980	17.4	15.9	15.1	13.3
35-39 in 1985	15.4	16.6	11.7	13.0
40-44 in 1990	15.4	17.0	11.2	13.0
Marriage Incidence				
% Never-Married by Age 50 in 1990	5.5	5.4	6.5	6.5
Age at Marriage				
	22.0	22.0	24.7	24.7
Percent aged 16 to 49 that are Married				
	56.7	50.9	52.8	50.7

Table 7: The demographic transition: 1870's to 1950's birth cohort

	1870	1950
Men per 100 women (aged 15 and above)	104.3	92.9
Life expectancy of women (at age 15)	45.6	61.0
Life expectancy of men (at age 15)	44.5	54.4

Table 8: The change in mortality rate: 1870's to 1950's birth cohort

Mortality Rate	$\pi^f(a)$	$\pi^f(y)$	$\pi^f(o)$	π^m
1950's	0.0166	0.0166	0.0166	0.0187
1930's	0.0173	0.0228	0.0173	0.0194
1870's	0.0205	0.0338	0.0205	0.0230

4 Long-Run Trend in Marital Statistics

In this section, we consider the extent to which changes in demographics alone account for the changes in marriage and divorce since the birth of the 1870s cohort (exactly 80 years earlier).

4.1 Changes in Demographics

The demographic trends on which we focus are the rise in life expectancy and the fall in the ratio of men to women in the population, as presented in Table 7. Targeting on those values, we recalibrate the demographic parameters. Then, we ask the extent to which changes in the structure of the population have contributed to the changes in the characteristics of marriages. When recalibrating the demographic parameters for the 1870s, we set $\pi^f(a)$ and $\pi^f(o)$ so that the rate of the change of the mortality to the the 1950s is same as men's. We adjust $\pi^f(y)$ for the 1870s to match women's life expectancy in those years as shown in Table 12.[2] Immigration is then set to match the sex ratio.

4.2 Model's Performance to Account for the Long-Run Trend

We study the effect of the demographic changes presented above on a set of four statistics: the fraction of individuals aged 16 to 49 that are married, the divorce rate for women aged 16 to 49, the fraction never-married by age 50, and the age at first marriage. We focus on these statistics presented in Table 7, as they summarize the main characteristics of the trends we wish to examine. We begin by considering the effects of the aging of the population and

[2](Albanesi and Olivetti 2010) talk on significant improvements in maternal health that started in the mid 1930s.

Table 9: Demographic experiments: 1870's to 1950's

	Data		Model	
	1870's	1950's	1870's	1950's
Age at Marriage				
Women (%Δ)	21.9	22.0 (+0.5)	21.9	22.0 (+0.5)
Men (%Δ)	25.9	24.7 (-4.6)	26.1	24.7 (-6.4)
% Aged 16 to 49 that are Married				
Women (%Δ)	55.2	56.7 (+2.7)	40.8	50.9 (+24.8)
% of Never-Married by Age 50				
Women (%Δ)	10.2	5.5 (-46.1)	5.9	5.4 (-8.5)
Men (%Δ)	14.4	6.5 (-54.9)	13.4	6.5 (-51.5)
Divorce Rate, per 1,000				
Women (%Δ)	0.7	5.2 (+742.9)	4.4	4.4 (+0.0)

the fall in the sex ratio between the 1870 cohort and the 1950 cohort. The result of the experiment is presented in Table 9.

How important is the structure of the population in explaining the trends in marriage? Together, the aging of the population and the fall in the ratio of men to women can simultaneously explain (i) the decrease in age at marriage for men (139.1%), and no change on age at marriage for women, (ii) the decrease of the gap in age at marriage, and (iii) the increased incidence of marriage for women (18.4%) and for men (93.8%). The intuition of the mechanism is simple: The population shifted from a high sex ratio/low life expectancy regime in 1870's to a low sex ratio/high life expectancy regime in 1950's. This represents a move towards an environment where; the average gains to marriage rise for women and fall for men, and, men drive the marriage decisions. As a result, the model predicts the earlier age at marriage for men because it became easier to find a wife, and the rise in marriage prevalence and incidence for women because there are larger average gains of marriage as their life expectancy has increased. In summary, the combination of increased longevity and a scarcity of men in 1990 served to increase the incentives of men to get married early but couples participate in marriage to a greater extent in the 1950s cohort than in the 1870s cohort.

Table 10: Unilateral divorce: 1870's to 1950's

	Data		Model	
	1870's	1950's	1870's	1950's
Age at Marriage				
Women (%Δ)	21.9	22.0 (+0.5)	21.67	22.0 (+1.5)
Men (%Δ)	25.9	24.7 (-4.6)	27.3	24.7 (-9.5)
% Aged 16 to 49 that are Married				
Women (%Δ)	55.2	56.7 (+2.7)	**47.6**	50.9 (+6.9)
% of Never-Married by Age 50				
Women (%Δ)	10.2	5.5 (-46.1)	6.3	5.4 (-16.3)
Men (%Δ)	14.4	6.5 (-56.9)	13.7	6.5 (-53.5)
Divorce Rate, per 1,000				
Women (%Δ)	0.7	5.2 (+742.9)	**0.7**	4.4 (+642.9)

4.3 The Shift Toward Unilateral Divorce

Although demographics can simultaneously account for both the age gap and rise in marriage, it fails to explain the large rise in divorce observed in the data. The reason for this is simple: although changing demographics altered the gains to marriage at different points in an individual's lifetime, the ease with which agents could divorce in the model remained unchanged. In reality, however, there were large changes in the ease with which men and women could obtain a divorce through the liberalization of divorce laws. For this reason, it is of interest to consider the introduction of unilateral divorce changes in the face of an aging population. To study unilateral divorce in our framework, we change the parameter governing the cost of divorce (ω) to match the divorce rate for the 1870 cohort. This exercise is consistent with the introduction of unilateral divorce.

The results of this exercise, presented in Table 10 indicate that the introduction of unilateral divorce, in combination with demographic changes can account for (i) the decrease in age at marriage for men (206.5%) and almost no change on age at marriage for women, (ii) the increased incidence of marriage for women (29.1%) and for men (94.0%), and (iii) the increase in prevalence of marriage (255.5%). Note that with the easing of restrictions on divorce, the model also well explains the rise in the prevalence of marriage, that is over-predicted in the benchmark case. Overall, with divorce liberalization, the demographic transition from 1870's to 1950's can account for most of the transition in marital status.

4.4 Model's Performance for the Short-Run Trend

In appendix, we also assess model's performance to account for the short-term trend in marital statistics. We recalibrate the demographic parameters so that they capture the age and sex structure of the population in the 1930's birth cohort. As a conclusion of the analysis in appendix, we find that demographics alone are not able to account for the delay in age at marriage and the decreased prevalence of marriage from the 1930's cohort to the 1950's cohort. We also find that the changes of divorce isn't an answer.

5 Conclusion

In this paper, we make three contributions to the economic literature on marriage. We document an important but overlooked feature of the data; the incidence of marriage has increased, and the gender gap of the median age at first marriage has decreased over time. We examine the role of the demographic transition in explaining the trends in marital status. In combination with the liberalization of divorce laws, we find that demographics can quantitatively account for much of the increased incidence of marriage, shrink of the age gender gap, and the rise in divorce. An appealing feature of this analysis is that the mechanism we consider here, namely changes in mortality rates, are directly observed and quantified in the data. Thus, it is straightforward to assess whether the demographic transition can account for the trends in marriage for other time periods and in other countries. It is also possible to extend our analysis to the other prominent feature of the demographic transition: the large decline in fertility. The role of demographics in accounting for the trends in fertility is the focus of our future work.

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Table 11: The demographic transition: 1930's to 1950's birth cohort

	1930	1950
Men per 100 women (aged 15 and above)	98.4	92.9
Life expectancy of women (at age 15)	56.7	61.0
Life expectancy of men (at age 15)	52.5	54.4

Table 12: The change in mortality rate 1930's to 1950's birth cohort

Mortality Rate	$\pi^f(a)$	$\pi^f(y)$	$\pi^f(o)$	π^m
1950's	0.0166	0.0166	0.0166	0.0187
1930's	0.0173	0.0228	0.0173	0.0194

Appendix. Short-Run Trend in Marital Statistics

In this appendix, we ask to what extent changes in demographics alone account for the changes in marriage and divorce since the birth of the 1930 cohort (exactly 20 years)

A.1. Demographics

The demographic targets we used in this analysis is listed in Table 11.

A.2. The Result for the Short-Run Trend

The demographic transition from 1930's to 1950's can explain only a few of the transition in marital status for women and none of the transition in marital status for men (See in Table 13). The model with changes in the age and sex structure between the 1930's and 1950's birth cohorts is consistent with: (i) The delay in marriage for women (15.4%). (ii) The fall in the incidence of marriage for women (128.8%). However, the model can't explain the delay in marriage, the fall in incidence of marriage for men and the decreased prevalence of marriage, and any of the rise in divorce.

A.3. The Shift Toward Unilateral Divorce

As in 4.3, we run change the parameter governing the cost of divorce (ω) to match the divorce rate for the 1870 cohort. The result is shown in Table 14.

Even if we adjust the costs of divorce, the model cannot account for the data from 1930's to 1950's. Especially, the model cannot match the following at the same time: (i) An increase of age at marriage both for men and for women, and (ii) a decrease of prevalence of marriage. Furthermore, the model can account for (iii) the change in the incidence of marriage.

Table 13: Demographic experiments: 1930's to 1950's

	Data		Model	
	1930's	1950's	1930's	1950's
Age at Marriage				
Women (%Δ)	20.3	22.0 (+8.4)	21.8	22.0 (+1.3)
Men (%Δ)	22.8	24.7 (+8.3)	24.8	24.7 (-0.5)
% Aged 16 to 49 that are Married				
Women (%Δ)	71.0	56.7 (-20.1)	49.2	50.9 (+3.5)
% of Never-Married by Age 50				
Women (%Δ)	4.5	5.5 (+22.2)	4.2	5.4 (+28.6)
Men (%Δ)	6.2	6.5 (+4.8)	7.2	6.5 (-9.7)
Divorce Rate, per 1,000				
Women (%Δ)	2.2	5.2 (+136.4)	4.6	4.4 (-4.4)

Table 14: Unilateral divorce: 1930's to 1950's

	Data		Model	
	1930's	1950's	1930's	1950's
Age at Marriage				
Women (%Δ)	20.3	22.0 (+8.4)	22.0	22.0 (+0.0)
Men (%Δ)	22.8	24.7 (+8.3)	25.1	24.7 (-1.6)
% Aged 16 to 49 that are Married				
Women (%Δ)	71.0	56.7 (-20.1)	57.9	50.9 (-12.1)
% of Never-Married by Age 50				
Women (%Δ)	4.5	5.5 (+22.2)	3.8	5.4 (+42.1)
Men (%Δ)	6.2	6.5 (+4.8)	4.4	6.5 (+47.7)
Divorce Rate, per 1,000				
Women (%Δ)	2.2	5.2 (+136.4)	2.2	4.4 (-104.5)