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)* a reduction in the gender gap of the age at first marriage, *(ii)* an increase in incidence of marriage, *(iii)* a relative increase in men's prevalence of marriage, and *(iv)* a large increase in the divorce rate. We pose a model of marriage and divorce in which preferences over partners depend on partner's age and where search frictions make it difficult to get new partners. We estimate our model using marital and population patterns of the 1950 birth cohort. Next, we combine the preference parameters estimated on the 1950 cohort and the age and sex structure of the 1870 cohort. The resulting marriage patterns are quite similar to those observed in the 1870 cohort, suggesting that shifts in preferences for marriage are *not* driving recent trends. In combination with the liberalization of divorce laws and the change in the gains to marriage, the resemblance is even 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 *(a)* 96% of the narrowing of the gender gap in the age at first marriage *(b)* 102% of the increase in the incidence of marriages for women and 109% for men.

Keywords: Demographic Transition, Sex Ratio, Marriage and Divorce, Two-Sided Search
JEL Classification: J10, J11, J12

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1 Introduction

The last century has seen four important changes in the characteristics of marriage in the United States. First, there has been a reduction in the gender gap in the age at first marriage (the gap between the medians of groom's age at first marriage and bride's age at first marriage).[1] Second, there has been an increase in incidence of marriage.[2] Third, there has been a rise in prevalence of marriage for men.[3] Fourth, the divorce rate has increased.[4] (See Figure 1 for the historical trends in all the marital statistics.) Simultaneously, there have been significant changes in the sex structure of the population both in terms of the relative number of men and women and the age characteristics of each sex: *(1)* The ratio of males to females aged 15 years and older fell from 1.040 to 0.939. *(2)* The life expectancy of women went from 43.9 to 60.5 years while for men went from 43.4 to 54.4 years. (See Table 1 for the demographic transitions.)

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. The demographic transition in the last century implies that the U.S. has experienced a large increase in the relative number of women (especially old women). This phenomenon might have had a significant impact on the marriage markets. 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 a "love shocks", whose structures are assumed to be invariant across birth cohorts.

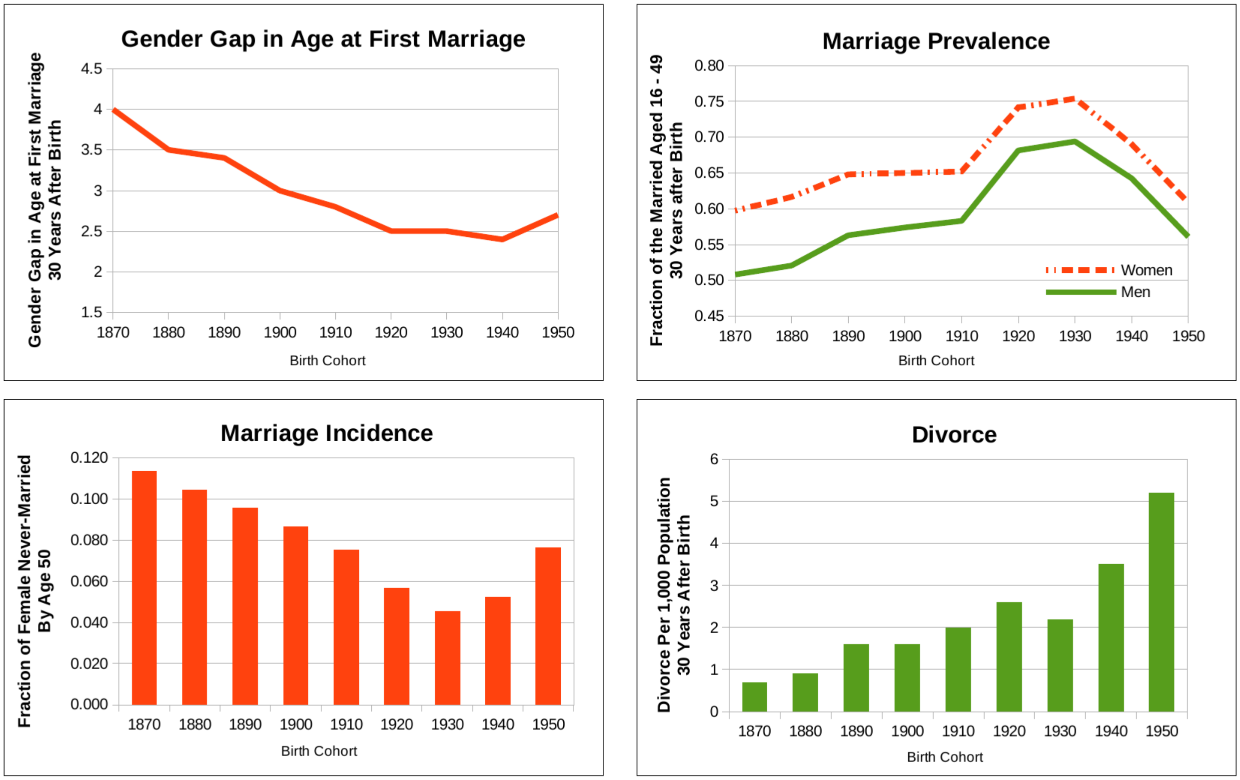
We map the model to the cohort born in 1950 by using an estimator of the relevant model parameters (for preferences, meeting technology, and the structure of shocks to create and maintain marriages and demographic turnover). We find that the model is able to fit the marital statistics for the 1950 birth cohort well. Then, we substitute the demographic characteristics of the 1870 cohort for those of the 1950 cohort, keeping preferences and the mating process as estimated for the 1950 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 cost of divorce and gains to marriage parameters. We estimate these parameters alone to

[1] The gap was 4.0 years in the 1870 cohort and 2.7 years in the 1950 cohort.

[2] The percent of the never married by age 50 went from 10.4% in the 1870 birth cohort to 5.3% in the 1950 birth cohort for women. It went from 12.9% in the 1870 birth cohort to 6.3% in the 1950 birth cohort for men.

[3] The percent of men aged 16 to 49 that are married went from 50.8% in the 1870 birth cohort to 56.1% in the 1950 birth cohort while that for women only changed from 59.7% to 60.8%.

[4] The number of divorces per 1,000 population was 0.7 in the 1870 cohort and 5.2 in the 1950 cohort.



(The sources of the data are documented in Appendix B.)

Figure 1 – Trends in Marriage: 1870 to 1950 Birth Cohort

match the divorce rate and the number of the married of the 1870 cohort keeping the other parameters at the values of the previous exercise. This is a way to estimate the extent of the social changes that eased the divorce process and altered the gains to marriage. By adding those changes for the 1870 cohort, we find that the model essentially matches all the other features of the data: *(a)* 96% of the narrowing of the gender age gap in the age at first marriage, and *(b)* 102% of the increase in the incidence of marriage for women and 109% for men.

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. First, 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. Second, differential mortality rates across gender and determine the timing and attractiveness of marriage for each gender. Furthermore, we assume men and women age at different rates within the model, in essence capturing biological constraints that determine the gains to marriage.

Table 1 – Demographic Transitions: 1870, 1930, 1950 Birth Cohort

Birth Cohort	Men per Women (aged 15 and above)	Life Expectancy (at age 15) Women	Men
1870	1.040	43.9	43.4
1930	0.997	55.0	51.4
	(-4.1)	(25.2)	(18.4)
1950	0.939	60.5	54.4
	(-9.7)	(37.8)	(25.3)

(The numbers in parenthesis are changes in percent from the 1870 birth cohort. For the data sources, see Appendix B.)

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.

Mechnism of the Model The mechanism that delivers our main results is quite intuitive: As the population shifted from a high sex ratio and low life expectancy regime in the 1870 cohort to a low sex ratio and high life expectancy regime in the 1950 cohort, the model predicts the earlier age at first marriage and a rise in prevalence of marriage for men. This is because it became easier for men to find a wife. Also, the model predicts a rise in marriage incidence for both gender after the transition. This is due to larger average gains to marriage as men and women's life expectancies has increased. In summary, the combination of increased longevity and a scarcity of men in the 1950 cohort served to increase the incentives of men to get married earlier and couples participate in marriage to a greater extent in the 1950 cohort than in the 1870 cohort.

Papers with Related Questions The recent empirical literature has documented siginificant evidence on the effects of the sex ratio on marriage markets. Abramitzky, Delavande, and Vasconcelos (2011) and Angrist (2002) are two papers whose results are consistent with our theory. Although the situation of large sex imbalance is limited, they use the data in France after WWI and that from the second generation of immigrants to the U.S., respectively, and show how the sex ratio imbalance alters people's marriage prospect.

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 (2009); Choo, Seitz, and Siow (2008)) 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, Guner, and Knowles (2005); Choo and Siow (2006)). Our work is also complementary to a recent literature on that examines the economic implications of the demographic transition (De Nardi, Imrohoroğlu, and Sargent (1999); Attanasio and Violante (2005)).

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 evaluate 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 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 draw a shock after they match to form and maintain relationships (the process of the shock is described in Section 2.2). Third, agents match randomly, where the matching rate depends on the relative supplies of unmarried men and women (outlined in Section 2.4). Fourth, 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 Section 2.5 and 2.6, respectively). 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, and form matches. Maturity (adolescent, young, or old) is not observed in the data but determines how attractive one is to the opposite sex. 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 equals the outflow of women through death. The measure of newborn males is equal to that for females. The measure of newborns is

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

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 be attributed 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 defined as $q = \mu + \epsilon$. A Markov component $\mu \in \{\mu_G, \mu_B\}$ has age-dependent transition probability Λ^i, and Λ_0 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

$$x^{f,i}(z,i^*,\mu,\mu^*) = x^{m,i^*}(z,i,\mu^*,\mu) \qquad \forall\ z \in \{1,2\}, i, i^*, \mu, \mu^* \tag{2}$$

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

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

$x^g(0)$ denotes the measure of single agents of gender g.

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 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 $u^g(i^*) = \alpha^g_{i^*} + q$. As mentioned earlier, one's maturity affects partner's preference.

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.

Single Agents

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

$$\begin{aligned} V^{g,i}(0,0,0,0) \quad = \quad & u^g(0) \quad + \beta \ \ (1-\pi^g_i) \ \ \sum_{i'} \Gamma^g_{i,i'} \Bigg\{ \ \ (1-\psi^g) \ V^{g,i'}(0,0,0,0) \\ & + \psi^g \sum_{i^*,\mu,\mu^*} p^g(i^*) \ \Lambda_0(\mu) \ \Lambda_0(\mu^*) \ V^{g,i'}(1, i^*, \mu, \mu^*) \ \Bigg\} \end{aligned} \tag{7}$$

for $i, i', i^* \in \{a, y, o\}$, 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^*. In the last term, $p^g(i^*)$ is the probability that an individual with gender g draws a partner with age i^*. The following expression holds in a steady state:

$$p^g(i^*) = \frac{x^{g^*,i^*}(1,.)}{x^{g^*}(1,.)}.$$

.

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:

$$
\begin{aligned}
V^{g,i}(z, i^*, \mu, \mu^*; \hat{\epsilon}_{g^*,i^*}) = \max_{\hat{\epsilon}_{g,i}} \int_{\hat{\epsilon}_{g,i}}^{\infty} \int_{\hat{\epsilon}_{g^*,i^*}}^{\infty} \Bigg\{ & \alpha^g_{i^*} \ + \ \mu \ + \ \epsilon_g \\
+ \ \beta \left(1 - \pi^g_i\right) \Bigg[& (1 - \pi^{g^*}_{i^*}) \sum_{i', i^{*\prime}, \mu', \mu^{*\prime}} \Gamma^g_{i,i'} \Gamma^{g^*}_{i^*,i^*} \Lambda^{i'}_{\mu,\mu'} \Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}} V^{g,i'}(2, i^{*\prime}, \mu', \mu^{*\prime}) \\
+ \pi^{g^*} \sum_{i'} \Gamma^g_{i,i'} \Big(& (1 - \psi^g) V^{g,i'}(0,0,0,0) + \psi^g \sum_{i^{*\prime}, \mu, \mu^*} p^g(i^{*\prime}) \Lambda_0(\mu) \Lambda_0(\mu^*) V^{g,i'}(1, i^{*\prime}, \mu, \mu^*) \Big) \Bigg] \Bigg\} \\
\times \, d\Phi(\epsilon_g) \, d\Phi(\epsilon_{g^*}) + \Big\{ & V^{g,i}(0,0,0,0) - \omega \mathbf{1}_{[z=2]} \Big\} \, \Phi(\hat{\epsilon}_{g,i}) \, \Phi(\hat{\epsilon}_{g^*,i^*})
\end{aligned}
\tag{8}
$$

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. If both of the partners agree, they continue their relationship and enjoy the utility from their partners and from the match quality. The first and the second line in the right-hand-side of the equation (8) include the flow utility and the value in the case where both parties agree on being married in the next period. Their marital state maintains until the next period unless one of the partners dies. Indeed, the third line in the right-hand-side of the the equation (8) shows the value in the case the partner dies. With probability $\Phi(\hat{\epsilon}_{g,i}) \times \Phi(\hat{\epsilon}_{g^*,i^*})$, the couple breaks up. If they break up, both partners pay the divorce cost ω if they have been married, and they go back to the singles' pool. The last term on the right hand side in the equation (8) is the value in the case they break up with the current partner.

2.7 Cutoff Strategies

The decisions on the cutoff values are taken in pairwise meetings by agents that play Nash. A member of the couple with gender g and age i solves:

$$
\begin{aligned}
\epsilon^{**}_{g,i}(z, i^*, \mu, \mu^*, \hat{\epsilon}_{g^*,i^*}) = \arg\max_{\hat{\epsilon}_{g,i}} \int_{\hat{\epsilon}_{g,i}}^{\infty} \int_{\hat{\epsilon}_{g^*,i^*}}^{\infty} \Bigg\{ \alpha^g_{i^*} \ + \ \mu \ + \ \epsilon_g \\
+ \ \beta \left(1 - \pi^g_i\right) \Bigg[(1 - \pi^{g^*}_{i^*}) \sum_{i', i^{*\prime}, \mu', \mu^{*\prime}} \Gamma^g_{i,i'} \Gamma^{g^*}_{i^*,i^*} \Lambda^{i'}_{\mu,\mu'} \Lambda^{i^{*\prime}}_{\mu^*,\mu^{*\prime}} V^{g,i'}(2, i^{*\prime}, \mu', \mu^{*\prime}) \\
+ \pi^{g^*} \sum_{i'} \Gamma^g_{i,i'} \Big((1 - \psi^g) V^{g,i'}(0,0,0,0) + \psi^g \sum_{i^{*\prime}, \mu, \mu^*} p^g(i^{*\prime}) \Lambda_0(\mu) \Lambda_0(\mu^*) V^{g,i'}(1, i^{*\prime}, \mu, \mu^*) \Big) \Bigg] \Bigg\} \\
\times \, d\Phi(\epsilon_g) \, d\Phi(\epsilon_{g^*}) + \Big\{ V^{g,i}(0,0,0,0) - \omega \mathbf{1}_{[z=2]} \Big\} \, \Phi(\hat{\epsilon}_{g,i}) \, \Phi(\hat{\epsilon}_{g^*,i^*}).
\end{aligned} \tag{9}
$$

A Nash equilibrium is a pair of values that are a fixed point denoted by $\hat{\epsilon}_{f,i}(z, i^*, \mu, \mu^*)$ and $\hat{\epsilon}_{m,i^*}(z, i, \mu^*, \mu)$ that satisfy

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

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 $g \in \{f, m\}$, $i, i^* \in \{a, y, o\}$, $z \in \{1, 2\}$, 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 agents with gender g is:

$$\tilde{x}^{g,i'}(0) = n^g \mathbf{1}_{[i'=a]} + i^m \mathbf{1}_{[g=m,i'=a]} + (1 \; - \; \psi^g) \Bigg[\sum_i \, (1-\pi_i^g) \; \Gamma_{i,i'}^g \; \Bigg\{ \tilde{x}^{g,i}(0)$$
$$+ \sum_{z\in\{1,2\},i^*,\mu,\mu^*} \Bigg(\; \pi_{i^*}^{g^*} \; \tilde{x}^{g,i}(z,i^*,\mu,\mu^*) + (1-\pi_{i^*}^{g^*}) \; \Phi(\tilde{\epsilon}_{g,i}) \; \Phi(\tilde{\epsilon}_{g^*,i^*}) \; \tilde{x}^{g,i}(z,i^*,\mu,\mu^*) \Bigg) \Bigg\} \Bigg], \tag{11}$$

for dating agents is

$$\tilde{x}^{g,i'}(1,i^{*\prime},\mu',\mu^{*\prime}) = \psi^g \Bigg[\sum_i \, (1-\pi_i^g) \; \Gamma_{i,i'}^g \; p^g(i^{*\prime}) \; \Lambda_0(\mu') \; \Lambda_0(\mu^{*\prime}) \; \Bigg\{ \tilde{x}^{g,i}(0)$$
$$+ \sum_{z\in\{1,2\},i^*,\mu,\mu^*} \Bigg(\pi_{i^*}^{g^*} \; \tilde{x}^{g,i}(z,i^*,\mu,\mu^*) + (1-\pi_{i^*}^{g^*}) \; \Phi(\tilde{\epsilon}_{g,i}) \; \Phi(\tilde{\epsilon}_{g^*,i^*}) \; \tilde{x}^{g,i}(z,i^*,\mu,\mu^*) \Bigg) \Bigg\} \Bigg], \tag{12}$$

and for married agents is

$$\tilde{x}^{g,i'}(2,i^{*\prime},\mu',\mu^{*\prime}) = \sum_{z\in\{1,2\},i,i^*,\mu,\mu^*} (1-\pi_i^g) \; (1-\pi_{i^*}^{g^*}) \; \Gamma_{i,i'}^g \; \Gamma_{i^*,i^{*\prime}}^{g^*} \; \Lambda_{\mu,\mu'}^{i'} \Lambda_{\mu^*,\mu^{*\prime}}^{i^{*\prime}}$$
$$\times \left[1 - \Phi(\tilde{\epsilon}_{g,i}) \; \Phi(\tilde{\epsilon}_{g^*,i^*})\right] \; \tilde{x}^{g,i}(z,i^*,\mu,\mu^*). \tag{13}$$

4. *The meeting probabilities ψ^g and $p^g(i^*)$ are consistent with the number and the distribution of people that end a period as single and with the meeting technology.*

2.9 The Role of Demographic Channels

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 channels in shaping marital status in the model.

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.

Immigration Rates

We model immigration as an inflow of adolescent 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 1950 Birth Cohort 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. In Section 3.1, we start by choosing the functional forms and listing the parameters that we need to calibrate. In Section 3.2, we discuss on the set of targets we use to solve for the parameter values. We describe our calibration procedure in Section 3.3. We present and interpret the parameter values in Section 3.4. Evidence on the ability of the baseline model to match the targets and other features of the data is presented in Section 3.5.

3.1 Parameters

In addition to the discount factor, which we set equal to 0.96, the model has 24 parameters. We divide the parameters into three groups: *(i)* demographic parameters (3), *(ii)* preference parameters (10), and *(iii)* parameters for the evolution of match quality (11). Each set of parameters is discussed in turn below.

Demographics

For the 1950 birth cohort, we assume that all the agents with gender g remain alive at the same rate π^g ($g \in \{f, m\}$) (that is, we assume $\pi^g = \pi_i^g$ for all $i \in \{a, y, o\}$). We relax this assumption later when we calibrating the demographic structure of the 1870 birth cohort. In addition to the mortality parameters (π^f, π^m), there is also an immigration parameter for men (i^m).

Preferences

The current period utility function takes the form: $u^g(j) = \alpha^g_j + q$ for married men and women and $u^g(0) = 0$ for singles. Preferences for a paired agent depend on gender and on the age of the agent's spouse and match quality. We assume all men and women start out adolescent and age stochastically over time. As a result, there are ten preference parameters to be determined;

$$\left\{\alpha^f_a, \alpha^f_y, \alpha^f_o, \alpha^m_a, \alpha^m_y, \alpha^m_o, \Gamma^f_{a,y}, \Gamma^f_{y,o}, \Gamma^m_{a,y}, \Gamma^m_{y,o}\right\}.$$

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, in addition to the cost of divorce, are;

$$\{\mu_G, \mu_B, \sigma, \Lambda_0, \Lambda^a_{GG}, \Lambda^y_{GG}, \Lambda^o_{GG}, \Lambda^a_{BB}, \Lambda^y_{BB}, \Lambda^o_{BB}, \omega\}.$$

3.2 Targets

We choose the parameters to match two sets of targets: *(i)* 3 demographic targets summarizing the age and sex structure of the population, *(ii)* 26 statistics summarizing detailed marriage behavior and divorce behavior by age.

Demographics

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

Table 2 – Demographic Targets

	1950
Men per 100 women (aged 15 and above)	0.939
Life expectancy (at age 15)	
Women	60.5
Men	54.4

(For the data sources, see Appendix B.)

Marital Status

There are three sets of marital status statistics that we want the baseline model economy to match, resulting in a total of 26 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 for both genders for the 1950 birth cohort (12 targets). The second set of targets we consider are the divorce rates per 1,000 married couples for six age groups (12 targets). Finally, to match the incidence of marriage, we target the fraction of men and women who never marry by the age of 50 for each sex (2 targets). Appendix B talks on the data sources for those targets. The values for marital status statistics targets are presented in Table 3.

There are four 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 20 to 24 both for 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 25, and high relative to those of women after the age of 25.[5] Both trends are consistent with the well documented fact that men tend to marry younger women. Third, for both men and women, the divorce rates peak at the youngest age group. Finally, fourth, as illustrated in Table 3, the data on the never-married implies that men have both higher rates of entry into and exit from marriage given the low sex ratio for the 1950 birth cohort.

3.3 Calibration Procedure

Our calibration consists of two steps. In the first step, we determine the values of demographics parameters based on the demographics targets described in Section 3.2. In the second step, we calibrate the remaining parameters by the Minimum Distance Estimation Method

[5] See Figure 3 in Appendix A.

Table 3 – Marital Status Targets

Age	Women	Men
Marriage rates by age, per 1,000 unmarried		
16-19 in 1965	134.6	59.0
20-24 in 1970	229.3	187.4
25-29 in 1975	132.9	146.6
30-34 in 1980	107.5	121.0
35-39 in 1985	70.0	81.3
40-44 in 1990	61.8	74.4
Divorce rates by age, per 1,000 married		
16-19 in 1965	19.8	30.1
20-24 in 1970	18.4	15.8
25-29 in 1975	17.4	15.4
30-34 in 1980	17.6	14.5
35-39 in 1985	15.8	12.3
40-44 in 1990	16.5	12.2
Percent of never-married by age 50 in 1990	5.3	6.3

(Appendix B talks on the data sources and how we construct the data targets.)

targeting on the marital status statistics. In our setup, a model period corresponds to one year of calender time. We assume both men and women enter the economy at age 15, and track their calender age since then in order to calculate the marital status targets.[6]

First Step

We first fix the values of the mortality rates (π^f, π^m) so that the model is able to match the life expectancy of men and women at age 15 in the data. Then, next, we choose the men's immigration parameter (i_m) so that the model can generate the sex ratio observed in the data. We set β equal to 0.96 throughout our analysis.

[6] Remember that agents' maturity $(i \in \{a, y, o\})$ changes stochastically over their life-cycle. Therefore, individuals at the same calender age could differ in their maturity. The distributions of the adolescent, the young, and the old at certain age are determined by the transition probabilities $(\{\Gamma^f_{a,y}, \Gamma^f_{y,o}, \Gamma^m_{a,y}, \Gamma^m_{y,o}\})$. We calibrate the transition probability parameters so that the model can fit the marriage and divorce rates by age group.

Second Step

The remaining 21 parameters for preferences and the evolution of match quality are determined through the Minimum Distance Estimation Method. The structural parameters to be estimated are stacked in a 21×1 vector:

$$\boldsymbol{\theta} = \left[\alpha_a^f, \alpha_y^f, \alpha_o^f, \alpha_a^m, \alpha_y^m, \alpha_o^m, \Gamma_{a,y}^f, \Gamma_{y,o}^f, \Gamma_{a,y}^m, \Gamma_{y,o}^m, \mu_G, \mu_B, \sigma, \Lambda_0, \Lambda_{GG}^a, \Lambda_{GG}^y, \Lambda_{GG}^o, \Lambda_{BB}^a, \Lambda_{BB}^y, \Lambda_{BB}^o, \omega\right]'$$

Targets are the 26 marital status targets described in Section 3.2. Define $\hat{\mathbf{g}}^{DATA}$ as the 26×1 vector which includes all the data targets and $\mathbf{g}^{MODEL}(\boldsymbol{\theta})$ as the 26×1 vector which includes all the model's counterparts. The minimum distance estimator is then defined as:

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}} \left(\hat{\mathbf{g}}^{DATA} - \mathbf{g}^{MODEL}(\boldsymbol{\theta}))\right)' \mathbf{W} \left(\hat{\mathbf{g}}^{DATA} - \mathbf{g}^{MODEL}(\boldsymbol{\theta}))\right).$$

We choose the weighting matrix, $\mathbf{W}$, such that the objective function is the squared sum of percentage deviations between the model and the data targets.[7] The variance-covariance estimator is calculated by

$$\hat{\mathbf{V}}(\hat{\boldsymbol{\theta}}) = \left(\hat{\mathbf{G}}'\mathbf{W}\hat{\mathbf{G}}\right)^{-1} \hat{\mathbf{G}}'\mathbf{W}\hat{\mathbf{V}}(\hat{\mathbf{g}}^{DATA})\mathbf{W}\hat{\mathbf{G}} \left(\hat{\mathbf{G}}'\mathbf{W}\hat{\mathbf{G}}\right)$$

where $\hat{\mathbf{G}} = \frac{\partial \mathbf{g}^{MODEL}(\boldsymbol{\theta})}{\partial \boldsymbol{\theta}} |_{\boldsymbol{\theta}=\hat{\boldsymbol{\theta}}}$, which we compute by using the numerical derivative of $\mathbf{g}^{MODEL}(\boldsymbol{\theta})$ at $\hat{\boldsymbol{\theta}}$. $\hat{\mathbf{V}}(\hat{\mathbf{g}}^{DATA})$ in the above expression is the variance-covariance estimator of the data targets that we compute by bootstrap.[8]

3.4 Parameter Values

In this subsection, we briefly summarize the calibration results. In Table 4, 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.[9] The parameter estimates indicate that *(i)* there exist different peak ages of attractiveness for men and women in the marriage market, *(ii)* women become attractive marriage partners at an earlier age than men (see the values of males' preference over females $\{\alpha_i^m\}$), and that *(iii)* men remain attractive marriage partners for a longer period of time than women (see the values of

[7] Based on Altonji and Segal (1996), we avoid using the optimal weighting matrix. We also didn't use an identity matrix, which tends to overemphasize moments that are larger in absolute value.

[8] We perform 999 bootstrap resampling from the IPUMS Census data to estimate the variance of the data targets.

[9] Standard errors and 95% confidence intervals for all the parameters are shown in Table 15 in Appendix A.

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)	-7.02
Female's preferences over young spouse (α_y^f)	-0.47
Female's preferences over old spouse (α_o^f)	1.97
Male's preferences over adolescent spouse (α_a^m)	-2.39
Male's preferences over young spouse (α_y^m)	4.02
Male's preferences over old spouse (α_o^m)	0.44
Average age at which women become young	22.4
Average age at which women become old	26.8
Average age at which men become young	21.2
Average age at which men become old	28.4

females' preference over males $\left\{\alpha_i^f\right\}$). 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 (Dunson, Colombo, and Baird (2002)).

Table 5 presents the calibrated values of the parameters governing the evolution of match quality. The estimates indicate that all the individuals start with bad regime ($\lambda = 0.000$). Then, couples who draw good transitory shocks (ϵ_f, ϵ_m) survive the dating state and get married. Also, the estimates show that the probability of switching from a good match (μ_G) to a bad match (μ_B) is highest for the adolescent both for men and women. This property of the estimates capture the notable pattern of the divorce rates in the data; for both men and women, the divorce rate is highest among the youngest age group.

3.5 Performance of the Baseline Model

In this subsection we assess the baseline model's performance to match the statistics in the 1950 birth cohort's data. Overall, our parsimonious model replicates the data very well. It is worth emphasizing that, in addition to the discount factor and demographic parameters, the benchmark model has 21 parameters and 26 targets; thus the model is over-identified.

Table 6 and Figure 3 in Appendix A show that the model is able to match important features of the 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 25 and the opposite trend at later ages. Those features of the marriage rates are well-captured by the preference parameters. Although the

Table 5 – Calibrated Values of the Match-Quality Parameters in the Baseline Model

Parameter	Value
Mean of match quality in good regime, μ_G	1.90
Mean of match quality in bad regime, μ_B	-4.99
Variance of match quality, σ	4.96
Initial dist. of good match, Λ_0	0.000
Initial dist. of bad match, $1-\Lambda_0$	1.000
Transition probability of regimes, $\Lambda^a_{G,G}$, for adolescent	0.689
Transition probability of regimes, $\Lambda^a_{B,B}$, for adolescent	0.471
Transition probability of regimes, $\Lambda^y_{G,G}$, for young	0.985
Transition probability of regimes, $\Lambda^y_{B,B}$, for young	0.036
Transition probability of regimes, $\Lambda^o_{G,G}$, for old	0.997
Transition probability of regimes, $\Lambda^o_{B,B}$, for old	0.880
Cost of divorce	11.33

model matches the peak marriage rates, we under-estimate the marriage rate for the group with age 20 to 24 both for men and women. Allowing for only three ages in the model does not provide enough flexibility to more accurately match the age profile of marriage rates.

The results in Table 6 and Figure 3 also indicate that the model is able to replicate the important pattern of the divorce rates in the data: For both men and women, the divorce rate is highest for the group with age 16 to 19. After age 20, the divorce rates are almost flat over the life cycle. Those patterns of the divorce rates are captured by the match quality parameters. Furthermore, Table 6 shows that the model is able to match the percent of the never-married by age 50 both for men and women.

Table 7 shows the additional statistics implied by the model. The first row is the divorce rate defined as the number of divorces per 1,000 of people, which the model under-estimate.[10] The second and the last rows show the percent of married people aged 16 to 49 and the age at first marriage for men and women. The model is able to replicate both statistics quite well. Note that we didn't directly target those statistics when we calibrate the model to the 1950 birth cohort data. In Section 4, we use the statistics in order to evaluate how much the model can account for the changes in marital behaviors over time.

[10]This failure is because we only ask the model to match the marital statistics up to age 50. Therefore, the model is not replicating the right tail of the age distribution above age 50. Also, age-specific divorce rate data is not available for all the cohorts in our analysis. Therefore, we have to use the statistics though our model can't perfectly match.

Table 6 – Model Performance: Marital Status Targets

	Women		Men	
	Data	Model	Data	Model
Marriage rates by age, per 1,000 unmarried				
16-19	134.6	130.8	59.0	71.2
20-24	229.3	203.3	187.4	161.9
25-29	132.9	154.2	146.6	151.2
30-34	107.5	101.3	121.0	117.7
35-40	70.0	67.9	81.3	89.8
40-44	61.8	49.7	74.4	71.4
Divorce rates by age, per 1,000 married				
16-19	19.8	22.3	30.1	28.7
20-24	18.4	15.5	15.8	17.6
25-29	17.4	14.4	15.4	14.4
30-34	17.6	14.7	14.5	14.3
35-39	15.8	15.1	12.3	14.8
40-44	16.5	15.4	12.2	15.3
Percent of never-married	5.3	4.7	6.3	6.2

(Appendix B talks on the data sources and how we construct the data targets.)

Table 7 – Model Performance: Other (Non-Targeted) Marital Statistics

	Data	Model
Divorce rate, per 1,000 of population	5.2	4.0
Percent of the married aged 16 to 49		
Women	60.8	63.5
Men	56.0	57.2
Age at first marriage		
Women	22.0	22.3
Men	24.7	24.5

(Appendix B talks on the data sources and how we construct the marital statistics.)

4 Can Demographics Account for the Trends in Marriage Since 1870?

In this section, we consider the extent to which changes in demographics alone can account for the changes in marriage and divorce since the birth of the 1870 cohort (exactly 80 years earlier). First, in Section 4.1, we discuss on the trends in marital statistics in the United States since 1870. Then, in Section 4.2, we document the transition of the demographic structure during the same period, and describe how we calibrate the demographic parameters. In Section 4.3, we assess our model's performance to account for the long-run trends since 1870. In Section 4.4, we consider other possible changes in the marriage environment (divorce liberalization and changes in gains to marriage). Finally, in Section 4.5, we show the failure of our model to account for the short-run trends in the data, and discuss on the possible causes for the failure.

4.1 Trends in Marital Statistics since 1870

In Table 8, we document the trends in marital statistics in the U.S. since 1870 birth cohort. Specifically, we consider age at first marriage for men and women, the percent of the never-married by age 50 for men and women, the percent of the married aged 16 to 49 for men and women, and divorce rate per 1,000 of population as the main targets of our analysis. We use the 1870 birth cohort because it is the earliest one for which all of the above statistics are available. With a similar reason, we pick the 1950 birth cohort because it was the latest one for which all of the statistics are available when we started this project.

As briefly discussed in Section 1, all the statistics in Table 8 exhibit significant changes from the 1870 cohort to the 1950 cohort: *(1)* There has been a decrease in the age at first marriage for men (25.9 to 24.7) while that for women hasn't been changed much (21.9 to 22.0). As a result, there has been a reduction in the gender gap of the age at first marriage. *(2)* For both genders, the incidence of marriage has significantly increased. The percent of the never-married by age 50 has changed from 10.4 to 5.3 for women and from 12.9 to 6.3 for men suggesting more men and women are experiencing marriage in the 1950 birth cohort. It amounts to about 50 percent decline of the number both for men and women. *(3)* The prevalence of marriage has increased more for men than for women. The fraction of married men aged 16 to 49 has increased by 10.4% while that for women has increased only by 1.8%. *(4)* The divorce rate per 1,000 of population has increased from 0.7 to 5.2. The change is 642.9%.

Table 8 – Trends in Marital Statistics, United States

	Birth Cohort			% Change in the Data	
	1870	1930	1950	Short run (1930 - 1950)	Long run (1870 - 1950)
Age at first marriage					
Women	21.9	20.3	22.0	8.4	0.5
Men	25.9	22.8	24.7	8.3	-4.6
Percent of the never-married by age 50					
Women	10.4	5.7	5.3	-7.7	-49.4
Men	12.9	6.6	6.3	-5.2	-51.5
Percent of the married aged 16 to 49					
Women	59.7	75.4	60.8	-19.3	1.8
Men	50.8	69.4	56.1	-19.2	10.4
Divorce rate, per 1,000 of population	0.7	2.2	5.2	136.4	642.9

(See Appendix B for the data sources.)

4.2 Demographic Transition from the 1870 to the 1950 Birth Cohort

The demographic trends we consider are the rise in life expectancies and the fall in the ratio of men to women in the population. In Table 9, we document changes in the life expectancy and the sex ratio from the 1870 to the 1950 birth cohort. During the period, the sex ratio (men per women) has decreased by 9.7%, and the life expectancy has increased by 37.7% for women and by 25.3% for men. Figure 2 in Appendix A plots the long-run trends in the sex ratio and life expectancies. It shows that both the sex ratio and the life expectancies have changed gradually but significantly during the time period. In Table 14, we also document sex ratios for different ages by tracking the 1870, 1930 and 1950 birth cohort. The numbers in the table clearly indicate that the sex ratios have significantly declined for those who are at prime age in marriage markets (e.g. 20 to 30 years-old) over time.

Targeting on the population structure of the 1870 birth cohort, we re-calibrate the demographic parameters. For men's mortality rate, we maintain the assumption that it is same for all the maturities ($\pi^m = \pi_i^m$ for all $i \in \{a, y, o\}$). However, for women, we relax that assumption so that our model can feature the improvements in maternal health that started in the mid 1930s as discussed in ?.

For the first step, we set the mortality rate for men (π^m) so that the life expectancy of men at age 15 is consistent with the one in the 1870 cohort data. Next, we set the mortality rates for adolescent and young women, π_a^f and π_o^f, so that the rate of the change of the mortality from the 1870 cohort to the 1950 cohort is the same as men's.[11] Then, we adjust π_o^f to match women's life expectancy of the 1870 cohort in the data. After we determine the mortality parameters, the immigration rate is set to match the sex ratio of the 1870 birth cohort. All the calibrated values are shown in Table 9.

Table 9 – Demographic Transition: 1870 to 1950 Birth Cohort

	Birth Cohort	
	1870	1950
Demographic target		
Men per 100 women (aged 15 and above)	1.040	0.939 (-9.7)
Life expectancy (at age 15)		
Women	43.9	60.5 (37.8)
Men	43.4	54.4 (25.3)
Model's parameter value		
Women's mortality rate		
Adolescent (π_a^f)	0.0205	0.0165
Young (π_y^f)	0.0517	0.0165
Old (π_o^f)	0.0205	0.0165
Men's mortality rate		
Adolescent (π_a^m)	0.0228	0.0184
Young (π_y^m)	0.0228	0.0184
Old (π_o^m)	0.0228	0.0184

(The numbers in parenthesis are changes in percent. For the data sources, see Appendix B.)

4.3 How Much Demographics Can Account for the Long-Run Trends?

How important are the changes of the population structure in explaining the trends in marriage? To answer this question, we run three experiments as described below. All the

[11] We solve $\frac{\pi^m(1950)}{\pi^m(1870)} = \frac{\pi_i^f(1950)}{\pi_i^f(1870)}$ for $i \in \{a, o\}$ to find the values for π_a^f and π_o^f.

Table 10 – Demographic Experiments for the Long-Run Trends: 1870 to 1950

Marital Statistics	% Change in Data	% Change in Model Life Exp. (1)	Sex Ratio (2)	Both (3)
Age at first marriage				
Women	0.5	-1.2	4.3	1.3
Men	-4.6	-4.5	-0.7	-4.6
% of the never-married by age 50				
Women	-49.4	-46.1	177.4	-9.7
Men	-51.5	-44.0	23.7	-42.3
% of the married aged 16 to 49				
Women	1.8	14.1	-8.4	5.7
Men	10.4	17.8	-1.2	17.1
Divorce rate, per 1,000 of population	642.9	-0.3	-5.0	-4.2

(All the numbers in the above table are changes in percent from the 1870 to the 1950 birth cohort.)

results of the experiments are presented in Table 10.

In the first experiment, we take the baseline model economy and replace the life expectancies of the 1950 birth cohort with the life expectancies of the 1870 birth cohort holding the sex ratio constant at the value of the 1950 cohort.[12] Column (1) of Table 10 indicates that the aging of the population can explain much of the rise in the incidence of marriage (i.e. the reduction in the never-married by age 50). The reason for this is simple: A fall in mortality increases the value of marriage as lower mortality rates increase the probability a married couple remains together in the future. Falling mortality rates alone can explain 93% of the rising incidence of marriage for women and 85% of that for men. Although consistent with the rising incidence of marriage, the model over-predicts the increase in marriage prevalence (percent of the married aged 16 to 49) for women. Nor can it account for the rise in divorce.

In the second experiment, we increase immigration in the model to match the sex ratio of the 1870 birth cohort while holding life expectancies constant at the values of the 1950

[12]We re-calibrate $\{\pi_i^g\}$ to match the life expectancies of the 1870 cohort, and then, adjust i_m to keep the sex ratio same as that of the 1950 cohort.

cohort.[13] We then ask whether the scarcity of men in the 1950 cohort relative to the 1870 cohort can explain the trends in marriage. Results of this exercise, presented in Column (2) of Table 10, indicate that the fall in the sex ratio has asymmetric effects for men and women on all the first three marital statistics. The first two rows of Column (2) show that the fall in the sex ratio increases women's age at first marriage while it slightly decreases men's age at first marriage. The main force behind this result is the effect of scarcity on the timing of marriage. For the 1950 birth cohort, men are scarce in the marriage market. Therefore, women face a difficulty to find a partner and their timing of marriage delays. Although the scarcity affects in the opposite way for men, the effect is not so large because men stay attractive longer than women, and have more incentives to delay marriage. This scarcity of men in marriage markets is the force behind the rise in the fraction of the never-married and the fall in the fraction of the married for women. In fact, the fraction of women that are married is lower at all ages, as there are fewer men available for marriage. For men, the abundance of women makes them selective for their partner. Indeed, the fraction of the never-married has slightly increased for men in the 1950 cohort despite the fact that there are relatively more women available for marriage in the 1950 cohort.

Finally, in the third experiment, we change the model's demographic parameters to match both the life expectancies and the sex ratio of the 1870 birth cohort. Column (3) of Table 10 shows that the aging of the population and the fall in the ratio of men to women can simultaneously explain *(i)* 100% of the fall in the age at first marriage for men, *(ii)* 20% of the rise in the incidence of marriage for women and 82% for men, and *(iii)* 164% of the rise in the prevalence of marriage for men. The results in Column (3) of Table 10 also indicate the importance of both the aging of the population and the fall in the sex ratio to account for the changes in the age at first marriage and the percent of the married. For the age at first marriage, the change in life expectancies decreases the number both for men and women. On the other hand, the change in the sex ratio mainly affects women's by increasing the number. In combination, those two changes decrease men's age at first marriage while keeping that for women only a little changed. For the percent of the married aged 16 to 49, the change in life expectancies increases the number both for men and women at the same extent. However, the change in the sex ratio only decreases men's fraction of the married singnificantly. Again, together, those two changes increase men's fraction of the married more than women's as observed in the data. Neither life expectancy alone or sex ratio alone can explain the changes in the age at first marriage and the percent of the married in the data.In summary, the combination of increased longevity and a scarcity of men in the 1950

[13]We keep $\{\pi_i^g\}$ unchanged, and then, adjust i_m to match the sex ratio in the model to the one of the 1870 cohort in the data.

cohort served to increase the incentives of men to get married earlier and couples participate in marriage to a greater extent in the 1950 cohort than in the 1870 cohort.

TABLE 11 – Marital Statistics in Data and Model: 1870 to 1950

	1870		1950	
	Data	Model	Data	Model
Age at first marriage				
Women	21.9	22.0	22.0	22.3
Men	25.9	25.7	24.7	24.5
% of the never-married by age 50				
Women	10.4	5.2	5.3	4.7
Men	12.9	10.7	6.3	6.2
% of the married aged 16 to 49				
Women	59.7	60.1	60.8	63.5
Men	50.8	48.8	56.1	57.2
Divorce Rate, per 1,000	0.7	4.2	5.2	4.0

(Appendix B talks on the data sources and how we construct the marital statistics.)

4.4 Other Possible Changes in Marriage Environment

Although demographics can simultaneously account for much of the long-run trends in marital statistics, it fails to explain the increase in marriage incidence for women and the large rise in the divorce rate observed in the data. This is because the model produces too small number of the never-married women and too large divorce rate for the 1870 birth cohort as presented in Table 11. In the model, with the abundance of men, women in the 1870 birth cohort easily get married and separate following the realization of match quality. Therefore, the number of the never-married women becomes too small and the divorce rate becomes high for the 1870 birth cohort. Although this mechanism intuitively makes sense in the situation where women are scarce, the fraction of female never-married and the divorce rate in the data indicate it was not happening in reality. In this subsection, we consider other possible changes in the marriage environment that can improve our model's performance to account for the long-run marriage trends.

Divorce Liberalization

Although changing demographics altered the returns 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 divorce liberalization in the face of an aging population. To study divorce liberalization in our framework, we change the parameter governing the cost of divorce (ω) to match the divorce rate for the 1870 cohort.

Changes in the Gains to Marriage

Another possible explanation for the model's failure is the change in the gains to marriage. To this end, we add and estimate a parameter (ϕ) determining the gains to marriage in our model. We assume, all the married people obtain additional utility from ϕ at the same extent.[14] We set ϕ_{1950} equal to 0 and adjust ϕ_{1870} to match the fraction of the married aged 16 to 49 for men and women in the 1870 birth cohort.

Results

In the first experiment, we re-calibrate the divorce cost parameter (ω_{1870}) and ask whether the divorce liberalization can account for the rest of the marriage trends our model failed to match. The results of this exercise, presented in Column (2) of Table 12, indicate that the divorce liberalization, in combination with demographic changes, cannot produce a favorable outcome. Contradictory to the data, the model predicts an increase in the never-married women and a decrease in the married women from the 1870 to the 1950 cohort when we raise the cost of divorce for the 1870 cohort. These results are due to the fact that the rise of the divorce cost makes marriage secured and too attractive to the individuals in the 1870 cohort.[15] Indeed, in the model, the value of marriage increases as the divorce cost increases, and too many couples get married in the 1870 cohort. Therefore, the model under-predicts the fraction of the never-married and over-predicts the number of the married for the 1870 cohort.

In the second experiment, we adjust the gains to marriage parameter (ϕ_{1870}) and ask whether demographic changes in combination with the changes in the gains to marriage

[14] Therefore, married people's current utility is $u^g(i^*) = \alpha^g_{i^*} + q + \phi$.

[15] There are two opposite effects when we increase the divorce cost. First effect decreases the value of marriage: An agent has to pay larger cost when he/she would like to divorce. Second effect increases the value of marriage: The parner does not initiate divorce easily. Our results shows that the second effect is dominant.

can account for the long-run marital trends. The results of this experiment, presented in Column (3) of Table 12, indicate that the change in marriage cannot improve the model's ability to explain the long-run trends. This is because the experiment with the demographic change alone has already produced a good fit to the fraction of the married people in the 1870 cohort. Therefore, even if we add and calibrate the gains to marriage parameter (ϕ_{1870}) targeting on the fraction of the married, the results don't significantly improve.

Finally, we allow our model to adjust both the cost of divorce and the gains to marriage, and ask how closely the model with demographic changes can match the trends in marriage in combination with the changes in the divorce cost and the gains to marriage. In this experiment, we calibrate the divorce cost parameter (ω_{1870}) and the gains to marriage parameter (ϕ_{1870}) to match the divorce rate per 1,000 of population and the fraction of married aged 16 to 49 for men and women for the 1870 birth cohort. The results of this experiment are shown in Column (4) of Table 12. In this experiment, we slightly decreased the parameter value of the gains to marriage (ϕ_{1870}) from 0, while increasing the cost of divorce at the same time. By doing so, the divorce rate decreases but the value of marriage remains unchanged in the 1870 birth cohort. As a result, unlike the first experiment, the model doesn't produce too many married individuals, and the number of the never married for women also rises in the 1870 birth cohort. In this experiment, our model is able to account for *(i)* 96% of the narrowing of the gender age gap in the median age at first marriage, and *(ii)* 102% of the increase in the incidence of marriage for women and 109% for men.

4.5 How Much Demographics Can Account for the Short-Run Trends?

In Figure 1, the short-run trends (the trends from the 1930 to the 1950 cohort) in all the marital statistics have different patterns from the long-run trends. In this subsection, we assess model's performance to account for the short-term trends in marital statistics from the 1930 to the 1950 birth cohort in the data. In the experiment, we re-calibrate the demographic parameters so that they capture the age and sex structure of the population in the 1930 birth cohort.[16] Table 13 shows the performance of our model to account for the short-run trends. The results clearly indicate that, for the short run, most of the marital statistics in our consideration cannot be explained by the demographic transition. Neither the changes in life expectancies nor the sex ratio can produce the results consistent with the marital trends from the 1930 to the 1950 birth cohort. During this period, many people started delaying marriage, less fraction of people were in marriage, and a significant number of couples started

[16]The details on the calibration are discussed in Appendix C.

Table 12 – Demographic Experiments with Other Possible Changes: 1870 to 1950

	% Change in Data	% Change in Model			
		Demographics Alone	(1) + Div. Cost	(1) + Marriage Gain	All
Marital Statistics		(1)	(2)	(3)	(4)
Age at first marriage					
Women	0.5	1.3	-1.5	1.3	-3.0
Men	-4.6	-4.6	-4.8	-4.1	-7.9
% of the never-married by age 50					
Women	-49.4	-9.7	9.1	2.2	-50.3
Men	-51.5	-42.3	-3.9	-34.0	-56.1
% of the married aged 16 to 49					
Women	1.8	5.7	-4.5	4.3	2.9
Men	10.4	17.1	0.7	13.9	14.9
Divorce rate, per 1,000	642.9	-4.2	468.7	-5.7	540.7

(All the numbers in the above table are changes in percent from the 1870 to the 1950 birth cohort.)

getting divorced (see Figure 1). Although our parsimonious model can account for the most of the long-run trends marital statistics, those rapid changes happened in the past 50 years cannot be captured by our model.

5 Conclusion

In this paper, we make three contributions to the economic literature on marriage. *(1)* We document important but overlooked facts on the long-run trends in marital statistics: The increase of the incidence of marriage and the relative increase of the prevalence of marriage for men and have not been emphasized in the literature despite the well-documented reduction in the gender gap in age at first marriage and the dramatic increase in the number of divorce. *(2)* We examine the role of the demographic transition in explaining the trends in those statistics, and find that the demographics alone can explain much of the trends in the data. *(3)* Furthermore, in combination with the liberalization of divorce laws and the change in

Table 13 – Demographic Experiments for the Short-Run Trends: 1930 to 1950

Marital Statistics	% Change in Data	% Change in Model Life Exp. (1)	Sex Ratio (2)	Both (3)
Age at first marriage				
Women	8.4	-0.5	1.8	1.1
Men	8.3	-1.2	-0.3	-1.4
% of the never-married by age 50				
Women	-7.7	-15.8	51.3	20.5
Men	-5.2	-15.1	-5.9	-19.8
% of the married aged 16 to 49				
Women	-19.3	3.4	-3.6	-0.3
Men	-19.2	3.9	0.8	4.8
Divorce rate, per 1,000 of population	136.4	-0.3	-2.1	-2.4

(All the numbers in the above table are changes in percent from the 1930 to the 1950 birth cohort.)

the gains to marriage, we find that demographics can quantitatively account for most of the marital trends. An appealing feature of this analysis is that the mechanism we consider here, namely changes in the sex ratio and 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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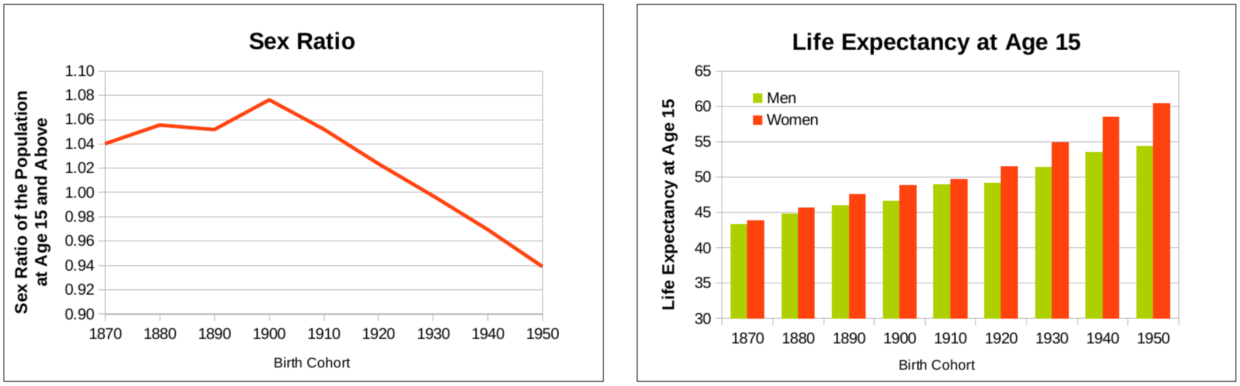
Appendix A. Additional Figures and Tables



(See Appendix B for the data sources.)

FIGURE 2 – Sex Ratio (Men per Women) and Life Expectancies

TABLE 14 – Sex Ratio (Men per Women) by Age: 1870, 1930, and 1950 Birth Cohort

	Birth Cohort		
Age	1870 birth cohort	1930 birth cohort	1950 birth cohort
0 years-old	1.017	1.034	1.044
10 years-old	1.058	1.013	1.035
20 years-old	1.178	0.929	0.924
30 years-old	1.105	0.976	0.974
40 years-old	1.134	0.935	0.972
50 years-old	1.112	0.927	0.960

(See Appendix B for the data sources.)

Figure 3 – Model Performance: Marriage and Divorce Rate

Appendix B. Data

B.1. Constructing Marriage and Divorce Rate from the Census Data

We construct marriage and divorce rates (flow variables) that are consistent with the fractions of people by age and marital status (stock variables) in the U.S. Census data.[17] Denote the stock of females at calendar age t that are never-married, married, divorced, and widowed by S_t^f, M_t^f, D_t^f, and W_t^f, respectively and likewise for men. Denote $p_{m,t}^f$ the probability a single female of calendar age t will marry and $p_{d,t}^f$ the probability a married female of calendar age t will divorce, and likewise for men. The stocks in each marital state evolve over time according to:

$$
\begin{aligned}
S_t^f &= S_{t-1}^f \left(1 - p_{m,t}^f\right)\left(1 - \pi_t^f\right) \\
M_t^f &= M_{t-1}^f \left(1 - p_{d,t}^f\right)\left(1 - \pi_t^m\right)\left(1 - \pi_t^f\right) + \left(S_{t-1}^f + D_{t-1}^f + W_{t-1}^f\right) p_{m,t}^f \\
D_t^f &= M_{t-1}^f \left(1 - \pi_t^f\right)\left(1 - \pi_t^m\right) p_{d,t}^f + D_{t-1}^f \left(1 - \pi_t^f\right)\left(1 - p_{m,t}^f\right) \\
W_t^f &= M_{t-1}^f \pi_t^m \left(1 - \pi_t^f\right) + W_{t-1}^f \left(1 - \pi_t^f\right)\left(1 - p_{m,t}^f\right)
\end{aligned}
$$

for women, where π_t^f is the mortality rate at age t for females. The stocks are defined in the same way for men.

In the Census data, we observe the fraction of women and men in each state, denoted s_t^g, m_t^g, d_t^g, w_t^g where $g \in \{f, m\}$. We obtain estimates of the mortality rates directly from outside data on mortality rates $\hat{\pi}_t^f$ and $\hat{\pi}_t^m$ for men and women at each calendar age (see Appendix B.2 for the data sources). After normalizing the total stock of female and male at age 15 equal to 1, we calculate the stock variable of the never-married by $S_t^g = s_t^g \times \left\{\prod_{\tau=15}^{t} (1 - \pi_\tau^g)\right\}$, and likewise for M_t^g, D_t^g, and W_t^g. We are now able to solve for the marriage and divorce rates that are consistent with the observed mortality rates and the stock data available in the Census data:

$$
\begin{aligned}
p_{m,t}^f &= \frac{S_{t-1}^f \left(1 - \pi_t^f\right) - S_t^f}{S_{t-1}^f \left(1 - \pi_t^f\right)} \\
p_{d,t}^f &= \frac{D_t^f - D_{t-1}^f \left(1 - \pi_t^f\right)\left(1 - p_{m,t}^f\right)}{M_{t-1}^f \left(1 - \pi_t^f\right)\left(1 - \pi_t^m\right)}
\end{aligned}
$$

for women, and likewise for men. The marriage and divorce rates for the group with age t

[17] The IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010)

to t' is define as:

$$p^f_{m,t-t'} = \frac{\sum_{\tau=t}^{t'} S^f_{\tau-1}\left(1-\pi^f_{\tau-1}\right) - \sum_{\tau=t}^{t'} S^f_{\tau}}{\sum_{\tau=t}^{t'} S^f_{\tau-1}\left(1-\pi^f_{\tau-1}\right)}$$

$$p^f_{d,t-t'} = \frac{\sum_{\tau=t}^{t'} D^f_{\tau} - \sum_{\tau=t}^{t'} D^f_{\tau-1}\left(1-\pi^f_{\tau-1}\right)\left(1-p^f_{m,\tau-1}\right)}{\sum_{\tau=t}^{t'} M^f_{\tau-1}\left(1-\pi^f_{t-1}\right)\left(1-\pi^m_{t-1}\right)}$$

for women, and likewise for men. The stocks and flows at each age are consistent with each other and with a steady state. This will also allow us to compare the age-specific marriage and divorce rates across all Census samples.

B.2.1. Data Sources for Demographics

Sex Ratio of the Population Aged 15 and Above (1870 to 1950 Birth Cohort) We calculate the sex ratio of the population aged 15 and above from the IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010). For each cohort, we assign the value that is in the year 10-years-after their birth. That is, we used the sex ratio of the population aged 15 and above in the 1880 data for the 1870 birth cohort.

Sex Ratio by Age (1870, 1930, and 1950 Birth Cohort) We calculate the sex ratio by age from the IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010). We track the 1870, 1930, and 1950 birth cohort to calculate the sex ratio for people at different age. Note that it's not possible to calculate the sex ratio at age 15 and above in this way because the Census data is only available every 10 years. We present this statistics in Table 14 in order to show significant variations in the sex ratio across cohorts for those who are at prime age in marriage markets (e.g. 20 to 30 years-old).

Life Expectancy at Age 15 (1870 to 1950 Birth Cohort) There are two data sources for the life expectancy at age 15. For the years from 1880 to 1890, the data is from Haines (1998). For the years between from 1900 to 1960, we used the data from Arias (2008). For each cohort, we assign the value that is in the year 10-years-after their birth. That is, we used the life expectancy at age 15 in the 1880 data for the 1870 birth cohort.

Age-Specific Mortality Rate (1950 Birth Cohort) Age-specific mortality rates are used to calculate the marriage and divorce rates as described in Appendix B.1. Those mortality rates are from the National Center for Health Statistic's United States Decennial Life Tables.

B.2.2. Data Sources for Marital Statistics

Marriage and Divorce Rate by Age Group (1950 Birth Cohort) Marriage and Divorce Rate by Age Group is calculate from the IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010) by using the method described in Appendix B.1. Because the U.S. Census data is only available every 10 years, we calculate the marriage and the divorce rate for the individuals aged 16 to 19 in 1965 by combining the samples aged 16 to 19 in 1960 and those in 1970 putting an equal weight to each group. In the similar manner, we calculated the marriage and divorce rates in 1975 and 1985.

Age at First Marriage (1870 to 1950 Birth Cohort) For the age at first marriage, we used the median[18] age at first marriage estimated by U.S. Census Bureau.[19] For each cohort, we assign the value which is in the year 30-years-after their birth. That is, we used the age at first marriage in the 1900 data for the 1870 birth cohort.

Percent of the Never-Married by Age 50 (1870 to 1950 Birth Cohort) The percent of the never-married by age 50 is calculate from the IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010) for each cohort.

Percent of the Married Aged 16 to 49 (1870 to 1950 Birth Cohort) The percent of the married aged 16 to 49 is calculated from the IPUMS Census data (Ruggles, Alexander, Genadek, Goeken, Schroeder, and Sobek, 2010). For each cohort, we assign the value which is in the year 30-years-after their birth. That is, we used the percent of the married aged 16 to 49 in the 1900 data for the 1870 birth cohort.

Divorce Rate per 1,000 of the Population (1870 to 1950 Birth Cohort) The data for the divorce rate is from Clarke (1995) for the period 1940 to 1990, and Plateris (1973) for the period earlier than 1940. For each cohort, we assign the rate which is in the year 30-years-after their birth. That is, we used the divorce rate in the 1900 data for the 1870 birth cohort.

[18] We also estimated the 'mean' age at first marriage from the IPUMS Census data, and conducted the benchmark analysis. However, our results didn't significantly change.

[19] U.S. Census Bureau, Current Population Survey, March and Annual Social and Economic Supplements.

Appendix C. 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).

C.1. Demographics

The demographic targets (sex ratio and life expectancies) we use in this analysis is listed in the 1st block of Table 16. Targeting on those values, we re-calibrate the mortality rates and men's immigration rate so that the model can replicate the population structure of the 1930 birth cohort.

TABLE 16 – Demographic Transition: 1870 to 1950 Birth Cohort

	Birth Cohort	
	1870	1950
Demographic target		
Men per 100 women aged 15 and above	1.040	0.997 (-4.1)
Life expectancy (at age 15)		
Women	43.9	55.0 (25.2)
Men	43.4	51.4 (18.4)
Model's parameter value		
Women's mortality rate		
Adolescent (π_a^f)	0.0175	0.0165
Young (π_y^f)	0.0276	0.0165
Old (π_o^f)	0.0175	0.0165
Men's mortality rate		
Adolescent (π_a^m)	0.0194	0.0184
Young (π_y^m)	0.0194	0.0184
Old (π_o^m)	0.0194	0.0184

(The numbers in parenthesis are changes in percent. For the data sources, see Appendix B.)

C.2. Results for the Short-Run Trend

The demographic transition can explain only a few of the marital trends from the 1930 to the 1950 birth cohort (see Table 13 and Table 17). The model with changes in the age and sex structure between the 1930 and 1950 birth cohorts is consistent with; *(i)* the delay in marriage for women (13%), and *(ii)* the fall in the incidence of marriage for men (381%). However, the model can explain none of other statistics.

Table 17 – Marital Statistics in Data and Model: 1930 to 1950

	1930		1950	
	Data	Model	Data	Model
Age at first marriage				
Women	20.3	22.1	22.0	22.3
Men	22.8	24.9	24.7	24.5
% of the never-married by age 50				
Women	5.7	3.9	5.3	4.7
Men	6.6	7.7	6.3	6.2
% of the married aged 16 to 49				
Women	75.3	63.7	60.8	63.5
Men	69.4	54.6	56.1	57.2
Divorce Rate, per 1,000	2.2	4.1	5.2	4.0

Table 15 – Estimated Values of All the Parameters in the Baseline Model

Name	Value	Standard Error	95% Confidence Interval
Preference and aging parameters			
α_a^f	-7.021	0.1956	[-7.403, -6.637]
α_y^f	-0.475	0.1937	[-0.854, -0.094]
α_o^f	1.971	0.1333	[1.709, 2.232]
α_a^m	-2.392	0.1009	[-2.590, -2.194]
α_y^m	4.018	0.2278	[3.571, 4.464]
α_o^m	0.444	0.1083	[0.231, 0.656]
$\gamma_{a,a}^f$ for $\Gamma_{a,a}^f \equiv \frac{\exp(\gamma_{a,a}^f)}{1+\exp(\gamma_{a,a}^f)}$	1.798	0.1544	[1.495, 2.101]
$\gamma_{a,a}^m$ for $\Gamma_{a,a}^m \equiv \frac{\exp(\gamma_{a,a}^m)}{1+\exp(\gamma_{a,a}^m)}$	1.535	0.0868	[1.365, 1.705]
$\gamma_{y,y}^f$ for $\Gamma_{y,y}^f \equiv \frac{\exp(\gamma_{a,a}^f)}{1+\exp(\gamma_{a,a}^f)}$	1.289	0.0756	[1.140, 1.437]
$\gamma_{y,y}^m$ for $\Gamma_{y,y}^m \equiv \frac{\exp(\gamma_{y,y}^m)}{1+\exp(\gamma_{y,y}^m)}$	1.964	0.0600	[1.846, 2.081]
Match quality parameters			
μ_G	1.900	0.1705	[1.565, 2.234]
μ_B	-4.995	0.2025	[-5.391, -4.597]
σ	4.956	0.1610	[4.640, 5.271]
λ_0 for $\Lambda_0 \equiv \frac{\exp(\lambda_0)}{1+\exp(\lambda_0)}$	-9.959	0.2337	[-10.417, -9.501]
$\lambda_{G,G}^a$ for $\Lambda_{G,G}^a \equiv \frac{\exp(\lambda_{G,G}^a)}{1+\exp(\lambda_{G,G}^a)}$	0.794	0.2179	[0.366, 1.220]
$\lambda_{B,B}^a$ for $\Lambda_{B,B}^a \equiv \frac{\exp(\lambda_{B,B}^a)}{1+\exp(\lambda_{B,B}^a)}$	-0.116	0.2796	[-0.663, 0.432]
$\lambda_{G,G}^y$ for $\Lambda_{G,G}^y \equiv \frac{\exp(\lambda_{G,G}^y)}{1+\exp(\lambda_{G,G}^y)}$	4.154	0.2048	[3.752, 4.554]
$\lambda_{B,B}^y$ for $\Lambda_{B,B}^y \equiv \frac{\exp(\lambda_{B,B}^y)}{1+\exp(\lambda_{B,B}^y)}$	-3.297	0.2371	[-3.761, -2.831]
$\lambda_{G,G}^o$ for $\Lambda_{G,G}^o \equiv \frac{\exp(\lambda_{G,G}^o)}{1+\exp(\lambda_{G,G}^o)}$	5.707	0.2104	[5.294, 6.119]
$\lambda_{B,B}^o$ for $\Lambda_{B,B}^o \equiv \frac{\exp(\lambda_{G,G}^o)}{1+\exp(\lambda_{G,G}^o)}$	1.996	0.1454	[1.710, 2.280]
ω	11.329	0.1873	[10.961, 11.695]

(Standard errors and asymptotic confidence intervals are calculated using a bootstrap estimator for the variance-covariance matrix of the data targets from the IPUMS Census.)