

**TECHNOLOGY AND THE CHANGING FAMILY: A UNIFIED
MODEL OF MARRIAGE, DIVORCE, EDUCATIONAL
ATTAINMENT AND MARRIED FEMALE LABOR-FORCE
PARTICIPATION***

by

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Abstract

Marriage has declined since 1960, with the drop being bigger for non-college educated individuals versus college educated ones. Divorce has increased, more so for the non-college educated vis-à-vis the college educated. Additionally, assortative mating has risen; i.e., people are more likely to marry someone of the same educational level today than in the past. A unified model of marriage, divorce, educational attainment and married female labor-force participation is developed and estimated to fit the postwar U.S. data. The role of technological progress in the household sector and shifts in the wage structure for explaining these facts is gauged.

Keywords: Assortative mating, education, married female labor supply, household production, marriage and divorce, minimum distance estimation

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1 Introduction

1.1 Facts

The shape of the American household has changed dramatically over the last 50 years. Some salient features of this transformation are:

1. *The Decline in Marriage.* The fraction of the population that has ever been married has fallen dramatically since 1960. At that time, about 86 percent of college educated individuals and 92 percent of non-college educated ones between the ages of 25 and 54 were married (or had been married)—see Figure 1. (Data sources for this and all other figures are provided in the Appendix.) Today, only 79 percent are.¹ Note that the fall in the fraction of the population that is married is greatest for non-college educated people. Part of the decline in marriage is due to a delay in the age of marriage. Part is due to a rise in divorce. In 1960 the fraction of the population that was divorced, as measured by the ratio of the currently divorced to the ever-married population, was 3 percent for the non-college educated populace and 2 percent for the college educated segment. Today, it is close to 17 percent for the former and 11 percent for the latter. Again, observe that divorce has risen more for the non-college educated vis-à-vis the college educated. The fact that the decline in marriage and the rise in divorce has affected college educated and non-college educated people differentially has been noted both by sociologists, Martin (2006), and economists, Stevenson and Wolfers (2007).
2. *The Rise in Assortative Mating.* When individuals marry today, as opposed to yesterday, they are more likely to pair with an individual from the same socioeconomic class. To see this split the world into two socioeconomic classes, viz non-college educated and college educated, and compare the two contingency tables contained in Table 1.

¹ Redoing Figure 1 with currently-married individuals, as opposed to ever-married ones, delivers a qualitatively similar pattern.

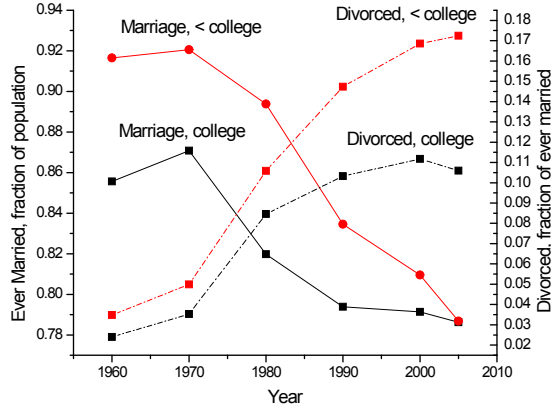


Figure 1: Marriage and Divorce by Education

TABLE 1: ASSORTATIVE MATING, AGE 25-54

1960			2005		
Husband	Wife		Husband	Wife	
	< College	College		< College	College
< College	0.856 (0.823)	0.024 (0.056)	< College	0.565 (0.450)	0.109 (0.223)
College	0.080 (0.113)	0.040 (0.008)	College	0.103 (0.218)	0.0223 (0.108)
$\chi^2 = 40,567$	$\rho = 0.41$	$n = 241,488$	$\chi^2 = 93,446$	$\rho = 0.52$	$n = 347,210$

The number in a cell shows the fraction of all matches that occur in the specified category. The figure in parenthesis provides the fraction that would occur if matching occurred randomly. First, note that there is positive assortative mating. The hypothesis of random matching is rejected by the χ^2 statistics. Second, the extent of positive assortative mating has become stronger over time. This is shown by the Pearson correlation coefficient, ρ , which measures the degree of association between the female and male educational categories.

To further illustrate the rise in assortative mating, consider running a regression for

married couples of the form

$$\begin{aligned} \text{EDUCATION}_t^w = \alpha + \sum_{j \in \mathcal{J}} \beta_t \times \text{EDUCATION}_t^h \times \text{DUMMY}_{j,t} \\ + \sum_{j \in \mathcal{J}} \gamma_t \times \text{DUMMY}_{j,t} + \varepsilon_t, \text{ with } \varepsilon_t \sim N(0, \sigma_t), \end{aligned} \quad (1)$$

where: $\text{EDUCATION}_t^w \in \{0, 1\}$ is the observed level of the wife's education in period t and takes value of one if the woman completed college and a value of zero otherwise; $\text{EDUCATION}_t^h \in \{0, 1\}$ is the husband's education; $\text{DUMMY}_{j,t}$ is a dummy variable for time such that $\text{DUMMY}_{j,t} = 1$ if $j = t$ and $\text{DUMMY}_{j,t} = 0$ if $j \neq t$; $t = 1960, 1970, 1980, 1990, 2000$, and 2005 gives the years in the sample and $\mathcal{J}$ is the subset of these years that omits 1960. The coefficient β_t measures the additional impact relative to 1960 that a husband's education will have on his wife's. Note that the impact of a secular rise in female educational attainment is controlled by the presence of the time dummy variable. So, how does β_t change over time? Figure 2 plots the rise in the β_t 's. The β_t coefficients are significantly different from one another at the 99 percent confidence level. The same finding obtains if instead logits or probits are run. The rise in assortative mating has been noted before by sociologists Schwartz and Mare (2005).

3. *The Increase in Education and Labor-Force Participation by Females.* Labor-force participation by married females has increased dramatically over the last 50 years. This is true for both college educated and non-college educated women. In 1960 a minority of both classes of women worked. Now, the majority do—see Figure 3. At the same time, the number of women choosing to educate themselves has risen sharply. This may have been stimulated by a rise in the college premium, shown in Figure 4. College-educated women have always worked more than non-college educated ones. As female labor-force participation rose so did a married woman's contribution to family income—again, see Figure 3. Figure 4 also shows how the gender gap has narrowed.

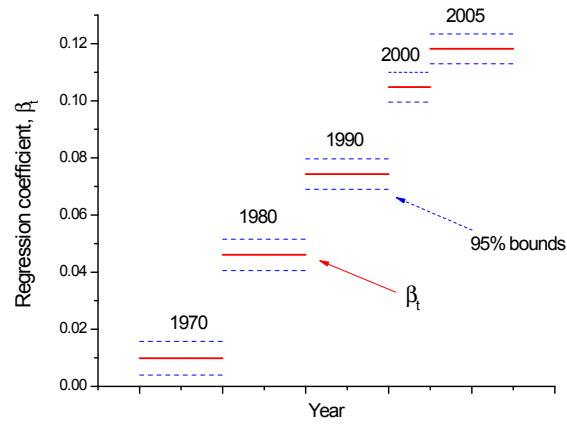


Figure 2: Rise in Assortative Mating. The solid line plots the regression coefficient, β_t . The dashed lines show the 95 percent intervals.

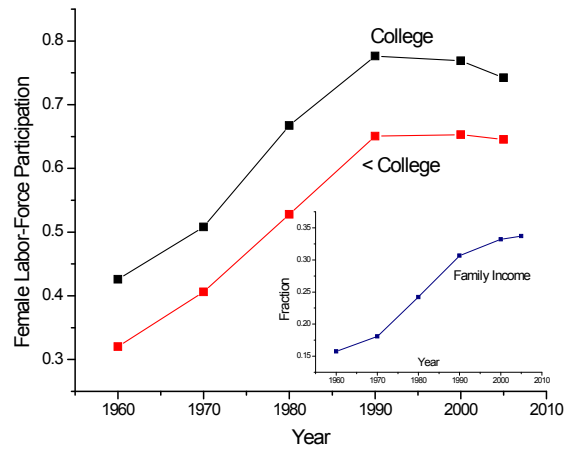


Figure 3: The Increase in Female Labor-Force Participation. The inset panel shows the contribution of married females to family income.

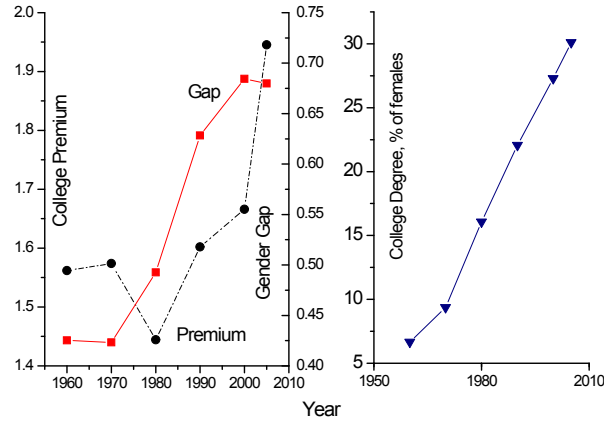


Figure 4: The Rise in Female Educational Attainment, the College Premium and the Narrowing of the Gender Gap

1.2 The Hypothesis

What are the economic forces behind this dramatic shift in household characteristics? The idea is described below in a nutshell. People marry for both economic and noneconomic reasons: material well-being and love. On the material side of things, a woman's labor is important for both home production and market production. Over time the value of a woman's labor in household production has declined, due to technological progress in the household sector. Specifically, inputs into home production, such as dishwashers, frozen foods, microwave ovens, washing machines, and most recently the internet, have reduced the need for household labor. Therefore, love and the value of a woman's labor on the market have come to play more important roles, relative to the value of a woman's labor in home production, in the decision about whether or not to get married and whom to marry.

The hypothesis here is that technological progress at home and in the market drove this transformation in households. What are the channels through which technological progress operates? They are delineated as follows:

1. Economies of scale in household maintenance.
2. Substitutability of labor and intermediate goods in household production.

3. Higher diminishing marginal utility for household goods vis-à-vis market ones.
4. Rising living standards.
5. Skilled-biased technological progress in the market.
6. A declining gender gap in wages.

An economic motive for marriage is provided for by Point 1. For example, suppose there is a fixed cost in terms of market goods of maintaining a household. Then, two-person households will be better off than single-person ones. As incomes grow in line with Point 4 such fixed costs will be easier to cover. Therefore, a trend to smaller households will emerge. This will be reflected in a lower marriage rate and a higher divorce rate. One would expect that this consideration will bite harder for poorer people than for richer ones. Hence, at low stages of development the theory suggests that non-college educated people will be more likely to marry. They will also experience a larger drop in their marriage rate and bigger rise in their divorce rate as incomes grow.

Point 2 implies that labor will be released from married households if the price of intermediate goods drops due to technological advance in the home sector. This promotes a rise in married female labor-force participation. (Assume that both single females and males work full time.) Now, single households will benefit the most from technological advance in the home sector, if Point 3 holds. This is because *at the margin* they will be the most intensive users of home production, as paradoxical as this may seem. That is, while the economically better off married couple (due to economies of scale) will consume more of all goods, relative to a single person, they will not consume twice as much home goods, because they will prefer to direct, at the margin, their larger consumption bundle toward market ones. Technological progress in the home allows for more home goods to be produced. It will improve single life the most because the marginal value for a home produced good is highest for singles. This operates to reduce household size.

Skilled-biased technological progress results in skilled labor becoming more valuable relative to unskilled labor. This leads to an upward movement in the college premium. As a consequence, more males will complete college. More females should finish college too.

Take a single female first. The income earned when single will now have risen for a college educated woman, relative to a non-college educated one. Thus, a college educated single female can now live better than before (again, relative to a non-college educated one). The extra income that a college education now provides means that a college educated single woman can afford to be choosier when selecting a husband. The same reasoning applies to being single because of a divorce. Now, consider a married female. If she works, the return to a college education will have risen because her family will have more income. This provides an incentive to become more educated. This fact will also make a college educated woman more attractive on the marriage market. The return from finding a better partner on the marriage market, in and of itself, may provide an extra return for females (and males) to invest in college. Even if female labor is required at home, more women could still go to college. Suppose that men desire women from the same socioeconomic group (and vice versa), say for compatibility reasons. Then, the fact that there are more college educated men around implies that there may be a bigger incentive for women to invest in college educations in order to become more desirable on the marriage market. A decline in the gender gap (Point 6) will reinforce women's incentives to acquire a college education. These forces should cause people to become pickier about their mate, causing a decline in marriage and a rise in divorce. Hence, one would expect a rise in assortative mating due to Point 5.

1.3 Relationship to the Literature

The framework developed here resembles, in some aspects, Greenwood and Guner (2009) who study the fall in marriage and the rise in divorce. The focus of the current research is on addressing: (1) the increase in assortative mating; (2) the differences in the fall in marriage and the rise in divorce that occurred across the college educated and non-college educated populaces. Addressing these questions involves introducing heterogeneity in both females and males, something absent in the Greenwood and Guner (2009) framework, where individuals only differ by their marital status. Plus, a schooling decision needs to be introduced. This is important given the rise in college attainment for both females and males. These factors complicate the analysis.

Another related paper is by Regalia and Ríos-Rull (2001), which was ahead of its time.

While in their marriage model there is heterogeneity in both females and males, the focus is on accounting for the rise in the number of single mothers. They stress market forces, such as a movement in the gender gap, as explaining this rise. A mechanism for studying the rise in assortative mating appears to be absent. The framework is not set up to analyze the trend in female labor supply; specifically, a woman splits her time between working and investing in her child's human capital formation. Jacquemet and Robin (2011) estimate a search and matching model of the marriage market for the U.S. Their analysis focuses on how female and male wages affect marriage probabilities and the share of the marital surplus received by partners. Given this goal, there is no need to include endogenous divorce or educational attainment in their model. The current research studies the role that technological progress in the household sector, in conjunction with market forces, played in transforming the American household. It tries to provide a unified explanation for the above set of stylized facts.

Parts of the picture have been addressed before elsewhere, in various ways. For example, Galor and Weil (1996) argue that technological progress in the market sector led to a change in the nature of jobs (from brawn to brain so to speak) that was favorable to women's participation. Greenwood, Seshadri and Yorukoglu (2005) analyze the importance of technological progress in the home sector for making it more feasible for married females to enter into the labor market. Advances in maternal medicine and pediatric care played a similar role, as has been noted by Albanesi and Olivetti (2010). Independent empirical work by Cavalcanti and Tavares (2008) and Coen-Pirani, Leon, and Lugauer (2010) suggests that labor-saving household products have increased married female labor supply. Adamopoulou (2010) shows that they also have contributed to the rise of cohabitation. The importance of the narrowing gender gap, also shown in Figure 4, is stressed by Jones, Manuelli and McGrattan (2003). Eckstein and Lifshitz (forth.) study the effect that different mechanisms (schooling, the gender wage gap, fertility, and marriage and divorce) had on the rise in the female labor-force participation during the twentieth century. They find that up to 42% of the change is left unexplained. They attribute this residual component to improvements in household technology and changes in social norms. [Changes in societal norms, a factor out of the purview of the current analysis, have been addressed by Fernandez, Fogli and Olivetti

(2004)]. This is consistent with the story told in this paper.

Bethencourt and Ríos-Rull (2009) and Salcedo, Schoellman and Tertilt (2009) model the rise in single families, but in contexts not involving marriage. On this, Choo and Siow (2006) estimate, using a non-transferable utility model of the U.S. marriage market, that the gains for marriage accruing to young adults fell sharply between 1971 and 1981. This suggests an incentive for delaying marriage.

The fact that high skill premiums are associated with more positive assortative mating has been noted by Fernandez, Guner and Knowles (2005). Chiappori, Iyigun and Weiss (2009) discuss how positive assortative mating provides a marriage market return for female educational investment, in addition to the traditional labor market one. Focusing on the fact that more educated females are less likely to divorce than less educated ones in recent years, Neeman, Newman and Olivetti (2008) argue that college educated working females might be more selective in the marriage market and as a result their marriages might be more stable. Households with a working wife might also be able to cope better with income shocks and consequently might be less likely to experience a divorce. Restuccia and Vandenbroucke (2009) provide a quantitative model of the recent rise in educational attainment.

1.4 A Snapshot of the Findings

The unified framework developed here is matched with the U.S. data using a minimum distance estimation procedure. The procedure targets a collection of stylized facts concerning educational attainment, marriage and divorce, and married female labor-force participation. The framework fits the data well. The structural parameter values obtained also look reasonable, and are tightly estimated. The shift in family structure can be decomposed into its underlying driving forces. The findings suggest that technological progress in the household sector accounts for the majority of the rise in married female-labor force participation. The narrowing of the gender gap in wages plays a secondary role here, too. Technological progress in the household sector also has a conspicuous effect in explaining the fall in marriage and the rise in divorce by education level. Changes in the structure of wages are important for the rise in educational attainment and the increase in assortative mating.

2 Model

To address the above issues three things are required. First, a model of marriage and divorce is needed. Second, the framework must include a decision about whether or not married females should work. Third, the structure should incorporate an education decision. This motivates the following setup.

2.1 Setup

Imagine an economy that is populated by equal numbers of females, f , and males, m . Some females and males are college educated, while others are non-college educated. Some individuals of each gender will be married, the rest either divorced or never married. A person faces a constant probability of dying, δ , each period. Upon death an individual is replaced by a young doppelganger who is about to begin his or her adult life.

A person enters adult life with an ability level $a \in \mathcal{A}$. The initial ability is distributed across the population in line with the distribution function $A(a)$. It will be assumed that a is log normally distributed so that $\ln a \sim N(0, \sigma_a^2)$, where σ_a^2 denotes the variance of this zero-mean distribution. The first decision that a young adult makes is whether or not to acquire an education. An uneducated male will earn the amount $w_0 a$ for each unit of labor supplied on the market, while an educated one earns $w_1 a$, where $w_1 > w_0$. A female earns the fraction $\phi \in [0, 1]$ of what a comparable male does. This reflects the gender gap in labor income. Acquiring an education has an up-front utility cost of $C(a)$, where

$$C(a) = \varepsilon/a^\omega.$$

The idea here is that the cost of learning is inversely related to a person's ability. Let $e \in \mathcal{E} = \{0, 1\}$ represent whether ($e = 1$) or not ($e = 0$) a person has acquired an education.

At the beginning of each period people must decide whether or not to work in market during the period. Each person has one unit of time per period, which can be used for market or home production. Let h_f and h_m denote the hours worked by a female and a male in the market, respectively. The workweek in the market is fixed. This is reflected in the

two possible values that h can take, $h \in \mathcal{H} \equiv \{0, \bar{h}\}$. Suppose single agents always work full time, allocating $\bar{h}$ to market and $1 - \bar{h}$ to household work. It is assumed that in marriage h is chosen only for the wife; the husband always works full-time.

Household goods are produced according to

$$n = [\theta d^\lambda + (1 - \theta)(z - h_T)^\lambda]^{1/\lambda}, \quad 0 < \lambda < 1, \quad (2)$$

where d is the amount of the household inputs, h_T is the total amount of time spent on market work, and $z \in \{1, 2\}$ is the household size. The restriction that $0 < \lambda < 1$ implies that inputs, d , and time, $z - h_T$, are substitutes in household production. Household inputs, d , can be purchased at the price p in terms of the market good.

At the end of each period a single person will meet someone else of the opposite sex, with ability level a^* . The couple will then draw two shocks. The first is a match-specific bliss shock $b \in \mathcal{B}$, taken from the distribution $F(b)$. In particular, b will be normally distributed so that $b \sim N(\bar{b}_s, \sigma_{b,s}^2)$, where $\bar{b}_s$ and $\sigma_{b,s}^2$ denote the mean and variance of this bliss distribution that an unmarried couple draws from. The second shock, $k \in \mathcal{K} = \{k_l, k_h\}$, measures the cost for a married woman of going to work. Without loss of generality, assume that $k_l < k_h$. Some families may place a greater value on the woman staying at home; perhaps they are more likely to have children, a factor abstracted away from here. The k shock is drawn from the distribution $K(k)$, which is assumed to be uniform, i.e., there is an equal probability of drawing either of these two values for the shock k . This shock is assumed to be permanent and hence does not change over time.² The couple then decides whether or not to marry. This decision will be based upon both economic and noneconomic considerations, as will soon become clear.

The noneconomic factors consist of the value of b , the value of k , and a measure of how compatible a couple is. For a couple with education levels e and e^* , this compatibility is represented by the function $M(e, e^*)$, where

$$M(e, e^*) = \mu_0(1 - e)(1 - e^*) + \mu_1(ee^*).$$

² Guner, Kaygusuz and Ventura (2011) employ a similar strategy to model female labor force participation.

If neither person went to college then this function returns a value of μ_0 , since $e = e^* = 0$, while if both are college educated then it gives a value of μ_1 . It yields 0 for all other cases. The economic factors are based upon each person's ability and educational attainment; that is, their (a, e) pair.

A married person must decide whether or not to remain with their current partner. In a marriage the bliss shock evolves according to the distribution $G(b'|b)$. Specifically, the bliss shock is assumed to follow the autoregressive process $b' = (1 - \rho_{b,m})\bar{b}_m + \rho_{b,m}b + \sigma_{b,m}\sqrt{1 - \rho_{b,m}}\varepsilon$, with $\varepsilon \sim N(0, 1)$. Here $\bar{b}_m$ and $\sigma_{b,m}^2$ represent the long-run mean and variance of this process, while $\rho_{b,m}$ is the coefficient of autocorrelation.

Last, let all people discount the future at the rate $\beta = \tilde{\beta}(1 - \delta)$, where $\tilde{\beta}$ is the subjective discount factor. Suppose for singles that tastes over the consumption of market goods, c , and nonmarket ones, n , are represented by

$$T_s(c, n) = \frac{1}{1 - \zeta} (c - \mathfrak{c})^{1-\zeta} + \frac{\alpha}{1 - \xi} n^{1-\xi},$$

where $\mathfrak{c}$ is a fixed cost in terms of market goods. Assume that in marriage the utility derived from consumption and love is a public good. Momentary utility for a married household is

$$T_m(c, n) = \frac{1}{1 - \zeta} \left(\frac{c - \mathfrak{c}}{1 + \chi} \right)^{1-\zeta} + \frac{\alpha}{1 - \xi} \left(\frac{n}{1 + \chi} \right)^{1-\xi},$$

where $\chi < 1$ is the adult equivalence scale. The equivalence scale reflects the fact that are economies of scale in household consumption, so that a two-person household requires less than the twice the consumption of a one-person household in order to realize the same level of utility as the latter.

To complete the description of the setting, the timing of events within a period is illustrated in Figure 5.

2.2 Singles

Consider the consumption decision facing a single. This is a purely static problem. For a single person of gender $g \in \{f, m\}$ with ability a and educational attainment $e \in \{0, 1\}$, the

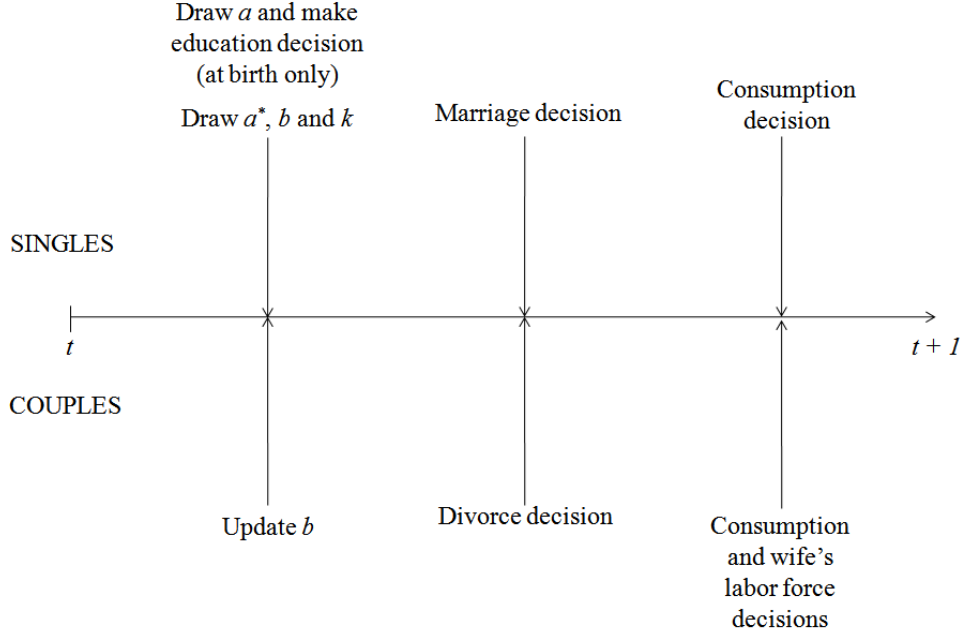


Figure 5: Timing of Decisions

problem is given by

$$U_s^g(a, e) \equiv \max_{c, n, d} T_s(c, n), \quad (3)$$

subject to

$$c = \begin{cases} w_e \phi a \bar{h} - pd, & \text{if } g = f, \\ w_e a \bar{h} - pd, & \text{if } g = m, \end{cases}$$

and

$$n = [\theta d^\lambda + (1 - \theta)(1 - \bar{h})^\lambda]^{1/\lambda}.$$

Next, turn to the marriage decision. Consider a single person of gender $g \in \{f, m\}$ with ability a and educational attainment e . Suppose that this individual meets someone of the opposite gender, g^* , who has ability a^* and education attainment e^* . Will they get married? To answer this question, let $V_s^g(a, e)$ and $V_s^{g^*}(a^*, e^*)$ represent the expected lifetime utilities that both parties will realize if they remain single in the current period. Likewise, denote the expected lifetime utility that is associated with a marriage in the current period by

$V_m^g(a, e, a^*, e^*, b, k)$. A marriage will occur if and only if

$$V_m^g(a, e, a^*, e^*, b, k) \geq V_s^g(a, e) \text{ and } V_m^{g^*}(a^*, e^*, a, e, b, k) \geq V_s^{g^*}(a^*, e^*). \quad (4)$$

Observe that for a marriage to happen it must be the first choice for *both* parties. Let the indicator function $\mathbf{1}^g(a, e, a^*, e^*, b, k)$ take a value of 1 if both people in the match want it and value of zero otherwise. Thus,

$$\mathbf{1}^g(a, e, a^*, e^*, b, k) = \begin{cases} 1, & \text{if (4) holds,} \\ 0, & \text{otherwise.} \end{cases} \quad (5)$$

[Observe that $\mathbf{1}^g(a, e, a^*, e^*, b, k) = \mathbf{1}^{g^*}(a^*, e^*, a, e, b, k)$.]

The value of being single in the current period will depend on the distribution of potential future mates on the marriage market. Each mate is indexed by their (a^*, e^*) combination. But, note that e^* will be chosen at the beginning of adult life as a function of a^* . Thus, one can write $e^* = E^{g^*}(a^*)$, so that this distribution is actually just one dimensional. The function E^{g^*} will be discussed later. Thus, the distribution of potential mates from the opposite gender can be represented by $\widehat{\mathbf{S}}^{g^*}(a^*)$. This too will be elaborated on later. The value function for a single person of gender g with ability a and educational attainment e can now be expressed as

$$\begin{aligned} V_s^g(a, e) &= U_s^g(a, e) \\ &+ \beta \int_{\mathcal{K}} \int_{\mathcal{B}} \int_{\mathcal{A}} \{ \mathbf{1}^g(a, e, a^*, E^{g^*}(a^*), b, k) V_m^g(a, e, a^*, E^{g^*}(a^*), b, k) \\ &+ [1 - \mathbf{1}^g(a, e, a^*, E^{g^*}(a^*), b, k)] V_s^g(a, e) \} d\widehat{\mathbf{S}}^{g^*}(a^*) dF(b) dK(k), \text{ for } g = f, m. \end{aligned} \quad (6)$$

Embedded in the above dynamic programming problem is the assumption that one will draw a mate next period with an ability level less than a^* with probability $\widehat{\mathbf{S}}^{g^*}(a^*)$.³

³ Other matching processes could be envisaged, such as the Gale and Shapley algorithm employed by Del Boca and Flinn (2006).

2.3 Couples

The static consumption problem for a married couple is

$$U_m^g(a, e, a^*, e^*, k) \equiv \max_{c, n, d, h^f \in \{0, 1\}} T_m(c, n) - h^f k, \quad (7)$$

subject to

$$c = \begin{cases} w_{e^*} a^* \bar{h} + w_e \phi a \bar{h} h^f - p d, & \text{if } g = f, \\ w_e a \bar{h} + w_{e^*} \phi a^* \bar{h} h^f - p d, & \text{if } g = m, \end{cases}$$

and

$$n = [\theta d^\lambda + (1 - \theta)(2 - \bar{h} - \bar{h} h^f)^\lambda]^{1/\lambda}.$$

Recall that all utility flows are public goods within a marriage. So, the couple picks c, n, d , and h^f together. Working in the market takes away the fraction $\bar{h}$ of a person's time endowment. Recall that husbands are assumed to work full-time. The variable $h^f \in \{0, 1\}$ represents the wife's participation decision. It takes a value of 1 when the woman works and a value of 0 if she doesn't. Once again, the variable k gives the cost for a married woman of going to work. This is netted out of household utility, when the woman works.

A divorce will occur if and only if

$$V_s^g(a, e) \geq V_m^g(a, e, a^*, e^*, b, k) \text{ or } V_s^{g^*}(a^*, e^*) \geq V_m^{g^*}(a^*, e^*, a, e, b, k). \quad (8)$$

Therefore, the indicator function $\mathbf{1}^g(a, e, a^*, e^*, b, k)$, specified by (5), will return a value of one if both the husband and wife want to remain married and will give a value of zero if one of them desires a divorce. Given this, the value function for a married person reads

$$\begin{aligned} V_m^g(a, e, a^*, e^*, b, k) &= U_m^g(a, e, a^*, e^*, k) + b + M(e, e^*) \\ &\quad + \beta \left\{ \int_{\mathcal{B}} [\mathbf{1}^g(a, e, a^*, e^*, b', k) V_m^g(a, e, a^*, e^*, b', k) \right. \\ &\quad \left. + [1 - \mathbf{1}^g(a, e, a^*, e^*, b', k)] V_s^g(a, e)] dG(b'|b) \right\}, \text{ for } g = f, m. \end{aligned} \quad (9)$$

This value function is used in equations (4), (5), (6) and (8); likewise, (6) is employed in (4), (5), (8) and (9).

2.4 Educational Choice

People choose their education level at the beginning of adult life. They do this based on their ability, a , and gender, g . The problem they face is

$$\max_{e \in \{0,1\}} \{V_s^g(a, e) - eC(a)\}, \quad (10)$$

where V_s^g is defined by (6). The decision rule stemming from this problem will be represented by $e = E^g(a)$. Assume that this function is characterized by a simple threshold rule:

$$E^g(a) = \begin{cases} 1 & \text{if } a \geq \tilde{a}^g, \\ 0 & \text{if } a < \tilde{a}^g. \end{cases} \quad (11)$$

This assumption holds in the numerical analysis.

2.5 Steady-State Equilibrium

The dynamic programming problem for a single person, or (6), depends upon knowing the solution to the problem for a married person, as given by (9), and vice versa. Furthermore, to solve the single's problem requires knowing the steady-state distribution of potential mates in the marriage market, $\mathbf{S}^g(a)$. The non-normalized steady-state distribution for singles is

$$\begin{aligned} \mathbf{S}^g(a') &= (1 - \delta) \int_{\mathcal{K}} \int_{\mathcal{B}} \int_{\mathcal{A}} \int_{\mathcal{A}}^{a'} [1 - \mathbf{1}^g(a, E^g(a), a^*, E^{g^*}(a^*), b, k)] d\mathbf{S}^g(a) d\widehat{\mathbf{S}}^{g^*}(a^*) dF(b) dK(k) \\ &\quad + (1 - \delta) \int_{\mathcal{K}} \int_{\mathcal{B}} \int_{\mathcal{B}} \int_{\mathcal{A}}^{a'} [1 - \mathbf{1}^g(a, E^g(a), a^*, E^{g^*}(a^*), b, k)] d\mathbf{M}^g(a, a^*, b_{-1}, k) dG(b|b_{-1}) \\ &\quad + \delta A(a), \text{ for } g = f, m. \end{aligned} \quad (12)$$

In the above recursion, $\mathbf{M}^g(a, a^*, b, k)$ represents the steady-state distribution over married people and $\widehat{\mathbf{S}}^{g^*}(a^*)$ denotes the normalized distribution for singles of the opposite gender and is defined by

$$\widehat{\mathbf{S}}^{g^*}(a^*) \equiv \frac{\mathbf{S}^{g^*}(a^*)}{\int d\mathbf{S}^{g^*}(a^*)}. \quad (13)$$

The first term in (12) counts those singles who failed to match in the current period. The second term enumerates the flow into the pool of singles from failed marriages. The last term represents the arrival of new adults (the doppelgangers).

In similar fashion, the distribution of married men and women is defined by

$$\begin{aligned}
\mathbf{M}^g(a', a^{*'}, b', k') &= (1 - \delta) \int_{\mathcal{K}}^{k'} \int_{\mathcal{B}}^{b'} \int_{\mathcal{A}}^{a'} \int_{\mathcal{A}}^{a^{*'}} \mathbf{1}^g(a, E^g(a), a^*, E^{g*}(a^*), b, k) \\
&\quad \times d\widehat{\mathbf{S}}_{e^*}^{g*}(a^*) d\mathbf{S}^g(a) dF(b) dK(k) \\
&\quad + (1 - \delta) \int_{\mathcal{K}}^{k'} \int_{\mathcal{B}}^{b'} \int_{\mathcal{B}}^{b'} \int_{\mathcal{A}}^{a'} \int_{\mathcal{A}}^{a^{*'}} \mathbf{1}^g(a, E^g(a), a^*, E^{g*}(a^*), b, k) \\
&\quad \times d\mathbf{M}^g(a, a^*, b_{-1}, k) dG(b|b_{-1}), \text{ for } g = f, m.
\end{aligned} \tag{14}$$

The first term on the righthand side measures the flow into marriage from single life. Only $1 - \delta$ of these matches will last into the next period. The second term counts the number of marriages that will survive from the current period into the next one. To compute a steady-state solution for the model amounts to solving a fixed-point problem, as the following definition of equilibrium should make clear. [Note that $\mathbf{M}^g(a, a^*, b, k) = \mathbf{M}^{g*}(a^*, a, b, k)$.]

Definition 1 *A stationary matching equilibrium is a set of value functions for singles and marrieds, $V_s^g(a, e)$ and $V_m^g(a, e, a^*, e^*, b, k)$, an education decision rule for singles, $e_s^g = E^g(a)$, a matching rule for singles and married couples, $\mathbf{1}^g(a, e, a^*, e^*, b, k)$, and stationary distributions for singles and married couples, $\mathbf{S}^g(a)$ and $\mathbf{M}^g(a, a^*, b_{-1}, k)$, all for $g = f, m$, such that:*

1. *The value function $V_s^g(a, e)$ solves the single's recursion (6), taking as given her/his indirect utility function, $U_s^g(a, e)$, from problem (3), the value function for a married person, $V_m^g(a, e, a^*, e^*, b, k)$, the matching rule for singles, $\mathbf{1}^g(a, e, a^*, E^{g*}(a^*), b, k)$, and the normalized distribution for singles, $\widehat{\mathbf{S}}^g(a)$, defined by (13).*
2. *The value function $V_m^g(a, e, a^*, e^*, b, k)$ solves a married person's recursion (9), taking as given her/his indirect utility function, $U_m^g(a, e, a^*, e^*, k)$, from problem (7), the matching rule for a married couple, $\mathbf{1}^g(a, e, a^*, e^*, b', k)$, and the value function for a single, $V_s^g(a, e)$.*

3. The decision rule $e_s^g = E^g(a)$ solves a single's education problem (10), taking as given $V_s^g(a, e)$ from (6).
4. The matching rule $\mathbf{1}^g(a, e, a^*, e^*, b, k)$ is determined in line with (5), taking as given the value functions $V_s^g(a, e)$ and $V_m^g(a, e, a^*, e^*, b, k)$.
5. The stationary distributions $\mathbf{S}^g(a)$ and $\mathbf{M}^g(a, a^*, b_{-1}, k)$ solve (12) and (14), taking as given the decision rule for an education, $e^g = E^g(a)$, and the matching rule $\mathbf{1}^g(a, e, a^*, e^*, b, k)$.

3 Estimation

The model developed will now be fit to the U.S. data. There are many parameters. A few of them are easy to choose and can be assigned on the basis of a priori information. Most of the parameters will be fitted using a minimum distance estimation procedure, however. The estimation procedure will focus on two years in the U.S. data, viz 1960 and 2005. It will be assumed that the model is in a steady state for each of these years.

3.1 A Priori Information

The easy ones will be done first. The length of period is one year. Let $\tilde{\beta}$ (the subjective discount factor) be 0.96. If one assumes an operational lifespan of 30 years then the survival probability is $1 - \delta = 0.97$. This would dictate a value for the discount factor of $\beta = 0.960 \times 0.97$. Assigning a value for the work week, $\bar{h}$, is straightforward. Assume a 40 hour work week. Since there are 112 non-sleeping hours in a week, let $\bar{h} = 40/112 = 0.36$. Last, the household production parameters, θ and λ , have been estimated by McGrattan, Rogerson and Wright (1997). Their numbers are used here.

How should wages be inputted into the model? Take males first. Wages are needed for non-college and college educated males for 1960 and 2005; viz, $w_{0,1960}$, $w_{1,1960}$, $w_{0,2005}$ and $w_{1,2005}$. Normalize the wage rate for a non-college educated male in 1960 to be one, so that $w_{0,1960} = 1$. Turn to the wage rate rate for a college educated male in 1960. The college premium was 1.34 in 1960. This is the average ratio of wages for a college educated male to a non-college educated one. Recall that $\tilde{a}^m$ is the threshold level of ability that

determines whether the male goes to college or not—see (11). The college premium for the model will read $(w_{1,1960}\bar{a}_{1,1960}^m)/(w_{0,1960}\bar{a}_{0,1960}^m)$, where the average abilities for non-college educated and college educated males are defined by $\bar{a}_{0,1960}^m \equiv \int_{\tilde{a}_{1960}^m} adA(a)/A(\tilde{a}_{1960}^m)$ and $\bar{a}_{1,1960}^m \equiv \int_{\tilde{a}_{1960}^m} adA(a)/[1 - A(\tilde{a}_{1960}^m)]$, respectively. This is an endogenous variable, because young single males decide whether or not to go to school. Set $\tilde{a}_{1960}^m$, given the assumed ability distribution, so that the number of college educated males, $1 - A(\tilde{a}_{1960}^m)$, will match the data for the year 1960. This ties down $\bar{a}_{0,1960}^m$ and $\bar{a}_{1,1960}^m$. Then, let $w_{1,1960}$ be specified by the relationship $w_{1,1960} = 1.34 \times w_{0,1960}(\bar{a}_{0,1960}^m/\bar{a}_{1,1960}^m)$. Of course, this procedure is predicated on the assumption that the estimation routine (discussed in the next subsection) can successfully replicate the fraction of males that went to college in 1960.

Move onto 2005. A non-college educated male earned 1.14 times as much as in 1960. Suppose that the estimation procedure yields the correct number of college educated males for 2005. This pins down $\bar{a}_{0,2005}^m$ and $\bar{a}_{1,2005}^m$, by the above argument. Set $w_{0,2005} = 1.14 \times w_{0,1960}(\bar{a}_{0,1960}^m/\bar{a}_{0,2005}^m)$. Last, the college premium in 2005 was 1.76. This dictates that $w_{1,2005} = 1.76 \times w_{0,2005}(\bar{a}_{0,2005}^m/\bar{a}_{1,2005}^m)$. Observe that if the estimation procedure matches the U.S. educational decisions for males for the years 1960 and 2005 then it will replicate the observed wage structure by construction.

What about females? Values for the two gender gap parameters, ϕ_{1960} and ϕ_{2005} , need to be assigned. This is done by estimating a wage regression using the Heckman correction procedure. Specifically, the following regression is run:

$$\ln w = \text{CONSTANT} + \alpha \times \text{EDUCATION} + \beta \times \text{AGE} + \delta \times \text{AGE}^2 + \tilde{\phi} \times \text{GENDER} + \varepsilon.$$

Here EDUCATION is a dummy variable returning a value of one if the person is college educated and zero otherwise. Likewise, GENDER is another dummy variable assigning a value of one when the respondent is female. A selection equation for labor-force participation is also estimated as part of the statistical model. It also includes dummy variables for the marital status of the person and whether or not s/he has children. After estimating this statistical model, the gender gaps for 1960 and 2005 can be recovered: $\phi_{1960} = \exp(\tilde{\phi}_{1960}) = 0.59$ and $\phi_{2005} = \exp(\tilde{\phi}_{2005}) = 0.83$. To summarize, the parameter values picked on the basis of a

priori information are displayed in Table 2.

TABLE 2: PARAMETERS – A PRIORI INFORMATION

<i>Category</i>	<i>Parameter Values</i>	<i>Criteria</i>
Preferences	$\beta = 0.96 \times (1 - \delta), \chi = 0.70$	A priori information
Household Technology	$\theta = 0.21, \lambda = 0.19$	McGrattan et al (1997)
Life span	$1/\delta = 30$	A priori information
Wages	$w_{0,1960} = 1, w_{1,1960} = 1.068$	Data
	$w_{0,2005} = 1.180, w_{1,2005} = 1.702$	Data
	$\phi_{1960} = 0.59, \phi_{2005} = 0.83$ (gender gap)	Data
Hours	$\bar{h} = 0.36$	Data

3.2 Minimum Distance Estimation

The rest of the parameters are chosen so that the model matches, as closely as is possible, a set of data moments for the years 1960 and 2005. Let DATA represent a vector of moments that are calculated from the U.S. data for the two years 1960 and 2005. In particular, it contains the following statistics for each of the two years:

1. *Educational Attainment.* The fraction of females and males that went to college.
2. *Vital Statistics.* The fraction of the population that has ever-been married by educational level, and that is currently divorced (out of the ever-married populace) by education level.
3. *Assortative Mating.* A contingency for marriage that contains the fractions of marriages for each possible combination of educational levels for both the husband and wife.
4. *Married Female Labor-Force Participation.* The fraction of married females that work by education level and the share of household income provided by wives.

A vector of the analogous 24 moments can be obtained from steady states of the model for the two years 1960 and 2005. The results for the model will be a function of the parameters to be estimated, of course. Therefore, represent this vector of moments by $\mathcal{M}(\omega)$ where ω

denotes the vector of 18 parameters to be estimated. Define the vector of deviations between the data and the model by $G(\omega) \equiv \text{DATA} - \mathcal{M}(\omega)$.

Minimum distance estimation picks the parameter vector, ω , to minimize a weighted sum of the squared deviations between the data and the model. Specifically,

$$\hat{\omega} = \arg \min G(\omega)'WG(\omega),$$

where W is some positive semi-definite matrix. The estimation assumes that the model is a true description of the world, for some value of the parameter vector, ω . The number of targets is larger than the number of parameters. The estimator, $\hat{\omega}$, is consistent for any weighting matrix, W . Let $\text{se}(\hat{\omega})$ represent the vector of standard errors for the estimator, $\hat{\omega}$. It is given by

$$\text{se}(\hat{\omega}) = \text{diag}\left\{\frac{[J(\hat{\omega})'WJ(\hat{\omega})]^{-1}J(\hat{\omega})'W\Sigma WJ(\hat{\omega})[J(\hat{\omega})'WJ(\hat{\omega})]^{-1'}}{n}\right\},$$

where $J(\hat{\omega}) \equiv \partial \mathcal{M}(\hat{\omega}) / \partial \hat{\omega}$, Σ is the variance-covariance matrix for the data moments, and n is the total number of observations. The data moments are calculated from two different sources in IPUMS-USA: viz, the census for 1960 and the American Community Survey for 2005. The moments are independent across these two samples. Therefore, Σ is block diagonal, with a block corresponding to a different sample size. Each block is weighted by the number of observations in the block relative to the total number of observations. (Additionally, within a block the number of observations may vary across moments. Hence, observations within a block may be weighted differently.) Set $W = I$, where I is the identity matrix.

Table 3 reports the parameter estimates and their associated standard errors. The fitted parameter values look reasonable and are tightly estimated, for the most part. The price of home inputs is estimated to decline at 7.4 percent annually. The 95 percent confidence interval for this estimate is [6.4, 8.4]. This is in accord with the quality-adjusted price declines reported by Gordon (1990) for consumer durables. The estimate of the degree of curvature in

the utility function for market goods ($\zeta = 1.82$) is in line with the macroeconomics literature, which typically uses a coefficient of relative aversion of either 1 or 2. Note that nonmarket goods have a weight of $\alpha = 1.18$ in utility. This can be thought of as corresponding to a weight assigned to consumption in a typical macro model of 0.43, with the remaining weight of 0.57 being assigned to leisure; i.e., $0.57/0.43 = 1.18$. Nonmarket goods play a role similar to leisure here. Thus, this coefficient does not seem unreasonable. The utility function for nonmarket goods is slightly more concave ($\xi = 2.99$). As was mentioned in the introduction, this implies that a household will tilt its allocation towards market goods as it gets wealthier. Therefore, single households gain the most from labor-saving household inputs, because a larger fraction of their consumption is devoted to nonmarket goods. Thus, an innovation in the home sector will favor the establishment of single households. A household spends about 13.7 percent of its market consumption on covering the fixed costs of a home (when $\mathbf{c} = 0.047$) in 1960. This number declines to 8.5 percent in 2005. Last, an educated person realizes 0.83 utils (μ_1) from marrying a similarly educated person. This compares to the mean level of bliss in a marriage of 0.92 in 1960 and 1.23 in 2005.

TABLE 3: PARAMETERS – ESTIMATED (MINIMUM DISTANCE)

<i>Category</i>	<i>Parameter Values</i>	<i>Standard Error</i>	<i>95% Conf Int</i>
Preferences	$\alpha = 1.18$	0.0030	[1.170, 1.182]
	$\xi = 2.99$	0.0094	[2.968, 3.005]
	$\zeta = 1.82$	0.0079	[1.806, 1.836]
	$\mathfrak{c} = 0.047$	0.0007	[0.046, 0.049]
	$\mu_0 = 0.07$	0.0041	[0.057, 0.073]
	$\mu_1 = 0.83$	0.0813	[0.674, 0.993]
	$\sigma_a = 0.015$	0.0017	[0.012, 0.018]
Ability Shocks			
Matching Shocks	$\bar{b}_s = -1.21$	0.0794	[-1.367, -1.056]
	$\sigma_{b,s} = 2.90$	0.0629	[2.778, 3.025]
	$\bar{b}_m = 0.36$	0.0105	[0.336, 0.377]
	$\sigma_{b,m} = 0.28$	0.0089	[0.260, 0.295]
	$\rho_{b,m} = 0.93$	0.0043	[0.924, 0.941]
	$k_l = 0.49$	0.0405	[0.411, 0.569]
Home Shocks	$k_h = 2.01$	0.1799	[1.656, 2.361]
Prices	$p_{1960} = 20.24$	0.8711	[18.537, 21.951]
	$p_{2005} = p_{1960} \times e^{-\gamma \times (2005 - 1960)}$		
	$\gamma = 0.074$	0.0051	[0.064, 0.084]
Cost of Education	$\varepsilon = 45.77$	2.6196	[40.638, 50.907]
	$\omega = 14.91$	0.8697	[13.202, 16.611]

4 Findings

The goal of the analysis is to see whether the above framework can explain: (i) the rise in assortative mating; (ii) the decline in marriage and the increase in divorce, which has impacted on non-college educated individuals more than college educated ones. Ideally, this should be done while simultaneously explaining the increase in college education and the rise in married female labor-force participation. The questions of interest are (i) how well can the two simulated steady states for the model match the set of stylized facts computed for these two years and (ii) what are the main forces driving the observed changes in household structure.

4.1 U.S. Stylized Facts and Benchmark Model Results

The set of stylized facts regarding American households and the corresponding results for the benchmark model are displayed in Table 4. All data variables are targets (but note that the fraction of people who are single or married, the correlation between a husband's and wife's education level, and total married female labor-force participation derive from the other statistics.) Overall the model does a good job matching the set of stylized facts presented for the years 1960 and 2005. First, it predicts a rise in education over this time period for both males and females. In 1960 more males (11.6 percent) went to college than females (6.7 percent) in the U.S. This situation had reversed by 2005 (28.4 percent versus 30.1). While the framework does not yield this reversal, females catch up with males. (For males it increases from 9.8 to 30.8 percent and for females from 8.6 to 30.8 percent).

Second, marriage became less important over this period. Specifically, the fraction of the population that is single more than doubled in the data (from 12.6 to 34.8 percent). The model generates a similar increase (16.8 to 34.2 percent). The rise in the number of singles and the fall in the fraction of marrieds is due to both a decline in the rate of marriage and an increase in the rate of divorce. This feature of the data is also matched. The model has some difficulty mimicking the very high rate of marriage for the non-college educated in 1960. The model does deliver a more pronounced decrease in the marriage rates between 1960 and 2005 for non-college educated people compared to the college-educated, however; marriage rates for less educated people decline by 10 percentage points in the model (compared to 13 in the data) whereas the decline for college-educated people is 8.7 percentage points (and 7 in the data). In the data the increase in divorce is greater for non-college educated people (3.4 percent to 17.2) vis-à-vis educated ones (2.4 percent to 10.6). The model has no trouble generating the differential increase in divorce. The fraction of divorced people increases by 12 percentage points for non-college educated people (versus 13.8 in the data) and only by 8.5 for college educated ones (compared with the 8.2 that was observed). The model yields a slightly higher level of divorce in 1960; 3.8 percent in the model versus 2.4 percent in the data for college educated people and 4.6 percent in the model versus 3.4 percent in the data

for non-college educated ones. As a result, the proportion of singles in the model is also higher than the data in 1960.

Third, the framework has no trouble generating a rise in assortative mating. In fact, the mechanism in the model is too strong. The correlation between a husband's and wife's education level for 1960 is lower in the model (0.41 in the data compared with 0.103 in the model) but is very close for 2005 (0.519 in data as compared with the model's 0.521). Additionally, for both years, the contingency tables generated by the model are also very close to their data counterparts.⁴

Finally, the model does a great job replicating the increase in labor-force participation by married females (from 31.5 to 71.0 percent in the data and 23.7 to 74 percent in the model). The model is also consistent with the relative labor-force participation by education levels: for females with less than college, this statistic increases from 30.9 to 68.4 percent in the data versus 21.7 to 72.6 percent in the model. For college educated females, it rises from 41.4 to 76.3 percent in the data and from 44.7 to 77.3 percent in the model. The model also explains well the upward movement in the share of family income that working wives provide (15.7 to 33.7 percent in the data versus 10 to 34.7 percent for the model).⁵

⁴ The model has difficulty generating the rise in marriages between skilled females and unskilled males. Coles and Francesconi (2011) study the emergence of these “toyboy” marriages within a model where individuals value both the wage as well as fitness of their partners.

⁵ The model generates a gender gap that is reasonably close to the observed gender gap in the data for 1960 and 2005. This suggests that if the ϕ 's for 1960 and 2005 are estimated to match the observed raw gender gaps, instead of being estimated directly from the data using a wage regression with an Heckman correction, the benchmark economy would not look very different.

TABLE 4: DATA AND BENCHMARK MODEL

	1960				2005			
	<i>Data</i>		<i>Model</i>		<i>Data</i>		<i>Model</i>	
<i>Education</i>	Fem	Males	Fem	Males	Fem	Males	Fem	Males
	0.067	0.116	0.086	0.098	0.301	0.284	0.308	0.308
<i>Marriage</i>								
Fraction	Sing	Marr	Sing	Marr	Sing	Marr	Sing	Marr
	0.126	0.874	0.168	0.832	0.348	0.652	0.342	0.658
Rates	< Coll	Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll
–Marriage	0.917	0.856	0.871	0.876	0.787	0.786	0.771	0.789
–Divorce	0.034	0.024	0.046	0.038	0.172	0.106	0.166	0.123
<i>Sorting</i>								
<u>Husband</u>	<u>Wife</u>		<u>Wife</u>		<u>Wife</u>		<u>Wife</u>	
< Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll
	0.856	0.024	0.827	0.072	0.564	0.109	0.571	0.089
Coll	0.080	0.040	0.083	0.018	0.104	0.223	0.121	0.218
Corr, educ	0.410		0.103		0.519		0.521	
<i>Work, Marr Fem</i>								
Participation, All	0.315		0.237		0.710		0.740	
Participation, < Coll	0.309		0.217		0.684		0.726	
Participation, Coll	0.414		0.447		0.763		0.773	
Income, frac	0.157		0.100		0.337		0.347	

4.2 Under the Hood

The forces underlying the rise in education, the decline in marriage, the increase in assortative mating, and the upswing in married female labor-force participation will now be inspected. These forces are labor-saving technological progress in the home, a rise in the general level of wages, a widening in the college premium, and a narrowing of the gender gap. Three experiments are considered here. First, technological advance in the household sector will be shut down. Hence, there are only changes in the wage structure in this experiment. Second, shifts in the wage structure are turned off. Now there is only technological progress in the home. Third, the gender gap is prevented from narrowing.

4.2.1 No Technological Progress in the Home (Change in Wage Structure Only)

To begin with, consider shutting down technological progress in the home. Thus, only changes in the wage structure are operational. Specifically, fix the 2005 price of household inputs, p , at the 1960 level. Think about this experiment as representing a comparative statics exercise, one done numerically as opposed to the more traditional qualitative analysis that uses pencil and paper techniques. The results of this experiment are shown in Table 5. As can be seen from the table, technological progress in the household sector is vital for promoting married female labor-force participation. Without it very few married women would work. In fact, a lower fraction of educated females would work in 2005 than in 1960. This is because households are richer in 2005 than in 1960, due to a rise in wages. The associated income effect leads to more women staying at home. This is especially true for the women who are married to educated (and therefore richer) men. These women also tend to be educated as well.

Producing home goods is labor intensive. Married households are better disposed to undertake household production relative to single ones, because they have a larger endowment of time. As can be seen, marriage is higher and divorce is lower in 2005 when there is no technological progress in the home. This establishes the fact that technological progress in the home is important for marriage and divorce. In particular, without technological progress in the home, the model is not able to deliver the observed rise in the divorce rates and decline in marriage rates, and misses the large differential trends in divorce by education that are observed in the data. In this situation, people are less well disposed to maintain single households, because the cost of household inputs is high. This is especially true for the non-college educated who are poorer.

There is still a rise in educational attainment. Surprisingly, slightly more males and females go to school in 2005 than in the benchmark model. This is because households are poorer than in the benchmark model. Individuals can go to college to make up for this, in part. They can't increase their labor supply, given the assumption of a fixed workweek. The number of females going to college increases more, even though very few of them will work when married. This is interesting. Women value a college education because it increases the income they earn when single. Young women are single for a time before they get married.

Having a college degree allows them to live better. Because of this they can be pickier about the husband they will marry. Having a college degree will also mitigate the impact of a divorce. There is still a large increase in assortative mating. Having a college degree is also beneficial for a female because it is intrinsically attractive for a college educated male.

TABLE 5: NO TECHNOLOGICAL PROGRESS IN THE HOME
(CHANGE IN WAGE STRUCTURE ONLY)

	1960		2005			
	<i>Benchmark</i>		<i>Experiment</i>		<i>Benchmark</i>	
<i>Education</i>	Fem	Males	Fem	Males	Fem	Males
	0.086	0.098	0.333	0.360	0.308	0.308
<i>Marriage</i>						
Fraction	Sing	Marr	Sing	Marr	Sing	Marr
	0.168	0.832	0.211	0.789	0.342	0.658
Rates	< Coll	Coll	< Coll	Coll	< Coll	Coll
–Marriage	0.871	0.876	0.838	0.846	0.771	0.789
–Divorce	0.046	0.038	0.071	0.043	0.166	0.123
<i>Sorting</i>						
<u>Husband</u>	<u>Wife</u>		<u>Wife</u>		<u>Wife</u>	
< Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll
	0.827	0.072	0.557	0.062	0.571	0.089
Coll	0.083	0.018	0.110	0.270	0.121	0.218
Corr, educ	0.103		0.628		0.521	
<i>Work, Marr Fem</i>						
Participation, All	0.237		0.363		0.740	
Participation, < Coll	0.217		0.450		0.726	
Participation, Coll	0.447		0.186		0.773	
Income, fraction	0.100		0.177		0.347	

The absence of technological progress in the home leads to a large drop in female labor supply. One might think that the equilibrium level of wages will rise in response. This could operate to dampen the withdrawal of labor effort by women. The structure employed here assumes that production is linear in male and female work effort, so such an effect is precluded. Consider relaxing this, somewhat.

In particular, imagine an aggregate production function of the form

$$\mathbf{o} = \mathbf{z}\mathbf{k}^\kappa \mathbf{h}^{1-\kappa},$$

where $\mathbf{o}$ is aggregate output, $\mathbf{z}$ is total factor productivity, $\mathbf{k}$ is the capital stock, $\mathbf{h}$ is the total stock of labor measured in efficiency units, and $\mathbf{z}$ is total factor productivity. Let $\mathbf{k} = 1$ and set $\kappa = 1/3$. The problem with using this production function is the introduction of capital. In particular, are people able to buy or trade capital? To keep things simple, this needs to be ruled out. Suppose that there is a government in the economy. It owns this capital stock. It rents it out at the rental rate r . The proceeds from this rental income are used to finance government spending, g . This government spending could be entered into the utility function in a separable way. This assumption implies that there is no need to think about capital income. Workers will only earn their wages, as before. The wage rate for a unit of raw unskilled labor, w_0 , is given by

$$w_0 = (1 - \kappa)\mathbf{z}\mathbf{h}^{-\kappa}.$$

Note that $\mathbf{h}$ is simply the sum of labor effort across all individuals, where each type of labor is weighted by their 2005 efficiency level in production; i.e., a college educated woman of ability level a is weighted by $\phi_{2005}(w_{1,2005}/w_{0,2005})a$. Total factor productivity, $\mathbf{z}$, is picked so that the model matches the unskilled wage rate for 2005. This implies that $\mathbf{z} = 1.58$.

The results are shown in Table 6 below. Somewhat surprisingly, married female labor-force participation drops even further. Why? It is true that the general level of wages does rise when married female labor-force participation drops. But, when there is no technological progress in the household sector, female labor is greatly valued at home. The rise in the general level of wages makes households better off, *ceteris paribus*, because males now earn more. The positive income effect associated with the increase in husbands' incomes induces more wives to stay at home.

TABLE 6: MARRIED FEMALE LABOR-FORCE PARTICIPATION

	<i>Experiment/G.E. Effects</i>	<i>Experiment/No G.E. Effects</i>	<i>Benchmark</i>
Participation	0.336	0.363	0.740

4.2.2 No Change in Wage Structure (Technological Progress in the Home Only)

Compare this to the situation where there is no change in wages. In particular, set wages for both females and males at the levels they had in 1960; i.e., $w_{0,2005} = w_{0,1960}$, $w_{1,2005} = w_{1,1960}$, and $\phi_{2005} = \phi_{1960}$. The results of this comparative statics experiment are shown in Table 7. Observe that the number of married women that work in 2005 is actually higher than in the benchmark model. Therefore, increases in wages are not the important drivers of the rise in married female labor-force participation. Technological progress in the household sector is. More women work relative to the benchmark, because households are less wealthy due to the fact that wages are fixed. This also raises the rate of marriage and lowers the rate of divorce vis-à-vis the benchmark. There are also more marriages. Still, wages play an important role in the analysis. The table illustrates that the increase in educational attainment for both women and men is influenced by the rise in the college premium. Without this, educational attainment for females and males change very little. Finally, the degree of assortative mating remains more or less constant when the wage structure is held fixed (as opposed to the strong increase in the benchmark model). Therefore, changes in wages drive the rise in assortative mating.

TABLE 7: NO CHANGE IN WAGE STRUCTURE
(TECHNOLOGICAL PROGRESS IN THE HOME ONLY)

	1960		2005			
	<i>Benchmark</i>		<i>Experiment</i>		<i>Benchmark</i>	
<i>Education</i>	Fem	Males	Fem	Males	Fem	Males
	0.086	0.098	0.111	0.086	0.308	0.308
<i>Marriage</i>						
Fraction	Sing	Marr	Sing	Marr	Sing	Marr
	0.168	0.832	0.339	0.661	0.342	0.658
Rates	< Coll	Coll	< Coll	Coll	< Coll	Coll
–Marriage	0.871	0.876	0.771	0.804	0.771	0.789
–Divorce	0.046	0.038	0.152	0.103	0.166	0.123
<i>Sorting</i>						
<u>Husband</u>	<u>Wife</u>		<u>Wife</u>		<u>Wife</u>	
< Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll
	0.827	0.072	0.809	0.105	0.571	0.089
Coll	0.083	0.018	0.062	0.024	0.121	0.218
Corr, educ	0.103		0.139		0.521	
<i>Work, Marr Fem</i>						
Participation, All	0.237		0.799		0.740	
Participation, < Coll	0.217		0.791		0.726	
Participation, Coll	0.447		0.851		0.773	
Income, fraction	0.100		0.306		0.347	

4.2.3 No Change in the Gender Gap, ϕ

For the last experiment, just shut down the rise in the gender gap; i.e., set $\phi_{2005} = \phi_{1960}$. This experiment does not shift the benchmark equilibrium as much as the other two do. It will only be briefly discussed. The full set of results is presented in Table 8 in the Appendix. First, there is little change in the education rates for females. This is not surprising because a change in the gender gap does not influence the return from going to college relative to not going. Second, the rate of marriage remains constant for college-educated people and decreases a bit for the less educated. Third, assortative mating declines somewhat. The correlation between educational types drops from 0.52 in the benchmark equilibrium to 0.47. Perhaps a single female can no longer choose to be as picky about her mate. Fourth, there is

a drop in married women's labor-force participation from 74% to 64%. So, the majority of the 50 percentage point rise in married female labor-force participation (in the model) can be attributed to technological progress in the home; recall that when technological advance in the home is shut down that married female labor force participation drops from 74% to 36%.

Taking stock of the results from the above three comparative statics exercises suggests that technological progress in the household sector plays an important role in stimulating labor-force participation by married females. The narrowing of the gender plays a significant, but secondary role, here. Technological progress in the household sector also contributes greatly to the decline in marriage and the rise in divorce. The widening in the college premium is instrumental in motivating females and males to go to college. Together with the rise in the gender gap this leads to an increase in assortative mating.

5 Conclusions

People today are more likely to marry someone of the same socioeconomic class than in the past. At the same time the prevalence of marriage has fallen and the occurrence of divorce has risen, especially for people without a college education. Women are much more likely to go to college now. Married ones work more. This has led to a dramatic transformation of the American household.

To address these facts a model of marriage and divorce is developed. In the constructed framework, individuals marry for both economic and noneconomic reasons. The noneconomic reasons are companionship and love. The economic ones are the values of a spouses's labor at home and in the market. Technological progress in the household sector erodes the value of labor at home. This reduces the importance for a marriage of the labor used in household production. As a result married women enter the labor market. Love becomes a more important determinant in marriage. An individual can now afford to delay marriage and wait to find a mate that makes him or her happy. This leads to a decline in marriage and a rise in divorce. Increases in the college premium provide an incentive for both young men and women to go to college. A college educated person earns more in both married and

single life. The fact that men now desire women that make a good income provides a extra incentive for a young woman to go to college, or vice versa. An additional motivation may be that people like to marry others with the same educational background.

The structural model developed is fitted to the U.S. data using a minimum distance estimation procedure. A collection of data moments summarizing educational attainment, the patterns of marriage and divorce, and married female labor-force participation is targeted. The estimated structural model matches the stylized facts describing the transformation of U.S. households well, yielding parameter values that are both reasonable and tightly estimated. Like almost everything in life there is still room for improvement. In particular, the model struggles somewhat to mimick the very high level of marriage that is observed in 1960 for the non-college educated segment of the population. Also, the degree of assortative mating predicted by the model for the early period is too weak. Technological progress at home is found to be an important factor for explaining the rise in married female labor-force participation. The narrowing of the gender gap plays an ancillary role here. Technological progress in home is also a significant driver of the decline in marriage and rise in divorce by education level. The structure of wages in the U.S. has a powerful influence on assortative mating and educational attainment.

6 Appendix

Unless stated otherwise, all data is obtained from IPUMS-USA. For the years 1960, 1970, 1980, 1990 and 2000 the data derives from federal censuses, while for 2005 it comes from the American Community Survey (ACS). The ACS has a sample size comparable to the one percent census samples that IPUMS provides for the other years. The age group for which the analysis is done is 25-54. A college educated individual refers to someone with 4 years of college or more, otherwise the person is labelled as being non-college educated. This applies to both males and females.

Figure 1. The fraction of the population that is ever married is one minus the fraction of the population that is never married. The fraction of the population that is currently divorced is calculated by taking the stock of currently divorced and then dividing it by the

stock of ever-married people.

Figure 2. The value of β_t is plotted from the regression equation (1). This equation is estimated for married couples using the data mentioned above. The regression coefficient measures the incremental likelihood (relative to 1960) that an educated male is married to an educated female in the year t , for $t = 1970, 1980, 1990, 2000$, and 2005 .

Figure 3. Female labor-force participation is calculated from the variable EMPSTAT in IPUMS. This variable reports whether or not an individual is in the labor force. This calculation is done for both college and non-college educated women. A wife's contribution to family income is calculated by computing the ratio of her labor income to total family labor income. This ratio is averaged across all married women.

Figure 4. A woman is labelled as having a college degree if she has 4 years of college or more. The college premium is calculated by dividing the average labor income for college educated men by the average labor income for non-college educated ones. For the gender gap, the average wage for employed women is calculated. The sample is trimmed to exclude women who report incomes that are above the 99th percentile and below the 1st. The same is done for men. The gender gap is the ratio of the two averages.

TABLE 8: NO CHANGE IN GENDER GAP, ϕ

	1960		2005			
	<i>Benchmark</i>		<i>Experiment</i>		<i>Benchmark</i>	
<i>Education</i>	Fem	Males	Fem	Males	Fem	Males
	0.086	0.098	0.360	0.308	0.308	0.308
<i>Marriage</i>						
Fraction	Sing	Marr	Sing	Marr	Sing	Marr
	0.168	0.832	0.377	0.623	0.342	0.658
Rates	< Coll	Coll	< Coll	Coll	< Coll	Coll
–Marriage	0.871	0.876	0.738	0.782	0.771	0.789
–Divorce	0.046	0.038	0.201	0.117	0.166	0.123
<i>Sorting</i>						
<u>Husband</u>	<u>Wife</u>		<u>Wife</u>		<u>Wife</u>	
< Coll	< Coll	Coll	< Coll	Coll	< Coll	Coll
	0.827	0.072	0.507	0.156	0.571	0.089
Coll	0.083	0.018	0.091	0.246	0.121	0.218
Corr, educ	0.103		0.476		0.521	
<i>Work, Marr Fem</i>						
Participation, All	0.237		0.645		0.740	
Participation, < Coll	0.217		0.653		0.726	
Participation, Coll	0.447		0.633		0.773	
Income, fraction	0.100		0.261		0.347	

References

- Adamopoulou, Effrosyni. 2010. “Will You Quasi-Marry Me? The Rise of Cohabitation and Decline in Marriages.” Manuscript, Universidad Carlos III de Madrid.
- Albanesi, Stefania and Claudia Olivetti. 2010. “Gender Roles and Medical Progress.” Manuscript, Columbia University.
- Bethencourt, Carlos and José-Víctor Ríos-Rull. 2009. “On the Living Arrangements of Elderly Widows.” *International Economic Review*, 50, no. 3: 773-801.
- Cavalcanti, Tiago V. de V. and Jose Tavares. 2008. “Assessing the ‘Engines of Liberation’: Home Appliances and Female Labor Force Participation.” *Review of Economics and Statistics*, 90, no. 1: 81–88.
- Chiappori, Pierre-André, Iyigun, Murat F. and Yoram Weiss. 2009. “Investment in

- Schooling and the Marriage Market.” *American Economic Review*, 99, no. 5: 1689-1713.
- Choo, Eugene and Aloysius Siow. 2006. “Who Marries Whom and Why.” *Journal of Political Economy*, 114, no. 1: 175-201.
- Coen-Pirani, Daniele, Alexis Leon and Steven Lugauer. 2010. “The Effect of Household Appliances on Female Labor Force Participation: Evidence from Micro Data.” *Labour Economics*, 17, no.3: 503-513.
- Coles, Melvyn G. and Marco Francesconi. 2011. “On the Emergence of Toyboys: The Timing of Marriage with Aging and Uncertain Careers.” *International Economic Review*, 52, no. 3: 825-853.
- Del Boca, Daniela and Christopher J. Flinn. 2006. “Household Time Allocation and Modes of Behavior: A Theory of Sorts.” Manuscript, NYU.
- Eckstein, Zvi and Osnat Lifshitz. 2011. “Dynamic Female Labor Supply.” *Econometrica*, forthcoming.
- Fernandez, Raquel, Fogli, Alessandra and Olivetti, Claudia. 2004. “Mothers and Sons: Preference formation and Female Labor Force Dynamics.” *The Quarterly Journal of Economics*, 119, no. 4: 1249–1299.
- Fernandez, Raquel, Guner, Nezih and John A. Knowles. 2005. “Love and Money: A Theoretical and Empirical Analysis of Household Sorting and Inequality.” *The Quarterly Journal of Economics*, 120, no. 1, 273-344.
- Galor, Oded and David Weil. 1996. “The Gender Gap, Fertility, and Growth.” *American Economic Review*, 86, no 3, 374-387.
- Gordon, Robert J. 1990. *The Measurement of Durable Goods Prices*. University of Chicago Press.
- Greenwood, Jeremy, Seshadri, Ananth and Mehmet Yorukoglu. 2005. “Engines of Liberation.” *Review of Economic Studies*, 72, no. 1: 109-133.
- Greenwood, Jeremy and Nezih Guner. 2009. “Marriage and Divorce since World War II: Analyzing the Role of Technological Progress on the Formation of Households.” *NBER Macroeconomics Annual 2008*, 23: 231-276.
- Guner, Nezih, Kaygusuz, Remzi and Gustavo Ventura. 2011. “Taxation and Household Labor Supply.” *Review of Economic Studies*, forthcoming.
- Jacquemet, Nicolas and Jean-Marc Robin. 2011. “Marriage with Labor Supply.” Manuscript, SciencePo (Paris).

- Jones, Larry E., Manuelli, Rodolfo E. and Ellen R. McGrattan. 2003. "Why Are Married Women Working So Much?" Staff Report no. 317, Federal Reserve Bank of Minneapolis, Minneapolis, MN.
- Martin, Steven P. 2006. "Trends in Marital Dissolution by Women's Education in the United States." *Demographic Research*, 15 (December 2006): 537-560.
- McGrattan, Ellen R., Rogerson, Richard and Randall Wright. 1997. "An Equilibrium Model of the Business Cycle with Household Production and Fiscal Policy." *International Economic Review* 38: 267-90.
- Neeman, Zvika, Newman, Andrew F. and Claudia Olivetti. 2008. "Are Career Women Good for Marriage?" Manuscript, Boston University.
- Ogburn, W.F. and M.F. Nimkoff. 1955. *Technology and the Changing Family*. Houghton Mifflin Company (Cambridge, MA).
- Regalia, Ferdinando and José-Víctor Ríos-Rull. 2001. "What Accounts for the Increase in the Number of Single Households?" Manuscript, University of Minnesota.
- Restuccia, Diego and Guillaume Vandenbroucke. 2009. "The Evolution of Education: A Macroeconomic Analysis." Manuscript, University of Toronto.
- Salcedo, Alejandrina, Schoellman, Todd and Michele Tertilt. 2009. "Household Size and the Demand for Private Goods: United States 1850-2000." Manuscript, Stanford University.
- Stevenson, Betsey and Justin Wolfers. 2007. "Marriage and Divorce: Changes and Their Driving Forces." *Journal of Economic Perspectives*, 21 (Spring): 27-52.
- Schwartz, Christine R. and Robert D. Mare. 2005. "Trends in Educational Assortative Marriage from 1940 to 2003." *Demography*, 42, (4): 621-46.