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The Evolution of Women's Choices in the Macroeconomy

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The Evolution of Women's Choices in the Macroeconomy

by

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To my family and friends.

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The Evolution of Women's Choices in the Macroeconomy

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Various macroeconomic effects resulted from the changing economic and societal structure in the second half of the 20th century, which greatly impacted women's economic position in the United States. Using dynamic programming as the main modeling tool, and U.S. data for factual evidence, three papers are developed to test the validity of three related hypotheses focusing on female employment, education, marriage, and divorce trends.

The first chapter estimates how much of the post-World War II evolution in employment and average wages by gender can be explained by a model where changing labor demand requirements are the driving force. I argue that a large fraction of the original female employment and wage gaps in mid-century, and the subsequent shrinking of both gaps, can be explained by labor reallocation from brawn-intensive to brain-intensive jobs favoring women's comparative advantage in brain over brawn. Thus, aggregate gender-specific employment and wage gap trends resulting from this labor reallocation are simulated in a general equilibrium model.

The material in the second chapter is based on an ongoing joint project with Fatih Guvenen. We argue for a strong link between the rise in the proportion of educated women and the evolution of the divorce rate since mid-century. As women become increasingly educated their bargaining power within marriage rises and their economic situation in singlehood improves making marriage less attractive and divorce more attractive. Similarly, a change in the divorce regime (e.g., U.S. unilateral divorce laws in the 1970s), making marriages less stable, incentivizes women to seek education as insurance against the higher divorce risk. A framework that models the interdependence between education, marriage and divorce is developed, simulated, and contrasted against United States data evidence.

The third chapter considers the implications of marital uncertainty on aggregate household savings behavior. To this end, an infinite horizon model with perpetual youth that features uncertainty over marriage quality is developed. Similarly to Cubeddu and Ríos-Rull (1997), I test how much of the savings rate decline from the 1960s to the 1980s can be explained by the changing United States demographic composition, specifically the rise in divorce rates and the fall in marriage rates.

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Chapter 1

Brain versus Brawn: The Realization of Women's Comparative Advantage

This chapter estimates how much of the post-World War II evolution in employment and average wages by gender can be explained in a model where changing labor demand requirements are the driving force. I argue that a large fraction of the original female employment and wage gaps in mid-century, and the subsequent shrinking of both gaps, can be explained by labor reallocation from brawn-intensive to brain-intensive jobs favoring women's comparative advantage in brain over brawn.

1.1 Introduction

One of the greatest phenomena of the 20th century has been the rise in female labor force participation. Using evidence from United States data, this study develops a general equilibrium model based on the following two facts of labor supply and wages since World War II:

1. Women's labor force participation, aged 25 to 64, rose from 32 percent in 1950 to 71 percent in 2005 (see Figure 1.1), while men's labor force participation stayed fairly steady.[1]

[1] All statistics reported in this chapter, unless noted otherwise are derived from the 1950 United States Census Integrated Public Use Micro-data Samples (IPUMS-USA, Ruggles et al., 2004) and

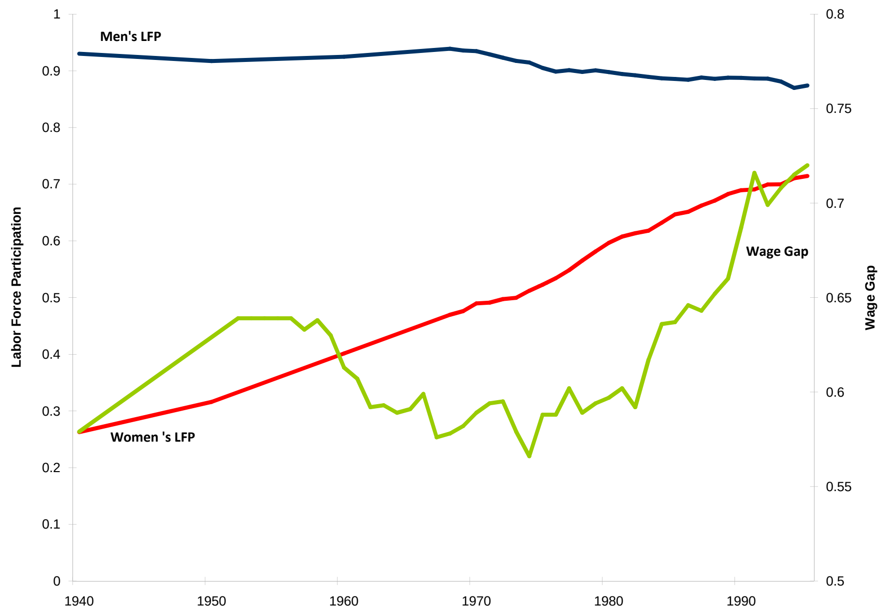
2. The gender wage gap, defined as average female to average male wages, changed quickly during the same period. After initially falling from about 64 percent to a low of 59 percent, the gender wage gap began rising again in the mid-1970s reaching around 77 percent by 2005 (see Figure 1.1).

While it is a popular perception that anti-discrimination laws focused on gender equality were the main reasons behind women's changing labor market participation and earnings, economic studies have found various other reasons played an important role in shaping women's labor market experience, such as changes in women's work experience, education, and occupational mix (see, for example, Black and Juhn, 2000; Blau, 1998; Mulligan and Rubinstein, 2005). The forces behind the changing female employment and wages should be of particular interest to economists and policy makers alike.

This chapter presents evidence from the United States and develops a general equilibrium model where women's improved labor market experience is driven by labor demand changes. I argue that the main factor in improving women's labor market opportunities, and their potential wages, is the shift in labor shares away from brawn-intensive occupations, as suggested by Galor and Weil (1996). The shift in labor shares is modeled by a linear exogenous "skill-biased" technical change, where skilled occupations are those requiring relatively more brain than brawn. This definition deviates from the traditional education-based skill classification. For example, while a department store sales worker is usually classified as

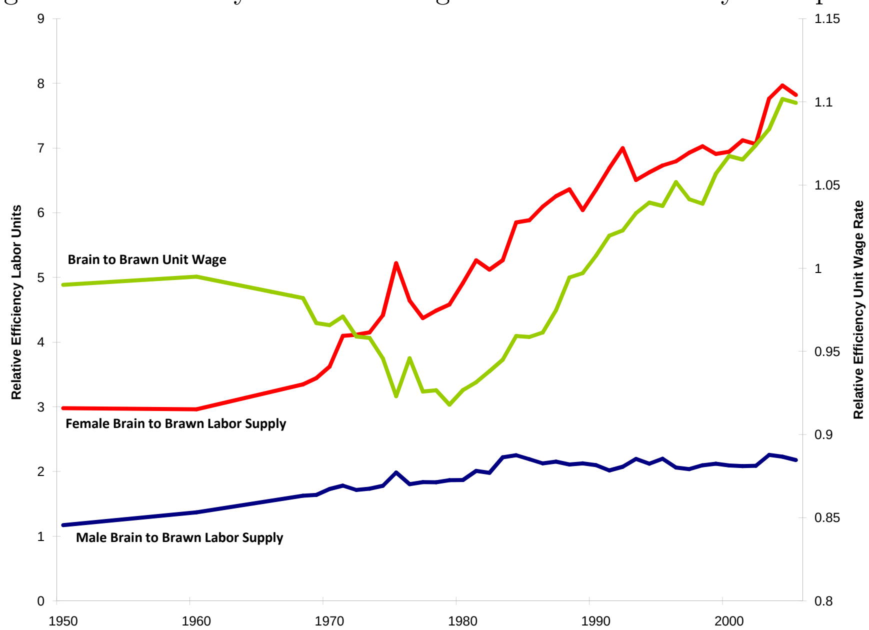
2000 Current Population Survey Integrated Public Use Micro-data Samples (IPUMS-CPS, King et al., 2004).

Figure 1.1: Female Labor Force Participation and Gender Wage Gap



unskilled, in this study he/she is part of the "skilled" labor force since a sales worker requires almost no physical strength in preforming his/her job effectively. More specifically, the model economy consists of two types of occupations, brain-intensive and brawn-intensive. These occupations are aggregated by a CES production function to produce a final market good. Heterogeneous agents differ in their innate intellectual aptitude (brain), physical ability (brawn) and, therefore, in their willingness to work in either occupation or in the labor market at all. Agents maximize consumption over market and home produced goods by allocating time between the labor market and their home. In addition, finitely lived myopic agents can increase their innate brain abilities by choosing to become educated when young.

Figure 1.2: Efficiency Units and Wages in "Female-Friendly" Occupations



A selection bias of women into brain-intensive occupations with initially lower wages (discussed in detail later), a rise in the relative returns to these occupations, and a rise in women's relative labor supply to these occupations since World War II is undisputable (see Figure 1.2). Therefore, I argue that female labor force participation rose following skill-biased technical change favoring women's comparative advantage in brain. Following this hypothesis, the wage gap closed for two reasons, (1) a rise in the returns to "female-friendly" occupations and (2) a faster increase in the female to male efficiency-unit labor supply to these occupations. Consequently, the goal of this chapter is to estimate the quantitative importance of labor demand changes in explaining the shrinking wage gap and the rise in female labor force participation.

The rise of female labor force participation has been the focus of many recent macroeconomic papers. Some of these studies argue that improvements in home technology, such as the invention and marketization of household appliances (see, for example, Greenwood et al., 2002, and references therein), or the improvements in baby formulas (see Albanesi and Olivetti, 2006), enabled women to enter the labor market. While improvements in home technology freed women from time-consuming household chores, theories only focused on home technology improvements do not and cannot effectively address the evolution of the wage gap over time.

Another set of research argues that certain observed labor market changes, such as the closing wage gap (see Jones et al., 2003) or the increased returns to experience for women (see Olivetti, 2006), are largely responsible for the rise in female employment. Neither of these studies explain why women suddenly earned higher wages or had higher returns to experience, thus leaving the mechanism behind the closing wage gap unexplained.

To summarize, while previous studies have been successful in explaining part of Fact 1, the rise of the female labor force, they say nothing about the closing gender wage gap beyond taking Fact 2 as given. That is, they only address one aspect of the events shaping women's labor market experience.

Two recent studies focus on the effects of cultural, social, and intergenerational learning on labor supply (see Fernández, 2007; Fogli and Veldkamp, 2007). As before, these models are successful in explaining part of the rise in female labor force participation. In addition, Fogli and Veldkamp (2007) extend their theory to explain the evolution of wages through women's self-selection bias, i.e., the characteristics of working women changed in the 20th century. However, this model is unable to match the complete wage evolution, only matching either the initial stagnation or the later rise.

All previously mentioned studies focus on labor supply side changes while keeping the labor demand constant. Naturally, this leaves one big unexplored fact: the changing labor demand. Two econometric studies analyze the effects of labor inputs in production on the gender wage gap. Wong (2006) finds that skill-biased technical change had a similar impact on men'and women's wages and, therefore, cannot explain the closing wage gap. Black and Spitz-Oener (2007) quantify the contribution of changes in specific job tasks on the closing wage gap from 1979 to 1999 for West Germany. The authors find that skill-biased technical change in West Germany, especially through the adoption of computers, can explain about 41 percent of the closing wage gap. While these two studies estimate the effects of relative labor demand changes on the wage gap, both assume an inelastic labor supply. Consequently, they cannot address the non-linear path of average female to male wages stemming from women's self-selection bias into the labor market.

Undoubtedly trends in demand changes are missing from macroeconomic theory focusing on the rise of the female labor force and the shrinking wage gap. I argue that these trends arise from one underlying economic process: technical change leading to labor reallocation from brawn-intensive to brain-intensive occupations. The mechanism developed in this chapter is able to explain: (1) about 79 percent of the rise in female labor force participation, (2) approximately 37 percent of the stagnation in average female to male wages from 1960 to 1980 and (3) about 83 percent of the closing wage gap between 1980 and 2005.

While the empirical results are specific to the United States, the model developed could also be used to study cross-country differences in women's labor market participation. Rogerson (2005) notes that the change in relative employment of women and the aggregate service share (a brain-intensive sector given data evidence) between 1985 and 2000 are highly correlated at 0.82, concluding that countries which added the most jobs to the service sector also closed the employment gap the most.

The remainder of this chapter is organized as follows. Section 1.2 provides further evidence on the changing labor market, focusing on (1) the evolution of physical and intellectual job requirements in the United States over time, (2) women's self-selection into low-strength jobs due to physical hurdles, and (3) the effects of the changing labor demand for physical and intellectual abilities on female and male wage differentials. The general equilibrium model is outlined in Section 1.3, and Section 1.4 provides analytical results of skill-biased technical change on labor demand, labor supply, and wages. Section 1.5 discusses the estimation and calibration procedure, and Section 1.6 presents labor market trends resulting from a linear exogenous skill-biased technical change starting in the 1960s. Lastly, Section 1.7 discusses extending the model to married households, and Section 1.8 concludes.

This study's main contribution is in presenting a theory that simultaneously explains Fact 1, the rise in female employment, and Fact 2, the evolution of the gender wage gap, through a rise in "female-friendly" occupations driven by skill-biased technical change.

1.2 United States Labor Facts

To explore the relationship between the rise in female labor force participation and changes in labor demand, this study focuses on the relative demand and supply of two types of labor inputs: intellect and physical strength. This study starts from the premise that women have, on average, less brawn than men. One well documented sector where women are barred from certain occupations because of physical strength requirements is the military. For example, a "Women Soldiers 'Face Frontline Ban'" (h 30) article notes that starting in 2002 the British military barred women from front-line combat since they failed to pass the required physical test, where, "soldiers under 30 had to carry 20 kg of equipment and their rifle while running a mile and a half in 15 minutes, as well as carrying a colleague for 50 yards." Accepting that women and men have similar levels of brain, men have a comparative advantage in brawn-intensive occupations. However, technological change shifts labor demand toward low-brawn occupations diminishing men's comparative advantage in the labor market.

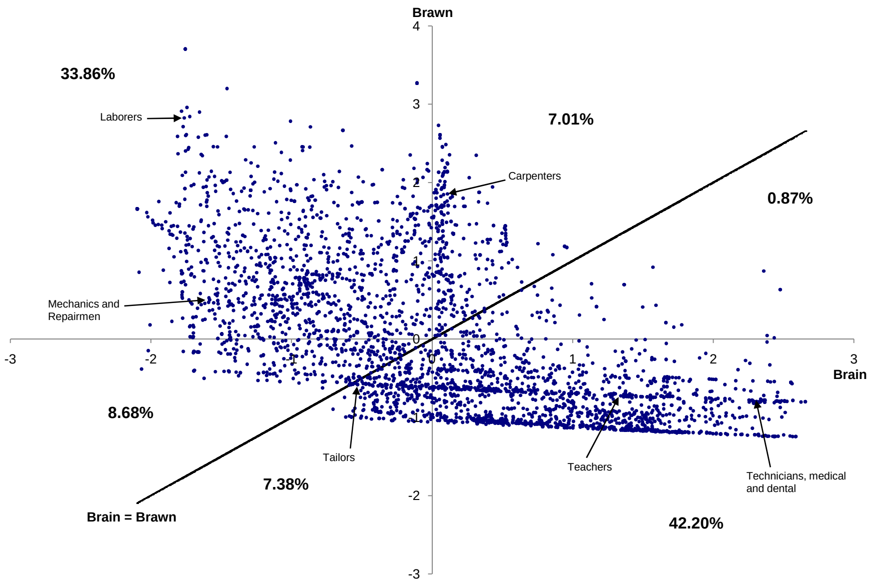
Using factor analysis, I obtain brain and brawn estimates by United States census occupation and industry classifications from the 1977 Dictionary of Occupational Title (DOT). The 1977 DOT reports 38 job characteristics for over 12,000 occupations, documenting (1) general educational development, (2) specific vocational training, (3) aptitudes required of a worker, (4) temperaments or adaptability requirements, (5) physical strength requirements, and (6) environmental conditions. For example, general educational development measures the formal and informal educational attainment required to preform a job effectively by rating reasoning, language and mathematical development. Each reported level is primarily based on curricula taught in the United States, where the highest mathematical level is advanced calculus, and the lowest level only requires basic operations, such as adding and subtracting two-digit numbers. Specific vocational preparation is measured in the number of years a typical employee requires to learn the job tasks essential to perform at an average level. Eleven aptitudes required of a worker (e.g., general intelligence, motor coordination, numerical ability) are rated on a five point scale, with the first level being the top ten percent of the population and the fifth level compromising the bottom ten percent of the population. Ten temperaments required of a worker are reported in the 1977 DOT, where the temperament type is reported without any numerical rating. An example of a temperament is the ability to influence people in their opinions or judgments. Physical requirements include a measure of strength required on the job, rated on a five point scale from sedentary to very heavy, and the presence or absence of tasks such as climbing, reaching, or kneeling. Lastly, environmental conditions measure occupational exposure (presence or absence) to environmental conditions, such as extreme heat, cold, and noise. I use factor analysis similarly to Ingram and Neumann (2006) to reduce the dimensionality of DOT job characteristics. Using factor analysis, a linear relationship between normally distributed broad skill categories (e.g., brain, brawn, motor coordination) and the 38 DOT characteristics is estimated from the associated 38 variable correlation matrix. For a detailed explanation of the estimation procedure see Appendix A.

1.2.1 Brain and Brawn in the United States

Using maximum likelihood estimation methods, three factors are determined sufficient in capturing the information contained in the 38 DOT characteristics. Given the estimated coefficients (factor loadings) I term these factors: brain, brawn, and motor coordination (see Appendix A Table A.1). These factors are merged with the 1950 and 1960 United States Census data and the 1968 to 2005 Current Population Survey (CPS) data to compute trends over time.[2] Figure 1.3, which plots all 1977 occupational brain and brawn combinations, clearly depicts the difference in brain and brawn requirements across the economy. Figure 1.3 also shows aggregate labor shares from the 1971 CPS civilian population. To compute aggregate factor demand changes in the United States over time, 1977 occupation-industry factor estimates are aggregated using United States Census and CPS civilian labor force weights. Figure 1.4 depicts aggregate factor standard deviations from the mean over time, with a normalized mean of zero in 1950. While motor coordination remains fairly constant over time, the brain supply steadily increases and the brawn supply steadily decreases. This rising trend in the supply of brain versus the falling trend in the supply of brawn is what I term skill-biased technical change. These trends are not specific to the 1977 DOT, since Ingram and Neumann (2006) obtain similar trends over time using the 1991 DOT (see Figure 3 in the referenced paper). Note that using a single DOT survey to determine job requirements implies that the specific job factor requirements did not change over the last five decades. For

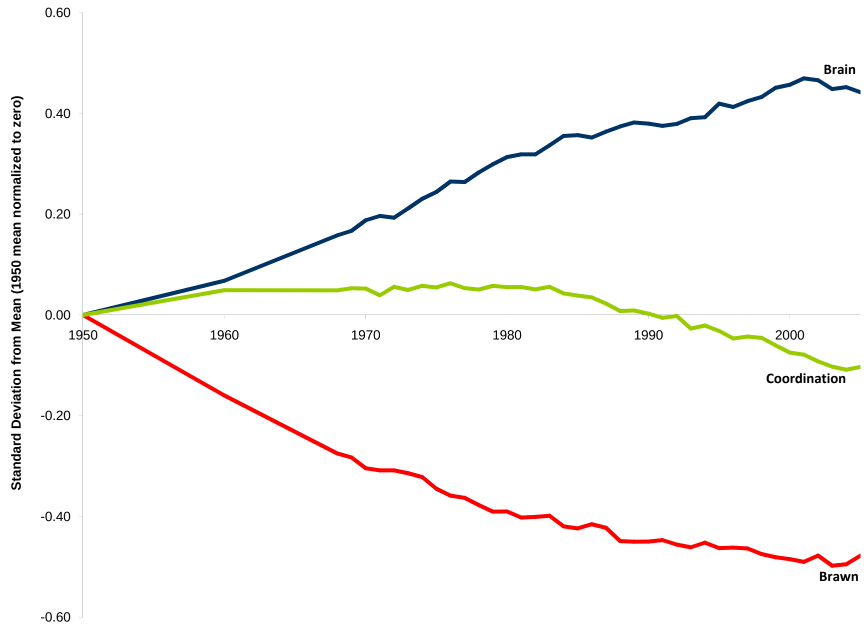
[2]The IPUMS Census and CPS projects provide a consistent 1950 United States Census classification of occupations and industries over the years, which is used in merging 1977 DOT brain and brawn factors.

Figure 1.3: Brain and Brawn Job Combinations from the 1977 DOT with 1971 CPS Labor Shares



example, a craftsman utilized the same brawn level in 1950 as in 2005. Ergo, all trends pictured are due to changes in the composition (mix) of occupations within the economy, and the rise in brain and fall in brawn requirements might possibly be greater than shown due to intra occupation skill-biased technical changes. Figure 1.5 depicts brain and brawn standard deviations by gender over time, with the selection of women into low-brawn occupations clearly evident. Given women's lower innate brawn levels, this bias toward low brawn occupations can be either due to employee self-selection or employer discrimination. Additionally, the total brain supply has risen continuously since the 1950s, with women's brain supply surpassing men's by the 1980s. This trend could possibly be linked with increased educational investment (discussed further in Chapter 2).

Figure 1.4: Standard Deviations of Labor Input Supply over Time



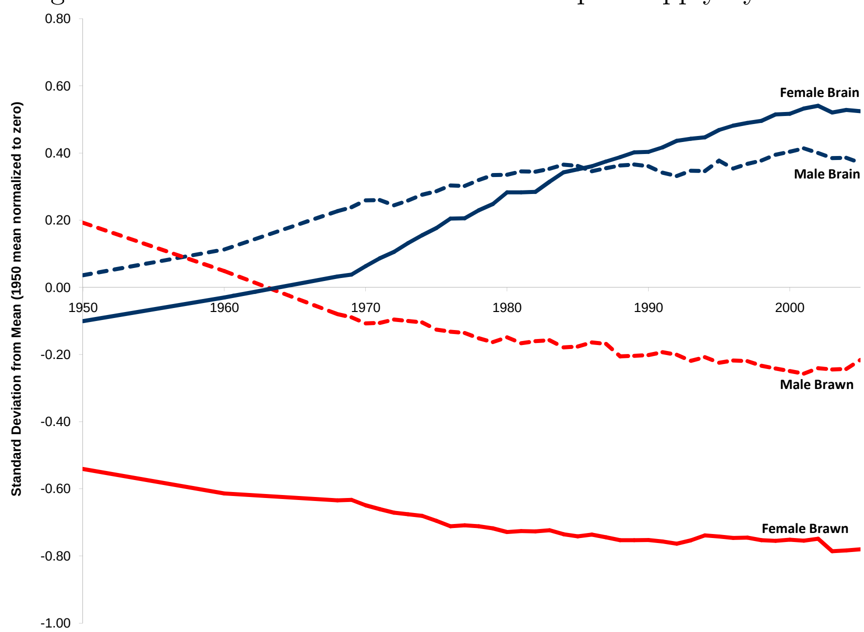
1.2.2 Wage Decomposition

The pictured brain and brawn trends suggest a strong relationship between the rise of female employment and skill-biased technical change. The combined effect of changes in relative factor prices and factor supplies by gender on the wage gap are computed from the following wage decomposition,

$$\begin{aligned}(\overline{w}_{m,T} - \overline{w}_{f,T}) \quad - \quad & (\overline{w}_{m,0} - \overline{w}_{f,0}) = \\ & \sum_j \overline{p}_j \left\{ \left(\overline{F}_{j,m,T} - \overline{F}_{j,m,0}\right) - \left(\overline{F}_{j,f,T} - \overline{F}_{j,f,0}\right) \right\} + \cdots \qquad (1.1) \\ & \sum_j \left(\overline{F}_{j,m} - \overline{F}_{j,f}\right) (p_{j,T} - p_{j,0}) \quad \text{for } j{=}\{brain, brawn\},\end{aligned}$$

where subscript 0 denotes the base year; $\overline{w}_{g,T}$ is the average natural logarithmic wage of gender g at time T; p_j is factor j's return; and $\overline{F}_{j,g}$ is the average sup-

Figure 1.5: Standard Deviation of Labor Input Supply by Gender



ply of factor j by gender g. Variables without time subscripts are averages of the two years, 0 and T. Unlike Black and Spitz-Oener (2007), factor returns are not allowed to vary across gender, since I argue men's and women's wages only differ because of their relative brain and brawn supplies.[3] Average factor demands by gender can be computed from the brain and brawn estimates using United States Census and CPS weights over time. Using standard explanatory variables (e.g., age, education) and an individual's brain, brawn, and motor coordination factor supplies, a log-linear wage regression is estimated to obtain factor returns. The resulting coefficients on brain and brawn are taken as a proxy of factor returns (see

[3] Allowing factor returns to differ by gender results in slightly higher contributions of relative price and supply changes on the evolution of the gender wage gap.

Appendix A, Table A.2 for coefficient estimates). The percentage contribution to movements in the wage gap through changes in relative factor supplies between men and women is captured in the first term of equation (1.1). The second term measures the percentage contribution to movements in the wage gap through changes in factor returns. These "quantity" and "price" percentages, combined, measure the total percentage contribution to changes in the wage gap resulting from skill-biased technical change between period 0 and period T. Table 1.1 provides a breakdown of these contributions for two time periods: 1950 to 1980 and 1980 to 2005.

Table 1.1: Wage Gap Decomposition

Percent Contribution	**1950-1980**[a]	**1980-2005**
Relative Brain Supply	-0.91	13.58
Relative Brain Prices	1.05	2.39
Relative Brawn Supply	11.07	-0.19
Relative Brawn Prices	-47.99	13.42
Total	**-36.79**	**29.20**

Notes: Regression source data 1950 Census and 1980, 2005 CPS.

[a]Wage gap widened during this period

Changes in brain and brawn over time can explain about one-third of the changes in female to male average wages. As the gender wage gap widened from 1950 to 1980 the total contribution was negative, with 37 percent of the widening wage gap mainly explained by rising returns to brawn. During this time period a fall in male brawn supply actually prevented the gap from widening further. From 1980 to 2005, the second period under consideration, the wage gap closed considerably. Relative female to male brain supply growth and falling returns to brawn had approximately equal impacts on the convergence of female to male wages.

Given the above facts, I argue that beginning in the 1950s women entered the labor market and their average wages improved due to the rise of brain-intensive occupations, which complemented women's comparative advantage. The remainder of this chapter is devoted to the development of a model consistent with:

1. The rise of a brain-intensive sector;
2. The rise in women's labor force participation;
3. Rising average female wages primarily driven by brain supply and brawn price changes; and
4. An initial wage gap stagnation.

1.3 General Equilibrium Model

The simulated economy consists of a unit measure of agents,[4] and two types of occupations, one brain-intensive and the other brawn-intensive. The two occupations' outputs are aggregated to a final market good, which is consumed by households. Agents can choose to work in the labor market or the home, and substitute consumption between market and home produced goods.

[4]While the rise in labor force participation was considerably greater for married women, adding married couples does not provided any further dynamics to the model.

1.3.1 Household Maximization

Given evidence on the intensive and extensive margin of labor supply,[5] it is assumed that agents can either work full-time in the labor market or not at all, $\ell_k = \{0, 1\}$ for agent k. Moreover, it is assumed that market and home produced goods are prefect substitutes

$$U(c, c_h) = \ln(c + c_h). \tag{1.2}$$

Agent k maximizes this utility function subject to a standard budget constraint, the home production technology, and a time constraint,

$$c_k \leq \ell_k \omega_k \tag{1.3}$$

$$c_{h,k} = A_h (1 - \ell_k) \tag{1.4}$$

$$\ell_k = \{0, 1\}. \tag{1.5}$$

Agent k can earn the wage $\omega_k = \psi(b_k, r_k)$, a function of his/her innate brain and brawn abilities in the labor market. To determine this functional form it is necessary to first describe the firm's problem. Lastly, given the discrete labor choice, agents work in the labor market if and only if

$$\omega_k > A_h. \tag{1.6}$$

1.3.2 Production Process

There are two types of occupations, a brain-intensive production process, b, and a brawn intensive production process, r. Each production process only uses one

[5]Single employed women worked nearly 40 hours per week in 1950 and slightly less than 40 hours per week in 2005, while married women worked about 38 hours per week both in 1950 and 2005.

of the inputs, brain $B_b \equiv B$ or brawn $R_r \equiv R$, where B and R are the aggregated individual labor supplies of brain and brawn. These brain and brawn units are combined in a CES production function to produce the final market good,

$$Y = \Big(\lambda_b (A_b B)^{\phi} + \lambda_r (A_r R)^{\phi}\Big)^{1/\phi}, \tag{1.7}$$

where A_j is occupation j's factor productivity; $\epsilon_\phi = \frac{1}{1-\phi}$ is the elasticity of substitution between the two occupations; and λ_j is occupation j's production share, with $\lambda_b + \lambda_r = 1$. A change in $\frac{A_b}{A_r}$ over time represents the exogenous skill-biased technical progress.

The relative wage follows from the cost minimization of the final good,

$$w = \frac{w_b}{w_r} = \frac{\lambda_b}{\lambda_r}\left(\frac{A_b}{A_r}\right)^{\phi}\left(\frac{B}{R}\right)^{\phi-1}, \tag{1.8}$$

with w_b and w_r representing the wages for brain and brawn occupations, respectively. The relative wage is a function of relative factor productivity as well as relative quantities supplied. Using equation (1.8), and the aggregate production function (1.7), an occupation's demand of efficiency-units per one unit of aggregate good is,

$$l_j = \frac{L_j}{Y_t} = (A_j)^{\epsilon_\phi - 1}\left(\frac{\lambda_j}{w_j}\right)^{\epsilon_\phi}\left[\lambda_b^{\epsilon_\phi}\left(\frac{A_b}{w_b}\right)^{\epsilon_\phi - 1} + \lambda_r^{\epsilon_\phi}\left(\frac{A_r}{w_r}\right)^{\epsilon_\phi - 1}\right]^{-1/\phi}, \tag{1.9}$$

where L_j equals either B or R, and the term in brackets is the unit cost of the aggregate production.

1.3.3 Wages and the Distribution of Brain and Brawn

We can now explicitly state an agent's wage, ω_k, which is determined by his/her innate brain and brawn ability. From the firm's problem it follows that

$\omega_k = \max\{w_b b_k, w_r r_k\}$. Moreover, brain and brawn are jointly distributed $(b_k, r_k) \sim \mathcal{A}_g(b, r)$ with differing distributions by gender. Since the premise of this study is the lack of women's brawn, the two gender distributions, $\mathcal{A}_m(b, r)$ and $\mathcal{A}_f(b, r)$, only differ in their distribution of brawn, $\mathcal{R}_g$. Consequently, the distribution of brain, $\mathcal{B}$, and the correlation of brain and brawn, ρ, are identical for men and women.

1.3.4 Decentralized Equilibrium

An equilibrium, given wages $\{w_b, w_r\}$, exists and is defined by:

1. The demand for market goods, c_k, the production of household goods, $c_{h,k}$, and the supply of labor, ℓ_k, that maximizes household utility;
2. The demand for labor inputs, B and R, that minimizes the final good's cost function; and
3. Factor returns, $\{w_b, w_r\}$ that clear,

   (a) The labor market, $B_{hh} = B$ and $R_{hh} = R$; and

   (b) The goods market, $C_{hh} = Y$,

   where B_{hh}, R_{hh}, and C_{hh} are aggregate household supply and demand levels obtained by integrating labor demand and market consumption of individuals over the brain and brawn distribution of all working agents.

1.4 Analytical Dynamics

Data presented in Section 1.2 clearly depicts that labor moved away from brawn and toward brain. Any technical change, defined as a change in A_b and

A_r, mimicking the movement from brawn-intensive to brain-intensive occupations must increase the relative demand for the brain-intensive efficiency units of labor. I analyze the changes in labor demand, supply, and wages resulting from a "one time" change in relative factor productivity, $\frac{A_b}{A_r}$. The dynamics of a steady change in relative technology parameters can be simply deduced by allowing this one time change to occur repeatedly, where $A_{j,t} = A_{j,t-1}(1 + \gamma_j)$ with γ_j defined as sector technology growth rates for $j = \{b, r\}$.

1.4.1 Relative Labor Demand

The relative labor demand follows from the unit labor demands in equation (1.9),

$$\frac{B}{R} = \left(\frac{A_b}{A_r}\right)^{\epsilon_\phi - 1} \left(\frac{\lambda_b w_r}{\lambda_r w_b}\right)^{\epsilon_\phi}. \tag{1.10}$$

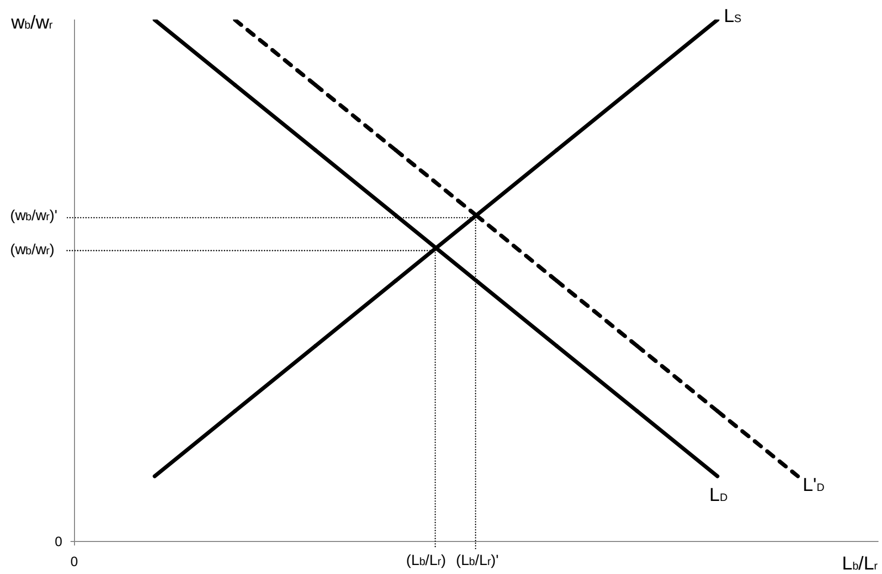
Taking the derivative of this relative demand with respect to $\frac{A_b}{A_r}$, *ceteris paribus*, results in the Proposition 1.4.1.

Proposition 1.4.1. *A rise in relative factor productivity of brain-intensive occupations increases relative labor demand efficiency units if $\epsilon_\phi > 1$, implying the two occupations are substitutes in the aggregate production process, since*

$$\frac{\partial \frac{B}{R}}{\partial \frac{A_b}{A_r}} = (\epsilon_\phi - 1)\left(\frac{A_b}{A_r}\right)^{\epsilon_\phi - 2} \left(\frac{\lambda_b w_r}{\lambda_r w_b}\right)^{\epsilon_\phi}. \tag{1.11}$$

Representing Proposition 1.4.1 graphically (see Figure 1.6), technological change shifts labor demand to the right. Thus, the relative quantity of brain-intensive to brawn-intensive labor efficiency units at any given wage ratio increases, and, as a consequence, the equilibrium wage $\frac{w_b}{w_r}$ rises as long as an outward shift in labor

Figure 1.6: Impact of Technological Change on Labor Demand and Relative Wage



supply does not offset the increase in labor demand. The relative wage equation (1.8) shows that a rise in $\frac{B}{R}$ will offset relative demand increases since $(\phi - 1) < 0$.

1.4.2 Labor Supply Decision

At the equilibrium wage rate, a change in relative factor productivity has no effect on the labor supply threshold $\omega_k > A_h$. Therefore, the relative labor supply does not shift and relative wages rise. However, a rise in the relative wage will change the type of person who enters the labor market, since the effect on ω_k will depend on an agent's innate brain and brawn levels. By normalizing $w_r = 1$, an agent with relatively low brain but high brawn will see no change in his/her labor threshold, while an agent with relatively high brain will experience a rise in

ω_k and, therefore, might change his/her labor supply decision. An agent works in a brain-intensive occupation if and only if

$$\frac{b_k}{r_k} > \frac{w_r}{w_b}. \tag{1.12}$$

To illustrate the effects of a rise in relative wages on the labor supply decision by gender, the following section elaborates on the dynamic effects by assuming two independent uniform distributions for brain and brawn. Brain and brawn are independently uniformly distributed with $B_g \sim [\underline{B}, \overline{B}]$ and $R_g \sim [\underline{R}_g, \overline{R}_g]$ for gender $g = \{m, f\}$, where $\overline{R}_g = \overline{R} + x_g$, $\underline{R}_g = \underline{R} + x_g$, and the only difference between men and women is the mean brawn level, $x_m > x_f \geq 0$.

The gender-specific labor force participation, LFP_g, is defined as,

$$LFP_g = \int^{\frac{A_h}{w_r}} \int_{\frac{A_h}{w_b}} a_g(b, r)\, db\, dr + \int_{\frac{A_h}{w_r}} \int a_g(b, r)\, db\, dr, \tag{1.13}$$

where $a_g(b, r)$ is the joint probability density function. The first term represents all agents that work in brain occupations, given home productivity and wages. The second term represents all remaining working agents, i.e., agents that work in either occupation. To not trivialize the results, it is assumed that $\underline{B} < \frac{A_h}{w_b}$ and $\underline{R}_g < \frac{A_h}{w_r}$, that is, some agents will not work in brain-intensive and/or brawn-intensive occupations. Given these special distributional assumptions, $LFP_m > LFP_f$.

Proposition 1.4.2. *Women are less likely than men to work in the labor market, since*

$$\frac{\partial LFP_g}{\partial x} = \left(\frac{A_h}{w_b} - \underline{B}\right) \frac{1}{\left(\overline{B} - \underline{B}\right)\left(\overline{R} - \underline{R}\right)} > 0. \tag{1.14}$$

Proposition 1.4.3. *As the returns to brain increase, ceteris paribus, the employment gap will shrink, since*

$$\frac{\partial LFP_g}{\partial w_b} = \frac{\frac{A_h}{p_b^2}\left(\frac{A_h}{w_r} - \underline{R}_g\right)}{\left(\overline{R} - \underline{R}\right)\left(\overline{B} - \underline{B}\right)} > 0 \tag{1.15}$$

and

$$\frac{\partial^2 LFP_g}{\partial w_b \partial x} = -\frac{A_h}{w_b^2}\frac{1}{\left(\overline{B} - \underline{B}\right)\left(\overline{R} - \underline{R}\right)} < 0. \tag{1.16}$$

To summarize, increased demand for low-brawn occupations, coupled with their rising returns, leads to a shrinking gender employment gap given women's comparative advantage in brain.

1.4.3 Wage Gap Evolution

The wage gap is defined as average female to average male wages in terms of average factor supplies to each occupation,

$$\frac{\overline{w}_f}{\overline{w}_m} = \frac{\pi_f w \overline{B}_f + (1-\pi_f)\overline{R}_f}{\pi_m w \overline{B}_m + (1-\pi_m)\overline{R}_m}, \tag{1.17}$$

where $\overline{B}_g$ is the average brain level conditional on the working population of gender g in brain occupations, $E\left(b_{g,k} \mid \frac{b_{g,k}}{r_{g,k}} > \frac{w_r}{w_b} \wedge \omega_{g,k} > A_h\right)$. Similarly, $\overline{R}_g$ is the average brawn conditional on the working population of gender g in brawn occupations, π_g is the fraction of working agents of gender g working in brain-intensive occupations, and $w = \frac{w_b}{w_r}$ is the relative wage.

There are two opposing effects shaping the evolution of the wage gap, a "price effect" and a "supply effect."

Proposition 1.4.4. *A rise in the relative wage results in a closing wage gap if*

$$\frac{\pi_f}{1-\pi_f}\frac{\overline{B}_f}{\overline{R}_f} > \frac{\pi_m}{1-\pi_m}\frac{\overline{B}_m}{\overline{R}_m}. \tag{1.18}$$

Thus, Proposition 1.4.4 holds if a greater fraction of women work in brain-intensive occupations and their average relative brain to brawn efficiency-unit labor supply is relatively higher than men's, which I call the price effect. However, this ignores any self-selection bias.

A rise in w_b raises wages for agents with relatively high brain to brawn ability levels. Moreover, a rise in w_b, *ceteris paribus*, also enables agents with a comparative advantage in brain, but lower brain ability compared to the working population, to enter the labor market. Consequently, the average brain supply, $\overline{B}_g$, in the labor market may fall with a rise in relative wages. The fall in average brain supply, however, will be greater for women than men. This second supply effect can be illustrated by returning to the simplified example of the uniform distributions. The sector specific labor force participation is simply,

$$\pi_g = \frac{\int^{\frac{A_h}{w_r}} \int_{\frac{A_h}{w_b}} a_g(b,r)\, db\, dr + \int_{\frac{A_h}{w_r}} \int_{\frac{w_r}{w_b} r_{g,k}} a_g(b,r)\, db\, dr}{LPF_g}. \tag{1.19}$$

The mean brain and brawn levels of gender g equal,

$$\overline{B}_g = \frac{\int^{\frac{A_h}{w_r}} \int_{\frac{A_h}{w_b}} b_{g,k} a_g(b,r)\, db\, dr + \int_{\frac{A_h}{w_r}} \int_{\frac{w_r}{w_b} r_{g,k}} b_{g,k} a_g(b,r)\, db\, dr}{\int^{\frac{A_h}{w_r}} \int_{\frac{A_h}{w_b}} a_g(b,r)\, db\, dr + \int_{\frac{A_h}{w_r}} \int_{\frac{w_r}{w_b} r_{g,k}} a_g(b,r)\, db\, dr} \tag{1.20}$$

and

$$\overline{R}_g = \frac{\int_{\frac{A_h}{w_r}} \int^{\frac{w_r}{w_b} r_{g,k}} r_{g,k} a_g(b,r)\, db\, dr}{\int_{\frac{A_h}{w_r}} \int^{\frac{w_r}{w_b} r_{g,k}} a_g(b,r)\, db\, dr}, \tag{1.21}$$

respectively. Using these identities, the gender wage gap can be written as,

$$\frac{\overline{w}_f}{\overline{w}_m} = \frac{w\frac{B_f}{LFP_f} + \frac{R_f}{LFP_f}}{w\frac{B_m}{LFP_m} + \frac{R_m}{LFP_m}}, \tag{1.22}$$

where B_g and R_g equal the numerator of the conditional expectations, which are the total brain and brawn supplies by gender g.

Given the distributions of brawn, that is, men's higher average brawn levels ($x_m > x_f$), the total brawn supply of men is greater than that of women ($R_m > R_f$) as long as some agents prefer to work in the brawn-intensive sector ($w_r\overline{R}_g > w_b\underline{B}$). Similarly, the total brain supply is greater for women than men as long as some agents prefer to work in the brawn-intensive sector than stay at home ($w_r\overline{R}_g > A_h$). More importantly, a rise in the returns to brain-intensive occupations will have a different effect on the average brain supplied by each gender, $\frac{B_g}{LPF_g}$.

Proposition 1.4.5. *A rise in the relative wage results in a stagnant/widening wage gap when*

$$\frac{\partial B_f/LFP_f}{\partial w_b} < \frac{\partial B_m/LFP_m}{\partial w_b}. \tag{1.23}$$

More specifically,

$$\begin{aligned}\frac{\partial B_g/LFP_g}{\partial w_b} \quad &= \quad \frac{1}{LFP_g^2}\left(\frac{1}{3}\frac{w_r^2}{w_b^3}\left(\overline{R}_g^3 - \left(\frac{A_h}{w_b}\right)^3\right)LFP_g + \cdots\right. \\ &\qquad \left.\frac{A_h}{w_b^2}\left(\frac{A_h}{w_r} - \underline{R}_g\right)\left(\frac{A_h}{w_b}LFP_g - B_g\right)\right),\end{aligned} \tag{1.24}$$

where all terms are positive except for the last term, $\frac{A_h}{w_b}LFP_g - B_g$, which can be positive or negative. Since $LFP_f < LFP_m$ and $B_f > B_m$ from above, this last term, which potentially slows the growth in the conditional mean brain supply, is smaller or negative for women compared to men. However, as women's and men's total and sectoral-specific labor force participation rates converge over time, this term will take the same value for men and women.

In summary, the price effect will close the wage gap, while the supply effect will widen the wage gap. The supply effect will dominate when women's labor force participation is considerably lower than men's, but will slowly disappear as these labor force participation rates converge. The natural evolution of these effects will initially cause a fall, or stagnation, of average female to male wages, which will close as the price effect begins to dominate.

These analytical results suggest that a model differentiating between brain-intensive and brawn-intensive jobs should replicate the initial United States employment and wage differences across gender. Moreover, it should reproduce the subsequent evolution of the female labor force participation rate and the gender wage gap, including some initial stagnation in average female wages as observed during the 1960s and 1970s.

1.4.4 Simulation Model Modifications

Two model modifications are introduced to match relevant United States data targets in the calibration. First, brain-intensive and brawn-intensive occupations utilize both input factors in linear combinations. Therefore, agents' efficiency wages are

$$\omega_k = \max\{w_b(\alpha_b b_k + (1-\alpha_b)r_k), w_r(\alpha_r b_k + (1-\alpha_r)r_k)\}, \tag{1.25}$$

where $\alpha_b > \alpha_r$. For the simplified example from Section 1.4.2, equation (1.25) implies $\alpha_b = 1$ and $\alpha_r = 0$. Linearity in brain and brawn inputs allows the aggregation of individual labor efficiency units by occupation,

$$L_j = \alpha_j B_j + (1 - \alpha_j) R_j, \quad \text{for } j = \{b, r\}. \tag{1.26}$$

An agent chooses to work in a brawn-intensive occupation if and only if

$$\frac{b_k}{r_k} \frac{w_b \alpha_b - w_r \alpha_r}{w_r(1 - \alpha_r) - w_b(1 - \alpha_b)} > 1. \tag{1.27}$$

The numerator is the difference in potential earnings of his/her brain ability between brain and brawn occupations, and the denominator is the difference in potential earnings between his/her brawn ability in brawn to brain occupations. If this ratio is greater than one, i.e., the additional returns to brain in brain-intensive occupations are greater than the additional returns to brawn in brawn-intensive occupations, the agent chooses to work in a brain occupation.

The second modification extends the model with an education choice allowing agents to increase their innate brain level. This modification enables the model to match the observed trend in brain supply in the United States more precisely (see Figure 1.4). Finitely lived myopic agents can choose to become educated when young at a cost of b^{η}, where $\eta < 0$. Education increases an agents brain endowment to B_e, such that all educated agents have the same brain level. However, education is cheaper for agents with initially higher levels of brain. Given the myopic nature of agents, agent k who lives N periods chooses to become educated when,

$$\begin{aligned}
\frac{1-\beta^N}{1-\beta} \quad & \max\{\ln(\max\{w_b(\alpha_b B_e + (1-\alpha_b)r_k), \\
& w_r(\alpha_r B_e + (1-\alpha_r)r_k)\}), \ln(A_h)\} - b_k^{\eta} \\
& > \\
\frac{1-\beta^N}{1-\beta} \quad & \max\{\ln(\max\{w_b(\alpha_b b_k + (1-\alpha_b)r_k), \\
& w_r(\alpha_r b_k + (1-\alpha_r)r_k)\}), \ln(A_h)\},
\end{aligned} \tag{1.28}$$

where β is the discount factor. The first line of equation (1.28) represents the lifetime utility of being educated, and the second line defines the lifetime utility of being uneducated. Since agents with high brawn, who prefer to work in brawn-intensive occupations, have less to gain from education, equation (1.28) is less likely to hold. In the context of this study, where men have on average higher brawn levels than women, fewer men will obtain education. As a consequence, average female brain supply, $\overline{B}_f$, surpasses average male brain supply, $\overline{B}_m$, once the returns to brain are sufficiently high to compensate for the cost of education. This is consistent with the United States brain supply trends (see Figure 1.5), where women's average brain supply exceeds men's average brain supply by the end of the 1980s. Therefore, in addition to the price effect, the "education effect" also contributes to the closing gender wage gap once the supply effect subsides.

1.5 Calibration

Simulating the model over time requires the calibration of individuals' brain and brawn distributions, and several household and production parameters. Given the pronounced hump-shape in the wage gap between 1940 and 1960, possibly due to the effects of World War II, the model is matched to various 1960 data targets.

1.5.1 Production Parameter Estimation

To determine the production parameters, A_b and A_r, their growth rates, γ_b and γ_r, and the substitution parameter, ϕ, the regression of Katz and Murphy (1992, pg. 69) is reestimated, where skilled labor is defined as brain-intensive labor and unskilled labor is defined as brawn-intensive labor. Occupations are sorted by their relative brain to brawn inputs in such a way that occupations with $b > r$ are brain-intensive and occupations with $b < r$ are brawn-intensive (see Figure 1.3). Full-time workers[6] are grouped according to their age group (eight five-year intervals from 25 to 64 years old), gender, education (less than high school, high school, some college, college), race (white, black, other), marital status (married, single), sector (industry, services), and the type of occupation (brain-intensive, brawn-intensive). I follow Hansen (1993) in estimating labor efficiency units at time t as

$$E_t = \sum_k \delta_k L_{t,k}, \tag{1.29}$$

where $L_{t,k}$ is the total labor supply of group k and δ_k is the group's weight. Weights are determined by

$$\delta_k = \frac{\overline{\omega}_k}{\overline{\omega}}, \tag{1.30}$$

the average hourly wage of group k over the average hourly wage of the whole population (across individuals over the entire time period). The resulting relative

[6]Full-time workers are defined as working at least 39 weeks and 35 hours per week (prior to 1976 only hours worked prior to the survey week are recorded).

unit wage of brain over brawn and relative efficiency unit labor supply is shown in Figure 1.2. This study assumes a log-linear skill-biased technical change over time,

$$\ln\left(\frac{A_b}{A_r}\right)_t = \zeta_0 + \zeta_1 t + \eta_t, \tag{1.31}$$

as in Krusell et al. (1997). Taking the natural logarithm of the relative wage equation (1.8), and inserting equation (1.31), leads to the following regression estimation,

$$\ln\left(\frac{w_b}{w_r}\right)_t = a_0 + a_1 t + a_2 \ln\left(\frac{E_b}{E_r}\right)_t, \tag{1.32}$$

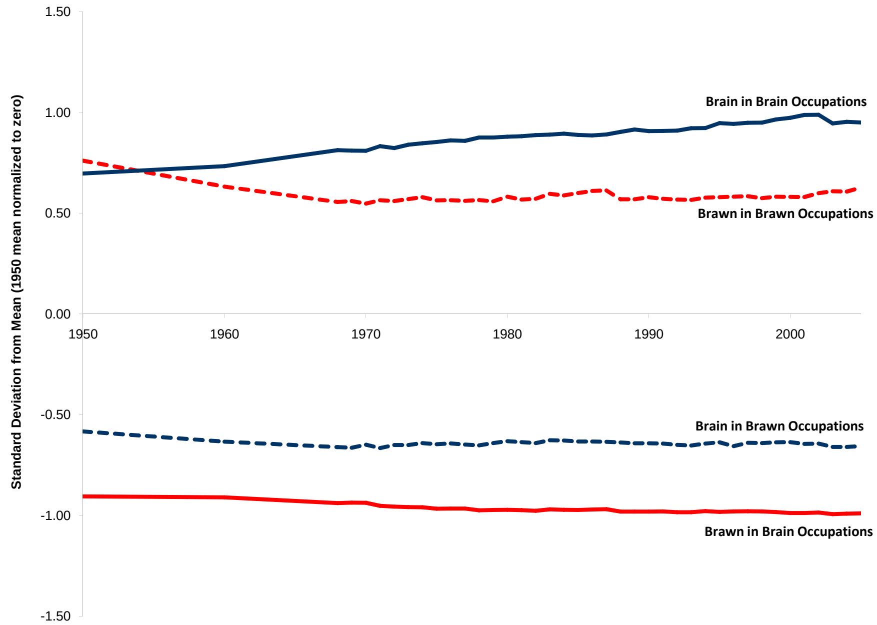
where $a_0 = \ln\left(\frac{\lambda_b}{\lambda_r}\right) + \phi\zeta_0$, $a_1 = \phi\zeta_1$, $a_2 = \phi - 1$, and $\frac{E_b}{E_r}$ is the relative efficiency unit of brain-intensive to brawn-intensive occupations. Table A.3 in Appendix A provides the regression estimates. By normalizing ζ_0 to zero, the parameter values of the annual skill-biased technical change growth rate, $\gamma_b - \gamma_r$, and the substitution parameter, ϕ, are obtained (see Table 1.2).

Table 1.2: Baseline Parameters

Production Parameters		
Substitution Parameter	ϕ	0.6032
Difference in Annual Relative TFP Growth Rate	$\gamma_b - \gamma_r$	0.0147

Additionally, the relative factor productivity, $\frac{A_b}{A_r}$, is normalized to one in 1960 and λ_b is set to match the 1960 labor share of brain-intensive occupations in the economy, which is about 51 percent. Lastly, the productivity parameters within occupations, α_b and α_r, are matched to brain and brawn standard deviations in 1960 for each

Figure 1.7: Factor Standard Deviations by Occupations Type



occupation (see Figure 1.7), together with the remainder of the parameters determining the distribution of brain and brawn of all individuals (see Section 1.5.2). The fairly steady brain and brawn standard deviations over time suggest that the grouping of occupations is fairly robust over time and appropriate for the simulation exercise.[7]

1.5.2 Agents' Ability

Brain and brawn are assumed to be joint normally distributed with correlation ρ. This assumption requires six parameter estimates: the mean of brain, μ_b;

[7]Other statistics (e.g., standard deviation, minimum, maximum) of this specific occupational classification are also fairly steady over time.

the standard deviation of brain, σ_b; the two means of brawn, $\mu_{r,m}$ and $\mu_{r,f}$; the standard deviation of brawn, σ_r; and the correlation, ρ. Nine data targets are selected to match nine parameters - the six parameters above, plus α_b and α_r from Section 1.5.1, and home productivity, A_h. The specific 1960 United States data targets are:

1. Female labor force participation;
2. Standard deviation of male brain supply;
3. Standard deviation of female brain supply;
4. Standard deviation of male brawn supply;
5. Standard deviation of female brawn supply;
6. Standard deviation of the brain-intensive occupation's brain supply;
7. Standard deviation of the brain-intensive occupation's brawn supply;
8. Standard deviation of the brawn-intensive occupation's brain supply; and
9. Standard deviation of the brawn-intensive occupation's brawn supply.

The standard deviations of brain and brawn by occupation provide a good representation of the economy. The standard deviations of male and female brain and brawn measure the main differences between gender in this study, i.e., women's lower brawn supplies, and men's and women's similar brain endowments. Lastly, η and B_e are matched to the difference in the standard deviations of female to male brain in 2005 and the difference in female to male brain-intensive labor shares in

2005. Both these measures, combined with the 1960 data targets, provide valuable information on the differences between men's and women's brain supply over time.

Parameters are obtained from preforming simulated annealing. To check the robustness of the estimates, the calibration is repeated numerous times with different initial parameter values chosen randomly from a grid of plausible values. The labor market trends discussed below are robust to all calibrations.

1.5.3 1960 Model Moments and Calibrated Parameters

Before analyzing the resulting employment and wage trends, Table 1.3 provides the parameter estimates and specific data targets of the calibration.

Table 1.3: Moments and Parameter Estimates

Moment	**1960s Data**	**Model**	**Parameters**
Brain Occupation Labor Share	0.51	0.48	$\lambda_b = 0.47$
Women Labor Force Participation	0.4	0.31	$A_h = 1.54$
Female Brain Std. Dev.	-0.03	-0.04	$\mu_b = 2.70$
Male Brain Std. Dev.	0.11	0.02	$\mu_{r,m} = 2.29$
Female Brawn Std. Dev.	-0.61	-0.61	$\mu_{r,f} = 0.76$
Male Brawn Std. Dev.	0.05	0.19	$\sigma_b = 2.03$
Brawn-intensive Occupation's Brain Std. Dev.	-0.63	-0.63	$\sigma_r = 1.03$
Brain-intensive Occupation's Brain Std. Dev.	0.73	0.71	$\rho = -0.98$
Brawn-intensive Occupation's Brawn Std. Dev.	0.63	0.63	$\alpha_b = 0.47$
Brain-intensive Occupation's Brawn Std. Dev.	-0.91	-0.91	$\alpha_r = 0.24$

The model closely matches the brain and brawn standard deviations for both occupations and women. While men's brain and brawn levels are not matched, this calibration still captures the differences between men and women. That is, women supply considerably less brawn, but similar brain. The model is unable to match the initial female labor force participation, underestimating it by nine percentage points. However, the model is able to generate a large difference in average female to male wages, where women earn about 66 percent of men's wages (four percentage points higher than in the data). Note that the wage gap is not a data target in the calibration.

1.6 Main Results

The results presented in this section show that the mechanism highlighted in this study does well in matching rising female employment rates in the United States. Moreover, the estimated growth rate difference between brain and brawn-intensive occupations, $\gamma_b - \gamma_r = 0.0147$, does extremely well in matching the rise in brain-intensive labor shares, not only for the economy as a whole, but also for men and women (see Figure 1.8, where dashed lines are the simulated labor share trends). In addition, the base model with education matches both the shape and magnitude of the wage gap from 1960 to 2005. In contrast, the counterfactual model without education is unable to match the wage gap evolution beyond the period of stagnant average female to male wages.

1.6.1 Simulated Employment and Wage Gap Trends

This model generates a linear rise in female labor force participation. Table 1.4 provides 1960 and 2005 labor force participation rates for women from the base model and the counterfactual model without education.

Figure 1.8: Simulated Brain-intensive Occupation Shares

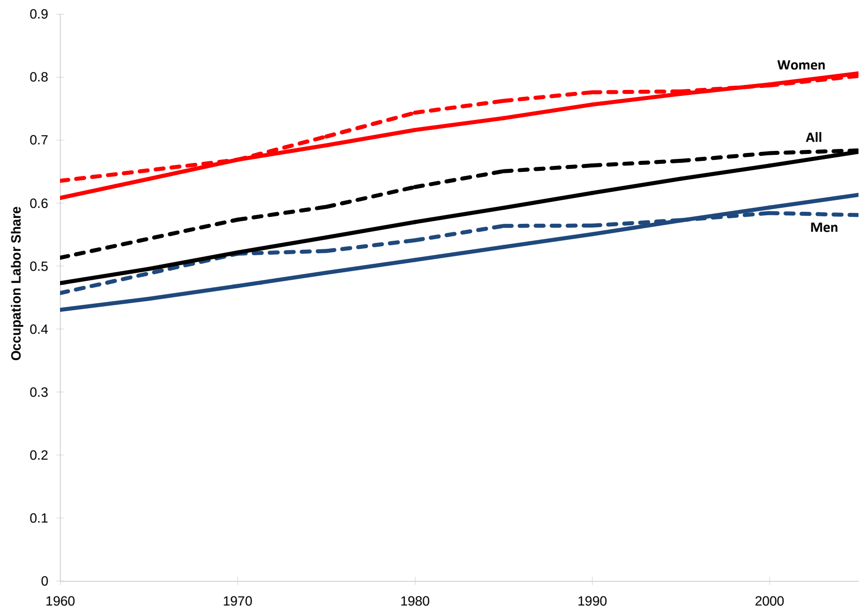
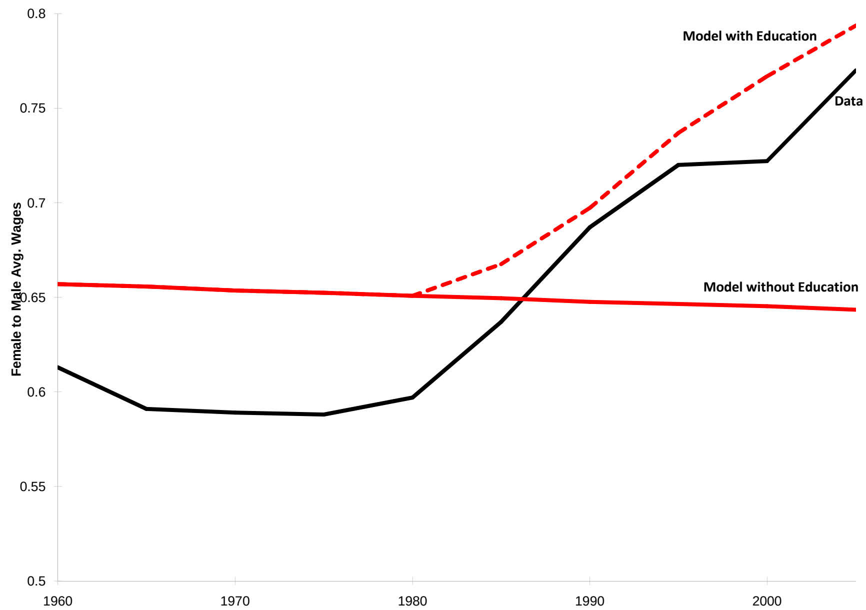


Table 1.4: Change in Women's Labor Force Participation

	United States (%)	**Base Model** (%)	**Counterfactual Model** (%)
1960	40.12	31.37	31.37
2005	71.39	56.10	54.85
Percent Explained		79.12	75.11

Both the base model and the model without education generate a large linear rise in female labor force participation, explaining about 75 to 79 percent of the total rise observed in the data. The rise in labor force participation is almost identical across the two models, suggesting that the rise in the returns to brain, rather than the modeled educational choice, is the primary driving force behind women's labor

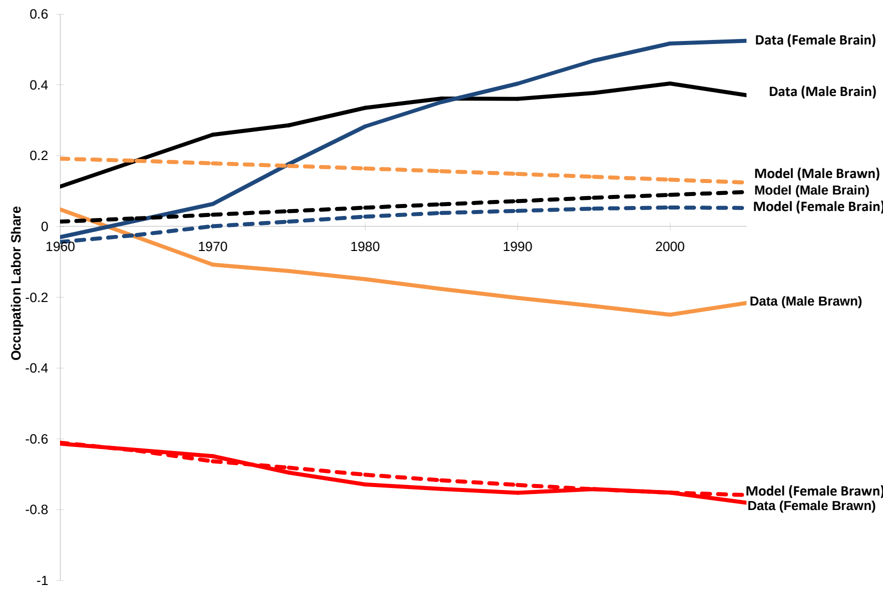
Figure 1.9: Simulated Wage Gap



force participation. Men's labor force participation is 100 percent in the model economy, in comparison to United States male labor force participation rates of 92 percent and 87 percent in 1960 and 2005, respectively.

The wage gap evolution, however, differs considerably between the two models. In the counterfactual model the supply effect dominates throughout the entire period, resulting in a virtually flat wage gap (see Figure 1.9). A large fraction of the stagnant wage gap in the counterfactual model is driven by the fact that women's average brain supply does not surpass men's average brain supply. Figure 1.10 shows female and male brain and brawn supply standard deviations over time. Although women's brain supply eventually exceeds that of men in the data, the model without education is unable to generate this effect. Therefore, I calibrate the base model

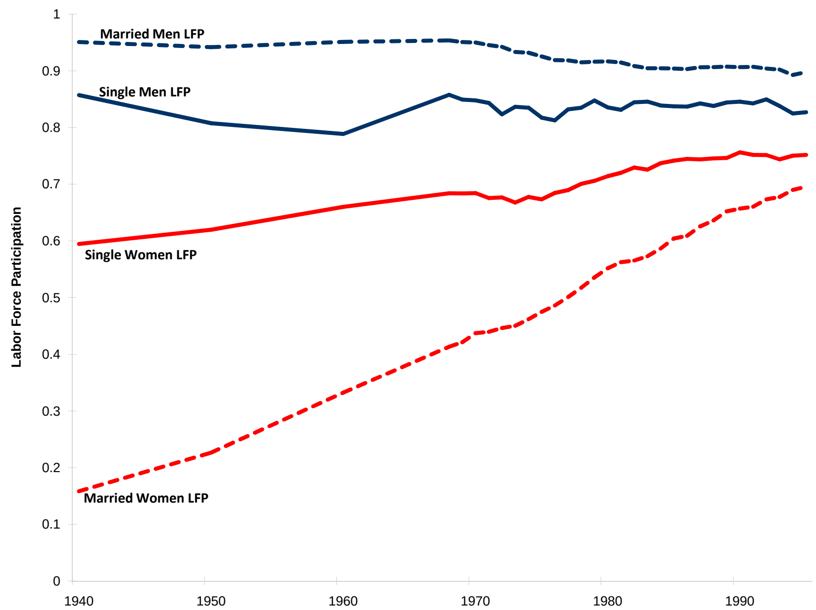
Figure 1.10: Simulated Standard Deviation of Labor Input Supply by Gender



with education to match the difference between men's and women's 2005 brain standard deviations. That is, given women's comparative advantage in brain, women are more likely to increase their educational investment once the returns to brain rise. As a consequence, women eventually surpass men in average brain supplies.

From the 1960s to the 1980s the model with education perfectly parallels the counterfactual model (see Figure 1.9), with both models producing virtually stagnant gender wage ratios. The models generate a 0.6 percentage point decrease in average female to male wages during these three decades, compared to a 1.6 percentage point fall in the data. Therefore, about 38 percent of the fall in the United States female to male wage ratio is explained by the models. However, starting around 1980, the base model is able to simulate most of the closing gender

Figure 1.11: Labor Force Participation by Gender and Marital Status



wage gap observed in the United States. The base model generates a rise of 14 percentage points in average female to male wages from 1980 to 2005, compared to a 17 percentage point increase in the data, thus replicating about 83 percent of the closing wage gap during this time period. The model with education generates a closing wage gap through its ability to match the faster relative rise in female brain supply, which ultimately exceeds men's average brain supply by about 0.15 standard deviations in 2005.

1.7 Extension: Married Households

I have, thus far, ignored addressing differences in married versus single women's labor force participation (see Figure 1.11). To model differences in labor force participation between single and married households, the assumption of perfect substitution between market and home production must be relaxed. If households maximize a CES utility function, where market and home goods are gross substitutes, the labor threshold, $\omega_g > T_\ell(A_h)$, will differ across married and single households. The single household's labor supply decision is identical to Section 1.3 assuming a discrete labor choice. Therefore, $\omega_g > A_h$ still determines a single agent's decision to work or stay at home. A married household, however, now has the following utility function

$$U(c, c_h) = \ln\left((c^\nu + c_h^\nu)^{1/\nu}\right), \tag{1.33}$$

where the substitution between market and home goods equals $\epsilon_\nu = \frac{1}{1-\nu}$. In a static environment, married household k maximizes this utility function subject to the budget constraint, household production function, and time constraints,

$$\max_{\{c_k, c_{h,k}, \ell_{f,k}, \ell_{m,k}\}} \quad U(c_k, c_{h,k}) \tag{1.34}$$

$$s.t.$$

$$c_k \leq \ell_{f,k}\omega_{f,k} + \ell_{m,k}\omega_{m,k}, \tag{1.35}$$

$$c_{h,k} = A_h \left(1 - \ell_{f,k} + 1 - \ell_{m,k}\right) \tag{1.36}$$

$$\ell_{f,k} = \{0, 1\} \text{ and } \ell_{m,k} = \{0, 1\}. \tag{1.37}$$

With perfect substitution in home production, households specialize with the higher wage earner, $\omega_{1,k} \geq \omega_{2,k}$, entering the labor market first. In households with equal wage rates the primary worker is assumed to be male, $1 \equiv m$. The primary wage earner of household k works in the market if and only if

$$\omega_{1,k} > A_h \left(2^\nu - 1\right)^{1/\nu}.^8 \tag{1.38}$$

The secondary wage earner enters the market if and only if the above condition is satisfied in addition to

$$\omega_{2,k} > \left(\omega_{1,k}^\nu + A_h^\nu\right)^{1/\nu} - \omega_{1,k}. \tag{1.39}$$

That is, the secondary agent's labor supply decision is also dependent on his/her spouse's wage. The higher a spouse's wage the less likely the secondary worker is to enter the labor market due to imperfect substitution between market and home consumption. Formally, the derivate of the right hand side with respect to $\omega_{1,k}$ is

$$\omega_{1,k}^{\nu-1} \left(\omega_{1,k}^\nu + A_h^\nu\right)^{1/\nu-1} - 1, \tag{1.40}$$

which is positive as long as $A_h > 0$. This dependence on spousal wages incentivizes married women to stay at home unless their wages are very attractive. However, the general mechanism behind the closing wage and employment gaps will not change. Due to the computational burden of calibrating the married household model, I leave this extension for future research. Moreover, there is little evidence about the appropriate matching function of brain and brawn abilities between spouses, except for some evidence of assortive matching in educational attainment.

---

[8]Note this is similar to the single agent's labor supply threshold, except for a scaling factor of $(2^\nu - 1)^{1/\nu}$.

1.8 Conclusion

The purpose of this study is to assess the importance of labor demand changes on women's labor force participation and wages. For proper policy development, it is necessary to establish the extent to which the female labor market experience has been shaped by discrimination or other factors. This study focuses on the changes in occupational brain and brawn input requirements, and their effect on women's labor force participation and average wages. A considerable rise in brain and fall in brawn requirements is estimated from the 1977 DOT. Preliminary time trends and wage regression estimates suggest these labor demand changes have had a sizable impact on women's wages and employment. Using a Mincer-type wage regression to estimate brain and brawn factor returns, I find the fall in relative brawn prices and the rise in female to male brain supplies to explain about 30 percent of both the initial stagnation and later rise of the post-World War II United States wage gap. The simulation of the general equilibrium model provides further insight into the dynamics of these labor demand changes, and their quantitative impact on women's labor force participation and the closing wage gap. Calibrating the model to the 1960s United States economy shows that skill-biased technical change is able to replicate about 79 percent of the rise in female labor force participation. While the model without education is unable to generate a closing wage gap, the base model with an educational choice is able to generate a similar trend as observed in the data. This model explains about 37 percent of the initial fall and 83 percent of the later rise in the female to male wage ratio.

Clearly, the simple model presented in this chapter, abstracting from many other potential factors influencing men's and women's labor market experiences, is unable to explain the complete evolution of the labor market over the last five decades. While this model is successful in explaining a significant portion of the changes in women's labor market experience, it fails to match certain aspects of men's labor market experience.

Some questions remain for future research. This study does not differentiate between married and single households. While theory suggests the general trends will still hold for a model differentiating between married and single households, I would like to quantify the explanatory power of a model accounting for marriage. Secondly, the model has made some simplifying assumptions, such as modeling skill-biased technical change as an exogenous process. The next research step is endogenizing this process by developing a model where the entrance of women into the labor force possibly spurs the skill-biased technological change observed in the data. Moreover, the educational choice in this study is very simplistic. A more realistic and richer educational investment choice over an agent's lifetime should be of interest. Lastly, the model calibrated to the 1960s United States economy is unable to match men's declining brawn supply, suggesting the above model should be modified to better match this trend.

Chapter 2

Emancipation through Education

This chapter argues for a strong link between the rise in the proportion of educated women and the evolution of the marriage and divorce rates since mid-century. As women become increasingly educated their bargaining power within marriage rises and their economic situation in singlehood improves, making marriage less attractive and divorce more attractive. Similarly, a change in the divorce regime (e.g. unilateral divorce laws in the 1970s), making marriages less stable, incentivizes women to seek education as insurance against the higher divorce risk. A framework that models the interdependence between education, marriage and divorce is developed, simulated, and contrasted against United States data evidence.[1]

2.1 Introduction

Most countries have seen a rise in educational investment, a rise in women's labor force participation, and a rise in divorce rates in conjunction with fall in marriage rate over the last five decades. According to estimates by Goldin et al. (2006), the discrepancy between male and female college enrollment reached 2.3 men to 1 woman attending college in 1947. However, since 1947, the proportion of women enrolling in college has risen continuously compared to men. In 1950, 24 percent of

[1]The material in this chapter is based on an ongoing joint project with Fatih Guvenen.

men aged 25 to 30 had some college education, compared to 18 percent of women, implying a ratio of 1.3; in 2000, these number were 55 percent, 61 percent, and 0.9, respectively; and by the mid-1980s the gender education gap of men and women with at least some college education had disappeared.[2] González and Viitanen (2006) find that almost all European countries had divorce rates below 2.5 divorces per 1,000 married people in 1960, including many with less than one. But by 2002, most of Europe experienced five or more divorces per 1,000 married people. Similarly, divorce rates in the United States doubled from roughly 10 divorces per 1,000 married women in 1950 to about 19 by 2000. Lastly, McGrattan and Rogerson (1998) find that age 35 to 54 married women's average weekly hours worked rose from less than 10 hours in 1950 to over 25 hours at the end of the century, while hours worked remained fairly steady for men and single women.

Given the rise in the college wage premium during the second half of the 20th century, the rise in the proportion of women seeking some college education is a natural response. However, women's wages and labor force participation rates are still lower than men's for all education levels, and as a consequence, the reversal of the education gap can be puzzling.

In this chapter we argue that a shift in labor and marriage markets had large effects on women's college enrollment, and at the same time women's educational investments had large effects on labor and marriage markets. A framework is developed that simultaneously models the interdependent relationship of three

[2]Sources: 1950 United States Census Integrated Public Use Micro-data Samples (IPUMS-USA, Ruggles et al., 2004) and 2000 Current Population Survey Integrated Public Use Micro-data Samples (IPUMS-CPS, King et al., 2004)

life choices: education, work, and marriage/divorce. The main focus is the additional benefit of education as a form of insurance in an economy with increasing divorce risks. An overlapping generations model is proposed, where agents make intratemporal labor decisions, intertemporal marital decisions and a one-time education decision when young. There are four types of agents, who differ in gender (men and women) and education (some college or none). In marriage agents consume a public good and an additional utility from love. When love turns "bad" agents can divorce. However, who has the final say in dissolving the marriage depends on the divorce regime (consent or unilateral). Under consent divorce laws the lower earning spouse is protect from involuntary marriage dissolution. There is no monetary divorce cost, however, upon divorce, an individual remains single for one period, while a single individual meets one potential spouse each period.

In the context of the model, the effects of a rise in the college wage premium and the effects of a switch in divorce laws, from consent divorce to unilateral divorce, are analyzed. A rise in the college wage premium results in a higher fraction of educated women, higher labor force participation and a rise in the divorce probability under consent divorce laws and a fall under unilateral divorce laws. The effects of a rise in the wage premium on marriage rates is ambiguous, since higher earning women are less likely to marry, but men prefer to marry higher earning spouses. A switch in divorce laws leads to an initial jump in the divorce rate, but a later decline, since marriages that are entered into under unilateral divorce laws are "better" (selection effect). Moreover, with a switch to unilateral divorce laws, the risk of divorce rises, and women obtain more education in an effort to insure themselves against the possible adverse effect of a divorce. These analytical implications of the model are consistent with empirical findings, for example Keeley (1977) finds that high earning men marry early in life, while high earning women marry late. Weiss and Willis (1997) find that an unexpected positive shock to earnings capacity makes the marriage more stable if it affects the husband's earnings and less stable if it affects the wife's earnings.

Cvrcek (2007) argues that woman's household role first changed in the late 19th and early 20th century. During this time period fertility fell, marriage first declined and then rose again, and women became an increasing presence in the labor market, first as single and later as married women. In the last five decades another significant reversal in woman's household role took place with a rise in education and divorce.

In explaining the reversal in the education gap, previous research has focused on higher female returns to education in marriage. For example, Peña (2007) reproduces the evolution of the education trends by modeling returns to education in marriage. Women obtain higher returns to education in the marriage market, since the gender ratio is tipped toward women, who, therefore, compete for men in the marriage market. Consequently, even though women receive lower returns to education in the labor market, they invest more in education as they compete for a "better" spouse. Lafortune (2008) studies the effects of gender imbalances on pre-martial schooling investment within immigrant populations in the late 19th and early 20th century obtaining similar results. Chiappori et al. (2006) argue that the smaller gender wage gap for higher education levels, combined with the fall in household labor hours, can explain women's higher educational attainment. Mulligan and Rubinstein (2005) provide empirical evidence of a smaller education gap for highly educated women, with advanced college degrees. Lastly, Ríos-Rull and Sañchez-Marcos (2002) develop a model to account for the gender education gap prior to the 1970s, where the gap can best be accounted for by assuming that women are more expensive to educate.

In this study, similar to most of the previous literature, educated women have better matching opportunities. However, rather than focusing on the returns to education in marriage with the declining marriage rates, we focus on the effects of divorce risks on educational choices and vice versa. The model is able to replicated most of the evolution in divorce rates for the United States. Moreover, from 1950 to 2000, it generates a 28 to 33 percentage point rise in the fraction of educated women, and a 9 to 17 percentage point rise in the fraction of educated men, compared to a 43 and 31 percentage point rise in the United States for women and men, respectively. The rise in the college wage premium alone can explain anywhere from 30 to 43 percent of the rise in the United States' fraction of women with some college education, and anywhere from 9 to 37 percent for men, depending on the assumed real wage growth rate from 1950 to 2000. Similarly, a switch in divorce laws, from consent to unilateral, generates about 37 and 20 percent of the observed rise in the fraction of educated individuals for women and men, respectively. Moreover, the model does well in replicating average weekly hours worked and the level of assortive matching in marriage. However, it fails in matching the sharp decline in marriage rates over the last five decades.

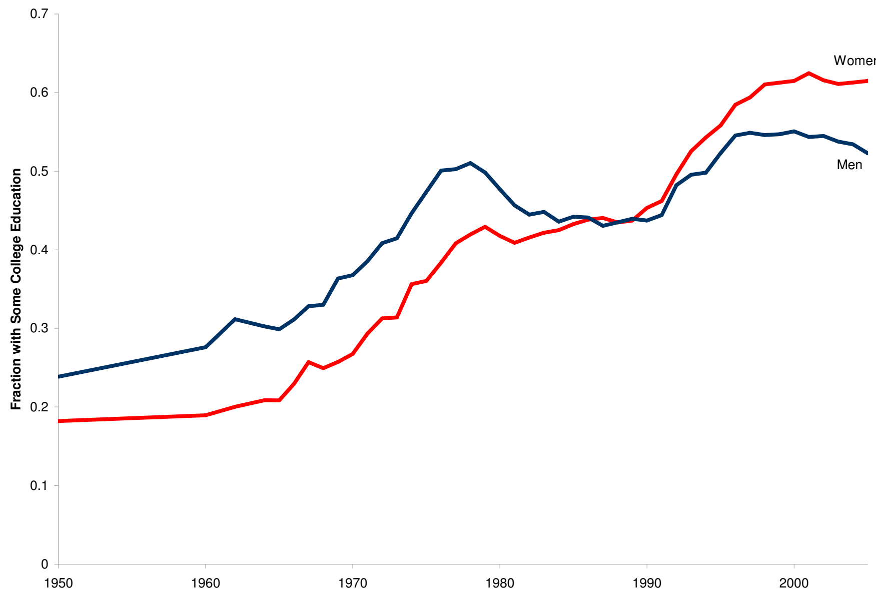
The remainder of this chapter is organized as follows, Section 2.2 provides United States facts on education, marriage, divorce and the labor market central to the discussion of this chapter. Section 2.3 outlines a simplified version of the model to provide the analytical results of the link between educational investments and divorce rates in Section 2.4. Section 2.5 discusses the model calibration and Section 2.6 provides the main results. Section 2.7 concludes. Mathematical derivations are left to the appendix, while the intuitive results are provided within the text.

2.2 Stylized Facts

The facts on educational attainment, the marriage market and the labor market central to the discussion are outlined below. All statistics reported in this section are derived from the 1950 and 1960 United States Census Integrated Public Use Micro-data Samples (IPUMS-USA) and from the 1962-2005 Current Population Survey Integrated Public Use Micro-data Samples (IPUMS-CPS), unless otherwise noted.

The fraction of the population aged 25 to 30 with some college education started rising in the late 1960s. However, while the fraction of women with some college education has steadily risen, the fraction of men with some college education leveled off initially in the early 1980s and then, after a small rise, again in the mid-1990s. As a consequence, women had surpassed men in their educational investment by 1990 (see Figure 2.1). As previously mentioned, various papers have suggested that women have higher returns to education in marriage, thus explaining part of the reversal in educational attainment. However, this theory is becoming less plausible

Figure 2.1: Fraction of 25-30 year old Men and Women with Some College Education

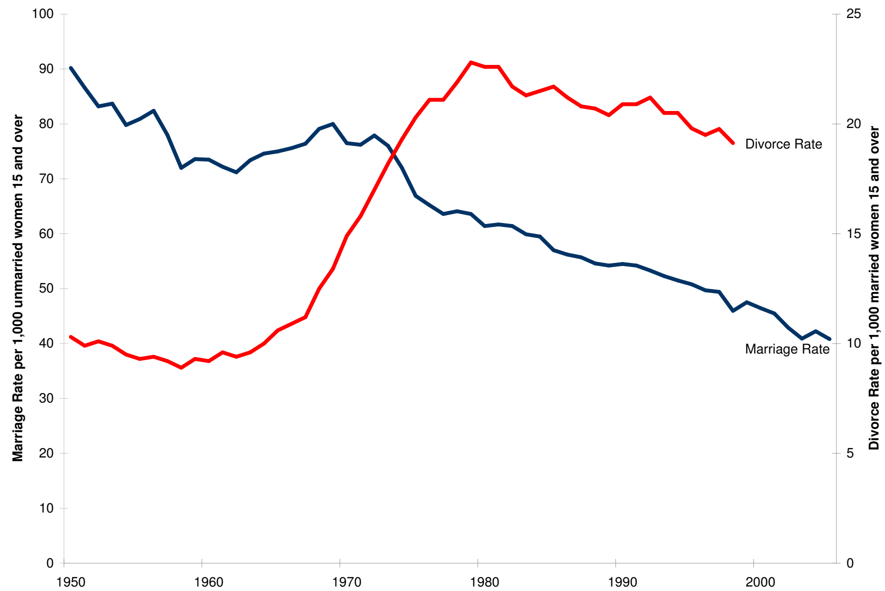


as marriage rates continue to decline.

Data from various *National Vital Statistics Reports* shows that the marriage rate halved in the the last five decades going from about 90 marriages per 1,000 unmarried women over the age of 15 to only 45 marriages. At the same time the divorce rate doubled, from roughly 10 divorces per 1,000 married women over the age of 15 to about 19 (see Figure 2.2). Thus, studying the link between divorce and education should be of greater interest, especially starting in the mid-1970s when divorce rates rose drastically, partially due to the introduction of unilateral divorce laws (for a discussion of the effects on the divorce rate in the switch to unilateral divorce laws see, Friedberg, 1998; Wolfers, 2006).

To insure against the rise in divorce rates, women who foresee a divorce are

Figure 2.2: Marriage and Divorce Rates



more likely to enter the labor market. For example, Johnson and Skinner (1986) find that a divorce increases the probability of participating in the labor market by about 20 percent within the last three years of marriage (see also Montalto, 1994, for similar results). In a similar manner, we argue that women seek more education to insure against the higher risk of divorce and exposure to single life. Intermediate estimation results form the study by Brenner et al. (1992) provide some evidence in support. The authors goal is to determine how important the rise in divorce risk has been in explaining the fall in aggregate savings. They estimate a simultaneous regression, were one regression estimates the relationship between a women's decision to become a student and the anticipated divorce rate. The authors conclude that a rise in divorce rates causes women to shift investment from financial and physical assets to investment in education and work experience.

Lastly, we can observe a "catching up" in women's wages for both women with and without some college education (see Table 2.1), where 1950 male wages with some college are normalized to one. Table 2.1 also reports the implied compounded annual growth rates in wages from 1950 to 2000. The rise in the college wage premium is evident, particularly for women with a 0.26 percent higher annual growth rate from 1950 to 2000. Moreover, growth rates for women with some college education have closed the gender gap faster, with educated women's wages growing annually 0.31 percent faster than educated men's wages compared to a 0.17 percent growth difference for uneducated individuals.

Table 2.1: Wages and Wage Growth Rates by Gender and Education

Education Group	**1950**	**2000**	**CAGR** (%)
Male with Some College	1	1.50	0.82
Male with No College	0.71	1.01	0.70
Female with Some College	0.67	1.18	1.13
Female with No College	0.50	0.77	0.87

Using this evidence on educational investment, and marriage and labor markets, the following section develops a model of educational investment, labor and marital choices, to explore the relationship between educational investment and the evolution of divorce rates.

2.3 Model Linking Education and Marital Choices

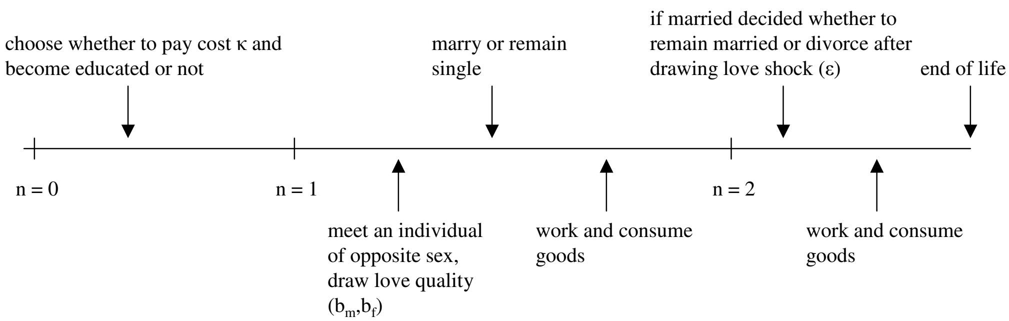
The model is largely based on the search-framework developed by Mortensen (1988) and closely follows the model by Greenwood and Guner (2004) who model the rise in female labor force participation through the rise in home technology. To model the possible feedback between educational investment, divorce risks, and marital choices, we develop an overlapping generations model with education, labor, marriage, and divorce. Agents live for N periods, and choose whether to attend college ("become educated") at a cost in period $n = 0$. During the remainder of their lives agents divide their time between home and market production, where they earn a market wage dependent on their educational attainment and gender. Agents also choose each period to marry, divorce or remain single.

To provide some intuition behind the results obtained in the simulation, we first develop a "three" period (including period zero) model without remarriage, where agents choose between attending college or not when young. In the simulation, the model is extended to N periods to allow for the possibility of remarriage.

2.3.1 Timing

Agents do not consume or work at age zero and only decided if to attend school. The cost of attending college can be spread over an agents lifetime. However, education is a permanent characteristic and remains constant after period zero. In period one an agent meets one individual of opposite sex from the same generation for certain. Upon meeting, each individual draws a love utility, $b_g \sim S(b)$, where this love draw is additive to the utility of consumption in marriage, and is allowed to

Figure 2.3: Three Period Model Timing



differ between spouses. Agents decide to marry or remain single. Marriage can only occur when both parties agree. Old married couples draw an additional love shock $\epsilon \sim M(\epsilon)$, i.e. the utility form marriage after one period evolves to $b_g' = b_g + \epsilon$. This love shock does not differ between spouses. Given the new love utility, couples decide to remain married or divorce. There is no marriage market for old agents, and there is no possibility of remarriage in this simplified three period model. In addition, in periods one and two households maximize a intratemporal utility function over purchased market goods, c_k, home produced goods, h_k, and time spent at home, n_k, where an agent's wages is determined by his/her gender and education. The timing of event within a lifetime is illustrated in Figure 2.3.

2.3.2 Household Decisions

A household chooses if to attend college in period zero, how much time to allocate to home and market production, whether to marry and remain single in period one, and between remaining married or divorcing in period two. We start with the household labor allocation, then determine the marriage and divorce decision, and, lastly, describe the education choice.

2.3.2.1 Household Intratemporal Utility Maximization

A single household $\{g, k\}$ maximizes,

$$\max_{c_{g,k}, h_{g,k}, n_{g,k}} \quad \left[\gamma_s c_{g,k}^{\alpha} + (1 - \gamma_s) h_{g,k}^{\alpha}\right]^{\frac{1}{\alpha}} \text{ where } g = f, m \text{ and } k = u, e \tag{2.1}$$

s.t.

$$c_{g,k} \leq \omega_{g,k}(1 - n_{g,k}) \tag{2.2}$$

$$h_{g,k} = A_h n_{g,k} \tag{2.3}$$

$$0 \leq n_{g,k} \leq 1, \tag{2.4}$$

where $\{g, e\}$ stands for an educated individual of sex g and $\{g, u\}$ for an uneducated individual. A_h is a home productivity factor, $\omega_{g,k}$ is the wage which depends on an individual's sex and education, γ_s is the weight a single household puts on market produced goods and $\sigma_\alpha = \frac{1}{1-\alpha}$ is the elasticity of substitution parameter. The price of the market produced good is set to one, and the shadow price of the home produced good is $\frac{\omega_{g,k}}{A_h}$.

Substituting the budget constraint (2.2) and the home technology function

(2.3) into (2.1) and maximizing with respect to $n_{g,k}$ yields time allocation,

$$n_{g,k} = \frac{(1-\gamma_s)^{\sigma_\alpha}}{(1-\gamma_s)^{\sigma_\alpha} + \gamma_s^{\sigma_\alpha}\left(\frac{\omega_{g,k}}{A_h}\right)^{(\sigma_\alpha - 1)}}, \tag{2.5}$$

where $0 < n_{g,k} < 1$ if $0 < \gamma_s < 1$. As a consequence, the maximized intratemporal utility when single is,

$$U_{g,k} = A_h \left[\gamma_s^{\sigma_\alpha}\left(\frac{\omega_{g,k}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_s)^{\sigma_\alpha}\right]^{\frac{1}{(\sigma_\alpha - 1)}}. \tag{2.6}$$

Assuming that consumption is shared equally among both spouses, a married household $\{k, k^*\}$, where an asterisk denotes the spouse, maximizes the same intratemporal utility function, only the budget constraint (2.2) and the home production function (2.3) are adjusted to account for two individuals. That is,

$$c_{k,k^*} \leq \omega_{f,k}(1 - n_{f,k,k^*}) + \omega_{m,k^*}(1 - n_{m,k,k^*}), \tag{2.7}$$

$$h_{k,k^*} = A_h(n_{f,k,k^*} + n_{m,k,k^*}), \tag{2.8}$$

$$0 \leq n_{f,k,k^*} \leq 1 \text{ and } 0 \leq n_{m,k,k^*} \leq 1, \tag{2.9}$$

where $k = u, e$ and $k^* = u, e$.

Perfect time substitution between spouses in home production leads to specialization in the labor market, with the higher wage earner entering the labor market first. Denoting the primary wage earner by 1, i.e. $\omega_{1,k,k^*} > \omega_{2,k,k^*}$, the time allocated to home production is,

$$n_{1,k,k^*} = \max\left\{0, \frac{(1-\gamma_c)^{\sigma_\alpha} - \gamma_c^{\sigma_\alpha}\left(\frac{\omega_{1,k,k^*}}{A_h}\right)^{(\sigma_\alpha-1)}}{(1-\gamma_c)^{\sigma_\alpha} + \gamma_c^{\sigma_\alpha}\left(\frac{\omega_{1,k,k^*}}{A_h}\right)^{(\sigma_\alpha-1)}}\right\}, \tag{2.10}$$

where γ_c is the weight couples put on market goods consumptions. A secondary wage earner will only consider working in the labor market if $n_{1,k,k^*} = 0$ or

$$\left(\frac{\omega_{1,k,k^*}}{A_h}\right) \geq \left(\frac{1-\gamma_c}{\gamma_c}\right)^{\frac{1}{\alpha}}. \tag{2.11}$$

Given (2.11) is satisfied, the time allocated to home production by the secondary worker is,

$$n_{2,k,k^*} = \min\left\{1, \frac{(1-\gamma_c)^{\sigma_\alpha}\left(1+\frac{\omega_{1,k,k^*}}{\omega_{2,k,k^*}}\right)}{(1-\gamma_c)^{\sigma_\alpha}+\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k,k^*}}{A_h}\right)^{(\sigma_\alpha-1)}}\right\}, \tag{2.12}$$

where $0 < n_{2,k,k^*} < 1$ if

$$\omega_{2,k,k^*} > \left(\frac{1-\gamma_c}{\gamma_c}\right)\omega_{1,k,k^*}^{\frac{1}{\sigma_\alpha}} A_h^{\alpha}. \tag{2.13}$$

As a consequence, if only the primary earner works, and assuming an interior solution, the utility of a married couple is,

$$U_{1,k,k^*} = 2A_h\left[\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{1,k,k^*}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}\right]^{\frac{1}{(\sigma_\alpha-1)}} \tag{2.14}$$

while the utility of both individuals working, with an interior solution, is,

$$U_{2,k,k^*} = A_h\left(1+\frac{\omega_{1,k,k^*}}{\omega_{2,k,k^*}}\right)\left[\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k,k^*}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}\right]^{\frac{1}{(\sigma_\alpha-1)}}. \tag{2.15}$$

2.3.2.2 Marriage and Divorce Decision

The assumptions of no remarriage, no cost to divorce, and public goods consumption in marriage, yields the following condition on the love quality for an individual of type k to prefer marriage to type k^*,

$$U_{k,k^*} + b_{g,k,k^*} \geq U_{g,k}. \tag{2.16}$$

Consequently, the love threshold to marry and divorce, for individual k of gender g and spouse k^*, is

$$\overline{b}_{g,k,k^*} = U_{g,k} - U_{k,k^*}. \tag{2.17}$$

2.3.2.3 Education Decision

To determine the threshold for attending college, we need to obtain agents' expected lifetime utilities, $V_{g,k}$, which is,

$$\begin{aligned} V_{g,k} \;\; = \;\; & \sum_{j=u,e} g_j^* \left\{ (1 - \mathscr{P}_{c,k,k^*}) \left[U_{g,k}^1 + \beta U_{g,k}^2 \right] + \mathscr{P}_{c,k,k^*} \left[U_{k,k^*}^1 + \cdots \right.\right. \\ & E(b_{g,k,k^*} | \mathbb{1}_c = 1) + \beta \left[(1 - E(\mathscr{P}_{d,k,k^*})) \left[U_{k,k^*}^2 + \cdots \right.\right. \\ & \left.\left.\left.\left. E(b_{g,k,k^*} + \epsilon | \mathbb{1}_c = 1, \mathbb{1}_d = 0) \right] + E(\mathscr{P}_{d,k,k^*}) U_{g,k}^2 \right] \right] \right\}, \end{aligned} \tag{2.18}$$

where superscripts denote the time period, $\mathbb{1}_c$ is the indicator function for being married and $\mathbb{1}_d$ is the indicator function for divorcing, and $\mathscr{P}_{c,k,k^*}$ is the probability for a type k agent to marry a type k^* agent, $\mathscr{P}_{d,k,k^*}$ is the probability for a type $\{k, k^*\}$ couple to divorce and g_j^* is the probability of meeting a j educated individual of the opposite sex. For example, m_e is the probability for a woman to meet an educated male, which, in this three period model, is also the fraction of educated men for each generation. Given the cost κ_g to attend college, an agent of gender g will attend college if

$$V_{g,e} - \kappa_g \geq V_{g,u}. \tag{2.19}$$

Consequently, the cost threshold to become educated is,

$$\overline{\kappa}_g = V_{g,e} - V_{g,u}. \tag{2.20}$$

In summary, an individual's decisions are determined by $\{n_{g,k}(\omega_{g,k}), n_{k,k^*}(\omega_{g,k}, \omega_{g,k^*}), \bar{b}_{g,k,k^*}, \bar{\kappa}_g\}$.

2.3.3 Marriage, Divorce and Education Rates

Assuming a distribution of $\kappa_g \sim K(\kappa)$ across the gender g population, the fraction of educated agents of gender g, g_e, for any generation is,

$$g_e = P(\kappa_g \leq V_{g,e} - V_{g,u}), \text{ for } g = f, m. \tag{2.21}$$

The probability that a marriage between two agents of type $\{g, k\}$ and $\{g^*, k^*\}$ ensues is,

$$\mathscr{P}_{c,k,k^*} = P(b \geq \bar{b}_{g,k,k^*})P(b \geq \bar{b}_{g^*,k,k^*}). \tag{2.22}$$

The probability of divorce depends on the current divorce law: consent or unilateral. In the case of consent divorce, and assuming that agents experience the same love shock ϵ when old, the agent with the lower divorce probability will ultimately decide on the divorce, that is

$$\mathscr{P}_{d,k,k^*} = \min\{P(b_{g,k,k^*} + \epsilon \leq \bar{b}_{g,k,k^*}), P(b_{g^*,k,k^*} + \epsilon \leq \bar{b}_{g^*,k,k^*})\}, \tag{2.23}$$

while with unilateral divorce laws, the probability of divorce is

$$\mathscr{P}_{d,k,k^*} = \max\{P(b_{g,k,k^*} + \epsilon \leq \bar{b}_{g,k,k^*}), P(b_{g^*,k,k^*} + \epsilon \leq \bar{b}_{g^*,k,k^*})\}. \tag{2.24}$$

With the marriage and divorce probabilities, and the fraction of educated individuals, it is possible to determine the marriage rate, MR, and the divorce rate,

DR, for a given generation:

$$MR = \sum_{k=e,u} \sum_{k^*=e,u} f_k m_{k^*} \mathscr{P}_{c,k,k^*}, \tag{2.25}$$

and

$$DR = \sum_{k=e,u} \sum_{k^*=e,u} f_k m_{k^*} \mathscr{P}_{c,k,k^*} \mathscr{P}_{d,k,k^*} \sum_{k=e,u} \sum_{k^*=e,u} f_k m_{k^*} \mathscr{P}_{c,k,k^*}. \tag{2.26}$$

2.3.4 Competitive Equilibrium

We can now define a stationary equilibrium. it consists of the decision rules for time allocated to home production $\{n_{g,k}, n_{g,k,k^*}\}$, the marriage decision rule $\mathbb{1}_c = \begin{cases} 1 \text{ if } b \geq \bar{b}_{g,k,k^*} \\ 0 \text{ otherwise} \end{cases}$, the divorce decision rule $\mathbb{1}_d = \begin{cases} 1 \text{ if } b + \epsilon \leq \bar{b}_{g,k,k^*} \\ 0 \text{ otherwise} \end{cases}$, and the value functions $V_{g,k}$, such that the decision rules solve the household maximization problem, and individual and aggregate behavior is consistent. Thus, the fraction of educated and uneducated agents $\{f_j, m_j\}$, which are fixed points of equation (2.21), are consistent with agents's beliefs of the probabilities of meeting an educated or uneducated potential spouse.

2.4 Model Dynamics

To account for the bidirectional relationship between the rise in education and the evolution of marriage and divorce rates, the following analysis focuses on the effects of a rising college wage premium, and the effects of the introduction of non-unilateral divorce laws on educational investment and marital choices. For ease of presentation, the following assumptions are imposed:

1. women earn lower wages than men at all education levels;

2. $\left(\frac{\omega_{1,k,k^*}}{A_h}\right) \geq \left(\frac{1-\gamma_c}{\gamma_c}\right)^{\frac{1}{\alpha}}$;

3. $\omega_{2,k,k^*} > \left(\frac{1-\gamma_c}{\gamma_c}\right) \omega_{1,k,k^*}^{\frac{1}{\sigma\alpha}} A_h^{\alpha}$;

4. $\kappa_f \sim U(\kappa_{l,f}, \kappa_{f,u})$, $b \sim U(b_l, b_u)$, and $\epsilon \sim U(\epsilon_l, \epsilon_u)$; and, lastly,

5. $\kappa_m \sim U(0, 0)$.

Assumption (1) guarantees that all women are secondary workers, (2) and (3) provide interior solutions for n_{2,k,k^*}, (4) allows me to derive relevant probabilities explicitly, and (5) yields $m_e = 1$ by (2.21) since $V_{g,k}$ is increasing in wages, which simplifies the notation and analytical results. To provide a short overview of the intuition derivations are left to Appendix B.

2.4.1 Who Marries?

The threshold of marriage and divorce depends on the primary and secondary wage, and together with equations (2.22), (2.23) or (2.24) determines who is more likely to be married and to whom. Since the focus is on the effects of a rising return to education on women's education choices, and women are by assumption (1) secondary workers, we analyze the effects of a rise of $\omega_{2,k}$ only. Note, since all men are educated, the spouses subscript k^* is omitted.

Proposition 2.4.1. *A primary worker gains more from marrying an educated secondary worker,*

$$\frac{\partial \bar{b}_{1,k}}{\partial \omega_{2,k}} < 0, \tag{2.27}$$

and, an uneducated secondary worker gains more from marriage

$$\frac{\partial \bar{b}_{2,k}}{\partial \omega_{2,k}} > 0, \tag{2.28}$$

In addition,

$$\bar{b}_{1,k} > \bar{b}_{2,k}. \tag{2.29}$$

Proposition 2.4.1 implies the following ordering of love thresholds $\bar{b}_{1,u_f} > \bar{b}_{1,e_f} > \bar{b}_{2,e_f} > \bar{b}_{2,u_f}$. Consequently, whether educated or uneducated women are more likely to marry is unclear. Divorce is decided by the secondary worker under consent divorce laws and by the primary worker under unilateral divorce laws from (2.29). The expected probability of divorcing, conditional on marrying in period one, under consent divorce, is

$$E(P_d|\mathbb{1}_c = 1) = \frac{.5(\bar{b}_{2,k} - b_u) - \epsilon_l}{\epsilon_u - \epsilon_l}, \tag{2.30}$$

and, under unilateral divorce, is

$$E(P_d|\mathbb{1}_c = 1) = \frac{.5(\bar{b}_{1,k} - b_u) - \epsilon_l}{\epsilon_u - \epsilon_l}. \tag{2.31}$$

Equation (2.28) implies that under consent divorce law, couples with an educated woman are more likely to divorce, while (2.27) implies that under unilateral divorce law marriages with an uneducated woman are more likely to dissolve.

2.4.2 The Effects of Liberalizing Divorce Laws

As previously mentioned, a switch from consent to unilateral divorce law changes the decision of divorcing from the secondary to the primary wage earner. Given the assumption of no divorce costs the marriage probabilities remain unaffected. However, given $\bar{b}_{1,k} > \bar{b}_{2,k}$, the divorce rate will initially "jump up" with the divorce law switch, as observed in the United States (see Figure 2.2 of Section 2.2). As the probability of a marriage ending in divorce is lower when the wife is educated under the unilateral divorce, the divorce rate will fall over time if the fraction of educated women does not fall.

To determine if a switch in divorce regimes leads to a rise in the fraction of educated women, we simplify equation (2.18) by substituting the distributional assumptions on b and ϵ, and assume no wage growth,

$$\begin{aligned} V_{f,k} \;&=\; (1-\mathscr{P}_{c,k})U_{f,k}\left[1+\beta\right]+\mathscr{P}_{c,k}\left\{.5\left(b_u-\bar{b}_{2,e_f}\right)\times\right. \\ &\left.\beta\left[(1-E(\mathscr{P}_{d,k})).5\left(\epsilon_u+.5\left(b_u-\bar{b}_{2,e_f}\right)\right)\right]\right\}, \end{aligned} \tag{2.32}$$

A move to unilateral divorce will increase the fraction of educated women since only the term $(1-E(\mathscr{P}_{d,k}))$ is affected under the change and $(1-E(\mathscr{P}_{d,e_f,uni})) > (1-E(\mathscr{P}_{d,u_f,uni}))$ with unilateral divorce and $(1-E(\mathscr{P}_{d,e_f,con})) < (1-E(\mathscr{P}_{d,u_f,con}))$ under consent divorce. These results follow from combining the effects of a rise in $\omega_{2,k}$ on the divorce threshold, from equations (2.27) and (2.28), and the expected divorce probabilities (2.30) and (2.31).

Proposition 2.4.2. *The fraction of educated women rises with a switch to unilateral divorce laws:*

$$f_{e,uni} = P\left(\kappa_f < (V_{f,e}-V_{f,u})_{uni}\right) > P\left(\kappa_f < (V_{e_f}-V_{f,u})_{con}\right) = f_{e,con}, \tag{2.33}$$

as $(V_{f,e}-V_{f,u})_{uni} > (V_{f,e}-V_{f,u})_{con}$.

The initial jump, and subsequent fall in divorce rates, is what Rasul (2006) terms the pipeline and selection effects of a switch to unilateral divorce laws, also observed in Figure 2.2 of Section 2.2 for the case of the United States. In contrast, the effect on the marriage rate is ambiguous and will depend on whether $\mathscr{P}_{c,e_f}$ is greater or less than $\mathscr{P}_{c,u_f}$, i.e. if $\mathscr{P}_{c,e_f} < \mathscr{P}_{c,u_f}$ the marriage rate will fall.

2.4.3 The Effects of a Rising College Premium

A rise in the returns to education, $\omega_{f,e}$, results in an increase in the fraction of educated women since $\frac{\partial V_{f,k}}{\partial \omega_{2,k}} > 0$. Given (2.27)−(2.29), and a rise in the returns to education divorce probabilities for educated women will fall under unilateral divorce and rise under consent divorce.

In conclusion, a switch from consent to unilateral divorce will lead to (1) a rise in female educational investment, (2) an initial rise in the divorce rate, with a later decline, and (3) either a fall or rise in the marriage rate. A rise in the returns to education (1) dampens the initial jump in divorce rates resulting from the regime switch, (2) accelerates the later decline, and (3) increases the fraction of educated women. The effect on divorce rates prior to the divorce law switch depends on the marriage probabilities, i.e. the effect here is ambiguous since men prefer to marry women of higher earning potential, but women of higher earning potential are less likely to marry.

2.5 Model Calibration

To test the validity of the model in explaining divorce and education trends in the United States, the three period model is extended to N periods.

2.5.1 N Period Model with Remarriage

Agents are now allowed to remarry, and the cost of divorcing is that agents have to remain single for at least one period. The threshold values for love can now be solved by backward induction starting at an individual's final period of life. Let, $V_{n,g,k}$ and V_{n,g,k,k^*} denote the value of a single, age n, type k, and gender g agent, and married, age n, type $\{k, k^*\}$ couple, respectively. The labor time allocation decision remains intratemporal, and labor choices and intratemporal utilities are as above in the three period model. The value of being single and married at each age n are,

$$\begin{aligned} V_{n,g,k} &= U_{n,g,k} + \beta \sum_k \frac{sg_{k^*}}{sg_e + (1 - sg_e)} \times \cdots \\ & \left\{ \int_{b_l}^{b_{n+1,g,k,k^*}} \int_{b_l}^{b_{n+1,g^*,k,k^*}} V_{n+1,g,k} \, dS(b) \, dS(b) + \cdots \right. \\ & \left. \int_{b_{n+1,g,k,k^*}}^{b_u} \int_{b_{n+1,g^*,k,k^*}}^{b_u} V_{n+1,g,k,k^*} \, dS(b) \, dS(b) \right\}, \end{aligned} \tag{2.34}$$

where $\frac{sg_{k^*}}{sg_e+(1-sg_e)}$ is the probability of meeting a type k^* of the opposite sex, and

$$V_{n,g,k,k^*} = U_{n,k,k^*} + b_g + \beta \left\{ \int_{\epsilon_l}^{\overline{d}} V_{n+1,g,k} \, dM(\epsilon) + \int_{\overline{d}}^{\epsilon_u} V_{n+1,g,k,k^*} \, dM(\epsilon) \right\}, \tag{2.35}$$

where $\overline{d} = \min \{b_{n+1,g,k,k^*} - b_g, b_{n+1,g^*,k,k^*} - b_{g^*}\}$ under consent divorce laws and $\overline{d} = \max \{b_{n+1,g,k,k^*} - b_g, b_{n+1,g^*,k,k^*} - b_{g^*}\}$ under unilateral divorce laws. The threshold for love is,

$$b_{g,k,k^*} = V_{n,g,k} - \hat{V}_{n,g,k,k^*}, \tag{2.36}$$

where $\hat{V}_{n,g,k,k^*} = U_{n,k,k^*} + \beta \left\{ \int_{\epsilon_l}^{\overline{d}} V_{n+1,g,k} \, dM(\epsilon) + \int_{\overline{d}}^{\epsilon_u} V_{n+1,g,k,k^*} \, dM(\epsilon) \right\}$, and the fraction of educated men and women is,

$$g_e = P\left(\kappa_g \leq \beta\left(V_{1,g,e} - V_{1,g,u}\right)\right)\}, \tag{2.37}$$

assuming that agents do not consume when young and can spread the cost of education across their lifetime.

Lastly, the marriage and divorce rates for a given generation, assuming that agents only marry within their generation, are,

$$MR = \frac{\sum_{k=e,u} \sum_{k^*=e,u} \frac{sm_{k^*}}{sm_e + (1 - sm_e)} sf_k \mathscr{P}_{c,k,k^*}}{\sum_{k=e,u} sf_k}, \tag{2.38}$$

and

$$DR = \frac{\sum_{k=e,u} \sum_{k^*=e,u} c_{k,k^*} \mathscr{P}_{d,k,k^*}}{\sum_{k=e,u} c_{k,k^*}}, \tag{2.39}$$

where c_{k,k^*} is the proportion of married agents of type $\{k, k^*\}$.

2.5.2 Calibration

The model is calibrated to the United States in 2000 and then simulated, the parameters to be determined are

$$\{\beta, \alpha, \gamma_s, \gamma_c, \kappa_l, \kappa_u, b_l, b_u, \epsilon_l, \epsilon_u\}.$$

To avoid widowed agents and individuals that have not made their education decisions yet, only individuals aged 25 to 54 are considered. The number of periods N is set to six and each period is five years long. Following Greenwood and Guner (2004), the annual discount factor is set to 0.96, which yields $\beta = 0.96^5$. The elasticity of substitution between market goods and home production has previously been estimated to range between 1.8 and 2.3 (see Aguiar and Hurst, 2006; Rupert et al., 1995; McGrattan et al., 1997; Chang and Schorfheide, 2003), implying $.4444 < \alpha < .5652$. Restricting α to lie between these boundaries, the parameters $\{\alpha, \gamma_c, \gamma_s\}$ are calibrated to match the total time allocated to the labor market by married couples , the time spend working by married women, and the time spent working by single women, which were about about 65.1, 25.6, and 30.5 hours per week, respectively, in the 2000 CPS survey.

The cost of education determines the fraction of educated women and men. The model as-is, is unable to match the education gap, and would predict men to obtain more education than women. In the current model, the lifetime utility of uneducated women is “too high.” We have ignored any fertility choice in this model. However, uneducated women have, on average, more children than educated women regardless of their marital status (see Table 2.2).

Table 2.2: Children by Marital Status 1950 to 2007 (Average)

Marital Status	**Uneducated**	**Educated**	**Ratio**
Married	1.66	1.47	1.13
Never Married/Single	.66	.22	3.03
Separated/Divorced	1.33	1.00	1.32

The optimal solution is to introduce a fertility choice. The focus of this study is not explaining fertility choices or the origins of the education gap per se, but rather to explore the link between education and divorce. Thus, the introduction of endogenous fertility is left for future research. There are two other possibilities to match the education gap.

1. The cost of education differs between men and women: letting the lower bound be zero, $\kappa_{l,f} = \kappa_{l,m} = 0$, and calibrating $\kappa_{u,g}$ to match the fraction of gender g with some college education aged 25 to 30, which is about 61 percent for

women and 55 percent for men in the 2000 CPS survey.

2. Alternatively, we could assume that women can only spend a fraction of their total time working, $\hat{\ell}_{f,k} < 1$, since they have to devote the remainder of their time to raising their children. The fraction of time spend at home is then $\hat{\ell}_{f,k} n_{f,k}$ or $\hat{\ell}_{f,k} n_{f,k,k^*}$ and the intratemporal utilities are $\hat{\ell}_{f,k} U_{f,k}$ and $\hat{\ell}_{f,k} U_{k,k^*}$ for single and married agents respectively. As only the difference $V_{g,e} - V_{g,u}$ matters, we can set $\hat{\ell}_{f,e} = 1$, $\kappa_l = 0$ and calibrate $\hat{\ell}_{f,u}$ to match the fraction of educated women in 2000 and κ_u to match the fraction of educated men.

The results reported use the second alternative, however, both choices produce fairly similar results on all the model dimensions.

The distribution of the initial love draw is determined by the marriage rate in 2000, which is about 46.5 marriages per 1,000 unmarried women. Since there is only one data target and two parameters, we set $b_u = 0$ and b_l to match the 2000 marriage rate. The model target is divided by five to account for each five-year period in the model.

The distribution of the love shock is determined by the divorce rate in 2000, which is about 19 divorces per 1,000 married couples. We assume that love shocks have mean zero, i.e. $\epsilon_l = -\epsilon_u$, and ϵ_u, is set, as with the marriage rate, to match the divorce rate in 2000.

To calibrate the model both 1950 and 2000 are assumed to be steady states, agents have perfect foresight regarding wages and divorce law changes, and divorce laws switch from consent to unilateral in 1970 (the first states to adopt unilateral divorce laws did so in 1968 (see for example Friedberg, 1998)).

Table 2.3 summarizes the chosen data targets, data moments and parameter values.

Table 2.3: Moments and Parameter Estimates

Moment	**2000 Data**	**Model**	**Parameter**
Married Couples Labor Hours	61.5	61.5	$\frac{1}{1-\alpha} = 1.9133$;
Married Women's Labor Hours	25.6	25.8	$\gamma_c = 0.6460$;
Single Women's Labor Hours	30.5	30.5	$\gamma_s = 0.5873$.
Fraction of Educated Women	0.61	0.615	$\hat{\ell}_{f,u} = 0.8232$
Fraction of Educated Men	0.55	0.55	$\kappa_u = 1.5983$
Marriage Rate	0.0465	0.0464	$b_l = -0.5963$
Divorce Rate	0.019	0.019	$\epsilon_u = -\epsilon_l = 0.3213$

Wages are taken from the 2000 CPS survey (see Table 2.1 of Section 2.2). To simulate the baseline model, with the parameter estimates from Table 2.3, an assumption on the wage growth rate has to be made. As mentioned in Section 2.2, it is evident that women's wages caught up with men's wages for all education levels. However, simply feeding a constant wage growth rate into the model assumes that household productivity did not grow since 1950. Ngai and Pissarides (2005), in their study on the trend of hours worked since 1930, assume that while household productivity did grow, it did so at an annual 0.004 percent less than the productivity in the service sector. Having no good estimates on the household productivity parameter, three different real wage growth rates are tested (see Table 2.4). Taking uneducated men's wages as the base, Scenario (1) assumes no home productivity growth, Scenario (2) assumes that uneducated men's wages grew at only 50 percent of the CAGR, and Scenario (3) assumes that wages did not grow at all. The parameters reported in Table 2.3 are from calibrating Scenario (1). Scenario (1), (2), and (3) parameter estimates differ by only a few thousandths of a decimal points, for example $\alpha = \{0.4773, 0.4759, 0.4748\}$.

Table 2.4: CAGR of Wages Adjusted for Home Productivity Growth

Education Group	**Scenario (1)**	**Scenario (2)**	**Scenario (3)**
Male with Some College	0.82	0.47	0.12
Male with No College	0.70	0.35	0
Female with Some College	1.13	0.78	0.43
Female with No College	0.87	0.52	0.17

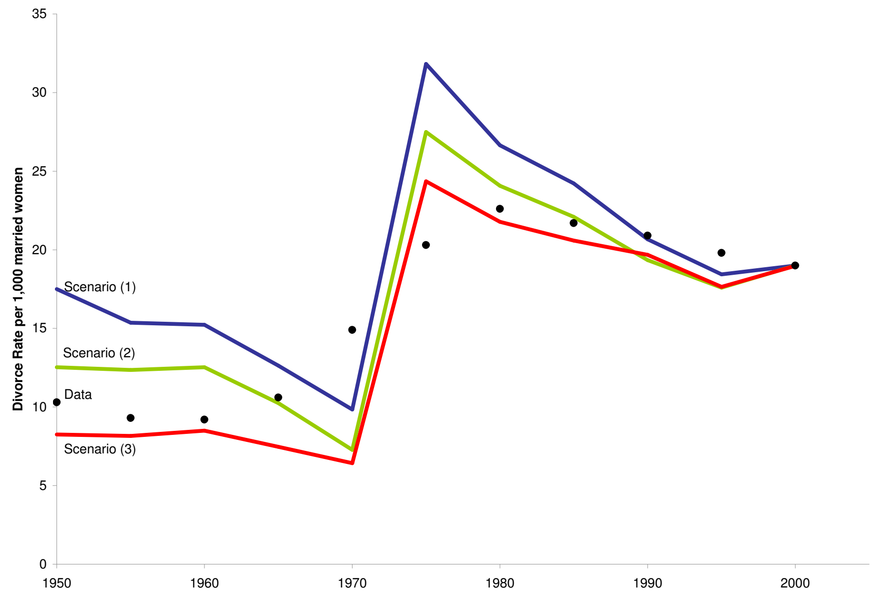
2.6 Main Results

The results presented in this section show that the mechanism highlighted in this study does well in matching the evolution of divorce rates in the United States. Moreover, it is able to generate up to 75 percent of the observed rise in female education in the United States. On other dimensions the framework is also able to replicated the United States' average weekly hours worked data and the level of assortive matching in education, but fails to match the fall in marriage rates.

2.6.1 Divorce and Education

Figure 2.4 and 2.5 show the simulated divorce rates and education trends. Scenario (1) does better in replicating the college attendance trend, while Scenario (3) does better in replicating the divorce rate trend. More specifically, with the highest real wage growth (Scenario (1)) the divorce rate is overestimated in 1950 and

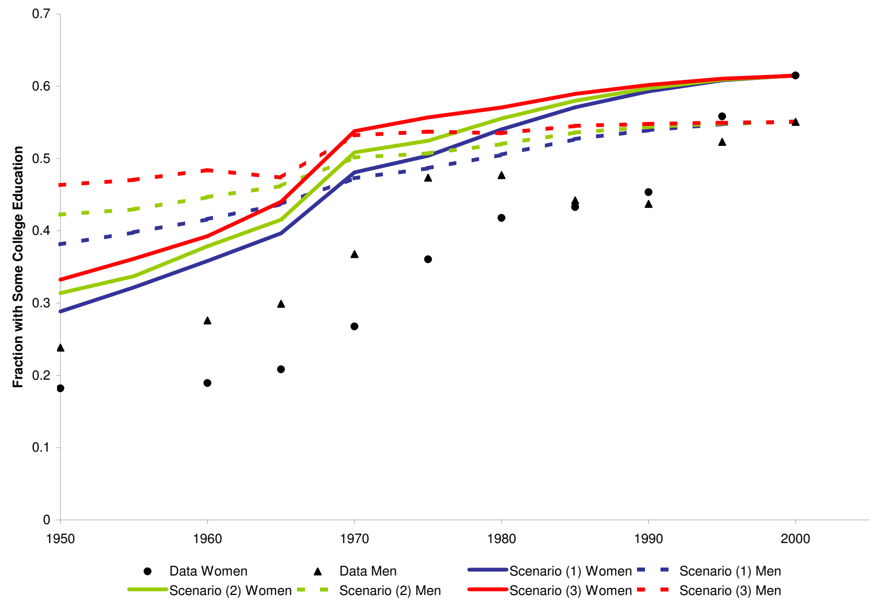
Figure 2.4: Simulated Divorce Rates



immediately after the divorce law switch in 1975. The model is unable to generate the precise pattern of the divorce rate from the mid-1960s to the mid-1980s, since, in the United States, states introduced unilateral divorce laws from 1968 to 1984. Introducing "states" in the model and allowing for a slow transition from consent to unilateral divorce across the entire population would result in a transition more similar to the one observed in the data. Taking this issue aside, the model does well in replicating the evolution of divorce rates in the United States.

In explaining the fraction of individuals with some college education, the model generates a reversal in the education gap, which coincides with the change in divorce laws in 1970. In the data, the reversal of the education gap is not observed until the mid-1980s. Similar to the observation on divorce rates, a slow introduction

Figure 2.5: Simulated Education Rates



of unilateral divorce laws shifts the date of the education reversal. However, the model is unlikely to replicate the precise date of the education reversal, even with the introduction of "states." To summarize the results on the education trends, the increase in individuals with some college education in the United States, which is replicated in the model is reported in Table 2.5.

Table 2.5: Percent Explained of the Rise in Education

Model	**Gender (SC)**	**(1)**	**(2)**	**(3)**
Base Model	Male	54.42	41.16	27.90
	Female	75.50	69.51	65.22
Constant Wages	Male	20.15	19.95	19.86
	Female	37.14	36.93	36.84
Consent Divorce	Male	37.18	23.19	9.03
	Female	43.47	36.03	29.42

As a comparison, Table 2.5 also reports the findings of two experiments, (1) only divorce laws are allowed to change, i.e. wages are held constant at the 2000 level throughout the whole time period, and (2) only wages are allowed to change, while consent divorce laws prevail throughout the whole period. Depending on the real wage growth rate, the model is able to explain anywhere from 65 to 76 percent of the rise in the fraction of women with some college education observed in the United States. In contrast, the base model does not preform as well in explaining the rise in male education, explaining anywhere from 28 to 54 percent. Eliminating the incentives of a rising college wage premium on attending college leads the model to generate roughly a 37 percent of the rise in education for women and 20 percent for men. While eliminating the added divorce risk of unilateral divorce laws generates a rise in the proportion of educated women from 30 to 43 percent and 9 to 37 percent for men. Given the nature of this last experiment, it is not surprising that the results are highly dependent on the "real" wage growth rate. The findings reported in Table 2.5 are consistent with the hypothesis that women are more exposed to the negative effects of increased divorce risks, but also experienced a faster rise in the returns to education than men. As we noted in Section 2.2, educated women's wages grew 0.31 percent annually faster than educated men's, compared to a 0.17 percent growth difference for uneducated individuals.

2.6.2 Hours Worked, Marriage, and Matching

On other dimensions, the model is able to replicate most of the change in weekly hours worked (see Table 2.6).[3]

Table 2.6: Average Weekly Hours Worked by Gender and Marital Status

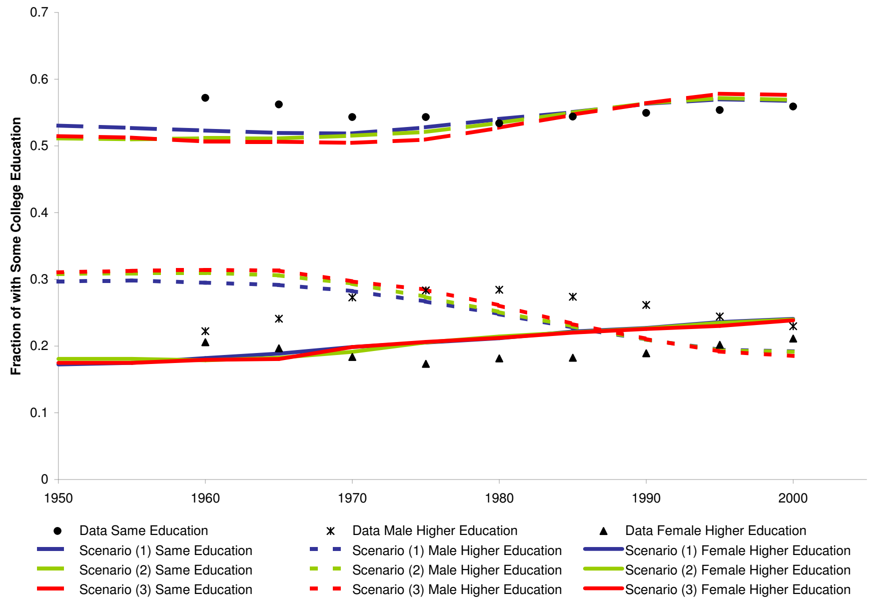
	Data		**(1)**		**(2)**		**(3)**	
Group	**1950**	**2000**	**1950**	**2000**	**1950**	**2000**	**1950**	**2000**
Married Men	40.93	40.51	44.55	39.00	44.51	39.00	44.48	39.00
Single Men	30.09	33.48	27.11	31.03	28.85	30.97	30.66	31.03
Married Women	10.01	25.57	10.92	25.83	13.18	25.85	16.31	25.87
Single Women	27.17	30.45	26.41	30.54	27.84	30.47	29.33	30.50

The model captures the overall rise in women's average weekly hours worked, almost matching it one-to-one in Scenario (1), but underestimating it by 40 percent in Scenario (3). It also matches, in all scenarios, the change in single women's weekly hours worked. However, the model underestimates the weekly hours worked for single men by about 2 hours and generates a fall in weekly hours worked for married men, which is inconsistent at the intensive margin. A fall in labor force participation for married men would only be consistent at the extensive margin (see Figure 1.11 in Chapter 1).

Figure 2.6 illustrates the matching in education levels, that is the fraction of couples with equal educational attainment, the fraction of couples where men have some college education while women do not, and vice versa. All wage growth sce-

[3]Average weekly hours measure the rise in the intensive margin in labor force participation. Thus, averages include all individuals of the civilian population aged 25 to 54, including individuals with zero hours worked per week.

Figure 2.6: Educational Matching in Marriage

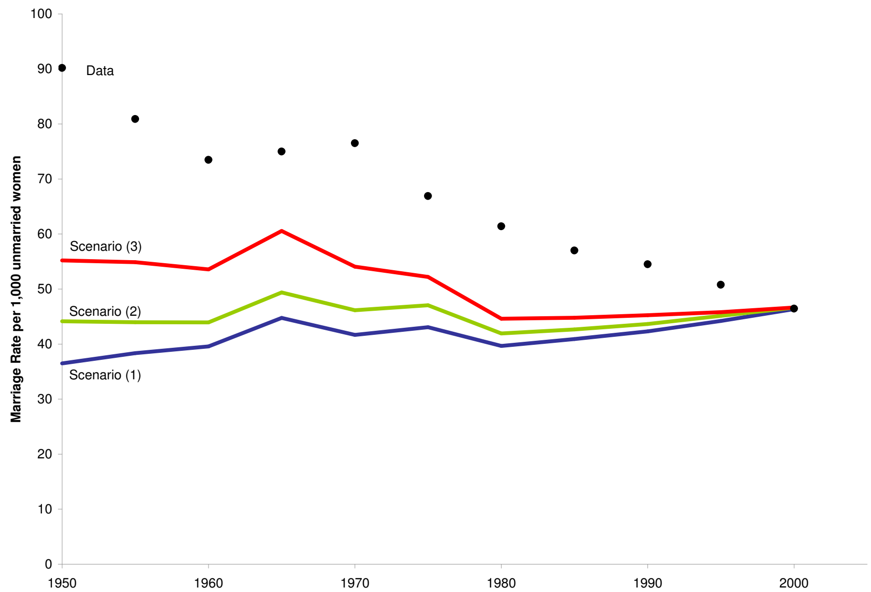


narios produce similar matching results, and do fairly well in matching the United States data, except for the early periods, where the model overestimates the fraction of couples with more educated males.[4] Moreover, the model produces findings consistent with Chiappori et al. (2006).

Lastly, the model fails in predicting the evolution of marriage rates in the economy. While, the framework does generate a downward trend starting in 1965, it is unable to match the 1950 marriage rate or the slope of the downward trend. This is where the omission of fertility is likely to play the biggest role. If we allowed men and women to derive pleasure from having children, men would likely be more

[4]The matching of couples in the United States 1950 Census was not possible.

Figure 2.7: Simulated Marriage Rates



willing to enter into a marriage in 1950, given that women would stay at home and birth more children. Over time, as women enter the labor market and fertility declines, the utility from marriage should decline as well, leading to a fall in the marriage rates.

2.7 Conclusion

The purpose of this study is to assess how much of the observed United States' divorce rate evolution and the female educational investment trend can be explained by a model that allows for an interdependent relationship between divorce and education. This simple overlapping generations model is able to explain a large fraction of the rise in the proportion of educated women. Even after eliminating any rise in the returns to education, a divorce law change to unilateral divorce is able to explain about 37 percent of the observed rise in female educational investment. As expected, the model does less well in predicting the rise in male educational investment, explaining only 20 percent of the data if wages are held constant and between 28 to 54 percent when including the rise in the college wage premium. In contrast, the base model is able to explain between 65 to 75 percent, depending on the “real” growth rate of wages, of the United States’ rise in the fraction of women with some college education. Moreover, the model does well in replicating the evolution of divorce rates in the United States from 1950 to 2000.

For robustness the model is also compared to the the evolution of weekly hours worked, the level of assortive matching on education in marriage, and the evolution of the marriage rate in the United States. While the model preforms well on the first two dimensions, it does poorly in matching the evolution of the marriage rate. This is most likely due to the omission of fertility and children in marriage. In this study only utility from love and public goods consumption is derived in marriage. An additional utility derived from having children would certainly increase the willingness of males to marry.

Lastly, this model has ignored the potential of insuring against divorce risks by increasing one’s labor force participation in the years prior to a divorce to accumulate work experience (see Johnson and Skinner, 1986; Montalto, 1994). Introducing work experience into the model will dampen the rise in educational attainment due to increased divorce risks and should, therefore, be incorporated into future research.

Chapter 3

Marriage, Divorce and Savings: Don't Let An Economist Choose Your Spouse

This chapter considers the implications of marital uncertainty on aggregate household savings behavior. To this end an infinite horizon model with perpetual youth that features uncertainty over marriage quality is developed. Similarly to Cubeddu and Ríos-Rull (1997), I test how much of the fall in the savings rate from the 1960s to the 1980s can be explained by the changing United States demographic composition, specifically the rise in divorce rates and the fall in marriage rates. It is assumed that these demographic changes are driven primarily by the shrinking gender wage gap and the relaxation of divorce-laws.

3.1 Introduction

"... when it comes to building wealth or avoiding poverty, a stable marriage may be your most important asset." - Waite and Gallagher (pg. 123, 2000)

The national savings rate has dropped drastically from 8 percent in mid-century to 2 percent in 1980 (see Bosworth et al., 1991). Moreover, according to estimates by Cubeddu and Ríos-Rull (1997) from the Consumer Expenditure Surveys (CES) (1960-1961, 1972-1973 and 1984-1990) the household savings rate out of disposable income fell from 8.95 to 4.17 percent from the 1960s to the 1980s. During this same time period the composition of households underwent drastic changes. While there were fewer married households in the 1980s, there where also considerable more divorces (see Figure 2.2 in Chapter 2). More specifically, the divorce rate per 1,000 married women doubled from the 1960s to the 1980s, by rising from 10 to 20 percent, and the marriage rate experienced a linear continuous downward trend. Part of this sharp rise in divorce rates can be attributed to the relaxation of divorce laws in the 1970s (see Friedberg, 1998; Wolfers, 2006), which allowed for unilateral divorce. With this law it became possible to petition for a divorce without the consent of the spouse. Moreover, since the mid-1970s the wage gap and employment difference between men and women started to close (see Figure 1.1 in Chapter 1) potentially contributing to part of the marital changes. In this study I present microeconomic evidence supporting significant differences in household savings behavior by martial status and marital "bliss", and develop a partial equilibrium model to determine the impact of the liberalization of divorce laws and rising female wages on the aggregate savings rate.

In analyzing the effects of demographic changes on household savings rates the focus has mainly been on the aging population (see for example Auerbach et al., 1989; Auerbach and Kotlikoff, 1992). Generally, these results show the aging population, *ceteris paribus*, unable to explain the sharp drop in saving rates.[1] However the importance of household formation and dissolution on savings and wealth accumulation has been pointed out by Quadrini and Ríos-Rull (1997). The authors suggest

[1] For a short survey on studies related to savings behavior and wealth inequality see DeNardi (2002).

that in order to obtain results more closely matching the main features, especially in the lower quintiles of the U.S. wealth distribution, models should incorporate the potential risks associated with marital status. They argue that since changes in marital status are uninsurable and not directly reflected in individuals' earnings data, theses shocks could be important factors when characterizing household wealth in the bottom quintiles, especially for young to middle-aged individuals.

Most closely related to this study is the research conducted by Cubbedu and Ríos-Rull (2002). The authors in their paper "Families as Shocks" develop a simple model where agents face uninsurable shocks to marital status over the life cycle. The main goal is to point out the importance of including marital status differences in models of macroeconomics. The study simulates various exogenous marital shock processes and subsequently determines optimal savings patterns. The authors find that uninsurable martial risk is "just as important" as uninsurable earnings uncertainty in determining savings patterns and the wealth distribution over the life cycle, thus, concluding that neglecting marital status in macroeconomic models can have a significant impact. However, the study neglects the importance of an endogenous marriage process, allowing agents no autonomy in choosing whom to marry, and at what point in time to divorce or marry. Guner and Knowles (2004) are, to my knowledge, the first to develop a model of savings and *endogenous* marriage decisions. The authors develop an overlapping generation model that relates the wealth of older households to their earlier decisions about work, marriage and divorce. Agents make decisions over savings and marriage in a three period set-up. The authors find that wealth differences across marital statuses are mainly a result of the following two facts: (1) differences in savings rates, and (2) high income people are more likely to have stable marriages. While I model marriage and divorce in a similar way, by using the richer marriage match quality evolution from Greenwood and Guner (2004), the focus in this study is on the impact of the closing wage gap and changes in divorce laws on the aggregate savings rate. Therefore, the central point of this chapter is to test the question first postulated by Cubeddu and Ríos-Rull (1997), who study whether the drastic rise in divorce rates and illegitimacy from the 1960s to late 1980s can explain the drop in aggregate savings rate. While the authors concluded divorce and illegitimacy only to have a minor impact on aggregated savings, the study neglects the potential importance of endogenizing the marriage process, and model divorce uncertainty by an exogenous shock process.

Why do people save? Most current wealth inequality and savings models use one of the following reasons to model household savings desires (listed in no particular order of importance):

- Precautionary savings. Individuals save due to uncertainty over labor earnings and the inability to insure against adverse events (incomplete markets). However, savings due to precautionary reasons found in recent studies are too small to explain U.S. savings patterns. Aiyagari (1994) finds precautionary savings to add around 3 percent.

- Retirement funds. Franco Modigliani developed the "life-cycle" model. Individuals save during their peak years of earnings in order to maintain consumption levels during retirement. However, the life-cycle principal in its most simple form does poorly in predicting savings patterns. Kotlikoff and Summers (1981) show that as much as 80 percent of current U.S. wealth is inherited and therefore conclude that the life-cycle component of aggregate U.S. savings is very small.

- Bequests. The dynastic model developed by Becker (1974) and Barro (1974), assumes wealth is accumulated for bequest purposes; i.e. individuals care about the welfare of their offspring and, therefore, save. However, the basic dynastic model does poorly in predicting wealth concentration. Aiyagari (1994) can only produce 4 percent of total wealth for the top 1 percent of the population compared to a 28 percent of total wealth in U.S. data.

Contrary, to the above three theories households' savings decisions in this study are driven by marital uncertainty. Marital uncertainty, is the uncertainty over a marriage match quality and the uncertainty of meeting a potential spouse. Why could it help explain the fall in aggregate savings? The model specified in this study plays on the following interactions of household structure and savings:

1. Married households have, on average, more disposable income than single households, through dual-earners and economies of scales, allowing them to save a greater fraction of their income;

2. Divorce has an evident negative impact on household finances, a multi-person household splits, some wealth is lost in the process, the remainder is divided and spouses lose the economies of scale in maintaining their home;

3. Rational households prepare for the probability of a divorce by changing their consumption and savings behavior. High earning members of a household that foresee/expect a divorce are less likely to save due to divorce costs and potential asset redistribution, spousal support, etc. while, low earning members or households where both spouses have similar earnings, save more as economies of scales are lost upon divorce; and

4. Single agents might save in order to differentiate themselves from other potential spouses in the marriage market. A lower marriage rate and higher divorce rate will likely dissipate this effect, as the benefits of marriage fall.

Therefore, an economy with a high fraction of married households and low divorce rate, should, in general, have a higher aggregate savings rate. Changes in divorce laws, that is an increase in marital uncertainty, and falling number of married households can greatly affect the aggregate savings rate.

The model developed in this chapter builds on the framework of Guner and Knowles (2004) and Cubeddu and Ríos-Rull (1997). While this study expands directly on the work done by Guner and Knowles, it contrasts Cubeddu and Ríos-Rull by internalizing marriage decisions. I depart form previous studies that include marriage decisions by following Aiyagari's infinite horizon model.[2] The infinite horizon model is preferable as it simplifies the calibration, lowering the parameters to

[2] An exception in this stream of literature is the study by Regalia and Ríos-Rull (1999) that uses an infinite horizon model to study the increase in single households from the 1970s to the 1990s, as well as Greenwood and Guner (2004) who study the effect of falling household goods prices on female labor supply, marriage and divorce.

be specified and matched over the life-cycle, therefore, reducing the computational time burden. In order to focus solely on the effects of marriage and divorce on savings, I abstract from productivity shocks following Cubeddu and Ríos-Rull work. However, contrary to this later study which studies a finite horizon model with evolving wage profiles over the life-cycle, households will not be saving for life-cycle purposes in this chapter, i.e. that is agents will *only* save due to marital uncertainty.

It should be stressed that this chapter only focuses on the effects of households' decisions of marriage and divorce on savings pattern and the resulting aggregate savings and wealth distribution. This is certainly a restrictive set-up given the results of other research in the area of wealth inequality and savings. In general, we expect earnings uncertainty, entrepreneurship, bequest motives, social security, fertility, etc. to have an important impact on savings and wealth inequality. However, the focus in this study is to isolate the effects of changing divorce laws and the shrinking wage gap on savings behavior and wealth inequality. I test how much aggregate savings is generated in a standard model such as Aiyagari's infinite horizon model of precautionary savings with endogenous martial uncertainty. The computational results indicate marriage and divorce risks to be an important factor in predicting aggregate savings. More specifically, endogenizing marriage and divorce leads to the following differences in savings behavior and wealth inequality: (1) lower divorce risk increase aggregate savings by about 13 percent alone. While, the combined effect of lower divorce risks and higher marriage rates is about 40 percent.

The remainder of this chapter is organized as follows: Section 3.2 provides U.S. facts on aggregate savings and marital distress on household savings behavior relevant to this study; Section 3.3 develops a model where agents differ in gender, wages, marriage match quality and divorce laws change in the 1970s; Section 3.4 provides details on the calibration; Section 3.5 compares the resulting savings rates in the 1960s and 1980s, as well as cross-sectional household savings behavior; lastly, Section 3.6 concludes.

3.2 U.S. Facts

The exercise focuses on the dramatic fall of the US aggregate savings rate over time. Estimates for aggregate household savings rate vary across studies, however, a drastic fall in savings is undisputed. I use the Survey of Consumer Finances (SCF) since it is the only study with considerable household wealth information to compute specific savings rates by three demographic groups: married households, single men and single women. The SCF reinterviewed household in 1963 from its 1962 survey, and again in 1986 from its 1983 survey.[3] Contrary the CES, which collects household consumption and income over a year, the SCF obtains detailed household wealth holdings. Therefore, rather than, as in Cubeddu and Ríos-Rull (1997), estimating savings as the difference between income and consumption, I estimate savings by the first difference of net worth across two years. Bosworth et al. (1991) estimate aggregate savings using both these surveys and find comparable estimates with aggregate savings rate falling by 4.3 percent in the 1972/1973 to 1882/1985 CES surveys and 4.5 percent in the 1962/1963 to 1983/1986 SCF sur-

[3] Note that in the 1960s the surveys were called the 1962 Survey of Financial Characteristics of Consumers and the 1963 Survey of Changes in Family Finances, but in this study are referred to as SCF.

veys. Since, the model abstracts from many income sources, in computing savings and wealth distribution estimates I restrict the sample as follows: (1) households headed by a person under the age of 25 in 1962 and 1983 or over the age of 64 are eliminated to capture only the working population; (2) households with savings or borrowings greater than reported income plus capital gains and gifts are eliminated; and (3) all households with wealth from own businesses exceeding 10 percent of total wealth in the base year are deleted. Therefore, leaving a sample of 1,077 and 1,459 households in the 1960s and 1980s, respectively. Savings are defined as the difference in net worth less own-home value appreciation between the two survey years.[4] In computing aggregate savings rate I use the standard specification of Bosworth et al. (1991), where the aggregate savings rate at time t is determined by the sum of all groups', (here married households, single males, and single females) weighted saving rates,

$$S_t = \sum_j \alpha_{j,t} \frac{y_{j,t}}{Y_t} s_{j,t}, \tag{3.1}$$

where $\alpha_{j,t}$ is the proportion of group j at time t and $\sum_j \alpha_{j,t} = 1$, $\frac{y_{j,t}}{Y_t}$ is the ratio of average income of group j to total average income Y_t at time t, and $s_{j,t}$ is the group's average savings rate. Aggregate savings fall from 17.18 to 9.37 percent, or by about 83 percent somewhat lower than Cubeddu and Ríos-Rull (1997) 115 percent CES estimates. However, the estimate is in line with estimates by Bosworth et al. (1991) given my more restricted sample. The authors obtain a slightly lower 1960s estimate of 14 percent mainly due to the addition of people above the age of 65. Table 3.1

[4]Since net worth estimates in 1983 and 1986 are provided I use these measures and follow Projector (1968) in computing net worth and savings for the 1962/1963 survey.

summarizes the specific components of the aggregate savings formula for the three groups in the 1960s and 1980s.

Table 3.1: Components of Aggregate Savings (SCF)

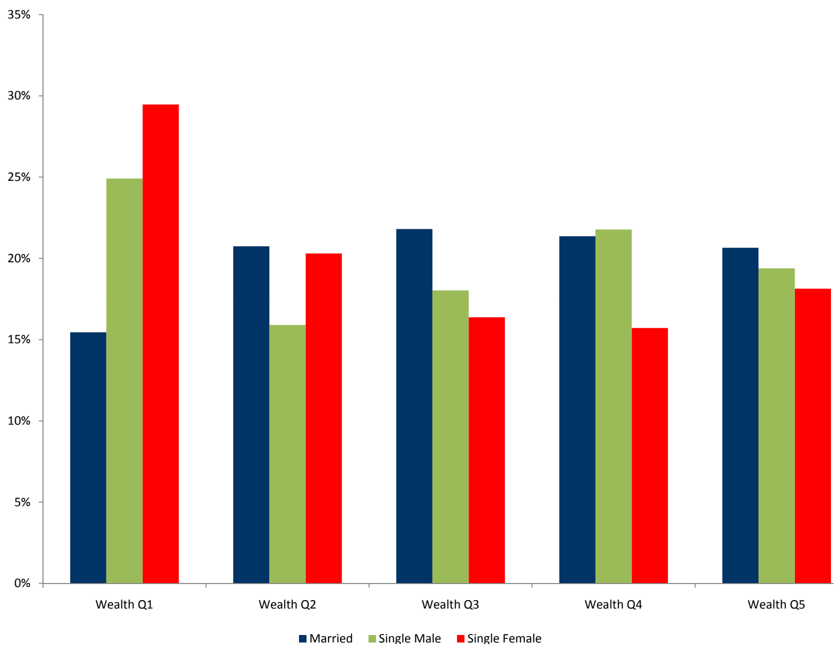
	Married		**Single Men**		**Single Women**	
	1960s	**1980s**	**1960s**	**1980s**	**1960s**	**1980s**
Fraction of Population α_j	77.68	64.58	7.05	12.69	15.27	22.74
Relative income share $\frac{y_{j,t}}{Y_t}$	1.12	1.15	0.71	0.86	0.52	0.65
Savings rate $s_{j,t}$	17.81	10.39	13.60	5.92	12.44	6.78

It is evident that most of the drop in savings is driven by a fall in the savings rate of each specific group, while the composition of the population, i.e. the fall in the fraction of married households only plays a smaller role. Aggregate savings in 1980 would have been one percentage point higher with the population structure of the 1960s, that is α_j stayed at the 1960s value. However, the drop in savings within each group could be partially driven by the fear of greater divorce rates and the lower incentive for single agents to attract a "better" spouse. Microeconomic studies provide some estimates on the effects of marital instability on savings. For example, Brenner et al. (1992) estimate that the introduction of unilateral-divorce would have lowered the savings rate by 1.3 percent after three years in the United States (their model has a two year lag structure) - according to the authors, a sizable fall in aggregate savings. Observing, in addition, a sharp rise in female labor force participation, the authors conclude that these divorce law changes changed the importance of savings in financial and physical assets toward investing in labor force participation and education. Similarly, Finke and Pierce (2006) study whether households that divorce within a 5 year time span from the Panel Study of Income Dynamics (PSID) 1994 to 1999 save more or less in anticipation of the impending divorce. The authors investigate whether the standard precautionary savings theory, that is households save more when future income is increasingly uncertain applies to marital uncertainty for all types of wage earner. It seems to only apply for spouses with similar earnings, that is a "divorcing" household, where each spouse contributes about 40 to 60 percent of total earnings, does save statistically significant more than a non-divorcing household with 40-60 earners. However, divorcing households with one high wage spouse have statistically significant lower wealth than non-divorcing households of the same type. More specifically, spouses that contributed 21 to 40 percent held $\$62,000$ compared to $\$99,000$ for non-divorcing households in wealth. Spouses that contributed 40 to 60 percent held almost $\$41,000$ more in assets than non-divorcing households. The variance in 61 to 90 percent contributers was large and wealth holding comparison inconclusive. And lastly, the highest contributers, that is 90 percent and above, held on average $\$28,000$ less in wealth than comparable married households. Therefore, in households with unequal earnings contributions precautionary savings motives are replaced by the possible asset and income redistribution upon divorce, e.g. through spousal and child support.

Given, the changes in savings behavior over time by households, a driving force that could have affected the population structure as well as the savings behavior by the three groups must have existed. What caused this sharp rise in divorce rates and the steady fall in marriages is heavily debated. Some argue that the liberalization of divorce laws, with the introduction of no-fault unilateral divorce starting in the late 1960s, had a considerable impact on divorce rates, e.g. Friedberg (1998) argues that divorce rates would have been 6 percent lower without unilateral divorce laws and the introduction of the law can account for 17 percent of the overall increase from 1968 to 1988. Others argue that the effect was less important, but nonetheless still significant. For example Wolfers (2006) finds a small and transitory rise in divorce for states that passed unilateral divorce laws, which fades within a decade. Since changes in divorce laws seem to explain only part of the rising divorce and falling marriage rates, I postulate that the drastic change of female wages and labor force participation also contributed to the changing marital environment (see also Chapter 2). In support of this theory Greenwood and Guner (2004) argue for the rise in female employment to be a substantial driving force in the falling marriage and increased divorce rates. Why female employment rose is another debate. Possible explanations are: (1) falling cost of household appliances (see Greenwood and Guner, 2004, and references therein) ; (2) the falling gender wage gap (see Jones et al., 2003); and (3) the rising returns to experience for women (see Olivetti, 2006). Since, it is unfeasible to add all these effects into the model, the closing wage gap (see Figure 2.2) and the introduction of no-fault unilateral divorce laws in the 1970s, are taken as the main driving forces in lowering marriage and increasing divorce rates. In summary, unilateral divorce and increased wages changes bargaining within a marriage by improving a spouses outside options. These two events/trends lead to a fall in the proportion of married households and a rise in divorces.

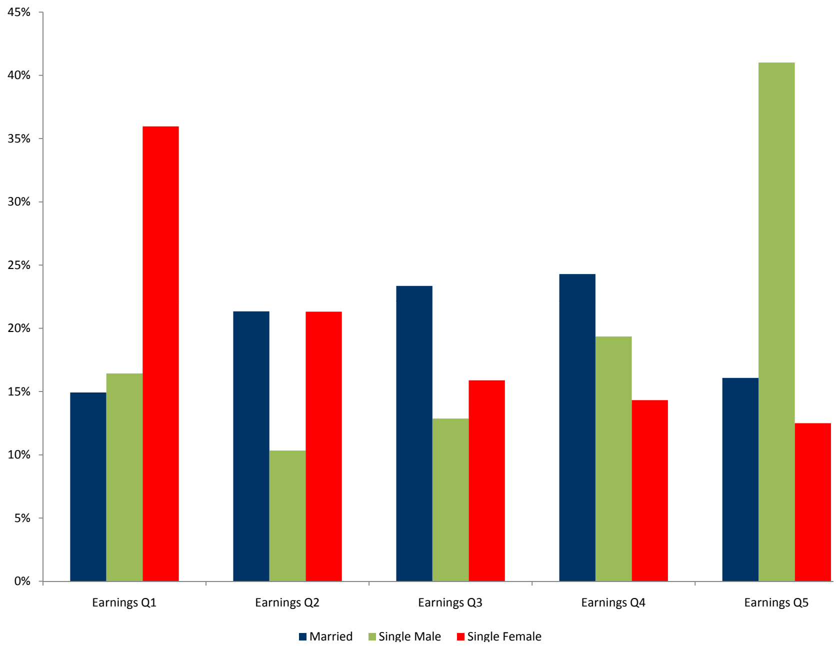
Lastly, Díaz-Gimnez et al. (1997); Budria et al. (2002) report the main facts

Figure 3.1: Distribution of Households by Wealth Quintiles



on earnings, income and wealth inequality in the U.S. economy. To this purpose the authors use data from the 1992 and 1998 Survey of Consumer Finances (SCF), respectively. Both papers conclude that households of different marital status have very different earnings, income, and wealth profiles. Figure 3.1 and 3.2 picture the distribution of each demographic group by earnings and wealth quintiles. Married households are evenly distributed between the quintiles, in both earnings and wealth, with a slightly greater concentration in the middle than the tails. Contrary, single women have a high concentration in the lowest wealth quintile and are more evenly distributed over the remaining, while their earnings distribution is highly skewed toward lower quintiles. Similarly, there is again a higher proportion of men in the lowest wealth quintile, but on average men do better than women, and men's earn-

Figure 3.2: Distribution of Households by Earnings Quintiles



ings distribution is reverse to women's, that is skewed toward the higher earnings quintiles. Moreover, Díaz-Gimnez et al. (1997) and Budria et al. (2002) find that married households have substantially higher earnings and income, while owning substantially more per capita wealth than single households.[5] Guner and Knowles (2004), when analyzing the Health and Retirement Survey (HRS), find that single men are wealthiest, while single women are poorest with $190,055 versus $65,425 average wealth. In addition, married couples hold on average $134,673 per capita wealth, while divorced agents hold $129,239 and $84,005 for men and women, respectively. It is evident that married households, even when accounting for the

[5]Results hold when adjusting for adult members in the household.

double income source, tend to be better off then single households. Moreover, Lupton and Smith (1999) find that divorced households have about 25 to 30 percent of the median net wealth of married households.

3.3 The Model

The model of precautionary savings by Aiyagari (1994) is modified to include precautionary savings due to marital uncertainty rather than labor uncertainty. Agents differ by gender, wealth holdings, ability, and marital status, which is determined endogenously through marriage and divorce decisions.[6] Moreover, the model is adjusted to include a perpetual youth feature to guarantee a steady fraction of single agents.

3.3.1 The Environment

Let the economy be populated by a large number of agents who differ by:

- Gender: $g \in \{f, m\}$, females and males, respectively;
- Marital status: $ms \in ms = \{s, c\}$, where s stands for single and c for married (coupled), respectively;
- Inherited (initial) wealth, which is randomly distributed;

[6]Results for a model with exogenous marriage uncertainty are also presented. In this scenario the marriage decision is substituted by a two-state Markov process with probability $\xi_{ij} = p(ms' = ms_j | ms = ms_i)$, where $i, j = s, c$ stands for single and "coupled" (married), respectively. Also, note, that for simplicity and without loss of generality a direct utility from the marriage is omitted in this case. The omission would only have an impact in welfare calculations, which are not computed in this chapter.

- By ability ϵ, which determines an agents efficient wage.

Agents derive utility from marriage γ and consumption $c > 0$. Agents also face a probability of death $0 < \delta < 1$, each period, and might therefore widow or leave accidental bequest. Lastly, agents cannot borrow. This is not important for the qualitative results of this chapter, however, it eases the computational burden.[7]

3.3.1.1 Preferences

Spouses are restricted to consume the same amount, but only care about own consumption. Following Cubeddu and Ríos-Rull (1997) I take into account household size in consumption calculations, such that \$1 of expenditure buys $\$\frac{1}{\eta_{ms}}$ of consumption for each agent. For single households $\eta_s = 1$, while in married households $2 > \eta_c > 1$. This feature captures the economies of scale, due to public goods consumption within the household unit,

$$u_{ms}(c) = u\left(\frac{c}{\eta_{ms}}\right) \quad \forall ms. \tag{3.2}$$

Married agents derive an additional utility from marriage, defined by match quality γ, which implies a one period utility for each spouse of

$$u_c(c) + \gamma, \tag{3.3}$$

where γ is the utility/disutility from being married. Single agents draw a common γ upon meeting. Following Greenwood and Guner (2004) γ is normally distributed and herein denoted by $S(\gamma)$,

$$\gamma \sim \mathcal{N}(\mu_s, \sigma_s^2). \tag{3.4}$$

[7] In quantitative terms, allowing for borrowing may lower equilibrium aggregate savings rates.

For married couples γ evolves according to the autoregressive progress,

$$\gamma' = (1-\rho)\mu_c + \rho\gamma + \sigma_c\sqrt{1-\rho^2}\xi, \quad \xi \sim \mathcal{N}(0,1), \tag{3.5}$$

where γ' is the next periods utility, given this period the marriage utility is γ. This implies that $\gamma'|\gamma$ is normally distributed, with the distribution denoted by $P(\gamma'|\gamma)$,

$$\gamma'|\gamma \sim \mathcal{N}((1-\rho)\mu_c + \rho\gamma, \sigma_c^2(1-\rho^2)). \tag{3.6}$$

3.3.1.2 Endowment and Factor Prices

The study solves the partial equilibrium, where wages and interest rates are set exogenously. As mentioned previously agents supply labor inelastically and only differ by their innate ability. The wage, $w_{g,t}$, as well as the set of ability ϵ_g, which differ for men and women, are determined from the data.[8] Consequently, an agent receives each period earnings of $\epsilon_g w_{g,t}$. The gender wage gap is captured by the fact that $w_{m,t} > w_{f,t}$.

3.3.1.3 Timing

The timing of events of one year is as follows:

1. Agents begin the period as either married or single (includes divorcees) with asset level $a \in A$;

2. The marriage market opens:

[8]Source: 1962-1999 Current Population Survey Integrated Public Use Micro-data Samples (IPUMS-CPS, King et al., 2004). See the following section for further details on the calibration.

(a) If an agent is single, he/she goes to the marriage market. A meeting is guaranteed, they observe each others characteristics, i.e. asset holdings and the common match quality γ. With this information as public knowledge agents decide on whether to accept the marriage. Marriage only ensues if both parties agree to the match.

(b) If an agent is married, he/she decides on whether to remain married or divorce. In order to maintain the marriage both spouses must agree.[9] However, prior to the 1960s in accordance with the stricter divorce laws agents have to agree on divorcing. If agents divorce, they remain single for the current period. In the event of a divorce assets are split, with some assets being destroyed due to divorce costs (defined in detail in the maximization problem).

3. Savings and consumption decisions: once all marriage and divorce decisions have taken place agents decide on savings and consumption.

4. Agents are born and die, and the marriage quality of married couples updates.

5. The period concludes.

From the above set-up it is evident that agents will differ in their marital status, earnings, asset holdings and gender. The next paragraphs outline the choices of each agent type.

[9] Utility is not transferable and, therefore, remaining married cannot be negotiated.

3.3.2 Maximization Problem

All agents decide whether to marry or divorce and how much to save. Let $V_{s,g}(a, \epsilon)$, be the value function of a single agent of gender g, who holds a wealth and has the innate ability ϵ. Similarly, let $V_{c,g}(\hat{a}, \epsilon, \epsilon_{g*}, \gamma)$ be the value functions for a married agent of gender g, who is married to a spouse (subscript $g*$), with marriage match quality γ and assets $\hat{a}$. The marriage and divorce decisions are then as follows:

- A single agent would marry the agent he/she meets for the set of match qualities,

$$\mathscr{G}_{s,g} = \{\gamma : V_{c,g}(\hat{a}, \epsilon, \epsilon_{g*}, \gamma) \geq V_{s,g}(a, \epsilon)\}; and \tag{3.7}$$

- A married agent would like to remain married for the set of match qualities,

$$\mathscr{G}_{c,g} = \{\gamma : V_{c,g}(\hat{a}, \epsilon, \epsilon_{g*}, \gamma) \geq V_{s,g}(\alpha_g a, \epsilon)\}, \tag{3.8}$$

  where α_g is the proportion of assets distributed to the spouse of sex g upon divorce.

Note, that there is no guarantee that the agent gets/remains married if a match quality from the given sets is drawn, as the decision also depends on the spouse. To model the change in divorce laws to unilateral-divorce, agents prior to the 1960s have to agree on divorcing, but after the late 1960s/early 1970s, each spouse can unilaterally decide on divorcing, therefore, increasing the divorce risk.

3.3.2.1 Single Agent Problem

The single agent's problem is complicated by the fact that the agent has to be aware of the distribution of single agents in the economy. The fraction of single agents (normalized to one) of opposite sex with assets a_{g*} and ability ϵ or state variable $x_{g*} = \{a_{g*}, \epsilon\}$ is denoted by $s(a_{g*}, \epsilon)$. The single agent then maximizes,

$$\begin{aligned} \max_{a'} \quad & u_s(c) + \beta\delta \Big\{ \sum_{x_{g*}} s(a_{g*}, \epsilon) \big[\int_{-\infty}^{\max(\bar{\gamma}, \bar{\gamma}_{g*})} V_{s,g}(a', \epsilon) dS(\gamma') + \cdots \\ & \int_{\max(\bar{\gamma}, \bar{\gamma}_{g*})}^{\infty} V_{c,g}(\hat{a}', \epsilon, \epsilon_{g*}, \gamma') dS(\gamma') \big] \Big\} \qquad (3.9) \\ & \text{s.t.} \\ & c = (1+r)a + w_g\epsilon - a', \qquad (3.10) \end{aligned}$$

where "primes" represent next period variables. Married assets are $\hat{a}' = a' + a'_{g*}$, as asset holdings are combined after marriage. The cut-off values for marriage $\bar{\gamma}$ and $\bar{\gamma}_{g*}$ are determined by γ that makes the inequality in the set $\mathscr{G}_{s,g}$ hold with equality. As both agents must agree on the marriage, the higher cut-off value ultimately determines the marriage choice.

3.3.2.2 Married Agent Problem

A married household chooses asset holdings for the next period in unison. This problem can be solved in various ways. The literature has traditionally focused on solving a weighted maximization problem, which leads to the Pareto optimal solution. A married household solves,

$$\max_{a'} \quad u_c(c) + \beta(1-\delta)^2\Big\{ \int_{-\infty}^{\max(\bar{\gamma}_m,\bar{\gamma}_f)} \nu_m V_{s,m}(\alpha_m a', \epsilon) + \nu_f V_{s,f}(\alpha_f a', \epsilon) dP(\gamma'|\gamma) + \cdots$$

$$\int_{\max(\bar{\gamma}_m,\bar{\gamma}_f)}^{\infty} \nu_m V_{c,m}(a', \epsilon_f, \epsilon_m, \gamma') + \nu_f V_{c,f}(a', \epsilon_f, \epsilon_m, \gamma') dP(\gamma'|\gamma)\Big\} + \cdots \tag{3.11}$$

$$\beta(1-\delta)\delta\big\{\nu_m V_{s,m}(a', \epsilon) + \nu_f V_{s,f}(a', \epsilon)\big\}$$

s.t.

$$c = (1+r)a + w_g\epsilon + w_{g*}\epsilon_{g*} - a', \tag{3.12}$$

where ν_g are spousal weights and $\nu_g + \nu_{g*} = 1$. If a couple divorces, agents, by assumption, remain single for the remainder of the period, while assets are split according to the proportions α_g (determined exogenously). Due to divorce costs $\alpha_g + \alpha_{g*} \leq 1$ is possible. The last term multiplied by $\beta(1-\delta)\delta$ is when one spouse passing away. Note that, $u_c(c)$ and γ are, by assumption, the same for both spouses. The above specification allows agents to decide on divorce unilaterally. In order to model the economy prior to the introduction of unilateral-divorce, $\max(\bar{\gamma}_m, \bar{\gamma}_f)$, is substituted with $\min(\bar{\gamma}_m, \bar{\gamma}_f)$. Once optimal asset holdings $\tilde{a}'$ are determined the value of being married is,

$$V_{c,g}(\hat{a}, \epsilon, \epsilon_{g*}, \gamma) = u_c(c) + \gamma + \beta(1-\delta)^2\Big\{ \int_{-\infty}^{\max(\bar{\gamma},\bar{\gamma}_{g*})} V_{s,g}(\alpha_g\tilde{a}, \epsilon) dP(\gamma'|\gamma) + \cdots$$

$$\int_{\max(\bar{\gamma},\bar{\gamma}_{g*})}^{\infty} V_{c,g}(\tilde{a}', \epsilon, \epsilon_{g*}, \gamma')\Big\} + \beta(1-\delta)\delta V_{s,g}(\tilde{a}, \epsilon). \tag{3.13}$$

Alternatively, agents could play a Nash bargaining game, where agents' threat points are the value of being single tomorrow $V_{s,g}(\alpha_g a', \epsilon)$. However, this is computationally more costly and will be left for future research.

3.3.3 Partial Equilibrium

As this study solves the partial equilibrium, the only equilibrium piece to analyze is the matching process of agents each period. However, agents decisions are influenced by the aggregate state of the economy. More specifically, the distribution of single agents over wealth levels influences an agent's decision on marriage, divorce and savings. This has to be accounted for when analyzing the transition of the population from one period to the next. Let the population be represented by the following three distributions, $\{p(a, \epsilon_m, \epsilon_f, \gamma), s_f(a, \epsilon_f), s_m(a, \epsilon_m)\}$ of married and single agents, respectively. Note that

$$\sum_{a,\epsilon,\epsilon_{g*},\gamma} p(a, \epsilon, \epsilon_{g*}, \gamma) + \sum_{g=m,f} \sum_{a,\epsilon} s_g(a, \epsilon) = 1, \tag{3.14}$$

must hold at all times.

The distributions of married and single agents of gender g are updated in three consecutive steps. Agents first decide to marry and divorce, where previously married couples now have an "updated" γ; then agents chose savings for the next period; and, lastly, some die with "new-born" individuals inheriting the accidental bequests of the deceased.

Suppose that the distribution of married agents over marriage quality at the beginning of the period was $\mathscr{P}_{-1}(a, \epsilon, \epsilon_{g*}, \gamma_{-1})$ for each asset level and ability combination. This period distribution after the marriage decision is,

$$\begin{aligned} \mathscr{P}(a, \epsilon_g, \epsilon_{g*}, \gamma) \quad &= \quad \int_{\infty}^{\gamma} \int_{\max\{\bar{\gamma}, \bar{\gamma}_{g*}\}}^{\infty} dP(\hat{\gamma}|\gamma_{-1}) d\mathscr{P}_{-1}(a, \epsilon_g, \epsilon_{g*}, \gamma_{-1}) + \cdots \\ & 2s_{g,-1}(a_g, \epsilon_g) s_{g*,-1}(a_{g*}, \epsilon_{g*}) \int_{\max\{\bar{\gamma}, \bar{\gamma}_{g*}\}}^{\gamma} dS(\hat{\gamma}), \end{aligned} \tag{3.15}$$

where the first term summarizes households with asset holdings a that remain married, and the second single agents that marry and remain with asset holdings $a = a_g + a_{g*}$.

The distribution of single agents is made up of the unmarried/unmatched portion of singles, plus all divorcees,

$$\begin{aligned} s_g(a,\epsilon) &= \sum_{a_{g*},\epsilon_{g*}} \frac{s_{g,-1}(a_g,\epsilon_g)s_{g*,-1}(a_{g*},\epsilon_{g*})}{\sum_{a_{g*},\epsilon_{g*}} s_{g*,-1}(a_{g*},\epsilon_{g*})} \int_{-\infty}^{\max\{\bar{\gamma},\bar{\gamma}_{g*}\}} dS(\hat{\gamma}) + \cdots \\ & \quad p(a_c,\epsilon_g,\epsilon,\gamma_{-1}) \int_{-\infty}^{\max\{\bar{\gamma},\bar{\gamma}_{g*}\}} dP(\hat{\gamma}|\gamma_{-1}), \end{aligned} \tag{3.16}$$

where the first terms is of "failed" encounters and the second terms are agents that divorce, where $a_g = \alpha_g a_c$. Updating the savings distribution with the policy function is straight forward. The fraction of married agents are,

$$p(a'(a,\epsilon,\epsilon_{g*},\gamma),\epsilon,\epsilon_{g*},\gamma) = p(a,\epsilon,\epsilon_{g*},\gamma), \tag{3.17}$$

and single agents are,

$$s_g(a'(a,\epsilon_g),\epsilon_g) = s_g(a,\epsilon_g). \tag{3.18}$$

Lastly, couples survive with probability $(1-\delta)^2$. The fraction $2(1-\delta)\delta$ becomes widowed and to maintain a steady population the difference is born with the asset levels of the deceased.

3.4 Parameter Calibration

The single agent maximization problem is complicated by the fact that an agent has to be aware of the distribution of other single agents in the economy. In order to simplify this problem, I make the reasonable assumption that agents only know the asset level of each quintile of the opposite sex, rather then knowing the full distribution.

Most parameters are taken from other related studies (see Table 3.3 for specific parameter values). However, the parameters that determine marriage matches, the initial distribution and the evolution of marriage match quality are chosen by matching marriage and divorce rates in the United States.[10] More specifically, I match the late 1980s (1984-1990) marriage rate of 58.10 percent per 1,000 unmarried women and the divorce rate of 21.45 percent per 1,000 married women. The marriage (75.10 percent) and divorce (10.64 percent) rates for the 1960s are only calibrated in one scenario (see Section 3.5).

When analyzing aggregate savings rates, all agents earn the normalized mean wage computed from the CPS. Wages are normalized to the male mean wage of each year. Table 3.2 lists all parameter values used in the simulations. Following Greenwood and Guner (2004), the annual discount factor is set to 0.96. The utility function is CRRA,

$$u(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma}. \tag{3.20}$$

The relative risk aversion parameter σ is set to 1.5 from previous studies (see Auerbach and Kotlikoff, 1987; Prescott, 1986; Huggett, 1996; Cubeddu and Ríos-Rull, 1997). The economies of scale parameter η_c is taken from the Organisation for Eco-

[10] In the exogenous marriage model the Markov transitions to match United States marriage and divorce rates are

$$\begin{pmatrix} (s, s') & (s, c') \\ (c, s') & (c, c') \end{pmatrix} \equiv \begin{pmatrix} 0.9249 & 0.0751 \\ 0.01064 & 0.98936 \end{pmatrix}, \begin{pmatrix} 0.94184 & 0.05816 \\ 0.02145 & 0.97855 \end{pmatrix} \tag{3.19}$$

for the 1960s and late 1980s, respectively.

nomic Co-operation and Development (OECD) household equivalence scale. The OECD assigns a value of one to the first household member, 0.7 to each additional adult and 0.5 to each child, implying $\eta_c = 1.7$ for this study.[11]

Table 3.2: Selected Parameter Values

Household	Discount factor (β)	0.96
	Relative risk aversion (σ)	1.5
	Household equivalence (η_c)	1.7
	Asset split female (α_f)	0.4
	Asset split male (α_f)	0.2
	Household weight ($\nu_f = \nu_m$)	0.5
Vital Statistics	Death probability (δ)	0.008
	Match quality single ($\mu_s; \sigma_s^2$)	-5.65; 7
	Match quality married ($\mu_c; \sigma_c^2$)	.462; .75
	AR(1) coefficient (ρ)	0.9
Factor Prices	Interest rate (r)	.04
	Male wage 60s and 80s($\bar{w}_{m,t}$)	1; 1
	Female wage 60s and 80s($\bar{w}_{f,t}$)	0.58; 0.77

Assets are split as in Cubeddu and Ríos-Rull (1997), 40 percent of a couples' assets are destroyed in the event of a divorce and the remainder is split by $\alpha_f = 0.4$ and $\alpha_m = 0.2$. According to the authors, this unequal asset split accounts for child/spousal support. Lastly, females and males have equal weights in the household decision problem, $\nu_f = \nu_m = \frac{1}{2}$.

[11] The study abstracts from the issue of fertility, children and dependents.

3.5 Main Results

The effects of rising divorce rates and falling marriage rates on aggregate savings are examined. As agents only face marriage uncertainties, all savings incentives are driven by the prospect of a better marriage and the prospect of divorce. Table 3.3 summarizes the results for various scenarios of the 1960s. The late 1980s serve as base period, i.e. the aggregate savings rate is normalized to one. All simulations use the parameters calibrated to the 1980s, unless otherwise specified. The scenarios simulated are,

1. Only wages are adjusted to reflect the higher wage gap in the 1960s;
2. Only the introduction of the unilateral divorce law is modeled;
3. Both points (1) and (2) are combined;
4. Same as point (3), but the initial draw of the marriage quality is raised to match marriage rates in the 1960s.

The first three scenarios show a poor match for the marriage/divorce rate of the 1960s (75.10 per 1,000 unmarried women and 10.64 per 1,000 married women). Therefore, the fourth case calibrates the mean of the initial marriage draw (μ_s) to the 1960s marriage and divorce rate. The initial marriage draw has to be raised since men receive a lower utility from marrying low wage women (see Chapter 2). As women have relative lower wages in the 1960s men are less likely to marry in the current model specification. Consequently, increasing the mean of the initial draw results in a greater number of successful meetings.

Table 3.3: Results

	Savings	**Marriage Rate**	**Divorce Rate**
(1):	1.19	54.91	23.44
(2):	1.12	84.23	19.51
(3):	1.13	50.75	11.91
(4):	1.41	75.87	10.65

Table 3.3 highlights the importance of marriage and divorce on aggregate savings. As reference the actual savings rate, computed Cubeddu and Ríos-Rull (1997), is 36 percent higher in the 1960s. Case (1) and (2) do poorly in matching marriage and divorce rates. The rise in aggregate savings is primarily due to increased savings of single females (on average 28 percent), and with a lesser extend by married households (14 percent). In contrast, the introduction of tighter divorce laws, Scenario (2), leads to an increase in the marriage rate, with divorce rates remaining almost at the 1980s level. Agents feel a lower thread to being divorced and are willing to marry with a lower match quality. The aggregate savings rate rises primarily due to married couples' behavior. While married couples save on average 27 percent more, singles save roughly 15 percent more.

Combining points (1) and (2) virtually matches the divorce rate in the 1960s. However, Scenario (3) underestimates the actual marriage rate. As explained above, this is due to the simplified version of the model. In this case, as women earn lower wages, men obtain a lower utility from marriage, ergo men are less likely to marry in the 1960s, ceteris paribus. Now increased savings are mainly driven by single women due to their lower wages, as well as the incentive structure of the marriage market that rewards savings with attracting a "better" husband. While women save on average 30 percent, married households save 13 percent and single male 5 percent more then in the 1980s.

Scenario (4) adjust for the decreased utility from marriage in the 1960s, by postulating that the initial mean marriage draw was higher in the 1960s. This implies that marriage has a benefit beyond combined wage income and economies of scale. We can think of this benefit as increased home production or fertility. The mean match quality is raised from $\mu_s = -5.65$ to $\mu_s = -4.05$. This calibrated version matches the actual fall in the aggregate savings rate remarkably well. Married couples and single females in the model save about 60 percent more in the 1960s then in the 1980s compared to 83 and 71 percent in the data (see Table 3.1), respectively. While single male in the model save roughly 40 percent more in the 1960s then in the 1980s compared to 130 percent in the data. This increase is due to lower female wages, lower divorce risk, as well as the incentive structure of the marriage market driving single agents to save more.

The exogenous version of the model fails in all aspects. The model predicts a 28 percent higher savings rate in the 1960s. In this case single females save the greatest fraction of their income (54 percent), while married couples save about the same as males (35 percent). When keeping wages constant across the time periods, aggregates savings rise by about 14 percent, with all types of households saving roughly 27 to 30 percent more. In contrast, Scenario (4) does well in matching the fall in married and single women's savings rate. However, Scenario (4) cannot account for the tremendous fall in single males savings rate from 1960 to 1980.

To summarize, marriage incentive and divorce risk have a sizable effect on aggregate savings and are more pronounced in the endogenous version, resulting from the different incentives to save in the two models. In the exogenous version, there is no incentive for single agents to save in order to attract a spouse. Moreover, in the endogenous version, married couples that have a better chance of remaining married save more, while in the exogenous version all couples face the same divorce probability. Ergo, if divorce risk is low, married agents increase savings almost twofold in the endogenous version. It should be noted that the increasing savings rate across match quality is concave, rather than monotonically increasing. More specifically, households with extremely high match quality save slightly less then a couple with an average match quality does, since savings function as an incentive to discourage divorce.

3.6 Conclusion

The purpose of this study is to assess the importance of marriage uncertainty when explaining household savings behavior. The results suggest marriage uncertainty to be a non-negligible factor in determining savings decisions within a household. Increased savings arise due to three reasons, (1) assortive matching in the marriage market leads singles to save more and attract better spouses, (2) marriage allows agents to increase savings and consumption levels due to economies of scale in consumption, and (3) savings incentives decrease considerable with increased divorce risk.

The results presented highlight the differences between the endogenous and exogenous model. Although the exogenous model allows economist to estimate more complex models due to less computational complexity, the resulting conclusions can potentially be misleading, e.g. the effect on aggregate savings is considerable greater in the endogenous version. Moreover, the reason for the fall in savings rate differ greatly between the two versions.

The above model has some shortcomings that to be analyzed in future research. As can be seen in Scenario (4) of the computational exercise the benefits from marriage in the 1960s cannot be solely explained by wages and economies of scale. This follows from omitting all decision on labor market participation, home production, and fertility. It should not be surprising that labor market choices differ considerably between married and single people. A great portion of women, especially in the past, worked primarily as housewives. In the early 1960s about 50 percent of married women were out of the labor force, but only 25 percent were so by the late 1980s. This allowed men to profit from marriage in a way not captured in this model.

Appendices

Appendix A

Chapter 1

A.1 Factor Estimation

I estimate brain and brawn requirements for United States census occupation and industry classifications from the 1977 Dictionary of Occupational Title (DOT).[1] This DOT survey set is particularly useful since, (1) it is readily available in an electronic format, (2) it has been merged with the 1971 Current Population Survey (CPS) allowing for civilian employment population weighted results, and (3) it lies mid-way through the period under study (the late 1970s). To estimate brain and brawn levels over time and gender I use factor analysis as in Ingram and Neumann (2006). Factor analysis is a technique to reduce a large number of variables, called characteristics, within a dataset to a few unobserved random variables, called factors. The 1977 DOT reports 38 job characteristics for over 12,000 occupations (see Section 1.2 for detail on these characteristics). These characteristics capture the heterogeneity across jobs and workers. While they measure different specific job requirements, they can be grouped into broader categories of skills in terms of their common underlying dimensions. This grouping reduces the dimensionality of heterogeneity allowing factor requirements to be matched in a simple general

[1]Data, including documentation, is available from the Inter-university Consortium for Political and Social Research (ICPSR).

equilibrium model.

Factor analysis uses the correlation matrix of a set of dependent variables to uncover the functional form of some undefined independent variables. In the general specification the characteristics, C_i, are modeled as linear combinations of the independent variables or factors, f_i, plus an error term ϵ_i,

$$C_i = \mu + \Lambda F_i + \epsilon_i \quad \textit{for i=1,\ldots, N}, \tag{A.1}$$

where N equals the number of occupations; C_i is the vector of characteristics (38×1); μ is the vector of characteristic means (38×1); Λ is a vector of coefficients $(38 \times n_f)$ called factor loadings; $F_i = (f_1, f_2, \cdots, f_{n_f})'$ is a vector of the factors $(n_f \times 1)$; and $\epsilon_i \sim N(0, \Sigma)$ is the uncorrelated error vector, with Σ being the diagonal variance covariance matrix.

To preform factor analysis certain variables of the DOT need to be rescaled, for example, the variable documenting a job's location is coded *I=indoors*, *O=outdoors*, and *B=both indoors and outdoors*. I follow Vijverberg and Hartog (2005) in rescaling all variables. Additionally, to obtain population representative estimates, the occupations in the DOT must be weighted. As the DOT itself does not record the number of workers for a given job, the 1971 CPS merge is used. In the 1977 DOT, the *Committee on Occupational Classification and Analysis of the National Academy of Sciences funded by the Department of Labor and the Equal Employment Opportunity Commission* merged the 12,431 1977 DOT jobs to 7,289 unique occupation-industry pairs from the 1970 United States Census providing 1971 CPS weights of the civilian labor force. The reduction from 12,431 to 7,289 is the result of more detailed occupational classifications in the DOT. For example, while there is only one "waiter/waitress" category in the census classification, the DOT contains multiple categories, such as "waiter/waitress formal", "waiter/waitress, head", "waiter/waitress, take out."

Since only information on the characteristics is available, this information is used to estimate both, Λ and F_i from

$$E\left(\hat{C}-\mu\right)\left(\hat{C}-\mu\right)' = \Lambda E\left(\hat{F}\hat{F}'\right)\Lambda' + \Sigma, \tag{A.2}$$

that is, the covariance in the 38 characteristics can be explained by a reduced number of factors, where $\hat{C} = [C_1 C_2 \dots C_N]$ and $\hat{F} = [F_1 F_2 \dots F_N]$. It is clear that Λ, $E\left(\hat{F}\hat{F}'\right)$, and Σ are not separately identifiable from this expression. Therefore, factor analysis generally assumes factors to follow a standardized normal distribution, which allows for the identification of Σ. To separately identify Λ and $E\left(\hat{F}\hat{F}'\right)$ additional restrictions must be imposed. In standard factor analysis the covariance between factors is set to zero,

$$E(\hat{F}\hat{F}') = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ & & \ddots & \\ 0 & \cdots & & 1 \end{bmatrix}, \tag{A.3}$$

allowing both Λ and Σ, which is diagonal by assumption, to be identified separately. In this specification each characteristic is a function of all factors. In practice, the first factor estimate will explain the maximum possible covariance between the characteristics. The second factor is estimated to explain the maximum covariance remaining, and so on. A maximum of 38 factors could be estimated, in which case 38 factors are necessary to explain the covariance between all characteristics. In this study three factors explain most of the characteristics' covariance structure (over 93 percent of the total covariance).[2] After preforming initial factor analysis as described above, the first factor is positively related to intellectual characteristics and negatively correlated with both motor coordination and physical characteristics, making it difficult to interpret the factor consistently. Therefore, I reestimate the factors assuming they are correlated, similarly to Ingram and Neumann (2006). However, for identification purposes, job characteristics that explain one factor are restricted and cannot explain another factor. For example, mathematical development only explains a job's intellectual requirements directly, while it is only informative on the job's physical requirements through the correlation of the aggregate brain and brawn factor. Table A.1 provides the classification of characteristics across factors as well as the factor loading coefficients, which are used to determine factor estimates for each occupation-industry combination present in the 1971 CPS. Given the grouping of characteristics and the estimates of factor loadings, I call the three factors brain, motor coordination, and brawn. Brain, brawn, and motor coordination trends over time (see Figure 1.4) are robust to either the standard identification restriction of uncorrelated factors or my reestimated identification of correlated factors.

[2] Ingram and Neumann use the 1991 DOT with over 53 characteristics, primarily expanded by detailing physical and environmental characteristics, to estimate a total of four factors: (1) intelligence, (2) clerical skill, (3) gross motor skill, and (4) ability to deal with physically and hazardous work.

Table A.1: Factor Loading Estimates (Λ)

Job Characteristic	**Coefficient** (Λ_i)
Brawn Factor	
Repetitive Work	0.30406
Climbing/Balancing	0.77651
Stooping/Kneeling/Crouching/Crawling	0.81000
Strength Requirement	0.88075
Environmental Exposure[a]	0.77673
Indoor or Outdoor Work	0.68110
Brain Factor	
Reasoning Development	0.96668
Mathematical Development	0.89217
Language Development	0.95275
Specific Vocational Preparation	0.77567
General Intelligence	0.94685
Verbal Aptitude	0.94068
Numerical Aptitude	0.83968
Clerical Aptitude	0.70447
Talking and Hearing	0.57950
Performs Variety of Duties	0.24961
Directing/Controlling	0.61560
Interpreting Feelings/Ideas/Facts	0.18598
Influencing People	0.37265
Making Evaluations Based on Judgment	0.60055
Making Judgments/Decisions	0.43480
Dealing with People	0.49332
Motor Coordination Factor	
Seeing	0.77650
Spatial Aptitude	0.43418
Form Perception	0.71349
Motor Coordination	0.84869
Finger Dexterity	0.88302
Manual Dexterity	0.66313
Eye-Hand-Foot Coordination	0.07607
Color Discrimination	0.37763
Attaining Precise Tolerances	0.72865
Reaching/Handling/Fingering/Feeling	0.50627
Making Decisions Based on Measurable Criteria	0.30894

Notes: Estimated using maximum-likelihood factor analysis.

[a] Environmental conditions, such as the presence of heat, cold, and humidity, were combined to one variable prior to the estimation.

A.2 Regression Estimates

Table A.2: Factor Price Estimates (p_b, p_r)

	1950-1980	**1980-2005**
Brain	0.1138981*	0.153931*
	(0.0002042)	(0.0000898)
Brawn	0.0446319*	0.13126*
	(0.0001997)	(0.0000963)
Brain×T	0.0629789*	0.0555917*
	(0.0002157)	(0.0001103)
Brawn×T	0.0793846*	-0.0600552*
	(0.0002184)	(0.0001233)
R-squared	0.3170	0.2576

Notes: * Statistically significant at the 1 percent confidence level. Standard errors are in parenthesis. The regression also includes controls for age, age squared, years of education, marital status, race, region, motor coordination factor, and a T-year dummy.

Table A.3: Production Regression Estimates

Constant	0.0416971
	(0.0393867)
Time Trend	0.0088655*
	(0.000657)
Brain to Brawn Labor	-0.3967528*
	(0.0593553)
R-squared	0.739

Notes: * Statistically significant at the 1 percent confidence level. Robust standard errors are in parenthesis.

Appendix B

Chapter 2

B.1 Omitted Derivations

This appendix provides some of the derivations of the equations in section 2.4. The partial derivative of marriage and divorce thresholds on wages, (2.27), is,

$$\begin{aligned}\frac{\partial \bar{b}_{1,k}}{\partial \omega_{2,k}} &= A_h \frac{\omega_{1,,k}}{\omega_{2,k}^2}\left[\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}\right]^{\frac{1}{(\sigma_\alpha-1)}} \times \cdots \\ &\left[\frac{(1-\gamma_c)^{\sigma_\alpha} - \frac{\omega_{2,k}}{\omega_{1,k}}\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)}}{\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}}\right], \end{aligned} \tag{B.1}$$

which is less than zero if $(1-\gamma_c)^{\sigma_\alpha} - \frac{\omega_{2,k}}{\omega_{1,k}}\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)} < 0$. Given condition (2.13) this is satisfied for any parameter values. The partial derivate for the secondary worker's threshold, (2.28), is,

$$\begin{aligned}\frac{\partial \bar{b}_{2,k}}{\partial \omega_{2,k}} &= A_h \frac{\omega_{1,,k}}{\omega_{2,k}^2}\left[\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}\right]^{\frac{1}{(\sigma_\alpha-1)}} \times \cdots \\ &\left[\frac{(1-\gamma_c)^{\sigma_\alpha}}{\gamma_c^{\sigma_\alpha}\left(\frac{\omega_{2,k}}{A_h}\right)^{(\sigma_\alpha-1)} + (1-\gamma_c)^{\sigma_\alpha}}\right], \end{aligned} \tag{B.2}$$

which is greater than zero as by definition $(1-\gamma_c)^{\sigma_\alpha}$ is non-negative.

The inequality from (2.29) follows from the assumption that the primary wage earner has a higher wage than the secondary wage earner, i.e.

$$\bar{b}_{1,k} > \bar{b}_{1,k} \tag{B.3}$$

$$\Rightarrow U_{m,e} - U_k > U_{f,e} - U_k \tag{B.4}$$

$$\Rightarrow U_{m,e} > U_{f,e} \tag{B.5}$$

$$\Leftrightarrow \omega_{m,e} > \omega_{f,k}. \tag{B.6}$$

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