Employment and the Sex Ratio in a Two-Sided Model of Marriage

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Abstract

The implications of the sex ratio for marriage and employment decisions are considered in a dynamic, equilibrium model of marriage. The sex ratio in the marriage market evolves endogenously over time in the model, driven by exogenous death rates and the marital status decisions of all agents in the previous period. In turn, the sex ratio influences the allocation of income within married households and the ease with which single agents contact prospective spouses. The structural parameters of the dynamic, two-sided model are estimated using a panel of young men and women from the U.S. The results indicate the presence of substantial search friction in the marriage market and the responsiveness of intra-household transfers to changes in marriage market opportunities. Together with large differences in death rates across sex and race, these results account for the observed trends in family structure and employment behavior in the U.S.

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1 Introduction

A growing literature has begun to recognize the important links between labor supply and marriage decisions. This recognition is driven in large part by several empirical regularities illustrating dramatic changes in family structure and employment behavior over time and across different groups in the U.S. One of the most striking trends concerns the wide variation in marriage and employment behavior across race: blacks are less likely to marry and are more likely to divorce than whites. Furthermore, black men have lower labor force participation rates than white men, while black married women are more likely to work than white married women. Married black women are also more likely to work than their single counterparts, while the converse holds for white women. The divergence in employment and marriage behavior across blacks and whites also coincides with differences in marriage market conditions, summarized by the sex ratio. The sex ratio, defined as the ratio of single men to women, is an important indicator of marriage market conditions as it measures the relative availability of men to women in the marriage market. The sex ratio is consistently lower for blacks than for whites throughout recent history due to exogenous racial differences in the sex ratio at birth and to differences in homicide, accident and infant mortality rates.[1] As a result, the marriage market conditions faced by black men and women differ considerably from those faced by whites.

In this paper, the relationship between the sex ratio and marriage and employment decisions is examined within an equilibrium model of marriage. The sex ratio evolves endogenously over time within the model as individuals flow in and out of the marriage market, driven in part by exogenous differences in death rates across men and women and across blacks and whites. Differences in the death rates drive gaps in the aggregate stocks of men and women over time and have important implications for the supply of single men relative to single women in the marriage market. In particular, individuals with high death rates are in relatively limited supply in the marriage market and therefore face more favorable marriage market opportunities than those with low death rates. Such imbalances in marriage market conditions, measured by the sex ratio, influence marriage and employment decisions through two channels. First, in the spirit of Becker (1973) and

[1] In addition, a disproportionate number of black men enter the armed forces (Guttentag and Secord, 1983).

Chiappori, Fortin and Lacroix (1998), supply and demand conditions play central roles in the intra-household allocation process: the sex ratio measures marital opportunities of both partners outside the current match and as such affects the share of marital income each agent can command within the current marriage. As a result, agents whose marital opportunities improve receive larger income transfers within the household and are therefore less likely to work. This feature of the model is consistent with the high employment rates of white men as compared to black men and the opposing trend for women, for the death rates observed in the data are higher for black men than for black women while the converse holds for whites.

Second, it is assumed marriage opportunities may not be available in every period and the sex ratio affects the amount of friction in the marriage market. In particular, the rate at which women and men meet in the marriage market is a function of the relative size of the pools of single men and women as in Pissarides (1985). As a result, individuals with high death rates meet potential spouses with relative ease, for the number of potential competitors relative to the number of prospective spouses is falling over time. Marriage market conditions therefore have two opposing effects on the decision to marry. On one hand, increases in intra-household transfers and higher contact rates increase the attractiveness of marriage and the opportunities to marry, respectively. On the other, persistence in the death rates over time imply that individuals in limited supply face a better marriage market tomorrow and therefore have incentives to delay marriage or initiate divorce in the current period.

The structural parameters of the model are estimated using a sample of men and women from the National Longitudinal Survey of Youth 1979 Cohort (NLSY79). The period of time covered by the NLSY79 (1979-1996) is characterized by substantial variation in the sex ratio, employment and marriage rates across race and over time. Several interesting empirical results are worth noting. First, the estimates confirm the importance of large differences in death rates across race and sex for this recent cohort in driving the trends in marriage market conditions over time. Second, the results indicate the presence of substantial search friction in the marriage market, where individuals with poor marriage market opportunities face relatively high search friction. Finally, individuals experiencing an increase in marriage market opportunities receive larger intra-household transfers, as consistent with the model and past studies (Chiappori et al, 1998). Together, these results provide new insight into the causes and consequences of differences in employment and marriage behavior across various groups in the population. Interestingly, ignoring the dynamics inherent in marital status decisions leads to a different interpretation of the observed marriage and employment trends: the estimates from a static version of the model suggest that the preferences of black males to remain single drive the low marriage and high divorce rates for blacks.

This paper is one of the first to estimate a dynamic, two-sided marriage model.[2,3] To my knowledge, the only other papers to estimate equilibrium models of marriage are the study of inter-racial marriage rates by Wong (1997) and the incorporation of differential fecundity in a matching model by Hamilton and Siow (1999). In Wong's model, a race-specific taste difference serves as a tax on household production, reducing the likelihood of matches between individuals of different ethnic backgrounds. In this particular framework, the marriage market is stationary over time, as individuals leaving the market are automatically replaced by identical agents, and the contact rate is constant over time. In contrast, the marriage market evolves in an endogenous, non-stationary way within my model. This particular component of the model can capture important changes in marriage and employment behaviour as individuals age, which can not be captured in a stationary marriage model. Hamilton and Siow (1999) develop an equilibrium marriage model with differential fecundity and search friction that is consistent with the assortative sorting on class and observed differences in age at marriage across social status and sex. The model is estimated on unique data from 18th century Quebec. The use of an early time period allows the authors to abstract from divorce decisions: in my model, the interaction between the sex ratio and divorce plays an important role in explaining the differences in behavior across blacks and whites.

[2]A recent literature has focused on various aspects of the dynamics of labor supply and marital status decisions (van der Klauuw, 1996; Brien, Lillard and Stern, 1999; Eckstein and Wolpin, 1989; Keane and Wolpin, 2000), illustrating the importance of labor supply and marital dynamics. However, the models are one-sided in nature and do not consider the effects of marriage market conditions on employment and marriage decisions.

[3]The incorporation of both sides of the marriage market is consistent with the burgeoning theoretical literature on two-sided search and matching. See, for example, Aiyagari, Greenwood and Güner (2000), Greenwood, Güner and Knowles (1999), Chade and Ventura (1998), Burdett and Coles (1998), and Burdett and Wright (1998).

2 Data

In order to estimate a dynamic model of marriage, it is necessary to employ a data set where individuals can be followed over time from the point they enter the marriage market. The NLSY79, comprising a sample of 12,686 men and women who are between the ages of 14 and 22 in 1979, is well suited for this purpose. The composition of the sample allows one to follow a large group of individuals for up to 18 years from ages at which they enter the marriage market. Furthermore, the data contain information on wages, race and standard economic characteristics as well as detailed information on marriage, cohabitation and employment transitions. The following restrictions are placed on the sample. First, individuals in the military and Hispanics are removed. Second, to accurately capture marital status transitions, observations following a break in an individual's history, as well as observations with missing or inconsistent information, are removed.[4] After restricting the age range in the sample as outlined below, the resulting sample size is 5,295 in 1979 with a total of 70,494 person-year observations from 1979 to 1996.

The NLSY79 sample is used to construct marital and employment status, as well as measures of labor market earnings and non-labor incomes, for use in estimation. An individual is defined as married if they are currently married or cohabiting and the marital history is constructed using annual information on marital status at the interview date in every year. Starting and ending dates of relationships are not used to construct the marital histories because this information is not available in all years for cohabitors.[5] As a result, some spells may be missed and the length of some spells may be measured inaccurately.[6] In particular, individuals who report being married or common-law in two consecutive periods are treated as if they are in the same relationship in both periods; in some instances it may be the case that the individual reports two distinct relationships that are treated as one relationship. Despite its shortcomings, this approach is used so that the definitions of marital status and the measurement of transitions are consistent across the years and

[4]Individuals with only one valid observation are also removed.

[5]Information on the starting date of cohabitations, on whether individuals lived with their spouses before marriage and whether the respondent lived with their spouse continuously before marriage is only available in 1990 and 1992-1996. In the remaining years, information on current cohabitation status, but not changes in status between interviews, is available in every year.

[6]It is assumed marital status in 1978 is single for all respondents, thus the durations for some marriages may be measured inaccurately for this reason as well. However, the low marriage rates in 1979 suggest this assumption only affects a small number of matches.

across cohabitations and marriages. This does not appear to be a serious cause for concern, as only 135 person-year observations reported more than one marriage from one interview date to the next over the 1979 to 1996 sample period.[7]

Employment status is measured by an indicator equal to one if individuals worked at least 775 hours in the interview year and zero otherwise. This measure thus includes individuals working at least 15 hours per week or at least 20 full time weeks per year.[8] Earnings are measured as annual income from wages, salaries and tips.[9] Non-labor income in this instance covers a broad range of categories, including farm income, unemployment benefits, alimony and child support. Income from social programs such as AFDC, food stamps, other public assistance and Supplement Security Income (SSI) is also included in non-labor income. In addition, income from other persons, veterans pay, workers compensation and disability benefits are included in non-labor income. The aforementioned sources of income are all included in order to maintain consistency over the sample period as non-labor income is grouped in wide categories in the early years of the sample.[10] Earnings and non-labor income are subsequently converted to real terms, where 1981 is the base year. Educational attainment is measured by an indicator equal to 1 if respondents have at least a high school education and 0 otherwise. Regional indicators for the northeast, south and western portions of the U.S. are defined. An indicator equal to 1 when children are present and 0 otherwise is also defined. In the empirical specification, time is measured in terms of the number of years the individual has been in the marriage market. Finally, a race indicator equal to 1 if the respondent is black and 0 if white is constructed.

Table 1 contains sample statistics by race and sex for selected years in the panel. The data illustrate several interesting patterns. Starting with the empirical evidence regarding

[7] It is important to emphasize that this figure includes cohabitations at, but not between, interview dates. It is likely the number of cohabitations between interview dates is greater than the number of marriages, given the relative ease with which cohabitations can be dissolved and the greater stability of marriages as compared to cohabitations. See Brien, Lillard and Stern (1998) for a more complete discussion of these issues. It is also possible that relationships are missed in the marital history if an individual was single at two consecutive interview dates but married or cohabited between interview dates.

[8] Employment status is not available for individuals under the age of 16 and for a small number of 17 year olds in the NLSY. This should not pose a problem in estimation as the vast majority of such individuals are enrolled in school full-time and are unlikely to have annual hours in the labor market above 775.

[9] The bottom of the earnings distribution is trimmed at the 5% level.

[10] In particular, for individuals not meeting any of a set of criteria (18 years and older, has child, enrolled in college, married or living outside their parent's home), all income with the exception of earnings and unemployment compensation is grouped in one category.

children, black women are more likely than whites and black men to have an early birth. The fact that the birth rates for black men tend to be quite low despite the high birth rates for black women suggests many of the births to black women result in single parenthood. There also exist large differences in earnings across race and sex. White women have higher labor market earnings than black women by 1996 despite the similarities in educational attainment and fertility. In contrast to the findings regarding earnings, black women tend to have the highest levels of non-labor income in the latter years in the sample, likely due to the high participation rates in social assistance programs of black women relative to white women.

Marriage rates also tend to differ widely across race: the fraction of married men and women in the sample is consistently higher for whites than for blacks across the sample period. Within race, black women are less likely to be married than black men, while the converse holds for whites. Turning to the trends in employment rates, men are more likely to work than women within each racial group as expected. In the initial sample period, it appears whites are more likely to work than blacks: by 1996, there remains a substantial gap in the employment rates of black and white men, although the employment rates for women across race are quite similar. Table 2 contains employment rates by race and marital status for men and women in the 1996 cross-section. Comparing employment rates across race and marital status for men and women illustrates several interesting trends. The data suggest married white females have lower employment rates than their single counterparts, while the opposite trend emerges for black women. For men, whites tend to work more than blacks and married men tend to work more than single men. The differences in employment rates for men across race stand in contrast to the pattern for women, where black married women have higher employment rates than white married women. It is next of interest to consider how the cross-sectional differences in employment and marriage rates across race and sex relate to the trends in the sex ratio. To answer this question, it is necessary to determine an appropriate measure of outside marriage market opportunities.

2.1 Measurement of the Marriage Markets

In constructing sex ratios for the empirical analysis, I attempt to measure the marriage market for this recent cohort in a way that is sufficiently narrow so that an accurate measure is captured, yet sufficiently wide so as to minimize the degree to which individuals may be matching outside their specified market in the data. For simplicity, the marriage market is segmented by age and race in the empirical analysis.[11,12] The sample is subsequently limited to women aged 15 to 19 in 1979 and men aged 17 to 21, an age range that is sufficiently wide to minimize the number of individuals who match outside the chosen age range but sufficiently narrow so that the age groupings included in the first year of the marriage market can be considered exogenous.[13] Measures of the marriage market are also limited to single agents, as consistent with the model outlined below.

Once the marriage market is segmented by age and race, I re-weight the NLSY79 sampling weights such that the stocks of single and married men and women in each marriage market and year match the corresponding stocks in the Current Population Survey (CPS), and I construct measures of the stocks of single men and women in each market using the revised weights.[14] The NLSY79 sampling weights are re-weighted using the CPS because the weighting scheme in the NLSY79 may not be representative of the population in terms of age, sex, race and marital status and because attrition in the NLSY79 may result in mismeasurement of the stocks of single men and women in the marriage markets over time.

Based on the above assumptions, sex ratios are constructed for each marriage market and are compared to the trends in employment and marriage rates as illustrated in Figures 1 and 2, respectively. Substantial differences exist in the initial sex ratios in 1979, where the

[11]With regard to age, data from the NLSY79 suggest men tend to be older than their spouses by 2 to 3 years on average, with 90% marrying women who are less than three years older and seven years younger. It should be noted that age differences across men and women narrowed over the same period the sex ratio declined. The median age at marriage for men is 23 and for women is 20 in 1950; in 1990 the median ages at marriage are 26 and 24 for men and women, respectively.

[12]Data from the Census indicate the strong presence of sorting on race: in 1980, 0.2% of all marriages in the U.S. were between black men and white women and 0.1% are between white men and black women. U.S. Bureau of the Census, Current Population Report, Series P20-509, "Household Characteristics: March 1997," and earlier reports.

[13]The NLSY79 contains limited sample sizes for individuals aged 14 and 22 in the data, making the use of a wider age category unattractive. In contrast to previous studies, I do not segment the marriage market by region because of the mobility of young men and women during the sample period. Using the same data, Kennan and Walker (2000) report that 21% of youths with at least a high school education move to a new state approximately 1.5 times within five years of leaving school. Considering the high degree of mobility evident in the sample, regional sex ratios can not reasonably be treated as exogenous.

[14]In an effort to match the CPS data to the NLSY79 data as closely as possible, individuals serving in the military are excluded from the CPS for the construction of the weights. Since data are not available on cohabitors for the majority of years in the CPS, individuals who are cohabiting in the NLSY79 are treated as single for the purposes of assigning CPS weights but are treated as married in the construction of the stocks once the NLSY79 has been reweighted.

sex ratio is 1 for whites and 0.85 for blacks. The differences continue to widen over time as individuals flow out of the marriage market into relationships. Interestingly, the sex ratio for blacks tends to decrease over time, while the opposite trend emerges for whites. For blacks, the decline in the sex ratio over time reflects differences in mortality and incarceration rates across black men and women. For whites, the increase in the sex ratio is due in part to the larger influx of male immigrants to the U.S. as compared to females within recent decades.[15] The differences in the sex ratio across race tend to coincide with the differences in employment and marriage rates over the same period. In general, the data indicate that those groups facing low sex ratios tend to have lower marriage and higher employment rates. In the following section, a model of employment and marriage is presented that can account for the differences in behavior across different groups within this cohort.

3 The Model

The model builds on the work of Becker (1973), Chiappori et al. (1998) and van der Klaauw (1996), capturing relationships between employment, marital status and the marriage market. In every period, individuals of gender G, $G \in \{M, F\}$, maximize the present discounted value of expected utility over a finite horizon through the choice of marital and employment status and consumption. Employment opportunities are available in every period and individuals are assumed to either work full-time in the market or full-time at home. Marital status and employment status decisions are discrete in nature. The combination of marital and employment status decisions is equivalent to choosing one of four potential states: single and not working (sn), single and working (sh), married and not working (mn), married and working (mh). Denote the choice set for the single states $K_s = \{sn, sh\}$ and the choice set for the married states $K_m = \{mn, mh\}$.

It is assumed only single individuals are in the marriage market and that marriage opportunities may not be available in every period.[16] When marriage opportunities arrive, individuals decide to match or to remain single. Both partners must agree to marry for a match to form. If a match is made, individuals remain married for at least one period

[15] U.S. Bureau of the Census, Current Population Report, Series P20-486, "Foreign-Born Population: March 1994".

[16] This assumption is consistent with other models of matching in marriage markets (Aiyagari, Greenwood and Güner, 2000; Brien, Lillard and Stern, 1998; Drewianka, 1998; and Wong, 1997).

after which they may divorce. If agents decide to divorce, they must remain divorced for at least one period after which they re-enter the marriage market. The model abstracts from the process by which agents sort in the marriage market and assumes individuals randomly meet within marriage markets segmented by known, exogenous characteristics. For ease of exposition, the model presented below considers the case of one marriage market. Under the assumption that individuals cannot choose their marriage market, the extension to several markets is straightforward and is considered in the empirical analysis.

Five factors determine the utility gains to marriage and employment. First, individuals receive utility directly from consumption (x_t) and each marital and employment state. Second, individuals receive utility from the presence of children (c_t), where children are represented by an indicator equal to one if a first birth occurred and where the utility from children can vary depending on employment and marital status in the current period. Third, the utility from each state may also differ for individuals depending on their exogenous individual characteristics, summarized by I possible types. Individual types may change over time but are assumed to do so in an exogenous, non-stochastic fashion. Fourth, individuals who leave their marriages through divorce or the death of their spouse are subject to separation costs (τ_t), such as the loss of marital-specific capital. Finally, utility depends on an idiosyncratic component that differs depending on current employment and marriage decisions and is uncorrelated over states, time and individuals. The shock realized by an individual in state k and period t is denoted ν_{kt}. It is assumed that utility is linear in ν_{kt} and that shocks to current period utility are observed by agents before they make employment and marriage decisions in each period. The resulting utility function for an individual of type i and gender G in state k and period t can be expressed as

$$u_k^G(x_t, c_t, i_t, \tau_t) + \nu_{kt}^G, \tag{1}$$

$k \in \{sn, sh, mn, mh\}$, $i_t \in I$. The budget constraint is a function of two potential sources of income in the current period, labor market earnings (w_t) and non-labor income (y_t)

$$x_t = w_t + y_t. \tag{2}$$

Labor market earnings are assumed to depend on the individual's type and an *i.i.d.* idiosyncratic component (e_{wt}), where the shocks to current period earnings are observed by agents before they make their employment and marriage decisions in each period

$$w_t = \begin{cases} w^G(i_t) + e_{wt} & \text{if } k \in \{sh, mh\}, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

Non-labor income differs depending on the current marital state to capture the notion that different sources of non-labor income may be available to individuals depending on their current marital status. If single, non-labor income may also differ depending on whether the individual is working or not working. If married, the couple receives total non-labor income y_{mt}, where y_{mt} is a function of exogenous characteristics of both partners in the marriage. In each instance, non-labor income is also a function of *i.i.d.* idiosyncratic components (e^G_{snt}, e^G_{sht}, e_{mt}) observed by agents before they make their employment and marriage decisions in each period.

Non-labor income for married couples is divided among the partners for personal consumption according to a sharing rule in the spirit of Chiappori (1992).[17] As in Chiappori, et al. (1998), the income transfer summarized by the sharing rule depends on the current sex ratio (R_t) in the marriage market. The sharing rule also depends on the potential earnings ($\overline{w}$) of both partners in the marriage. It is assumed for simplicity that potential earnings are known by all agents in every period and are determined by the same characteristics that determine realized earnings. All three arguments influence the intra-household transfer through their effect on an individual's opportunities outside the current marriage. The sharing rule for a married couple with a type i wife and a type j husband in period t can therefore be expressed as

$$\phi(R_t, \overline{w}^F(i_t), \overline{w}^M(j_t)).$$

The hypothesis that men transfer more resources to women when women face better opportunities outside the marriage is consistent with a sharing rule that is increasing in R_t.[18] Non-labor income can therefore be defined as

$$y_t = \begin{cases} y^G_k(i_t) + e_{kt} & \text{if } k \in \{sn, sh\}, \\ \phi(R_t, \overline{w}^F(i_t), \overline{w}^M(j_t)) & \text{if } G = F \text{ and } k \in \{mn, mh\}, \\ y_m(i_t, j_t) + e_{mt} - \phi(R_t, \overline{w}^F(i_t), \overline{w}^M(j_t)) & \text{if } G = M \text{ and } k \in \{mn, mh\}. \end{cases} \tag{4}$$

[17] Within Chiappori's (1992) general framework, it is assumed that married individuals retain separate utility functions after matching. The model abstracts from the details of the bargaining process and requires only the assumption that intra-household allocations are Pareto efficient.

[18] There is no constraint restricting the transfer to be less than or equal to y_{mt}; therefore, individuals may transfer non-labor and labor income to their spouses.

In this framework, as in Chiappori et al. (1998), the sex ratio affects current period employment decisions directly through its effect on the intra-household allocation of income for married couples. In contrast to Chiappori et al., (1998), the relationship between intra-household tranfers and the sex ratio can also influence the behavior of single agents: since the model incorporates the decisions to marry and divorce, movements in the sharing rule may change the desirability of marriage.

3.1 Fertility

Children are not treated as choice variables in the model due to the complexity inherent in modeling fertility decisions explicitly in this framework. However, children play important roles in employment and marital status decisions for men and women. Therefore, it is assumed first births arrive stochastically within the model, where the probability of a first birth varies with individual characteristics as well as with the agent's state in the previous period

$$\Pr(c_t = 1 | c_{t-1} = 0) = B^G(i_t, k_{t-1}).$$

It is further assumed $c_t = 1$ is an absorbing state to abstract from child mortality and the loss of access to children through divorce.

3.2 Marriage Market Friction

Individuals determine the utility they expect to receive in each marital and employment state as outlined above. However, it may be the case that marriage opportunities are not available in every period. A natural way to capture this idea is to introduce search friction in the model. In this context, the sex ratio determines the degree of difficulty agents face in contacting potential partners in the marriage market. Friction in the marriage market is modeled in the spirit of Pissarides (1985), where the process by which men and women contact each other can be described by a technology in which the total number of contacts (C_t) is a function of the stocks of single men (S_t^M) and women (S_t^F) in the marriage market in the current period

$$C_t = C(S_t^F, S_t^M).$$

The probability that an individual will be contacted in the marriage market is equal to the total number of contacts in the marriage market divided by the total stock of single individuals of the same gender

$$p_t^G = \frac{C_t}{S_t^G}.$$

Following den Haan, Ramey and Watson (2000), a contact technology of the following form is adopted

$$C_t = \frac{S_t^F S_t^M}{[(S_t^F)^\varphi + (S_t^M)^\varphi]^{\frac{1}{\varphi}}}, \tag{5}$$

where the parameter φ can be interpreted as a measure of search friction in the marriage market. Under this specification, the contact technology is constant returns to scale and is increasing in the numbers of single men and women in the marriage market. This particular specification is appealing in that, for values of $\varphi > 1$, it generates matching probabilities between 0 and 1 for all values of S_t^F and S_t^M.

The effect of the sex ratio on search friction is readily observed, as the probability women are contacted in the marriage market is proportional to the probability men are contacted, where the factor of proportionality is the sex ratio

$$p_t^F = R_t p_t^M.$$

In other words, the sex ratio measures the degree of search friction faced by women relative to men, where a higher sex ratio translates into relatively less search friction for women than for men.

When a contact is made in the marriage market, agents draw a spouse of type j, $j \in \{1, 2, .., I\}$ and fertility status c', $c' \in \{0, 1\}$. Let G' denote the gender of an agent's spouse or potential spouse. Conditional on making a contact, the probability of drawing a potential spouse of type j and fertility status c' in period t is denoted $q_s^{G'}(j_t, c'_t)$ and is simply the fraction of potential spouses of type j and fertility status c' in the marriage market in period t. The probability of contacting a potential spouse of type j and fertility status c' can then be expressed as

$$p_t^G q_s^{G'}(j_t, c'_t),$$

where $\sum_j \sum_{c'} q_s^{G'}(j_t, c'_t) = 1$.

3.3 Value Functions

For ease of exposition, preferences are expressed in terms of the reduced form utility corresponding to each state in the following sections.[19] The reduced form utility of each agent varies depending on whether the agent is currently married or single. A currently single agent is subject to divorce costs if married in the previous period; the transfer received by a currently married individual depends on the sex ratio in the marriage market and their spouse's type. Substituting (2)-(4) into (1) yields

$$U_k^G(i_t, c_t) + \varepsilon_{kt}^G = \begin{cases} \widetilde{U}_k^G(i_t, c_t, \tau_t) + \varepsilon_{kt}^G & \text{if } k \in K_s \\ \widetilde{U}_k^G(i_t, j_t, c_t, R_t) + \varepsilon_{kt}^G & \text{if } k \in K_m, \end{cases}$$

where the stochastic component of utility in the reduced form for state k (ε_{kt}^G) is a function of the random components of utility, earnings and non-labor income.

Given the specification for current period utility and search friction in the marriage market, it is of interest to consider the discounted expected utility of each alternative available to individuals when they make their employment and marital status decisions in every period. Let Ω_t denote the information set for an individual in period t. The information set in period t contains information on exogenous characteristics of men and women in the marriage market, divorce costs, the current sex ratio and the stochastic components of utility in reduced form. Note that the value function for the single states depends only on the individual's type; the value function for the married states depends on the individual's type as well as their spouse's type

$$V_{kt}^G(\Omega_t, i_t, c_t) = \begin{cases} \widetilde{V}_{kt}^G(\Omega_t, i_t, c_t) & \text{if } k \in K_s \\ \widetilde{V}_{kt}^G(\Omega_t, i_t, j_t, c_t) & \text{if } k \in K_m. \end{cases}$$

The present discounted value of utility in state k can be then expressed as the sum of current period utility, given the realized value of the shocks in t, and the expected discounted value of future utility. The value function for a single agent of type i and fertility status c is

$$\widetilde{V}_{kt}^G(\Omega_t, i_t, c_t) = \widetilde{U}_k^G(i_t, c_t, \tau_t) + \varepsilon_{kt}^G + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_s] \qquad (6)$$

and the value function for an agent of type i and fertility status c, married to a spouse of

[19] The Appendix contains further details on the reduced form representation of the model and is available from the author upon request.

type j is

$$\widetilde{V}_{kt}^G(\Omega_t, i_t, j_t, c_t) = \widetilde{U}_k^G(i_t, j_t, c_t, R_t) + \varepsilon_{kt}^G + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_m]. \quad (7)$$

The expectations in (6) and (7) are taken with respect to the stochastic components to utility in $t+1$ and with respect to the realization of next period's choice set. The stochastic realization of a child in the next period is incorporated in $v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})$, where

$$v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1}) = \begin{cases} V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1}=1) & \text{if } c_t = 1, \\ B^G(i_{t+1}, k_t)V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1}=1) & \\ +(1-B^G(i_{t+1}, k_t))V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1}=0) & \text{if } c_t = 0. \end{cases} \quad (8)$$

The discount factor is denoted β and δ^G, $\delta^G < 1$, is the net exogenous rate at which agents of gender G flow out of the model.[20] The value of being single for an individual of type i is defined as

$$\widetilde{V}_{st}^G(\Omega_t, i_t, c_t) = \max_{k \in K_s} \{\widetilde{V}_{kt}^G(\Omega_t, i_t, c_t)\},$$

and the value of being married to a spouse of type j for an agent of type i can be expressed as

$$\widetilde{V}_{mt}^G(\Omega_t, i_t, j_t, c_t) = \max_{k \in K_m} \{\widetilde{V}_{kt}^G(\Omega_t, i_t, j_t, c_t)\}.$$

One important feature of the model is that individuals take into account the likelihood of being accepted as a mate while single should they meet someone in the marriage market or, if currently married, of continuing to be accepted by their current spouse. This feature of the model is captured as follows. Define an indicator function that is equal to 1 if an agent of type i wants to marry a spouse of type j in period t. In particular,

$$J_t^G(i_t, j_t, c_t) = \begin{cases} 1 & \text{if } \widetilde{V}_{mt}^G(\Omega_t, i_t, j_t, c_t) \geq \widetilde{V}_{st}^G(\Omega_t, i_t, c_t) \\ 0 & \text{otherwise,} \end{cases}$$

which can be used to give an explicit form for the value functions on the right hand side of (6) and (7) as follows. Consider first agents who are single in t. If an agent of type i makes a contact in the marriage market with a potential spouse that wants to marry, the agent can choose among all four possible states. If the potential spouse does not want to marry

[20] The death rate is allowed to vary across race in the empirical analysis to capture differences in mortality and incarceration rates between blacks and whites in the U.S.

or if no contact was made in the marriage market, agents must remain single and can only choose their employment status

$$E\big[V^G_{t+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_s\big] = p^G_{t+1}\Big(\sum_j \sum_{c'} q^{G'}_s(j_{t+1}, c'_{t+1}) J^{G'}_t(j_{t+1}, i_{t+1}, c'_{t+1})\Big)$$
$$E_{\varepsilon_{t+1}} \max\Big\{\widetilde{V}^G_{st+1}(\Omega_{t+1}, i_{t+1}, c_{t+1}), \widetilde{V}^G_{mt+1}(\Omega_{t+1}, i_{t+1}, j_{t+1}, c_{t+1})\Big\}$$
$$+ \Big[1 - p^G_{t+1}\Big(\sum_j \sum_{c'} q^{G'}_s(j_{t+1}, c'_{t+1}) J^{G'}_t(j_{t+1}, i_{t+1}, c'_{t+1})\Big)\Big] E_{\varepsilon_{t+1}}\big[\widetilde{V}^G_{st+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})\big].$$

Agents of type i who chose to be married in t are not in the marriage market in $t+1$. If their type j spouse is still alive and wants to remain married, individuals must decide whether to work and whether to remain with their current spouse. Individuals remain single and can only choose their employment status if they are exogenously separated from their current spouses or if their spouses no longer want to remain married

$$E\big[V^G_{t+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_m\big] = (1 - \delta^{G'}) J^{G'}_{t+1}(j_{t+1}, i_{t+1}, c'_{t+1})$$
$$E_{\varepsilon_{t+1}} \max\Big\{\widetilde{V}^G_{st+1}(\Omega_{t+1}, i_{t+1}, c_{t+1}), \widetilde{V}^G_{mt+1}(\Omega_{t+1}, i_{t+1}, j_{t+1}, c_{t+1})\Big\}$$
$$+ \big(1 - (1 - \delta^{G'}) J^{G'}_{t+1}(j_{t+1}, i_{t+1}, c'_{t+1})\big) E_{\varepsilon_{t+1}}\big[\widetilde{V}^G_{st+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})\big].$$

The expected value function in $t+1$ for an individual of type i and fertility status c can then be expressed as

$$E\big[V^G_{t+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t\big] = \begin{cases} E\big[V^G_{t+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_s\big] & \text{if } k_t \in K_s, \\ E\big[V^G_{t+1}(\Omega_{t+1}, i_{t+1}, c_{t+1})|k_t \in K_m\big] & \text{otherwise.} \end{cases}$$

3.4 The Evolution of the Sex Ratio

The sex ratio evolves endogenously in the model, as the current marital status decisions of all the agents determine next period's sex ratio. Current marital status decisions depend on future conditions in the marriage market. Therefore, individuals must determine the value of the sex ratio in the next period when choosing their employment and marital status. The stocks of single men and women in the marriage market in period $t+1$ are a function of the flows in and out of the marriage market in the current period and are composed of two groups: the number of single agents in t that did not make a match and the number of married agents who divorce or are exogenously separated from their spouses

$$S_{t+1}^{G}=\Big\{\Big[1-p_t^G(1-\delta^{G'})\Big(\sum_i\sum_c\sum_j\sum_{c'}q_s^G(i_t,c_t)q_s^{G'}(j_t,c_t')J_t^G(i_t,j_t,c_t)J_t^{G'}(j_t,i_t,c_t')\Big)\Big]S_t^G$$
$$+\Big[1-(1-\delta^{G'})\Big(\sum_i\sum_c\sum_j\sum_{c'}q_m^G(i_t,j_t,c_t,c_t')J_t^G(i_t,j_t,c_t)J_t^{G'}(j_t,i_t,c_t')\Big)\Big]M_t^G\Big\}(1-\delta^G)\tag{9}$$

$i,j\in\{1,2,..,I\}$ and $c,c'\in\{0,1\}$. The stock of married agents of gender G in the marriage market in t is denoted M_t^G and $q_m^{G'}(i_t,j_t,c_t,c_t')$ is the exogenous fraction of individuals of type i and fertility status c' married to spouses of type j and fertility status c' in period t, $\sum_i\sum_j\sum_c\sum_{c'}q_m^G(i_t,j_t,c_t,c_t')=1$. The stock of married individuals in period $t+1$ is the sum of the number of married agents in t who remain married and the number of single agents in t who formed a match

$$M_{t+1}^G=(1-\delta^G)(1-\delta^{G'})\Big[\Big(\sum_i\sum_c\sum_j\sum_{c'}q_m^G(i_t,j_t,c_t,c_t')J_t^G(i_t,j_t,c_t)J_t^{G'}(j_t,i_t,c_t')\Big)M_t^G$$
$$+p_t^G\Big(\sum_i\sum_c\sum_j\sum_{c'}q_s^G(i_t,c_t)q_s^{G'}(j_t,c_t')J_t^G(i_t,j_t,c_t)J_t^{G'}(j_t,i_t,c_t')\Big)S_t^G\Big].\tag{10}$$

Clearly, $M_{t+1}^G=M_{t+1}^{G'}$ as each marriage is composed of one individual of each sex. The sex ratio in period $t+1$ is defined as the ratio of single men to single women in the marriage market

$$R_{t+1}=\frac{S_{t+1}^M}{S_{t+1}^F}.\tag{11}$$

Equations (9), (10) and (11) describe the manner in which the marriage market evolves over time. Marital status decisions in the current period depend on the value of the sex ratio in the following period and the value of the sex ratio in $t+1$ is determined by the marital status decisions made by individuals in the current period. In equilibrium it therefore must be the case that the decisions of all the agents in t generate a value of R_{t+1} that is consistent with the marital status decisions made by all men and women today.

3.5 Reservation Values

The solution to the model outlined above is based on a set of reservation values, determined by individuals as follows. At the beginning of every period, individuals realize their current choice sets and the shocks to utility, wages and non-labor income. Once realized, it is possible to compute the value of each employment and marital status combination in the period t choice set. Individuals then choose the state yielding the highest level of utility.

The sequence of reservation values that form the solution to the problem faced by individuals in every period can be expressed in terms of the stochastic component of utility. For every state k , $k \in \{sh, mn, mh\}$, define ε_{kt}^{G*} such that individuals would like to remain single and not working for values of $\varepsilon_{snt}^{G} - \varepsilon_{kt}^{G}$ above ε_{kt}^{G*} and would like to choose state k for values of $\varepsilon_{snt}^{G} - \varepsilon_{kt}^{G}$ below ε_{kt}^{G*}. Define an indicator (d_{kt}^{G}) that is equal to one if state k is chosen by an individual of gender G in period t and 0 otherwise; ε_{kt}^{G*} is the value such that

$$
\begin{aligned}
&U_{k}^{G}(i_t, c_t) + \beta(1-\delta^{G})E[v_{t+1}^{G}(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{kt}^{G} = 1] \\
= \; &U_{sn}^{G}(i_t, c_t) + \beta(1-\delta^{G})E[v_{t+1}^{G}(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{snt}^{G} = 1] + \varepsilon_{kt}^{G*}.
\end{aligned} \tag{12}
$$

Now consider two possible states, $k, l \in K_t$, where K_t is the choice set available to the agent in the current period. State k is preferred to l if the value of choosing state k exceeds the value of choosing state l

$$
\begin{aligned}
&V_{kt}^{G}(\Omega_t, i_t, c_t) \geq V_{lt}^{G}(\Omega_t, i_t, c_t) \iff \\
&U_{k}^{G}(i_t, c_t) + \varepsilon_{kt}^{G} + \beta(1-\delta^{G})E[v_{t+1}^{G}(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{kt} = 1] \\
\geq \; &U_{l}^{G}(i_t, c_t) + \varepsilon_{lt}^{G} + \beta(1-\delta^{G})E[v_{t+1}^{G}(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{lt} = 1],
\end{aligned} \tag{13}
$$

The latter can be rewritten in terms of the reservation and realized values for the composite errors, using (12) and (13). The state yielding the highest level of utility satisfies

$$\varepsilon_{kt}^{G} - \varepsilon_{lt}^{G} \geq \varepsilon_{lt}^{G*} - \varepsilon_{kt}^{G*}.$$

The optimal policy for any $k \in K_t$, is therefore:

$$
d_{kt}^{G} = \begin{cases} 1 & \text{iff } \varepsilon_{kt}^{G} - \varepsilon_{lt}^{G} \geq \varepsilon_{lt}^{G*} - \varepsilon_{kt}^{G*}, \forall l \in K_t \\ 0 & \text{otherwise.} \end{cases} \tag{14}
$$

4 Econometric Specification

I estimate the structural parameters of the model using the three-stage estimation procedure of van der Klaauw (1996). In the first stage of estimation, the reduced form choice probabilities are derived from the solution to the dynamic programming problem and are jointly estimated with fertility via maximum likelihood. In equilibrium, the aggregate conditions governing the evolution of the marriage market as defined by (9) and (10) must be satisfied and are thus imposed as constraints during estimation. In the second stage, seven earnings and non-labor income equations are estimated as specified by (3) and (4). In particular, an earnings equation for each gender, non-labor income equations in the single, not-working and single working states for each gender and a non-labor income equation for married couples are estimated. In the final stage of estimation, the structural parameters of the model are recovered from the fertility and reduced form choice probabilities in combination with the earnings and non-labor income equations using a minimum distance estimator.

The primary advantage of the three stage method is the computational ease with which earnings and non-labor income are incorporated in estimation. It is necessary to estimate earnings and non-labor income equations for men and women: under van der Klaauw's (1996) approach, all seven equations can be estimated independently of the dynamic model. To do so, I assume the idiosyncratic components of earnings (e_{wt}) and non-labor income (e_{kt}) are linear in the reduced form choice probability errors (ε_{kt}).[21] Alternatively, if the model is estimated using full-information maximum likelihood, it is necessary to specify the joint distribution of the seven non-labor income and earnings equations, the two fertility probabilities for individuals and the choice probability errors. Therefore, while the three stage estimator does impose assumptions regarding the form of the underlying errors, it is likely they are no more restrictive than the more demanding approach that imposes assumptions on the underlying errors directly.

Before proceeding with estimation, the following assumptions are imposed regarding the functional forms for preferences, divorce costs and the sharing rule. It is assumed the utility function is linear in all arguments

$$\begin{aligned} u_k^G(x_t, c_t, i_t, \tau_t) &= \gamma_k^G + \gamma_{xk}^G x_t + \gamma_{ck}^G c_t + \gamma_{ik}^G i_t^G \\ &\quad + \tau^G (d_{mnt-1}^G + d_{mht-1}^G)(d_{snt}^G + d_{sht}^G), \end{aligned} \tag{15}$$

where the γ's are utility conversion factors.[22] Divorce costs enter as a constant equal to

[21] See Dubin and McFadden (1984) and van der Klaauw (1996) for further details

[22] The utility from children and exogenous characteristics while single and not working are normalized to zero for identification purposes. Therefore, γ_{csh}^G, γ_{cmn}^G and γ_{cmh}^G are interpreted as the utility from children when in states sh, mn and mh, respectively, relative to the utility from children while single and not working. The parameters γ_{ish}^G, γ_{imn}^G and γ_{imh}^G are interpreted in an analogous fashion. Furthermore, the utility from

τ^G if the individual transits from married to single in the current period and equal to 0 otherwise. The sharing rule is specified as a linear function of the ratio of single men to women in the marriage market and the potential earnings of the type-i agent and their type-j spouse

$$\phi(R_t, \overline{w}^F(i_t), \overline{w}^M(j_t)) = \phi^R R_t + \phi^F \overline{w}^F(i_t) + \phi^M \overline{w}^M(j_t).$$

The parameters in the sharing rule can be interpreted as the change in the dollar value of the transfer resulting from a unit change in the corresponding argument. Finally, earnings and non-labor incomes are specified as linear functions of exogenous individual characteristics and the random components of earnings and non-labor income in each state, respectively.

4.1 Estimation of the Choice Probabilities and Fertility

The reduced form choice probabilities are estimated according to the optimal policy described by (14). Assuming the composite errors in period t are distributed *i.i.d.* extreme value,[23] the probability of choosing state k, conditional on choice set K_t, for an individual of type i can be expressed as

$$\begin{aligned}\Pr(d_{kt}^G = 1|K_t, i_t, c_t) &= \Pr[\varepsilon_{kt}^G - \varepsilon_{lt}^G \geq \varepsilon_{lt}^{G*} - \varepsilon_{kt}^{G*}, \forall l \in K_t] \\ = \frac{\exp\{U_k^G(i_t, c_t) + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{kt}^G = 1]\}}{\sum_{l \in K_t} \exp\{U_l^G(i_t, c_t) + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{lt}^G = 1]\}}.\end{aligned}$$

Information on the respondent's race, the presence of children, education, region of residence, year in the marriage market and spousal education if married is used to estimate the reduced form choice probabilities.

Individuals are married if they choose state mn or state mh. Therefore, the probability individuals want to marry or remain married is

$$\begin{aligned}&\Pr\left(J_t^G(i_t, j_t, c_t) = 1\right) \\ &\quad = \frac{\sum_{k \in \{K_m\}} \exp\{U_k^G(i_t, c_t) + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{kt}^G = 1]\}}{\sum_{l \in \{K_s \cup K_m\}} \{U_l^G(i_t, c_t) + \beta(1-\delta^G)E[v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1})|d_{lt}^G = 1]\}},\end{aligned}$$

consumption $(\gamma_{xsn}^G, \gamma_{xsh}^G, \gamma_{xmn}^G, \gamma_{xmh}^G)$ is normalized to one, so that the $\gamma' s$ in (15) are expressed in terms of consumption utils.

[23]This assumption is commonly imposed in the estimation of dynamic discrete choice models, as it implies a convenient closed form solution for the choice probabilities. See van der Klaauw (1996), Rust (1987), Stinebrickner (1998) and Berkovec and Stern (1991) for examples. The Appendix describes the expressions relating the composite errors to the underlying shocks to utility, earnings and non-labor income.

where from (8)

$$v_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1}) = \begin{cases} V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1} = 1) & \text{if } c_t = 1 \\ B^G(i_{t+1}, k_t)V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1} = 1) & \\ +(1 - B^G(i_{t+1}, k_t))V_{t+1}^G(\Omega_{t+1}, i_{t+1}, c_{t+1} = 0) & \text{if } c_t = 0. \end{cases}$$

The probability an agent of gender G experiences a first birth in period t is logistically distributed, where the set of variables assumed to determine fertility includes the number of years since the agent initially entered the marriage market, race, education and marital status. The incorporation of state-specific utility from children and the dependence of the first birth arrival rate on marital status captures, albeit in a limited way, the notion that fertility and marital status decisions are inter-related.[24] I therefore specify the probability of a first birth as

$$B^G(i_t, k_{t-1}) = \frac{\exp(\lambda_0^G + \lambda_1^G i_t + \lambda_2^G(d_{mnt-1}^G + d_{mht-1}^G))}{1 + \exp(\lambda_0^G + \lambda_1^G i_t + \lambda_2^G(d_{mnt-1}^G + d_{mht-1}^G))}.$$

Since the problem faced by potential spouses is identical to that faced by individuals of the same gender in the sample, the same characteristics (region, children, education of the potential spouses, education of the individual) that determine the individual choice probabilities determine the acceptance probabilities of the potential spouse.[25]

The probability of choosing state k in period t for an individual of type i is thus a function of the probability of contacting a potential spouse in the marriage market, the probability that the current or potential spouse finds the individual acceptable as a mate and the probability of realizing a particular choice set

$$\begin{aligned} &\Pr\left(d_{kt}^G = 1 | i_t, c_t\right) = \\ &\quad p_t^G\Big(\sum_j \sum_{c'} q_s^{G'}(j_t, c_t') Pr\left(J_t^{G'}(j_t, i_t, c_t') = 1\right)\Big) \Pr(d_{kt}^G = 1 | k \in \{K_s \cup K_m\}, i_t, c_t) \\ &\qquad + \Big[1 - p_t^G\Big(\sum_j \sum_{c'} q_s^{G'}(j_t, c_t') Pr\left(J_t^{G'}(j_t, i_t, c_t') = 1\right)\Big)\Big] \Pr(d_{kt}^G = 1 | k \in K_s, i_t, c_t) \end{aligned}$$

[24] In the current specification, it is assumed that prior marital status is an exogenous determinant of fertility. By estimating fertility and marital status jointly in the first stage of estimation, it is straightforward to augment the likelihood function to allow unobserved preferences for marriage and fertility to be correlated. This is a primary advantage of estimating fertility in conjunction with the choice probabilities as opposed to estimating fertility independently of the full model.

[25] The implicit assumption being made is that both spouses share the same household (in the same region) after marriage. It is also assumed that individuals and spouses do not receive utility from step-children.

if $k_{t-1} \in K_s$ and

$$\Pr\left(d_{kt}^G = 1 | i_t, c_t\right) =$$
$$(1-\delta^{G'})J_t^{G'}(j_{t+1}, i_{t+1}, c_{t+1}') \Pr(d_{kt}^G = 1 | k \in \{K_s \cup K_m\}, i_t, c_t)$$
$$+ \left[1 - (1-\delta^{G'})J_t^{G'}(j_{t+1}, i_{t+1}, c_{t+1}')\right] \Pr(d_{kt}^G = 1 | k \in K_s, i_t, c_t)$$

if $k_{t-1} \in K_m$.

Finally, the contact probabilities are estimated using the functional form in (5) and the death rates are specified as

$$\delta^G = \frac{\exp(\xi^G)}{1+\exp(\xi^G)}.$$

The likelihood function for the N individuals in the sample is

$$\pounds = \prod_{i=1}^{N} \Pr[d_{kT}^i | d_{kT-1}^i, ...d_{k2}^i, d_{k1}^i, i_T, \Theta] \cdots \Pr[d_{k2}^i | d_{k1}^i, i_2, \Theta] \cdot \Pr[d_{k1}^i | i_1, \Theta],$$

where Θ is the vector of reduced form parameters from the model.

4.2 Estimation of Earnings and Non-Labor Income

The estimation of earnings and non-labor income for individuals, spouses and potential spouses constitutes the second stage of estimation. The samples used to estimate the earnings and non-labor income equations depend upon the employment and marital status decisions of each individual. Earnings are only observed for labor market participants and thus are estimated on samples of working individuals only. The samples used to estimate non-labor income are also state dependent, since non-labor incomes are only observed in the data for individuals occupying a particular state. To control for the bias that may result from the use of non-random samples, the non-labor income and earnings equations are selection-corrected in estimation using the choice probabilities obtained in the first stage.[26]

Earnings and non-labor income equations are estimated for men and women as well as for their spouses if married or potential spouses if single. The vector of characteristics that determine earnings for individuals of type i (i_t^G) and spouses of type j ($j_t^{G'}$) include region of residence indicators, race, education, where education in i_t^G refers to the individual's

[26] A similar approach is implemented in Dubin and McFadden (1984).

education level and education in $j_t^{G'}$ refers to the education level of the spouse, and the number of years since the individual first entered the marriage market.[27] The vector of characteristics that determine non-labor income is the same as that determining earnings with the addition of children which are included to capture differences in the availability of social programs, such as AFDC, that depend on the presence of children.

4.3 Estimation of the Structural Parameters

In the final stage of estimation, parameter estimates from the first two stages are used to obtain consistent estimates of the structural parameters of the model (Ψ). The combined system of reduced form choice probabilities, earnings, non-labor income and fertility probabilities results in a set of moment conditions relating the reduced form parameters to the structural parameters. Generalized method of moments (GMM) estimation is used to recover the structural parameters from the over-identified system. In particular, the structural parameters are estimated as

$$\widehat{\Psi} = \arg_{\Psi} \min[\widehat{\Theta} - g(\Psi)]W^{-1}[\widehat{\Theta} - g(\Psi)],$$

where g is the set of moment conditions imposing the restrictions between the reduced form and structural parameters of the model and $\widehat{\Theta}$ is the vector of reduced form parameters. The weighting matrix W is estimated using estimates of the covariance matrices from the first two stages in estimation and the outer-products of the first order conditions.[28] The asymptotic covariance matrix of this estimator (Hansen, 1982) is

$$\Sigma = [G'W^{-1}G]^{-1},$$

where G is a matrix of derivatives of the moment conditions, $G = \partial g(\widehat{\Psi})/\partial \Psi'$, and

$$\sqrt{N}(\widehat{\Psi} - \Psi) \to^{D} n[0, \Sigma]. \tag{16}$$

4.4 Identification

The parameters of the model are identified as follows. The coefficients in the earnings and non-labor income equations are identified by the data on earnings and non-labor income,

[27] For full details regarding the estimation of the earnings and non-labor income equations, see the Appendix, available from the author upon request.

[28] For full details, see the Appendix and van der Klaauw (1996).

respectively. Annual data on the presence of children is used to identify the parameters in the first birth probabilities for respondents and potential spouses. Note that the sex ratio and spousal education enter the choice probabilities, and therefore the selection correction terms, but do not directly enter the earnings and non-labor income equations. Data on the fractions of men and women in each education and fertility category in every year identify $q_s^G(i_t, c_t)$ and $q_m^G(i_t, j_t, c_t, c_t')$.

The death rates, preference parameters and the search friction parameter are identified by the data on current employment status, current and previous marital status, the stocks of married and single men and women in the marriage market in each year, the normalization of the utility from consumption to one and the normalization of the remaining preference parameters in the single, non-working state to zero. The identification of each set of parameters shall be discussed in turn.

The death rate parameters (δ^F, δ^M) are identified by the movements of the aggregate stocks over time. In particular

$$S_t^G + M_t^G = (1 - \delta^G)(S_{t-1}^G + M_{t-1}^G).$$

Since data are available for every sample year on the stocks of single and married men and women, these data directly identify the death rates.

The choice probabilities and equilibrium flow conditions for men and women are functions of the search friction parameter (φ), the preference parameters in the acceptance probabilities $(J_t^G(i_t, j_t, c_t))$ and the individual conditional choice probabilities $(\Pr(d_{kt}^G = 1|k \in \{K_s \cup K_m\}, i_t, c_t), \Pr(d_{kt}^G = 1|k \in \{K_s\}, i_t, c_t))$. Consider the choice probabilities used to estimate the model

$$\begin{aligned} &p_t^G \Big(\sum_j \sum_{c'} q_s^{G'}(j_t, c_t') Pr\big(J_t^{G'}(j_t, i_t, c_t') = 1\big)\Big) \Pr(d_{kt}^G = 1|k \in \{K_s \cup K_m\}, i_t, c_t) \\ &\qquad + \Big[1 - p_t^G \Big(\sum_j \sum_{c'} q_s^{G'}(j_t, c_t') Pr\big(J_t^{G'}(j_t, i_t, c_t') = 1\big)\Big)\Big] \Pr(d_{kt}^G = 1|k \in K_s, i_t, c_t) \end{aligned}$$

if $k_{t-1} \in K_s$ and $k_t \in K_s$,

$$\begin{aligned} &(1 - \delta^{G'}) J_t^{G'}(j_{t+1}, i_{t+1}, c_{t+1}') \Pr(d_{kt}^G = 1|k \in \{K_s \cup K_m\}, i_t, c_t) \\ &\qquad + \Big[1 - (1 - \delta^{G'}) J_t^{G'}(j_{t+1}, i_{t+1}, c_{t+1}')\Big] \Pr(d_{kt}^G = 1|k \in K_s, i_t, c_t) \end{aligned} \quad (17)$$

if $k_{t-1} \in K_m$ and $k_t \in K_s$,

$$p_t^G\Big(\sum_j \sum_{c'} q_s^{G'}(j_t, c_t')Pr\big(J_t^{G'}(j_t, i_t, c_t') = 1\big)\Big)\Pr(d_{kt}^G = 1|k \in \{K_s \cup K_m\}, i_t, c_t)$$

if $k_{t-1} \in K_s$ and $k_t \in K_m$, and

$$(1-\delta^{G'})J_t^{G'}(j_{t+1}, i_{t+1}, c_{t+1}')\Pr(d_{kt}^G = 1|k \in \{K_s \cup K_m\}, i_t, c_t) \tag{18}$$

if $k_{t-1} \in K_m$ and $k_t \in K_m$. Since the death rates are identified from the stock data and current matches can only stay together if both partners are alive and agree to match, information on current employment decisions and current and past marital status decisions of men and women allow for the separate identification of the parameters in $J_t^{G'}(j_t, i_t, c_t')$ and those in the individual conditional choice probabilities in (17) and (18).

The preference parameters are identified as follows. Comparing the utility from the single, non-working state to each of the remaining states identifies the parameters representing the utility from exogenous characteristics, children, marriage and employment $(\gamma_{ik}^G, \gamma_{ck}^G, \gamma_k^G,\ k \in \{sh, mn, mh\})$. Comparing the utility from the married, non-working state to the single, non-working state identifies the parameters in the sharing rule (ϕ^R, ϕ^M, ϕ^F). The sharing rule parameters are identified by the assumption that the male earnings potential only enters the female's utility function through intra-household transfers and likewise for females. Similarly, the parameter ϕ^R is identified by assuming that the sex ratio only influences utility directly through the sharing rule. The parameter representing divorce costs (τ^G) is identified by comparing currently single individuals who were married in $t-1$ to those married in both periods.

Data are not available on rejections and acceptances of offers by both potential spouses in a match; however, the symmetry inherent in the two-sided model implies that the same parameters that determine the utility from each state also determine the probabilities that potential spouses want to marry. The identification of the preference parameters in $J_t^{G'}(j_t, i_t, c_t')$ as discussed above implies the search friction parameter can also be identified separately from the acceptance probabilities for single agents.

5 Results

Structural estimates for the full two-sided model are presented below. To limit the computational burden, the model is estimated on a random subsample of 523 men and women over the 12 year period from 1979 to 1990.[29] Three specifications of the model are estimated. First, the model is estimated under the assumption the discount factor is equal to 0.95, capturing the forward-looking behaviour of agents.[30] This dynamic version of the model is first estimated with a flexible specification for preferences, where the set of exogenous characteristics assumed to influence the utility from each state includes region indicators, education and a quadratic in the number of years the individual has been in the marriage market. A restricted version of the dynamic model, where the only exogenous characteristic assumed to enter the utility function is race, is also estimated. In general, the estimates from the restricted version of the model are qualitatively similar to those from the full model, although the full model provides a better fit to the data. Finally, I estimate a static version of the restricted model ($\beta = 0$), where agents do not take into account the manner in which current marital status decisions impact future periods.[31]

Regarding the effects of earnings potential on the intra-household allocation process, the results in Table 3 are consistent with those of Chiappori et al. (1998). In particular, the results from the full dynamic specification predict that an increase of $1.00 in the potential earnings of the wife results in a decrease in transfers from her spouse by approximately $0.66, while an equivalent increase in the potential earnings of her spouse induces an increase in transfers to the female of $0.57.[32] Considering the signs of the sharing rule parameters, Chiappori et al. (1998) interpret the results as evidence of altruism within married couples. It is also of interest to emphasize that increases in potential earnings of the husband and wife have opposing effects on the transfer within the household. One implication of this result is that the probability a match forms between any two agents is decreasing in the difference between their potential earnings, a result consistent with positive sorting on

[29] For the purposes of this paper, 1990 is treated as the terminal period. To extend the time horizon, it is necessary to construct stocks of single agents using the equilibrium flow conditions for the years beyond the end of the sampling period. This extension is to be incorporated in future work.

[30] The estimates did not converge when attempts were made to estimate the discount factor.

[31] Parameter estimates from the reduced form model are contained in the Appendix.

[32] The corresponding parameter estimates reported by Chiappori et al. (1998) are approximately $0.53 for women and $0.24 for men.

earnings potential. More specifically, the transfers paid by spouses with higher earnings potential increase as the gap in earnings potential across the husband and wife increases. If the transfer paid by the high income spouse becomes sufficiently large, the probability that the utility from being single exceeds that from being married increases. As a result, the estimation results predict that matches between spouses with low potential earnings and high potential earnings are less likely to form.

The parameter estimate for the sex ratio in the sharing rule indicates that a 10% increase in the sex ratio increases annual transfers to the female by $229 or approximately 16% of average non-labor marital income. This result is consistent with the interpretation that more favorable opportunities in the marriage market translate into greater bargaining power within the marriage. The effect of the sex ratio on the distribution of income within married households is of the same sign as in Chiappori et al. (1998) but smaller in magnitude. This difference likely arises for two reasons. First, the sex ratio reported by Chiappori et al. (1998) varies by state as well as by age and race. As discussed by the authors, there may be a spurious positive correlation between the sex ratio and male employment if quality in the marriage market and labor market are correlated. Second, the analysis of Chiappori et al. (1998) is limited to married couples in which both partners are working. Therefore, the estimated effect of the sex ratio on the sharing rule confounds the effect of marriage market conditions on the distribution of marital income and the effect on search friction: both serve to benefit individuals facing favorable marriage market opportunities.

Together, the parameter estimates in the sharing rule translate into average annual transfers of $3,100 and $3,300 to black and white women, respectively. The transfers received by women tend to be composed of non-labor income and spousal labor market earnings, as the transfers to wives exceed total non-labor income by $1,200 and $1,900 for black and white men, respectively. The differences across males and females in intra-household transfers likely reflect differences in earnings potential across sex and the higher level of non-labor income available to single women relative to single men through programs such as AFDC.

The results from the restricted dynamic model are consistent with those from the full model, although changes in marriage market conditions play a larger role in the sharing rule and intra-household transfers are less sensitive to changes in earnings potential. In contrast, the myopic model suggests improvements in the marriage market for females results in a small decrease in intra-household transfers: a 10% decline in the sex ratio results in a \$23 reduction in transfers. Furthermore, increases in the earnings potential of either spouse result in an increase in transfers to women within the household.

The estimated contact probabilities and death rates, displayed in Table 4, indicate the presence of substantial search friction in the dynamic specifications, with relatively higher friction faced by those with poor marriage market opportunities. The contact technology generates a larger spread in contact rates across sex for blacks than for whites. This result is consistent with the greater imbalance in marriage market conditions for blacks: it is predicted that 9 out of 10 single black women are unable to make a contact in the marriage market over the course of a year. When individuals do make a contact in the dynamic model, they are very likely to remain married or marry, as the acceptance probabilities are close to one. In the restricted version of the dynamic model, the probability a black male chooses to marry or remain married is substantially lower than that for whites and for black females. This result is consistent with the notion that black males may be more choosy regarding whom they are willing marry or stay married to because they face favorable future marriage market opportunities.

The high acceptance rates predicted by the model do not provide an explanation for the low marriage rates and high divorce rates of blacks relative to whites. Instead, it appears the source of the difference in dissolution rates across race is due to the high death rates for blacks. This finding is quite consistent with the high mortality and incarceration rates of blacks relative to whites observed in the data and provides an interesting explanation for the differences in marriage behavior across race.

Different conclusions are drawn upon examination of the predictions from the static model. With the exception of black females, the static model suggests that search friction in the marriage market is relatively modest. This result is not surprising considering the fact that individuals in the static version of the model do not take into account the probability of meeting a spouse in the next period when making current marital and employment status decisions. Instead, the differences in behavior across sex and race are driven by differences in acceptance probabilities: black males in particular are unlikely to accept a potential spouse in the marriage market and black males are very likely to initiate a divorce. The myopic results therefore suggest that differences in marriage rates are more likely to be driven by differences in preferences rather than by search friction, in contrast to the dynamic estimates.

This conjecture is verified upon examination of the preference parameters in Table 5.[33] In contrast to the past literature, the lower marriage rates of blacks as compared to whites is not reflected in the preference parameters in the dynamic models: black females have greater preferences for marriage than white females and there is no significant difference in preferences over marriage across race for men. The dynamic estimates suggest, therefore, the model does not rely heavily upon differences in preferences to account for the relatively low marriage rates of blacks. However, black males in the myopic specification have significantly lower preferences for marriage than white males as is reflected in the low acceptance rates for black males.

Regarding the remaining preference parameters, women prefer marriage and working to the other available alternatives, while men prefer the single, not working state in the dynamic model. Turning to the preference parameters for children, single working men and women receive disutility from children relative to the single, non-working state, while the utility from marriage is increasing in the presence of children for both men and women in the dynamic specification. Although the data used to estimate the effects of children do not directly identify whether the child was a product of the current marriage, the estimates likely reflect the importance of children as marital-specific capital. Interestingly, the divorce costs incurred by men, presented at the bottom of Table 5, are smaller in magnitude than those for women in all specifications. A commonly cited benefit of marriage is specialization of labor within the household and women tend to devote more time to home production than men. For this reason, the difference in divorce costs across sex likely represents a penalty of investing in human capital for home versus market production, as the former may not provide as many benefits outside the marriage as the latter.

A comparison of the employment and marriage rates generated by the model to those observed in the data provides an assessment of the performance of the full dynamic model. Employment and marriage rates across sex and race are presented in Table 6. In Table **??**, the proportion of respondents in the sample who choose each marital and employment

[33] The preference parameters for region, year and education are presented in the Appendix and are available from the author upon request.

status combination are compared to those predicted by the model. The model is able to fit the marriage and employment rates across blacks and whites, replicating the relatively low marriage rates for blacks and high employment rates for whites. The model is also able to match the large differences in employment rates across men and women.

To illustrate some interesting implications of the model and the corresponding parameter estimates, a number of experiments are considered in Table 7. The first panel of Table 7 contains the predicted marriage and employment rates across race and sex from the full dynamic model. Since search friction plays an important role in the dynamic model, the contact rates are increased by 10% in the first experiment. A reduction in search friction results in a large rise in marriage rates for both blacks and whites. Since married females tend to prefer working and males make positive transfers to their wives, a reduction in search friction in the marriage market also results in an increase in employment rates for men and for women, with black males experiencing the largest increase. A policy experiment consistent with a reduction in the relatively high incarceration rate for blacks as compared to whites can be achieved by reducing the estimated death rates of blacks to those for whites. As in the former experiment, a reduction in death rates for blacks is also predicted to result in a rise in marriage rates for blacks and a rise in employment rates for black males. Finally, consider the effects of reducing the initial stock of single men in the marriage market. A reduction in the stock of available men serves to increase the gap in marriage rates for blacks and reduce the gap for whites, as marriage rates for men rise and marriage rates for women are reduced. In contrast to the previous experiments, a shift in initial marriage market conditions does not appear to have a large influence on employment rates, primarily due to the small effect of the sex ratio on intra-household transfers.

6 Conclusion

This paper provides new insight into the causes and consequences of the dramatic differences in family structure and employment across sex and race that characterize recent U.S. history. The theoretical model is consistent with many of the stylized facts, including the low marriage rates of blacks relative to whites, the high employment rates for black married women relative to white married women and the corresponding low employment rates for black men as compared to white men. The estimation results suggest that the presence of substantial search friction in the marriage market and differences in mortality and incarceration rates across blacks and whites are important in explaining the observed differences in behaviour.

The model and estimation results are able to account for the differences in marriage rates and employment rates across race and sex for a recent cohort. The model may also have the potential to explain the dramatic changes in family structure and employment behavior since the 1960s. The U.S. witnessed a large rise in the labor force participation rates of women and a fall in the participation rates of men[34] alongside declines in marriage and increases in the incidence of divorce. The trends in employment and marriage were accompanied by important demographic changes in the marriage market over the same period. In 1945, the birthrate was at its lowest point in the history of the U.S. after which it increased steadily for the next 12 years.[35] The implications of the changes in fertility rates for the trends in marriage rates in the 1940s and 1950s have been studied extensively by demographers. In combination with the tendency for women to marry men two to three years older on average, the baby boom resulted in substantial changes in marriage market conditions. In particular, the pool of potential spouses a few years older was small relative to the pool of potential competitors for women born during the 1940s and 1950s; as a result, women faced low sex ratios when they reached marriageable ages in the 1960s (Guttentag and Secord, 1983; Grossbard-Schectman, 1993). An assessment of the model's ability to account for the time series trends in employment, marriage and the sex ratio in the U.S. will provide further evidence on the importance of marriage market conditions in determining employment and marital status decisions and is the goal of future work.

[34] Although the dramatic fall in participation rates for men is primarily concentrated among men aged 60 to 65 due an increase in early retirements, other groups in the male population also experienced a decline. Employment statistics from the Current Population Survey for the years 1965 to 1995 suggest participation rates for single black males aged 25 to 40 fell from 93% to 82% and from 94% to 86% for married black men. In contrast, participation rates for white males aged 25 to 40 were high and stable over the same period.

[35] The birth rate was 1.94% in 1940, climbing to 2.4% for the 1950s and 1960s and falling to 1.84% by 1970 (U.S. National Center for Health Statistics, annual and monthly *Vital Statistics Report*).

Table 1: Sample Statistics by Race and Sex (Selected Years)

Variable	Black Men	Black Women	White Men	White Women
		1979		
Children	0.0413	0.1479	0.0398	0.0531
High School Diploma	0.4247	0.2152	0.5856	0.2871
Married	0.0465	0.0372	0.0825	0.0902
Working	0.4210	0.1180	0.6251	0.2541
Non-Labor Income	252.37	221.93	325.48	135.40
Earnings	6,781.28	4,620.12	7,845.96	4,629.34
		1985		
Children	0.2696	0.6028	0.3140	0.3455
High School Diploma	0.8073	0.8132	0.8448	0.8610
Married	0.2773	0.2632	0.4815	0.5366
Working	0.7508	0.4896	0.8908	0.6990
Non-Labor Income	541.05	1,440.42	737.82	693.08
Earnings	10,916.63	7,679.74	14,491.13	8,867.56
		1996		
Children	0.6361	0.8050	0.7043	0.7529
High School Diploma	0.8652	0.8475	0.8636	0.8869
Married	0.4979	0.3981	0.7127	0.7630
Working	0.7980	0.7101	0.9372	0.7030
Non-Labor Income	795.85	1,716.66	1,201.23	1,470.07
Earnings	17,937.47	13,474.80	24,616.36	15,386.95

Note: earnings are calculated on the samples of working men and women only.

Table 2: Employment Rates by Race and Marital Status, 1996 Cross Section

		White	Black
Men			
	Single	0.9091	0.6917
	Married	0.9486	0.9052
Women			
	Single	0.7751	0.6696
	Married	0.6806	0.7713

Table 3: Sharing Rule Parameters and Intra-Household Transfers

	Dynamic Model (β =0.95)
ϕ^R	3,339.48
	(60.00)
ϕ^F	0.44
	(0.13)
ϕ^M	0.12
	(0.01)
Average Intra-Household Transfers, Full Dynamic Model	
Black Women	2,723.08
White Women	4,658.06
Black Men	-2,018.04
White Men	-3,755.50

Note: standard errors in parentheses.

Table 4: Estimated Contact, Acceptance and Death Rates

	Contact Rate	Acceptance Rate (Single)	Acceptance Rate (Married)
		Full Dynamic	
Black Females	0.1424	0.7443	0.9349
White Females	0.1615	0.6832	0.9118
Black Males	0.1837	0.8063	0.8044
White Males	0.1638	0.9059	0.8877

Table 5: Preference Parameters

	Full Dynamic	
	Females	Males
γ^G_{sh}	-2.0348	-7.0183
	(1.7321)	(1.7321)
γ^G_{mn}	2.2431	4.1614
	(1.1009)	(1.4873)
γ^G_{mh}	1.3410	1.2911
	(1.7584)	(1.7214)
	Blacks	
γ^G_{Bsh}	1.5290	3.3273
	(1.7321)	(1.7321)
γ^G_{Bmn}	1.0315	-1.3836
	(1.1004)	(1.4869)
γ^G_{Bmh}	3.0154	2.3161
	(1.7581)	(1.7211)
	Children	
γ^G_{csh}	0.9280	-0.2308
	(1.4143)	(1.4143)
γ^G_{cmn}	7.0980	2.6548
	(1.0001)	(1.0010)
γ^G_{cmh}	5.5918	2.3805
	(1.0001)	(1.0002)
	Divorce Costs	
τ^G	-$5,235.00	$5,416.00
	(120.04)	(120.04)

Note: standard errors in parentheses.

Table 6: Comparison of Actual and Predicted Marriage and Employment Rates - Full Dynamic Model

	Actual	Predicted
Marriage Rates		
Black Females	0.2184	0.2479
White Females	0.4382	0.3850
Black Males	0.2372	0.2192
White Males	0.4606	0.3570
Employment Rates		
Black Females	0.3619	0.3430
White Females	0.5823	0.5117
Black Males	0.5845	0.5840
White Males	0.7773	0.7511

Table 7: Experiments

	Marriage Rate	Employment Rate
Baseline Predictions		
Black Females	0.2341	0.4232
White Females	0.4383	0.6430
Black Males	0.2976	0.6731
White Males	0.3750	0.7975
Increase the contact probability by 10% (increase φ by 50%)		
Black Females	0.3166	0.4395
White Females	0.5091	0.6591
Black Males	0.3942	0.7028
White Males	0.4514	0.8113
Reduce the death rates for blacks to those for whites		
Black Females	0.2711	0.4238
White Females	0.4367	0.6422
Black Males	0.3210	0.6805
White Males	0.3767	0.7976
Reduce the stock of single men by 20%		
Black Females	0.2252	0.4210
White Females	0.4308	0.6401
Black Males	0.3079	0.6763
White Males	0.3834	0.7990

Figure 1: Sex Ratios and Employment Rates of Married Individuals by Race

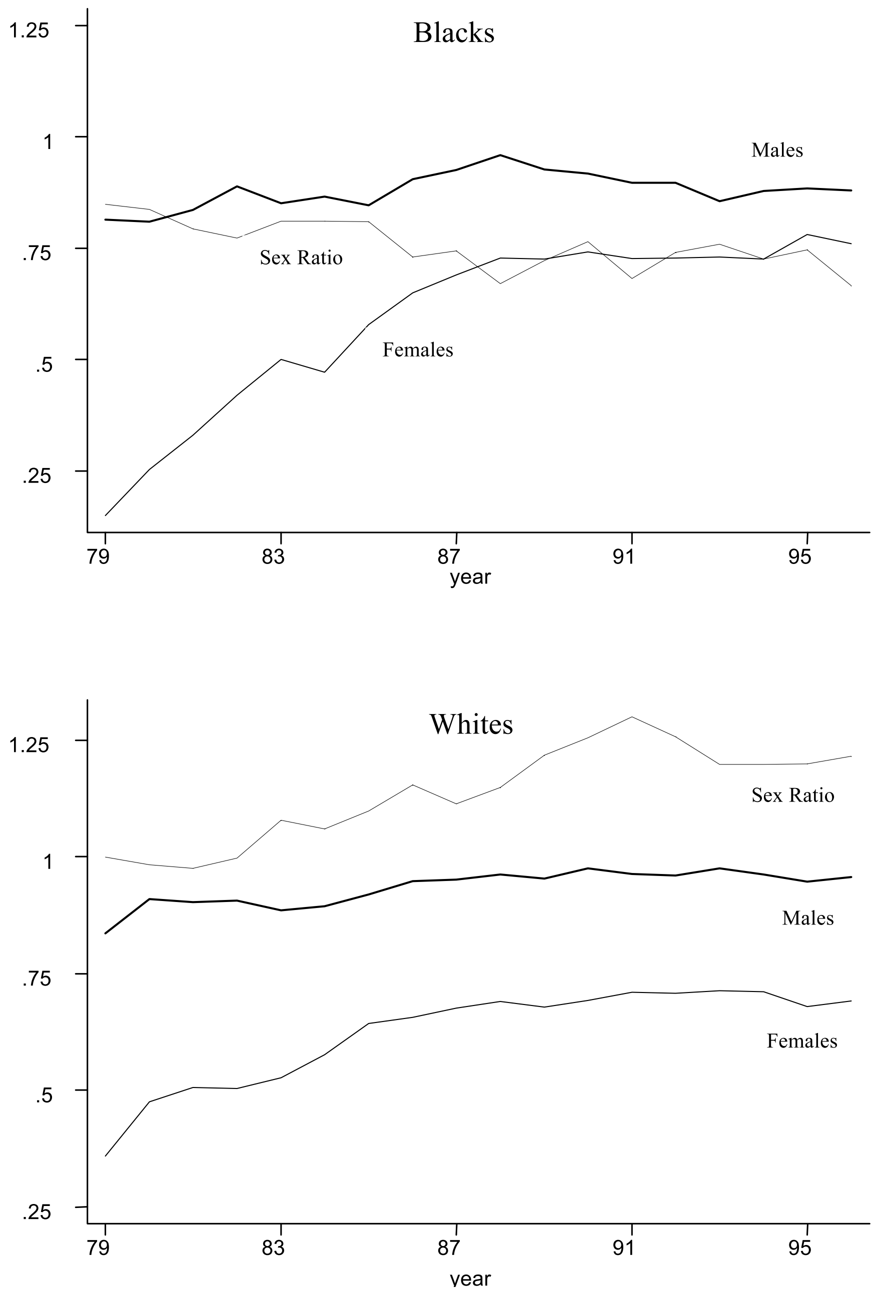
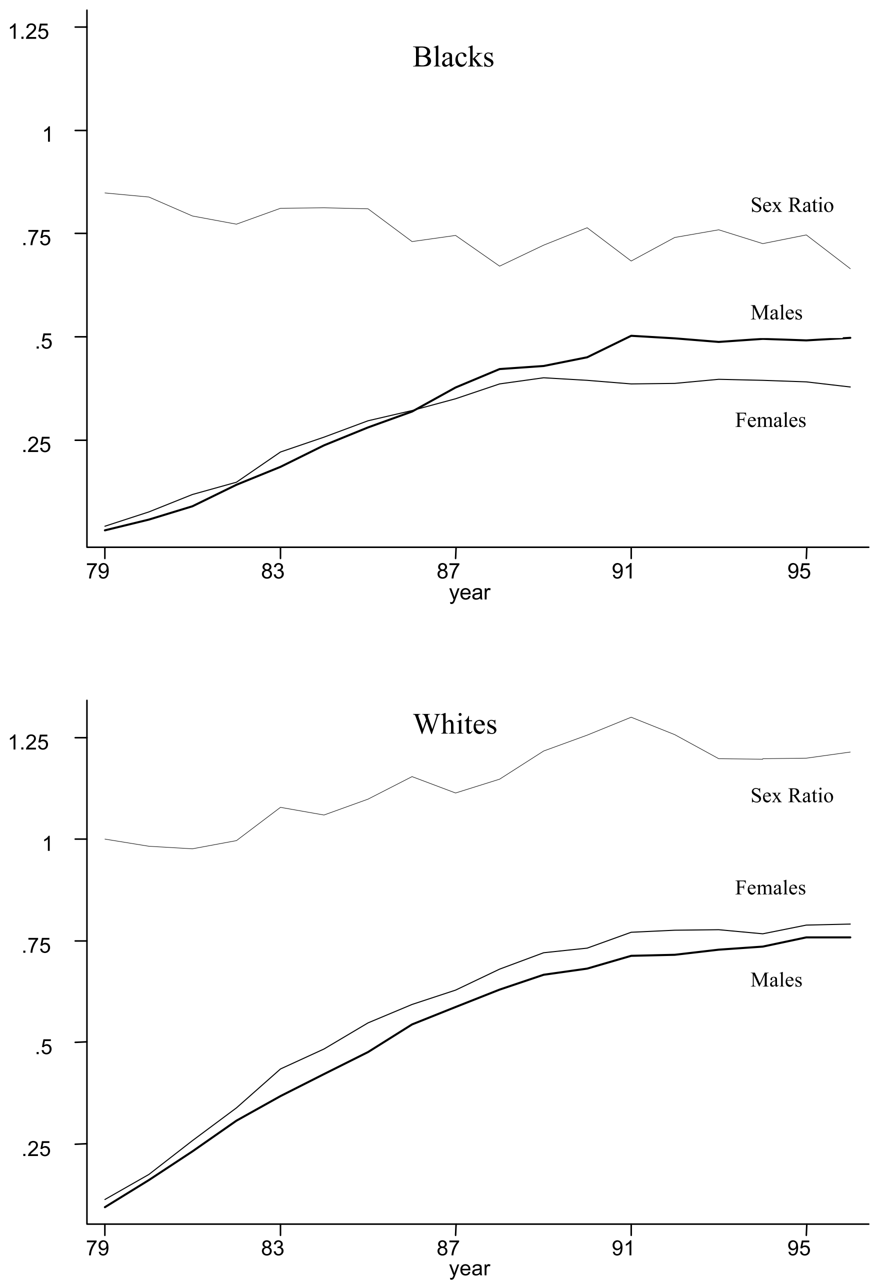


Figure 2: Sex Ratios and Marriage Rates by Race



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