Liberalization of Birth Control and the Unmarried Share of Births*

Evidence from Single Mothers in the Marriage Market

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Abstract: Half of unmarried births are to women who are already mothers, and a quarter to women who were previously married. We develop a model of equilibrium matching and fertility to replicate these facts. We use the model to revisit the hypothesis that liberalization of the Pill and abortion caused the massive increase since 1960 in the share of US births to unmarried women. Our results suggest that liberalization alone is ineffective; what matters are interactions between liberalization and the decline in the stability of marriage, and, secondarily, the rising status of single mothers.

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1 Introduction

Is it plausible that the liberalization of birth control, by reducing the cost of sex for unmarried women, causes unmarried women's share of total births to increase? Births to unmarried women, as a share of total births in the US, rose from about 5% in 1960 to 35% by 1995, a fact that occasioned a Congressional hearing in 1995. Evidence presented there showed that of the women who had a non-marital birth between 1983 and 1987, only 16% had married by 1988, and 23% had been previously married. This suggests a large and genuine shift in both sexual behavior and the role of marriage in the raising of children.

This change is broadly based; although unmarried black women have generally had higher rates of births, Ventura and Bachrach (2000) report that the birth rate for unmarried white women tripled from 0.015 in 1960 to 0.045 by 1995; teenage births account for less than a third of the total. Unmarried cohabiting parents constitute an increasing share of these births, but even by 1994, Ventura and Bachrach (2000) report that they accounted for about a third of the total, and cohabitation tends to be much less stable than marriage, so excluding from unmarried births those to cohabiting parents would perhaps be misleading.

That contraception plays an important role is clear from the fact that unmarried women report a much higher fraction of pregnancies to be "unintended"; according to Ventura and Bachrach (2000), 88% of pregnancies of never-married women in 1987 were unintended, compared to 40% for married women. They also show that access to abortion plays a big role; in 1980, the fraction of pregnancies terminated by abortion was 59% for unmarried women, compared to 10% for married.

In the economics literature, variants of the sex-cost argument were first formalized in papers that stressed sociological mechanisms: access to improved contraception and legalized abortion undermines a social arrangement, and this in turn induces more women to participate in non-marital sexual relationships. In Akerlof et al. (1996), for instance, the social arrangement that is undermined is the norm that unmarried couples must marry on pregnancy. In Greenwood and Guner (2005) it is the segregation of unmarried people into promiscuous and chaste social groups, while in Fernández-Villaverde et al. (2014), it is the investment by parents in shaping the preferences of their daughters. All of these papers focus on the behavior of young women with no previous children, and treat the consequences of unmarried births as parametric, excluding mothers from the model entirely.

In the current paper we take a complementary approach. We re-examine the relationship between liberalization of birth-control technology and and the unmarried birth share in a purely economic framework in which social interactions play no explicit role except through the abstraction of matching markets. We concede that our approach is simplistic, but we believe it is important to ask:

1. to what extent can the "cost-of-sex" argument on its own account for the changes in promiscuity and unmarried births since 1960?

2. what sort of additional effects, whether economic or sociological, might be required to provide a more complete explanation?

We develop and calibrate an equilibrium model of marriage and non-marital fertility with sexual and contraception decisions. Our model puts decisions concerning sex, birth control and marriage into a lifecycle context in which single mothers and married people are included as decision-makers. In contrast to previous papers, we model the entire fertility trajectory as women progress through marriage, divorce and remarriage, creating along the way a distribution of children in various living arrangements, such as single-parent households and step-families.

The key feature of our model is that unmarried mothers also may eventually marry. This means that the penalties for unmarried births, which were treated as free parameters in previous work, are disciplined in our model by being generated as equilibrium outcomes. The model also distinguishes between marriages with step children and those without, so we can calibrate the effect of step children on the value of the marriage. To the extent that the birth rate of unmarried women tells the impact of being an unmarried mother, then the effect of previous children on the marriage rate identifies the impact of step children on the value of the marriage.

Akerlof et al. (1996) showed that the rise in unmarried birth rates in the 1970s was due not so much to an increase in pregnancies among unmarried women, but rather a decline in marriages among pregnant unmarried women. Our interpretation is that single women choose between relationships that lead to marriage and those that do not; if an unmarried-woman pregnancy is closely associated with a marriage, then in the interest of simplification, we consider that as occasioned by sex between marriage partners, rather than unmarried sex. We use the model to ask to what extent birth-control improvements make the second option more attractive and hence contribute to the unmarried birth rate.[1]

We implement our strategy by calibrating a benchmark version of the model such that the sexual participation rate of unmarried women is very responsive to the probability of unmarried motherhood. The model's steady-state matches relevant statistics for a representative sample of age 16-44 women in the 1991-1995 period, drawn from the National Survey of Family Growth. These statistical targets include rates of marriage, birth, and contraception usage, as well as the birth rate to contracepting women. The fraction of women sexually active and the fraction ever divorced turn out to be especially important for our results. We also assess the benchmark model along non-targeted dimensions. For instance, in the survey data, women who are already mothers, essentially ignored in previous models, account for 53% of unmarried births. In our benchmark calibration, these women account for 47% of unmarried births.

We first use the benchmark parameterization to carry out a simple computational experiment. What would happen to unmarried births if sexually active singles faced a minimum birth rate of 15-20%? We find that this type of restriction results in a large decrease in the unmarried birth share, from 28% to 9%. This is driven by a decline in the sexual participation rate of unmarried women. This result is consistent with the hypothesis that birth-control liberalization explains the rise in promiscuity and in the unmarried share of births by reducing the cost of sex. In fact, about 70% of the observed change in the unmarried share of births is explained in this way.

However birth-control restriction in the benchmark model cannot be the whole story. Relative to 1960, the resulting increase in marriage rates is too small, and the prevalence of divorce actually increases, whereas in 1960 it was much lower. We therefore re-calibrate a subset of the benchmark parameters to match marriage, divorce and birth rates, for the age 16-44 sample of women in 1955-1960, with restricted birth control. One of the main challenges is to generate higher marriage rates in 1960 along with lower divorce risk per marriage. This turns out to require increasing the persistence of match quality, while generating lower unmarried birth rates requires decreasing the value of being a single mother.

[1] See Kennes and Knowles (2011) for an extension in which this distinction is more explicitly modeled as men and women choosing whether to establish casual or more committed relationships.

Now re-consider liberalization of birth control, starting from this 1960 steady-state equilibrium. In contrast to the previous computational experiment, access to birth control now has little impact on the unmarried births share, which increases to only 5%. This is because unmarried women are no longer at the sexual-participation margin, as the effective penalty for becoming a single mother is 60% higher in the 1960 calibration.

We conclude from these computational experiments that other kinds of social change must be critical for understanding the sexual revolution, and this change must be centered on the stability of married couples. This is partly because previously married women account for a significant share of unmarried births, about 23% according to the 1995 NSFG. But the main reason is that incentives to marry are weak when marriages are unstable. The annual marriage probability in 1960 for women aged 15-44 without children was about 15%. Our results suggest that liberalization alone would have reduced this to 10%; destabilizing marriages to match the divorce rates of the 1990s depresses this much further, to about 3% annually. Liberalization of birth control can explain 97% of the change in the unmarried share of births, but only if marital stability exogenously falls at the same time. If instead it is the utility of single mothers that changes exogenously, then liberalization can explain only 43% of the change.

The previous papers cited above considered aspects of social change as part of the mechanism. Could these be pointing in the right direction for resolving the issues raised in our analysis? In Akerlof et al. (1996), the focus was on strategic interactions between unmarried sexual partners, in Greenwood and Guner (2005) on the choice of unmarried people between promiscuous and chaste social groups, and in Fernández-Villaverde et al. (2014) on socialization by the parents of daughter's preferences for unmarried sex. Our results suggest that the full explanation must generate changes in marriage stability and in the value of being a single mother, neither of which are addressed by these papers. We discuss at the end our paper the potential roles of changing female labor-market prospects and government social programs.

Several of the most important features of our analysis are borrowed from the existing literature; the stochastic modeling of aging and fertility for instance, derives from Regalia and Ríos-Rull (1999), and the assumption of competitive search is borrowed from the labor-market search literature; see Shimer (2005) for a general framework. Households in our model fully commit to a Pareto-optimal allocation of fully-transferable utility; this assumption, which is the basis of the "collective model" in the micro-econometric literature of the household, derives from the canonical model of Becker (1973), and has been applied in a host of papers, including Choo and Siow (2006) which considers the impact of birth control on the assortment of spouses by education in the marriage-matching equilibrium. Another related literature, such as Guvenen and Rendall (2014), focuses on the interaction of marriage markets with higher education and women's career prospects. However this comes at the price of abstracting from the implications of fertility and birth control that we explore here. Our analysis also abstracts from wage/education heterogeneity and many other important features of marriage-market equilibria. Such features could be introduced into our approach; for instance Knowles and Vandenbroucke (2013) adds more life stages to the model in order to match age profiles for marriages and births, but abstracts from divorce and unmarried births. However in the current paper, the addition of such features would obscure the more original aspects of our framework, i.e. the focus on combining repeated marriage/divorce over the life-cycle in the presence of children.

2 Equilibrium Model

Consider a large number of men and women choosing between single and married life in a stationary, infinite-horizon setting where time is discrete. Individual agents of either sex have zero mass and are ex-ante identical.

The lifecycle consists of two stages; active and terminal, an absorbing state. Agents begin life in the active stage and transit each period with probability δ to the inactive stage. Men are all the same. Women may have k children where $k \in \{0, 1, 2, ..., K\}$. Adults either live alone, as singles, or with a spouse of the other sex, as married.

Married couples receive an output flow $y^M(k, k_M)$, enjoyed at the end of the period, that depends on the number of children k the woman has prior to entering the marriage, and the number of children k_M produced by the marriage. In addition, the output of the marriage also includes the couple's match quality, which is given by the sum of two random variables, (q, ϵ_q). The first of these follows a Markov chain with support $Q = \{q_0, q_1 ... q_N\}$ and transition probabilities $\pi^Q(q_k|q_j)$, where $j, k \in \{1, 2, ...N\}$. The second follows a normal iid with CDF $F^q(\epsilon_q)$ and support on the real line.

The output of a couple is fully transferable between the spouses, and the couple can commit to any feasible future allocation of the output. Transferability is the basic assumption in much of the collective-model literature on the behavior of married couples; Chiappori et al. (2002) for instance, show that this assumption is consistent with patterns of household labor-supply in micro-level data. The alternative assumption is more difficult to implement when there is heterogeneity: see Burdett and Coles (1999) for marriage-markets with non-transferability. Knowles (2013) models a marriage market with partial transferability, but abstracts from *ex ante* heterogeneity.

At the start of each period, singles match with those of the other sex in a marriage market. Due to search frictions, some people of each sex remain single after the marriage market closes. The population of singles also includes those who divorced in the current period. Single women then choose whether to have sex, which results in a utility flow ϵ_x. The magnitude of this utility flow is a random variable, with CDF $F^x(\epsilon_x)$, whose realizations are iid across women and over time, and are realized each period after the closing of the marriage market. There is only one long-term consequence of sex; the probability of becoming an unmarried mother, which depends on the choice of birth-control effort a. The disutility per unit effort is given by the parameter $\eta > 0$.

After the marriage market closes, married couples learn their current realization of match quality, which is added to their output flow, and decide whether to divorce. If they divorce, they pay a cost d_C and finish the period as singles, forgoing the output the couple would have produced had they stayed together.

Women in the first stage of life are sexually active if $k < K$ and they are either married or chose to have sex after the marriage market closed. Children are born to sexually-active women at rate $\theta(a) \in (0, 1)$, where a is the disutility or effort required by the current birth-control technology to attain birth probability θ. To allow for interior solutions, we assume $\theta'(a) < 0$ and $\theta''(a) > 0$. Children remain with the mother forever; this affects both utility from single life $u_F(k)$ and the output of marriage $y^M(k, k_M)$. The arrival of a child entails a one-time utility shock ϵ_k.

Inactive agents remain in the same status forever. They get a constant utility each period, as determined by their marital status and number of children in their last period as active agents.

2.1 Bellman Equations: Married Couples

Let the effective discount factor be denoted $\tilde{\beta} \equiv \beta(1-\delta)$. Let $V^M(k, k_M, q_{-1})$ denote the expected value of a married couple on entering the period, conditional on q_{-1}, the previous-period's realization of q. Define the value of having one more child as:

$$\Delta V^M(k, k_M, q) \equiv V^M(k+1, k_M+1, q) - V^M(k, k_M, q)$$

. Let $R^M(k, k_M, q, \epsilon_k)$ be the value of the marriage, net of the iid shock ϵ_q, after the match-quality and child-preference shocks are realized, but before fertility is realized. The couple chooses birth control effort a to solve

$$\begin{aligned} R^M(k, k_M, q, \epsilon_k) = \max_{a \geq 0} \Big\{ & u(a, k, k_M) + q + \widetilde{\beta} V^M(k, k_M, q) \\ & + \widetilde{\beta}\theta(a)\left[\Delta V^M(k, k_M, q) + \epsilon_k\right] \Big\} \end{aligned} \tag{1}$$

. We denote the resulting birth probability as

$$\pi_M^B(k, k_M, q) \equiv \int_{-\infty}^{\infty} \theta\left(a\left(\left[\Delta V^M(k, k_M, q) + \epsilon_k\right]\right)\right) dF^k(\epsilon_k)$$

In the appendix we work out the optimal birth-control effort, and the resulting expected birth rates and the impact of fertility on the value of each state. A key property of these functions is that they are integrals over the child-preference shocks, and hence can be represented to a very high degree of accuracy as spline functions of ΔV^M.

Let R^H, R_k^F represent the continuation values of single men and women, respectively, after the marriage market closes in the current period. Divorce decisions maximize the present discounted value of the marriage:

$$\begin{aligned} V^M(k, k_M, q) &\equiv \sum_{q'} \left[\pi(q'|q)\right] \\ &\times \int_{-\infty}^{\infty} \max\left[W^S, W^M\left(k, k_M, q', \epsilon_k\right)\right] dF^q(\varepsilon_q) \end{aligned} \tag{2}$$

, where

$$W^M\left(k, k_M, q', \epsilon_q\right) \equiv \int R^M\left(k, k_M, q', \epsilon_k\right) dF^k(\epsilon_k) + \epsilon_q$$

$$W^S \equiv R^H + R_k^F - d_C$$

. Let the resulting divorce rule be $\varepsilon^D(k, k_M, q)$. We define the divorce rate, conditional on the initial state as:

$$\pi^D(k, k_M, q) \equiv \sum_{q'} P(q'|q)\, \varepsilon_q^D(k, k_M, q')$$

. The ex ante value of a marriage can be written as

$$\begin{aligned} V^M(k, k_M, q) \equiv \Bigg\{ & \sum_{q'} \pi(q'|q) \left[W^M(k, k_M, q', \epsilon_k) + \int_{e^D(q')}^{\infty} \epsilon_q dF^q(\epsilon_q) \right] \\ & + F^q\left(\varepsilon^D(k, k_M, q')\right) \\ & \times \left[W^M(k, k_M, q', \epsilon_k) - W^S F^q\left(\varepsilon^D(k, k_M, q')\right) \right] \Bigg\} \end{aligned}$$

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2.2 Bellman Equations: Single Women

After the marriage market closes, single women decide whether to be sexually active. The optimal decision depends on the realizations of the child-utility shock ϵ_k and the sex-utility shock ϵ_x. Although the two preference shocks are realized simultaneously, we proceed by backwards induction from the birth-control decision to characterize the sex decision. Let V_k^F the continuation value of a single woman with k children, at the start of the period; let the impact of having one more child on the continuation value at the start of the next period be $\Delta V_k^F \equiv V_{k+1}^F - V_k^F$.

Let $a_k(\epsilon_k, \Delta V_k^F)$ be the optimal birth-control effort. Woman's net pay off from sex is:

$$u_k^x(\epsilon_x, \epsilon_k, \Delta V_k^F) \equiv \epsilon_x + \max_a \left\{ -\eta a + \widetilde{\beta}\theta(a) \left[\Delta V_k^F + \epsilon_k \right] \right\} \tag{3}$$

Define ϵ_k^C such that $a_k(\epsilon_k, \Delta V_k^F) = 0$ for all $\epsilon_k > \epsilon_k^C$. We now define a threshold function $\epsilon_x^*(k, \epsilon_k)$ such that sex is optimal iff $\epsilon_x \geq \epsilon_x^*(k, \epsilon_k)$. . The expected contribution of sexual activity to the value of remaining single this period is

$$v_F^X(k) \equiv \int_{-\infty}^{\infty} \left[\int_{\epsilon_x^*(k,\epsilon_k)}^{\infty} u_k^x(\epsilon_x, \epsilon_k, \Delta V_k^F) dF^x(\epsilon_x) \right] dF^k(\epsilon_k)$$

. In the appendix, we derive the expected birth rate, $\pi_F^B(\Delta V)$ and expressions for

$a_k\left(\epsilon_k, \Delta V_k^F\right)$ and $v_F^X(k)$, given the simple parametric form that we will use in the calibration.

. The reservation value of a single woman in the matching stage is:

$$R_k^F \equiv u_F(k) + v_F^X(k) + \tilde{\beta} V^F(k)$$

. Let the values on entering submarket k, for men and women, respectively, be denoted $V^H(k, \phi)$ and V_k^F .Now we can define the surplus from a new marriage where the bride already has k children as:

$$S(k) \equiv V^M(k, 0, q_1) - R_k^F - R^H \tag{4}$$

, where $R^H = \frac{\beta}{1-\beta}\gamma$ is the reservation value of a single man.

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2.3 Matching and Surplus Allocation

The essential feature of the matching process for singles is that, unlike a random-search process, it generates a unique Pareto-optimal matching each period. This implies that our implementation, described below, is equivalent to other matching frameworks, such as the labor-market auctions described by Julien et al. (2000) , or the preference-shocks marriage model of Choo and Siow (2006), that also generate a unique Pareto-optimal matching. The implementation we describe below is essentially a dynamic version of the labor-market model of competitive search with wage posting, as described in Shimer (2005). It must be stressed however that our results do not depend on this particular framework. As we are going to work exclusively with the stationary equilibrium (ie the steady state of the model), we suppress time subscripts in our description of the model. [2]

Matching occurs in a set of K sub-markets; women with $k < K$ children match in sub-market k. Women with K children are assumed not to marry.[3] Each sub-market is associated with an announced utility level w_k that women award to the men that

[2] See Knowles and Vandenbroucke (2013) for an analysis of the transition dynamics of a related model.

[3] This makes the model slightly easier to solve. As K can be made arbitrarily large, it should not have much impact on women with a small number of children.

they marry; since the women in a sub-market are identical, this is consistent with individual optimization. Men observe these K announcements and choose among sub-markets; they can also choose not to participate this period. Each man makes these decisions after observing his current realization of an iid utility cost γ, with CDF $F^{\gamma}(\gamma)$, which he pays only if he decides to participate in one of the submarkets.

Let the mass of women with k children be P_k^F and let the mass of men who choose sub-market k be N_k^H. We define the queue length in sub-market k as $\phi_k \equiv N_k^H / P_k^F$. In each submarket, men are randomly assigned to the women, which results in a Poisson distribution of the number of suitors per woman[4]. We can therefore write the female marriage probability as $\rho(\phi_k) = 1 - e^{-\phi_k}$. Note that the female marriage rate is increasing in ϕ_k while the male rate, given by $\rho(\phi_k)/\phi_k$, is decreasing in ϕ_k .

The allocation of the surplus of a marriage is determined by the utility offer w_k . This in turn is assumed to maximize the expected utility of women in sub-market k, subject to the constraint that men must weakly prefer participating in the sub-market. Let the value of a man participating in the marriage market be v^H. This represents his expected value from participating in his preferred submarket. Now if sub-market k is active, it must be that men weakly prefer participation in this sub-market, which delivers expected utility $w_k \rho(\phi_k)/\phi_k$. Therefore for a man who is indifferent, it must be that the participation constraint is binding: $w_k \rho(\phi_k)/\phi_k = v^H$. Since single men are identical once the participation cost is sunk, this condition must hold for all men who choose sub-market k. Therefore the utility offer w_k determines the queue length ϕ_k, given v^H.

Let the value of a marriage where the woman enters with k children be V_k^M ; recall that the woman's value of not marrying this period is R_k^F . The problem that women solve is:

$$\max_{w_k,\phi_k} \left\{ \rho(\phi_k) \left[V_k^M - w_k \right] + (1 - \rho(\phi_k)) R_k^F \right\} \tag{5}$$

, subject to the participation constraint:

$$w_k \rho(\phi_k)/\phi_k = v^H \tag{6}$$

.

Substituting for the wage from the participation constraint, we can write this as an

[4]This is known in the labor-market literature as "Urn-Ball" matching. The Poisson distribution arises from having an infinite number of men and women. See Shimer (2005).

unconstrained problem:

$$\max_{\phi_k} \left\{ \rho\left(\phi_k\right) \left[V_k^M - R_k^F\right] - v^H \phi_k \right\}$$

. At an interior solution, the optimality condition is:

$$\rho'\left(\phi_k\right) \left[V_k^M - R_k^F\right] = v^H \tag{7}$$

, which implies that the constrained-optimal queue length from the women's point of view is $\phi_k^* = \log\left(\frac{V_k^M - R_k^F}{v^H}\right)$.

We let $v_k^F \equiv \rho\left(\phi_k^*\right)\left[V_k^M - R_k^F\right] - v^H \phi_k^*$ denote the contribution of marriage prospects to a women's expected value each period.

For single women with k children, the *ex ante* net value of entering the marriage market is:

$$V_k^F = R_k^F + v_k^F$$

.

In equilibrium it must be that the queue lengths equate the demand and supply for single men. The demand for men is given by $\sum_{k=0}^{K} \phi\left(k; v^H\right) N^F(k)$. Let P^H represent the population of active single men. It is only optimal for men with relatively low participation-cost realization to participate; for marginal men, $\gamma_i = v_M$, therefore the fraction of men who participate in a given period is $F^\gamma\left(v^H\right)$. The expected value of entering the marriage market must solve the following equation:

$$\sum_{k=0}^{K} \phi\left(k; v^H\right) N^F(k) = F^\gamma\left(v^H\right) P^H \tag{8}$$

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2.4 Laws of Motion

Once the decision rules are known, the laws of motion of the distribution of women over children and marital states form a recursive linear system that can be easily solved by beginning with $k = 0$ and proceeding in sequence to $k = K$. This relies on the model's assumption that children never disappear from the mother's state variable. Let

$$P_0(k) \equiv \begin{bmatrix} P_k^F \\ P^M(k,0,q_1) \\ P^M(k,0,q_2) \\ \vdots \\ P^M\left(k,0,q_{n_q}\right) \end{bmatrix}$$

be a vector representing the distribution of active-stage women with k children over all possible marital states where there are no children of the husband.

We show in the appendix that we can write the law of motion for $P(0)$ as a linear system:

$$P(0) = M_0(0)\,P(0) + D_0(0) \tag{9}$$

, where $M(0)$ is a square matrix with dimension n_{q+1} and $D(0)$ is a vector of length n_{q+1} with the only non-zero entry being $D_1(0) = \delta$.

Now define

$$P^M(k,k_M) \equiv \begin{bmatrix} P^M(k,k_M,q_1) \\ P^M(k,k_M,q_2) \\ \vdots \\ P^M\left(k,k_M,q_{n_q}\right) \end{bmatrix},$$

the distribution of married households with $k > 0$ and $k_M > 0$ over marital quality q. We show in the appendix that we can write the law of motion for $P^M(k,k_M)$ as a linear system of dimension n_q:

$$P^M(k,k_M) = M(k,k_M)\,P^M(k,k_M) + D(k,k_M) \tag{10}$$

, where $B(k,k_M)$ is a square matrix of coefficients. In this case $D(k,k_M)$ is a vector of intercept terms that includes terms from the solution for the system of $k' = k-1$.

Finally, consider the system of households where there are children ($k > 0$) but no father present ($k_M = 0$). This includes single females with children and married couples with step children but no children of the husband. We show in the appendix that we can write the law of motion for $P_0(k)$ as a linear system:

$$P_0(k) = M_0(k)\,P_0(k) + D_0(k) \tag{11}$$

, where $M_0(k)$ is a square matrix with dimension n_{q+1} and $D(k)$ is a vector of length

n_{q+1} with the only non-zero entry being $D_1(k)$. This requires that we first know the solution for $P^M(k, k_M)$, as $P_0^{'}(k)$ will include women who divorced this period but gave birth while married in previous periods.

2.5 Equilibrium

A stationary equilibrium with an excess supply of men is comprised of, for each $q \in \{q_1, ..q_{n_q}\}$, $k \in \{0, 1, ...K\}$ and $k_M \in \{0, 1...k\}$:

1. Value functions:
   (a) for unmarried men: V^H, R^H
   (b) for unmarried women: V_k^F, R_k^F, for each $k \in \{0, 1, ...K\}$
   (c) for married couples: $V^M(k, k_M, q), R^M(k, k_M, q, \epsilon_k)$
2. Decision rules:
   (a) birth-control effort: $a_k(\epsilon_k), a(k, k_M, q, \epsilon_k)$
   (b) divorce: $\varepsilon^D(k, k_M, q)$
   (c) unmarried sex: $\epsilon_x^*(k, \epsilon_k)$
3. Utility offers: w_k
4. Queue lengths: ϕ_k
5. Population-distribution matrices $P_0(k)$, $P_0^0(k)$, and $P^M(k, k_M)$

such that the following conditions are satisfied in every period:

1. Optimality
   (a) women's utility offers solve the problem in equation (5)
   (b) single men's participation constraint (6) binds for all active markets
   (c) single woman's sex threshold $\epsilon_x^*(k, \epsilon_k)$ sets equation (**??**) equal to zero
   (d) birth-control effort $a(k, k_M, q, \epsilon_k)$ solves equation (1)
   (e) birth-control effort $a_k(\epsilon_k)$ solves equation (3)

(f) matched singles marry if and only if the surplus defined in (4) is positive

2. Market clearing

   (a) The demand for men equals the supply: equation (8) is satisfied

3. The population-distribution matrices are the fixed points of the laws of motion, equations (9) (10) and (11) .

3 Solving for the Stationary Equilibrium

The structure of the model ensures that the number of children in a household is either constant or increases by one each period. This makes it relatively straightforward to solve, because each level of k can be dealt with sequentially, rather than simultaneously. The decision rules in market k depend on the other markets $k' < k$ only through the values of ϕ_k. Therefore, given a conjectured distribution $P^F(k)$, a value for v^H , and an approximation method for the value functions, we can solve the Bellman equations for each level of k sequentially, by backwards induction from $k = K$. Given the complete system of decision rules, we then solve the laws of motion for the steady-state distribution, starting from $k = 0$. We then repeat the procedure, using the new distribution, until the distribution converges. We then use the results to update v^H and iterate on this procedure until this too converges.

Normally a procedure like this would require us to solve for the fertility decisions separately at every point in the state-space repeatedly for each iteration. This would be quite demanding. Instead, we pre-compute the related functions, such as $\pi_M^B(\Delta V)$, $a(\Delta V)$, and $V^M(\Delta V)$, over a grid of the expected gain ΔV from a birth. Because of the iid shocks ϵ_k and ϵ_x associated with the fertility decisions, these are smooth functions which can be accurately approximated by spline functions. We feed these pre-computed spline functions into the model, using them to compute the fertility-related variables as needed.

Given a stationary equilibrium, we then use the decision rules to simulate a cohort of 10,000 women from ages 16 to 44. We compute statistics from the simulated population that can be compared to statistics drawn from surveys of the US population.

4 Empirical Analysis

In this section we conduct a statistical analysis of marital/fertility data related to the model. Ideally, we would have preferred to rely on the excellent empirical analyses already in print, such as those of Akerlof et al. (1996) or Goldin and Katz (2002). However our emphasis on the distinction between mothers and non-mothers requires us to cut the data in a radically different way for which there is no published precedent: by number of previous children.

The data that is used to compile the statistical targets for the 1990s comes from the 1995 wave of the National Survey of Family Growth. This data set is based on in-person interviews of 10,847 women 15-44 years of age, conducted from January to October 1995. The data set contains histories of pregnancies, births and marriages, as well as a monthly calendar of recent (since January 1991) of contraception methods employed. Frequency of sexual intercourse over the three months prior to the survey is reported as well as any extended periods of sexual inactivity since 1990. For each of the 21,332 pregnancies covered by the data set, the month of termination, the outcome, and estimated conception date are given. The data set also contains a set of sampling weights that allow for the construction of nationally representative sample statistics.

For each woman in the sample, we construct one observation for each month in the years 1991 to 1994 that she is between ages 16 and 44. Since we know the complete marriage trajectory up to 1995, we know whether the respondent married within a year of any birth that occurred at least one year before the interview date. Because we are concerned about family structure rather than promiscuity or unmarried births per se, we count as married births those cases where marriage followed within a year of the birth of a child. Therefore we exclude from the computations any observations for months less than a year before the interview date, which varies from January to October 1995. This gives rise to 523,906 observations, which includes 3398 births, of which 1149 are to unmarried women.

We categorize women in our monthly sample according to the number of own children living with them in the preceding month. This is computed from a separate "interval" file, which lists variables specific to each pregnancy, including the month of death or of leaving home for all children ever born who are not living with the respondent at the time of the interview. Similarly, we compute the woman's marital status for each month using the marital history, which has dates for the start and end of each spell of marriage or cohabitation. To compute marriage or birth hazards for any group of women, we first take as the monthly hazard the group average x of an indicator (e.g. 0=no-marriage begins, 1=a marriage begins) variable , and then compound this average to compute the annual hazard as $H = 1 - (1 - x)^{12}$.

Table 1: Unmarried Women Sample

Statistic	Previous Children			Teenage	Previously Married
	0	1	2+		
Share of UMB	0.468	0.278	0.254	0.182	0.198
Birth Hazard	0.028	0.063	0.047	0.035	0.030
Marriage Hazard	0.073	0.083	0.082	0.025	0.091
Cohabitation	0.099	0.204	0.218	0.046	0.208

Table 1 shows how different categories of unmarried women contribute to the total number of unmarried births (UMB) in 1990-1995. The first row shows that women with no previous children account for less than half of unmarried births, hence the importance of including unmarried mothers as active agents. Mothers of one child contribute 28% of unmarried births, and mothers of two or more children 25%. We also see that previously married singles contribute more births (20% of total) than do unmarried teenagers (18%); this is striking because it indicates an important role for divorce. The annual birth hazard for unmarried women with one child (6.3%) is much higher than for non mothers (2.8%), which accounts for the relative importance of mothers. Heterogeneity across number of children would appear to be quite important. Previously married women and teenagers are much closer to the overall average of 3.7%,

Table 1 also reports marriage hazards, the rates per unmarried woman. The key features we learn about marriage is that women with a previous child are as likely to marry as women with no children. The similarity of the marriage rates for parents and non-parents may appear to be problematic for the theory that parenthood reduces future prospects, but it is far from fatal, as high marriage rates can result from a low value of single life. This would show up as lower birth rates to unmarried non-mothers, which is precisely what we see here. Again previously married women have marriage rates (9.1%) similar to the overall average, which is 7.6% annually.

At the time of the interviews in 1995, co-habitation ("informal marriage" in the survey), was still relatively uncommon among single non-mothers, accounting for only about 10% of our sample, as shown in the final row of Table 1 . The overall average was 21% of singles; this is higher because 20% of single parents were in informal marriages at the time of the interview. Our analysis abstracts from co-habitation; we treat cohabiting unmarried women as single, unless they have a pregnancy that is followed by marriage with a year of the birth. Since cohabitation is known to be much less stable than marriage, we treat it as a form of dating. This admittedly casual approach may be justified by the low rate of cohabitation; dealing with children, remarriage and divorce appear to be much more important at this stage in the literature.

4.1 The 1960s

Although our main calibration is based on the 1995 NSFG, statistics for 1960 will play an important role in our quantitative analysis later on. Ideally, we would have used an analog for the NSFG that covers the early 1960s. Such a data set is not available; the earliest representative survey that includes single never-married women is the 1982 version of the NSFG[5]. We rely therefore on the 1960 Census for the computation of statistics analogous to those in the previous table, with the exception of cohabitation, which is not available in the Census.

Because the Census is not as rich in demographic variables as the NSFG, the hazard variables we compute are not exactly analogous to those for 1995, but aggregates computed using this method are a close match with vital statistics for 1960, suggesting that our computations are quite accurate. Furthermore, rates of marriage, birth and divorce for 1965 are very similar at the aggregate level to those for 1960, suggesting the 1960 data is a good proxy for the early 1960s: the annual birth rates to married and unmarried women (aged 15-44), for instance, are relatively stable at around 14% and 2%, respectively, the marriage probability at 14.5%, and the divorce rate at 1%.

[5]The first version of the NSFG, in 1973, only includes single women if they are previously married or have an own child living with them. The 1965 National Fertility Survey includes only married women.

Table 2: Census 1960 Marriage and Births

		Previous Children		
		0	1	2+
Share of UMB		0.506	0.228	0.266
Birth Hazard	Married	0.180	0.167	0.127
	Single	0.004	0.146	0.199
Marriage Hazard		0.129	0.333	0.227

For each woman in the Census, we construct one observation for each year between 1955 and 1959 that she is between ages 16 and 44. For each of these observations, we determine whether the woman was married at that time, and whether a marriage begins in that year [6]. Similarly, we use the age of the respondent's children currently (i.e. at the interview date) living with her to compute the number of children she had at each year, and to determine whether a child was born to her in that year. Divorces and remarriages within this 5-year window are potential pitfalls for computing marriage hazards for this method, but these are relative rare in the early 1960s. The resulting marriage rate for the age 16-44 group is 13%; according to vital statistics, the national average for 1965 is 14.4%, so our method yields a good approximation.[7] Relative to birth rates, our results are almost as close; we get a married birth rate of 13% per married couple, compared to 14% in the vital statistics for 1965.[8]

In Table 2, we report the results by number of births. Similar to the 1995 NSFG, women who are already mothers contribute half of the unmarried births; 23% by mothers of one child, 27% by mothers of two or more children. The birth rates to unmarried women without children are much lower, about 0.4%; however for mothers of one child the birth rate is 14.6%, significantly higher than in 1991-95,

[6] We use the age-at-first-marriage variable and quarters of birth and marriage. As a result, our determination of marriage rates excludes higher-order marriages; this makes little difference for 1960, as these marriages were comparatively rare.

[7] National Center for Health Statistics: Advance report of final marriage statistics, 1982. Monthly Vital Statistics Report. Vol. 34, No. 3 Supp. DHHS Pub. No. (PHS) 85–1 120. Public Health Service. Hyattaville, Md., June 28, 1985.

[8] Ventura SJ, Bachrach CA. Non-marital childbearing in the United States, 1940–99. National vital statistics reports; vol 48 no 16. Hyattsville, Maryland: National Center for Health Statistics. 2000. Since our measure is based on children in the household, rather than children ever born, we expect some deviation due to deceased and non-resident children. This is not a concern, as our main analysis is focused on women with co-resident own children.

and for mothers of two children, it is 17%. Thus a strong reduction in birth rates to unmarried mothers may be a potentially important effect of improved birth control.

We also see that for all cells, the marriage rate plummeted between 1956-1960 and 1991-1995. The average marriage rate for non-mothers aged 16-44 in Table 2, was 13%, while for mothers of one child it was 15%, and 20% for mothers of more children. As we saw in Table 1, by 1995 the non-mother marriage rate had fallen to 7.3% and for women with one child, to 8.1%.

In Table 2, we see the fraction of women ever divorced ranges from 2.7% for women with no children to 7.5% for mothers of one child. Despite the much lower share of marriage in 1991-95, the fraction of childless women who were previously married is much higher, about 8.4%

Why does the birth rate increase for women without children and decrease for those with a child already? An obvious explanation is that unmarried women with children were much more active sexually in 1960 than women with no children (outside of a relationship leading to marriage), and so the effect of better birth control is not confounded, as it is for the non-parents, by a simultaneous increase in sexual activity.

4.2 Sexual Activity and Contraception

We consider two ways to measure sexual activity and contraception behavior in the 1995 NSFG. The first is based on a set of variables that refer to behavior during the three months preceding the interview, which provide a cross-sectional "snapshot" . The second is based on the retrospective variables, especially the monthly birth-control calendar, which runs from January 1991. In principle, we also know which periods the respondent was sexually active over this period.

Sexual activity can be measured most directly using the first method. Table 3 gives the fraction of women who reported having sex at least 2-3 times a month in the three months preceding the interview date. Among singles, the fraction is about 78%, while for married it is about 90%; in both cases, it does not appear to vary much with the number of previous children. Invariance to the number of children appears to hold for more detailed breakdowns as well; as we go from women with 0, to those with 2 children, the fraction reporting sex 2-3 times weekly varies from varied from 24.8 to 26% among singles, and 34.2% to 33.7% among married.

Table 3: Sexually Active

	Previous Children					
	Single			Married		
	0	1	2+	0	1	2+
Sexually Active	0.774	0.786	0.756	0.916	0.878	0.906
No Contraception	0.151	0.173	0.165	0.388	0.282	0.107
Safe Contraception	0.472	0.435	0.171	0.295	0.277	0.141

For the birth-control analysis, we drop observations where the woman is not sexually active, and those corresponding to an ongoing pregnancy. Table 3 shows that the fraction of sexually active women with no children who are not contracepting is much lower for singles (15%) than for married (39%), and the fraction using a safe contraception method, such as the Pill, IUD or sterilization is also higher for single women (47%) than for married (29%), pattern that also holds for women with one child, and to a much lesser extent for women with more than one. Single women who are sexually active therefore appear more concerned than do married women with preventing births.

More detail is available in Table 4, which shows that even among sexually active contracepting women, there is a wide range of contraception practices, including those that are clearly ineffective, relative to the ones labeled 'Safe' in the previous table. The effectiveness of contraception methods is measured by the "typical-use" annual pregnancy rate, as reported by Trussell et al. (1990) .

In 1995, the largest categories of contraception used by unmarried contracepting women were birth-control methods associated with much lower pregnancy rates than those in general use before 1960. This refers mainly to the Pill, but also includes physician-administered methods, such as the IUD and injectables such as Depo-Provera, and sterilization. This accounts for 46% of unmarried women and 41% of married. The only other category of comparable importance consists of women who rely on the male condom , which accounts for 17% of unmarried and 16% of married. Very few sexually-active unmarried women report relying on ineffective methods such as "withdrawal" and "rhythm" , about 1% of singles, 2.2% of married.[9]

[9] According to Piccinino and D.Mosher (1998), about 0.4% of women relied on contraceptive

The table also suggests that sterilization, despite its effectiveness, does not appear to be an important option for single women, accounting for only 4% of non-mothers.

Table 4: Contraception Methods

Method	Pregnancy Rate	1995 Single	1995 Married	1965 Married
Pill/PA	0.03-0.09	0.288	0.193	0.177
Condom	0.12-0.18	0.169	0.135	0.159
Sterile	0.00	0.121	0.259	0.199
Diaphragm	0.18-0.21	0.017	0.028	0.047
Vasectomy	0.00	0.009	0.026	0.087
Other	0.18-0.32	0.009	0.022	0.068

Our direct evidence of technical change is therefore that the most important birth control methods for singles in 1995 were simply not available in 1960. So what did women do instead? Ideally we would like to compare the usage patterns in 1995 to those before 1960. However we are not aware of any available data that would permit this exercise. A limited sort of comparison is possible however by using the 1965 National Fertility survey. This includes only married women, and while it does have a retrospective contraception calendar, it indicates only whether the respondent was using the pill each month. Fortunately, it does permit us to compare contraception usage rates of married women in 1965, which turns out to be suggestive of the difficulties facing all contracepting women in the early 1960s.

Table 4 shows that in 1965, when the pill had been available to married women for five years, about 18% of them were using it. Sterilization was much less common, accounting for only 18% of married non-mothers, and 20% of mothers. What is really striking however is the fall in the fraction of married women using ineffective contraception methods [10]. In 1995, less than 3% of married mothers, and 1% of non-mothers used such methods; in 1965 the share was 23% of mothers and 17% of non-mothers. Relative to 1965, it is the most ineffective methods that have all

foam in the 1995 NSFG, and 1.3% on “other”, including douche.

[10] One of the most popular of these methods, the “douche” , is not known to have any contraceptive value, and is not even listed as an option in the 1995 survey. The rhythm method was widely known to ineffective, as admitted in 1968 by the Catholic church, the main institutional proponent of this method. As quoted in Wikipedia, in 1968 the encyclical Humanae vitae included the statement, "It is supremely desirable... that medical science should by the study of natural rhythms succeed in determining a sufficiently secure basis for the chaste limitation of offspring." .

but disappeared among contracepting married women. Since usage rates of the Pill+Sterilization were so much higher in 1995 (60%) than thirty years earlier (38%), while condom usage rates remained stable, this suggests a shift in the entire birth-control frontier over time, rather just the marginal improvement of Pill relative to the next-best method.

Abortion is also an important method of birth control; based on vital statistics reports, there were 33.2 abortions per 100 live births over this period[11]. Over the 91-94 period, there were 3282 normal pregnancies in the sample, where by normal we mean one that ended either in abortion or a live birth. In Table 5 we show the average number of reported abortions per normal pregnancy[12]. Three facts emerge from this. First abortions account for a significant share of unmarried pregnancies, 20% for singles with fewer than two children. Second, married pregnancies are much less likely to end in abortion: 2% for couples without children, 5% for the rest.

Third, abortion appears much less likely in the NSFG sample than in the national data. In fact the sample average is 9.6 abortions per pregnancy, which implies an abortion ratio of 10.6, about a third of the aggregate ratio. Under-reporting of abortion is a well-known weakness of the NSFG survey methods; this suggests that abortion is actually much more important for unmarried birth control than indicated by our results.

From the work of demographers, such as Trussell et al. (1990), the annual natural birth rate to young married women who are not contracepting is about 0.85. The bottom row of Table 5 shows that the birth rate to married, sexually active non-contracepting women aged 19-23 is much lower, about 0.63 on average, and for singles even lower, about 0.29. [13] We attribute this discrepancy to non-reporting of pregnancies that ended in abortions. For instance for unmarried non-mothers, the

[11]Abortion Surveillance – United States, 1995. Lisa M. Koonin, M.N., M.P.H. Jack C. Smith, M.S. Merrell Ramick Lilo T. Strauss, M.A., Division of Reproductive Health National Center for Chronic Disease Prevention and Health Promotion. The difficulty of obtaining accurate abortion statistics at a disaggregate level is one reason why our analysis focuses on birth hazards rather than pregnancies, and why we model abortion as part of birth-control technology rather than an explicit decision.

[12]Thus we are excluding ectopic pregnancies, and those that ended in either miscarriage or still birth

[13]These numbers correspond to 1991-1994, when sexual-activity measurement is less precise, so the differential between married and singles will reflect in part, different rates of sexual activity. For instance , for the last 3 months of the survey, 51% of contracepting single women report sexual activity rates less than once weekly, compared to 32.6% of contracepting married women. However these effects are likely to be small relative to the role of abortion.

Table 5: Abortion 1991-1995

		Previous Children					
		Single			Married		
Age		0	1	2+	0	1	2+
16-44	Abortions	0.213	0.196	0.122	0.019	0.046	0.046
	Pregnancies	0.161	0.318	0.361	0.392	0.400	0.280
19-23	Abortions	0.221	0.167	0.105	0.021	0.035	0.051
	Pregnancies	0.196	0.515	0.629	0.657	0.569	0.666

pregnancy rate is 0.2. Given the reported abortion rate of 0.22, we get a predicted birth rate in the absence of abortion of 0.25, less than a third of the natural birth rate. Of course some of this may be due lower rates of sexual activity, conditional on being sexually active, unmarried and not using birth control; 51% of contracepting single women report sexual activity rates less than once weekly, compared to 32.6% of contracepting married women. We would expect therefore lower pregnancy rates to single women who are contracepting than to married women, but neither the sexual-activity nor the contraception-method differences seem large enough to explain away the pregnancy rate differential. Instead we surmise that reliance on abortion is even more concentrated on singles than the NSFG data suggests.

4.3 Divorce

Divorce hazard rates increased significantly over the period of our study. For instance the number of divorces tripled between 1960 and 1982, from an annual rate of 0.9% per married couple in 1960, to 2.26% in 1981. While divorce rate per capita peaked in the early 1980s, in the 1990s it remained twice as high as in 1960, despite declining marriage rates[14]. In the next table we examine the shift in divorce in terms of our sample population, by number of children. In Table 6 we see that the fraction of childless women, married or not, who had ever been divorced stood at 8% in 1995, and at only 2.7% in 1960. For mothers, the contrast is just as stark; in 1995, 25%

[14]For per-capita divorce rates, see Table 68 of the Statistical Abstract of the United States, 2001.

of mothers of one child had been divorced, compared to 7.5% in 1960. Considering that women were much less likely to be married in 1995 than in 1960 suggests an even larger magnitude of change; the ratio of ever divorced to married among the non-mothers rises from 0.075 in 1960 to 0.33 in 1995, and from .07 to 0.42 among the mothers of one child. Divorce therefore plays a much more important role for parents in the 1990s, and this may be related to the decreased tendency to marry before having children. We therefore include among our targets the fractions of women ever divorced, by number of children.

Table 6: Divorce: 1990s vs 1960s

Year	Statistic	Previous Children		
		0	1	2+
1995	Ever Divorced	0.080	0.249	0.286
	Married	0.243	0.597	0.726
1960	Ever Divorced	0.027	0.075	0.044
	Married	0.335	0.995	0.997

5 Calibration

The order of business in the calibration procedure is: choosing functional forms, setting non-critical parameter values, and finally setting the values of the critical parameters inside a parameterization loop. This procedure is quite standard in the macro literature; the loop consists of choosing a set of parameter values, solving for the optimal decisions, given the parameter values, simulating a cohort of 16-44 year old women and then computing model statistics from the simulation. The model statistics are compared to statistical targets based on the empirical analysis above, and then the procedure is repeated until the Euclidean distance between model and target statistics has been minimized. The choice of parameter values in this procedure is left to a standard multi-dimensional minimization function, though the loop may be repeatedly restarted with new guesses, to ensure that the procedure does not get stuck in a sub-optimal local minimum.

Our strategy is to parameterize the model so as to match transition-rate statistics from the 1990s for marriages, divorces and births for women aged 18-44, by number of children the woman already has, and by whether or not the woman is married. For the 1990s, the NSFG appears to be best source of these statistics; for earlier years, they can be compiled from the US Census, but after 1980 the Census drops the relevant marriage variables. Thus we rely on Table 1 for marriages and birth targets. As detailed statistics on divorce rates are no longer made available by the US Vital Statistics reports, we also require the model to match, by number of children, the fraction of women ever divorced, as reported in Table 6 above. In addition, the model is required to generate contraception-usage rates and birth rates for women using birth control, as reported in Table 3.

The logic of the identification is very straightforward. The lower the value of being a single mother, ceteris paribus, the lower is the birth rate to unmarried women, and the higher the marriage rate of single mothers. Thus the non-mother birth rate and the marriage rate of women with one child help to identify the utility parameter for single mothers, and the disutility of step children. The marriage rate of non-mothers then identifies the utility from single-woman households, relative to married households with no husband's children, for any given number of wife's children.

5.1 Functional Forms

The functional form for the birth-control technology is chosen to ensure that birth rates are declining in contraceptive effort a over the positive real line:

$$\theta(a) = \theta_0 + \frac{\theta_1}{1+\psi a}$$

. Note that this requires three parameter values. For stage-1 women, the natural birth rate in the model is $\theta_0 + \theta_1$. Further implications of this function for birth rates are derived in the Appendix. According to Trussell and Wilson (1985), based on the analysis of married women in England from the 16th to the 19th centuries, the natural (non-contracepting) birth rate was roughly 80% annually for sexually active women under age 25. The maximum effectiveness of modern birth control,as measured by the "perfect-use" pregnancy rate, according to Trussell et al. (1990) corresponds to an annual pregnancy rate of 0.3% under the pill, while for the IUD this would 0.6%, and female sterilization about 0.5%. We therefore set $\theta_0 = 0.005$; in our model this is the birth rate that corresponds to infinite contraceptive effort a , which would never be observed in equilibrium. We set $\theta_1 = 0.75$; this generates a birth rate under zero effort that is slightly lower than the above estimates of pregnancy rates, but allows for the possibility that not all pregnancies of women who want children result in births. Values for the cost parameter η and the frontier-location parameter ψ will be determined in the calibration loop.

In regards to utility flows generated by different household types, we set single-female utility as:

$$u_F(k) = \begin{cases} \alpha_F^1 + \alpha_F^2 \log(k) & k > 1 \\ \alpha_F^1 & k = 1 \\ \alpha_F^0 & k = 0 \end{cases}$$

, and married household utility as:

$$u_M(k, k_M, q) = \begin{cases} \alpha_M^1 + \alpha_M^2 \log(k) - v(k - k_M) & k > 0 \\ \alpha_M^0 & k = 0 \end{cases}$$

, where $v(k - k_M)$ represents the disutility of step children:

$$v(k) = \begin{cases} \alpha_M^3 + \alpha_M^4 \log(k) & k > 1 \\ \alpha_M^2 & k = 1 \\ 0 & k = 0 \end{cases}$$

.

5.2 Parameterization Strategy

We set the maximum number of children to $K = 3$. The stochastic processes for the child-preference ϵ_k ,marriage-quality shock ϵ_q, the entry cost, ζ, and sex-utility ϵ_x shocks are set to iid normal processes. Our empirical strategy is not informative about the variance of these processes, so we set the standard deviations, arbitrarily, equal to 1.0, except for the standard deviation of the sex-preference shock set to 0.1. The persistent component of the marriage-quality variable q follows a Markov chain with transition probabilities $\pi(q, q')$ and support size equal to $n_q = 3$, with the transition matrix and the support set to approximate a zero-mean Markov process with persistence ρ and standard deviation equal to 1. [15]

The annual discount factor is set to $\beta = 0.96$, a standard value in the macroeconomics literature. The divorce cost is set arbitrarily, to $\delta_D = 5$, as it turns out to have little or no effect on the calibrated results. A number of preference parameters are set, arbitrarily, to zero. These include the utility flows for married households without children, α_M^0, and the marginal contribution of 2nd or 3d kids to single-woman households, α_F^2. The utility flow for single men is fixed at $\alpha_H = 2$.

The remaining parameters include the birth-control parameters (η, ψ), the transition probability δ, the preference parameters for married households $\left(\alpha_M^1, \alpha_M^2, \alpha_M^3, \alpha_M^4\right)$, the means of the sex-utility and child-preference shocks and the utility flow from single-woman households, $\left(\alpha_F^0, \alpha_F^1\right)$. These are set inside the calibration loop, as discussed above, by matching the statistical targets derived in our empirical section to analogous statistics based on model's steady state.

In regards to contraception, the calibration loop targets the birth rate to contracepting women and the usage rate of contraception, taking as given (θ_0, θ_1) , which are set that the birth-rate support ranges from 0..5 to 0.8, as discussed in the empirical section. This implies 4 additional targets (2 for non-mothers, 2 for mothers), and 1 additional parameter, ψ. The utility cost of effort is normalized to 0.025.

Overall, there are eleven targets; seven corresponding to non-mothers and four to women with one previous child. For non-mothers, the calibration is required to match the fraction of non-mothers ever divorced, as well as the birth rates for both married and unmarried women. To ensure that the birth-control effectiveness is in the relevant range, the calibration also targets birth rates for contracepting women for both married and unmarried non-mothers, as well as the sexual activity rate for unmarried non-mothers. For mothers of one child, the calibration is required to match the married and unmarried birth rates, the fraction of singles not using birth control and calibration and the fraction of the sample ever divorced.

6 Results

We report results for two versions of the model; the 1990s Benchmark is calibrated to the NSFG statistics from 1990-1995, and the 1960 Benchmark where some param-

[15]We use Karen Kopecky's Matlab code to implement the Rouwenhorst transformation: http://www.karenkopecky.net/rouwenhorst.m

eters have been recalibrated to match Census statistics from 1960. In both cases, the other fixed parameters are kept at the values described above, and the remaining parameters are set so as to match the model's steady state to the target statistics.

6.1 The Benchmark Calibrations

The statistical targets, their values, and those generated by the Benchmark model are listed in Table 7.

Table 7: Benchmark Calibration: Targets and Results

		1955-1960		1990-1995	
		Targets	Results	Targets	Results
Non- Mothers	Marriage rate	0.15	0.163	0.073	0.06
	Single birth rate	0.006	0.002	0.035	0.035
	Married birth rate	0.185	0.182	0.154	0.16
	Ever-divorced fraction	0.081	0.064	0.125	0.114
	Controlled birth rate, single	0.175	0.147	0.04	0.047
	Unmarried Share of Births	0.0062	0.009	0.28	0.281
	Fraction sexually active			0.725	0.722
Mothers of One Kid	Marriage rate	0.298	0.295	0.081	0.057
	Single birth rate	0.14	0.142	0.115	0.075
	Married birth rate			0.185	0.197
	Ever-divorced fraction			0.248	0.224

Table 7 shows very close matches for most of the targets corresponding to non-mothers, including the single and married birth rates and the fraction of unmarried women sexually active, as well as the unmarried share of births. The marriage rate of non-mothers, at 6% annually, is about 17% below the target, which was 7.3%, and the average birth rate to contracepting women is 4.7% in the model instead of 4% in the data. These deviations are small, 9% and 6%, respectively, of the total change relative to 1960. For mothers of one child, the marriage rate is 5.7% in the model, compared to an 8.1% target value, roughly 11% of the total change since 1960.

The model also delivers reasonably close matches for some crucial non-target statistics. The fraction of unmarried births due to women with previous children is 53% in the 1990-1995 sample drawn from the NSFG; in the model it is 46%. The fraction of sexually-active single non-mothers not using contraception in the empirical sample is 18%; in the model it is 15%. Other statistics are not as close a match, but do not appear to be so unrealistic as to distort the results. These include the fraction of unmarried births due to teenagers, which is 19% in the model, compared to 28% in the data, and the fraction of non-users of birth control, which in the model is 8% for sexually-active mothers of one child, compared to 17% in the data, and 18% for married non-mothers, compared to 25% in the data. These deviations for statistics that are further removed from our immediate analysis should not distract from the fact that the model succeeds in matching the most relevant statistics for the scope of this paper.

Table 8: Non-Target Statistics

	Sub-sample	NSFG 1990-1995	Benchmark Model
Share of Unmarried Births	Mothers Already	53%	47%
	Previously Married	23%	28%
	Teenagers	28%	19%
Fraction Not Using Birth Control	Single, No Kids	18%	15%
	Single,1 Kid	17%	8%
	Married, 0 Kids	25%	18%

The parameter values that generated this calibration are shown in Table 9, in the section labeled Constant Parameter Values, which refers to those parameters that do not change when the model is recalibrated to 1960, and in the column labelled 1995 in the table section below.The aging rate $\delta = .0367$ implies an average fecundity duration of 28 years; the unmarried utility parameters imply that women without children get higher utility flows when unmarried ($\alpha_F^0 = 1.81$), but those with two or more children get higher utility flows when married ($\alpha_F^2 = -0.539$). Step children reduce the utility flow from marriage, but this effect is comparatively small ($\alpha_M^3 = -0.086$).

This parameter set succeeds in delivering the flavor of the 1990s, and we see no reason to believe that the minor deviations observed will influence the results of the analysis below.To match the targets for 1960, we proceeded in two steps. First the birth-control technology was adjusted to reflect a world where neither the Pill nor abortion were available to unmarried women; the perfect-use birth rate for unmarried women was raised to $\theta_0 = 0.2$, instead of the Benchmark value of 0.005. This higher value of θ_0 is based on estimates by Vaughan et al. (1977) of the normal-use pregnancy rates of contracepting women for methods other than the Pill and other highly-effective methods introduced in 1960 or later, such as the IUD.

Second, by trial and error, we found that it was necessary to change the values of two parameters to match the 1960s; the persistence of marriage quality ρ_q was increased from 0.92 to 0.97, and the utility from being a single mother was reduced, from $\alpha_F^1 = 1.1$, to 0.5. These values are shown in the lower section of Table 9, in the Column marked "1960s". The change in the persistence of marriage quality is required to match the fact that the fraction of women who have ever been divorced was substantially lower in 1960, and the reduction in the utility from being a single mother to match the high marriage rates of single mothers[16]. The remaining parameter values retain the same values they had in the 1990s benchmark, including those set in the calibration, whose values are displayed in the upper section of the table.

Table 9: Benchmark Calibration: Parameters

Constant Parameter Values:				
	Aging rate	δ	0.0367	
	Unmarried utility, $k > 1$	α_F^2	-0.5388	
	Unmarried utility, $k = 0$	α_F^0	1.8052	
	Birth-control effort coefficient	η	0.0449	
	Birth-control effectiveness coefficient	ψ	2.23	
	Marginal utility per step kid	α_M^3	-0.0859	
Variable Parameter Values:			1960s	1990s
	Persistence of marriage quality	ρ_q	0.97	0.9181
	Utility from being single with kids	α_F^1	0.504	1.0986
	Mean utility from single sex	μ_S	0.5	0.5706
	Min. birth rate, singles	θ_0^F	0.2	0.005

6.2 The impact of restricting birth control

How important are changes in birth-control restrictions for generating changes in the unmarried-birth share? According to the results of computational experiments that we run on the two benchmark calibrations, the answer depends on which period we consider. In Table 10 , the top two rows reproduce, for comparison purposes, some of

[16]Simply shifting divorce costs does not suffice because that generates positive covariance of marriage and divorce, and we need marriage and divorce rates to diverge.

the Benchmark results for each period. Below, the row labeled 'Birth Control/1990s' shows that with the model calibrated to the 1990s, if we reduce the effectiveness of birth control for unmarried women, as described above, we get a large decrease in the unmarried birth share, from 28% to 9%; this amounts to 70% of the total change between the two steady states in the benchmark model. However the next row shows that if we start from the 1960 calibration and then liberalize access to the best technology, the change in the unmarried birth share is relatively minor, an increase from 1% to 5%, which amounts to about 15% of the total change between the benchmark models. In other words, if the restrictions matter in the 1990s, something else must explain the change since the 1960s; conversely, if birth-control liberalization explains the change since 1960, it cannot be very important in the 1990s.

The mechanism that generates the changes in unmarried share of births is largely through the sexual participation rate, which declines from 72% in the 1995 Benchmark to 7% when birth-control access is restricted. The essential feature of the 1995 calibration for generating this response is that a large mass of sexually-active women are close to indifference about sexual activity: when the variance of the gain from sex is relatively low, a participation rate on the interior of the unit interval implies most women must be at or close to the participation margin.

In the 1995 calibration, Table 10 shows that restriction of birth control also results in a significant increase in the marriage rate of non-mothers, from 6% to 10%, about 40% of the total change between the 1960 and 1995 Benchmarks. Furthermore, we see that the divorced fraction actually increases instead of decreasing; this is because more women are getting married, but with the variance of match quality held constant, the divorce probability remains stable at the 1990s level. To generate the remaining 60% of the marriage rate differential, and to match the lower fraction of ever-divorced women, therefore other parameters had to change, as described above, and this effectively increases the penalty for unmarried motherhood. According to the last column of Table 10, the expected gain from becoming an unmarried mother is -2.3 in the 1995 calibration. In the 1960 calibration however, this number falls to-3.7. In other words, the penalty for becoming an unmarried mother is 60% higher. However the birth-control experiments show that very little of this change (7-9%) is due to the endogenous response of the equilibrium to changing birth technology:

this is due instead to the other parameter changes required to match the statistics

Table 10: Summary of Experiments

Experiment	Base Model	Unmarried Share of Births	Marriage Rate	Single Birth Rate	Sexually-Active Fraction	Ever Divorced Fraction	Unmarried Birth Value
Benchmark	1990s	0.281	0.0602	0.0354	0.7223	0.1145	-2.2948
	1960	0.0092	0.1632	0.0018	0.0088	0.0645	-3.6596
Birth control	1990s	0.0896	0.1	0.0113	0.0679	0.1734	-2.4157
	1960	0.0498	0.1532	0.0195	0.6	0.0808	-3.562
Share of Total Change	1990s	70%	39%	72%	92%	-118%	9%
	1960	15%	10%	53%	83%	33%	7%

for divorce and single-mother birth rates in 1960.

Since women were marginal in the 1995 calibration, they cannot also be marginal in the 1960 calibration, unless we increase the value from unmarried sex. But this would result in an unrealistically high unmarried birth rate for 1960. If, as claimed by Akerlof et al. (1996), the improvement in birth control reduced the ability of unmarried men to commit to marrying in the event of pregnancy, then we could, by assuming a higher valuation of sex before 1960, construct a competing model where women were at the margin in both eras. However under full commitment this is ruled out by the low observed birth rates in the 1955-1960 sample.

In Table 11, we decompose the changes required to move from the 1995 benchmark to the 1960 benchmark. First we show the impact of each parameter shift separately, then we show the impact of liberalization in combination with each of the other parameter changes. On their own, both the change in single-mother utility and the change in match-quality persistence account for modest increases in the unmarried-birth share, amounting to 14% and 7%, respectively, of the difference between the benchmarks. However the increase in single-mother utility accounts for 40% of the increase in the birth rate of unmarried non-mothers, but only 12% of the decline in non-mother marriage rates, while the decline of persistence accounts for 60% of the change in marriage rates, and has no impact on the single birth rate. Now consider the impact of changing both parameters at the same time. Together, they explain

43% of the increase the unmarried birth share, far more than the sum of their solo effects. Hence the actions of these parameters appears to be highly complementary.

Table 11: Decomposition of Experiment Results

Experiment		Unmarried Share of Births	Marriage Rate	Single Birth Rate	Single's Sexual-Active Share	Ever Divorced Fraction
Single-Mother Utility		14.4%	12.6%	41.4%	13.9%	-16.2%
Match-quality persistence		6.8%	60.2%	-0.6%	0.3%	259.0%
Match-quality persistence	Single-Mother Utility	43.2%	65.3%	47.3%	14.4%	197.0%
Birth-Control	Match-quality persistence	97.6%	129.9%	79.2%	106.4%	24.0%
Birth-Control	Single-Mom Utility	36.1%	41.4%	91.7%	127.9%	-35.0%

Which of these parameters matters most when assessing the effects of liberalizing birth control? When we recompute the impact of liberalization in the 1960 calibration, but with match-quality persistence reduced to the 1995 benchmark value, we find the model generates 90% of the change in unmarried births accounted for by the benchmark calibrations, over and above the effect of changing persistence alone. In this experiment, the marriage rate falls from 16% to 2.9%, and the unmarried birth rate rises from 0.18% to 2.8%, accounting for 91% and 41%, respectively of the difference between the benchmark models. Changing only the utility of single mothers, on the other hand, implies much smaller effects of liberalization; the net effect is about 20% of the benchmark change. This suggests that the fall over time in the stability of marriage is the critical element in explaining why the impact of liberalization on the unmarried share of births is so dependent on the base year.

7 Discussion

In effect, our results have uncovered two competing stories of the rise in unmarried birth share. The first story, that liberalization of birth control reduced the cost of unmarried sex, can explain 98% of the rise in the unmarried birth share, but does this largely through the decline of marriage. The other story, that conditions improved for single mothers, reducing the penalty for single motherhood, explains 43%, largely through the decline of birth rates to non-mothers. The overall message of our results is that both of these stories are required to describe the rise of unmarried births in a manner consistent with the other changes that accompanied it. Both stories rely on the reduced stability of marriage; hence modeling this must a key element in future research on the rise in the unmarried birth share.

These stories rely on three separate elements: liberalization of birth control, reduced stability of marriage, and increased utility of single life. While these elements are distinct in our model, it may be that in a more fully articulated model, liberalization would lead to the required changes in the other two models. Thus our analysis leaves open the question of whether there is a unifying explanation or whether the changes required to generate the rising unmarried birth share should be thought of as a 'perfect storm' of three separate shocks.

In the existing literature, liberalization of birth-control technology leads to other changes in social interactions, which in turn explain the rise in unmarried births or the spread of promiscuity. If we were to incorporate the key elements of these earlier models into our analysis, would liberalization on its own be enough to explain the sexual revolution? This seems unlikely, because existing papers abstract from the modeling of divorce, and hence cannot address the reduced stability of marriage; our results suggest this class of explanation would account for at most 43% of of the rise in unmarried births. However even that latter number relies on an improvement in the welfare of single mothers (relative to married women), whereas the previous literature takes this as a fixed parameter.

In Akerlof et al. (1996), for instance, improved birth control undermines the social norm that requires an unmarried man to marry his sexual partner should she become pregnant. If unmarried men cannot commit to these "shotgun" marriages, then the pregnancy rate among sexually active singles , and hence the unmarried birth rate, will increase, so it's possible that we would no longer need to shift the utility of single mothers. Similarly Greenwood and Guner (2005) focus on the allocation of young singles to two competing social groups; the unmarried birth rate rises when improved contraception causes unmarried people to shift from the "chaste" group to the "promiscuous" group. In Fernández-Villaverde et al. (2014), the focus is on young non-mothers, whose birth rates rise when their parents stop training them to avoid sexual activity. None of these papers address the value of being an unmarried mother or the stability of marriage; all focus on the promiscuity of never-married non-mothers, so extending our model to incorporate elements from these papers would not resolve the issues raised by matching changes in the behavior of married couples and single mothers.

In our analysis, we have also abstracted from the direct effects of birth-control innovation on married couple's behavior. In their equilibrium analysis of birth-control and the marriage market, Chiappori and Oreffice (2008) points out that birth-control improvements for unmarried women improves the bargaining position of wives relative to husbands, shifting the household allocation along a fixed Pareto frontier. However birth control does not *change* the frontier, so the stability of marriage in our model would not be affected by this mechanism.

Is it important to model effort in birth control? We think of this as a way of abstracting from the various discrete margins involved in the choice of birth control, such as which contraception method to adopt or whether to have an abortion. However there may well be an intensive margin associated with the use of contraception, as evidenced by the correlation between the pregnancy rates of contracepting women and socio-economic indicators, such as race and education, documented in Jones and Forrest (1989). Empirical evidence from clinical trials seems to make clear that variations in pregnancy rates are not explained by information variations across different categories of users.[17]

A more traditional literature on the rise of single motherhood emphasizes the role of government redistribution, such as welfare (AFDC/TANF). In 1995, according to the NSFG, 71% of single mothers were living in households below the 25th sample

[17] Another piece of evidence is that women who are contracepting because they want to delay children are much more likely to get pregnant than women who are using the same method because they do not want any more children.

percentile in family income; 32% were on welfare and 43% received Food Stamps. Single women who were not mothers on the other hand were less likely (48%) to be below the first quartile in family income, and much less likely to receive welfare (3%) and food stamps (7%). The eligibility and generosity of these programs were significantly expanded in the 1960s, which would appear to make single mothers better off. The effect on family decisions is the subject of a host of empirical papers, summarized in Moffitt (1997), who concludes that US welfare programs had negative effects marriage and positive effects on unmarried births, though important empirical issues remain. A matching-equilibrium version of this mechanism was modeled in Greenwood et al. (2000).

In our model, government redistribution, to the extent that it favors single mothers, would on its own account for very little of the change in the unmarried birth share. In other words, holding constant the birth-control technology, or the divorce rate, as regression analyses tend to do, would obscure the true importance of the effect of redistribution. This is because it is only through interactions with the other two elements of our story that the the impact of higher single-mother utility can be observed. Anything that makes single mothers better off, relative to non-mothers, can potentially explain a large part of the rise in the share of unmarried births, even if it our results imply it is not the main factor.

Our analysis focused exclusively on the cost-of-sex argument. However birth control may also impact women's career opportunities, as argued by Goldin and Katz (2002). Would adding this channel to the model endogenize the other parameter shifts, and hence give birth-control access a more central role? If two-career families are more likely to divorce, then our results suggest that this would be a promising area for future research. But is it indeed the case that two-career families are more likely to divorce? Recent papers, as summarized in Neeman et al. (2008), come down on both sides of the question; theory implies various conflicting effects of female careers on marriage stability, and it is not clear from the empirical analyses which effects dominate. Furthermore, labor-market prospects are likely to improve the value of non-mothers more than that of mothers, so other elements would still be needed to offset this effect, since non-mothers tend to work much more than mothers.

8 Conclusions

Our goal was to assess the hypothesis that liberalized birth control access for unmarried women caused an increase in the unmarried share of births by reducing the expected cost of unmarried sex.

Relative to previous analyses, our main contribution is to model the behavior of married households and single mothers. This is critical for two reasons:

1. these values determine the incentives to avoid unmarried births, and they clearly have shifted drastically over the period of the analysis,
2. roughly half of unmarried births are to women who already have a child, and previously-married women account for nearly a quarter of unmarried births.

We used a calibrated version of the model to assess the magnitude of the impact of improved birth control on the incentives to participate in sex outside of a relationship that leads to marriage. Our contribution here was to use the birth and marriage rates of single mothers to pin down the value of becoming an unmarried mother, something that previous work took as parametric. We also developed a simple model of birth control that allows for the fact that not all sexually-active women choose the best available method, and some appear to use none at all.

Our main finding was that the cost-of-sex story is inadequate on its own because it does not account for the impact of the decline in the stability of marriage. Calibration of the model to 1990-1995 implies that liberalization only generates large effects if the distribution of the expected gain from unmarried sex has a very low variance, so that unmarried women (non-mothers) are close to the sexual-participation margin in the 1990s. A partial re-calibration of the model to match the difference in marriage stability between the two eras implies that the effective penalty for becoming an unmarried mother was 60% higher in 1955-1960. These two results imply in turn that women were far from the participation margin in 1955-60, relative to the magnitude of the cost-change implied by improved birth control. Liberalization of birth control does generate an increase in the unmarried share of births, but the effect is small, amounting to 15% of the total change.

Our results show that the cost-of sex story does much better when combined with a rise over time in the value of single mothers, where the magnitude is set by our two benchmark calibrations. This type of story can explain 43% of the rise in unmarried births. The previous literature combines the cost-of-sex story with other mechanisms that affect the value of single life, such as strategic or social interactions. But these stories are about non-mothers; what matters in our model is the value of being an unmarried mother. Even more important is the role of the reduced marital stability; combined with liberalization, this explains essentially all of the rise in unmarried births. As in the previous literature, interactions between the different channels are critical, but the interactions required to complete the explanation are quite different than those proposed in the previous literature.

We conclude that future research on the impact of birth control liberalization on the rise in the share of unmarried births should focus on understanding the decline in marital stability and the rise in the well-being of single mothers, and modeling the interaction of these factors rather than treating them in isolation.

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