# The Timing of Births: A Marriage Market Analysis*

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**Abstract**

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This paper explores the interaction between the labor supply of young women and their marriage and fertility decisions. We develop an equilibrium search model of marriage, divorce, and investment in children that allows for differential timing of fertility. We show how patterns of fertility timing in US data can be explained by the incentives for fertility delay implied by marriage and labor markets. We find that these incentives help explain both the cross-sectional relationship between women's wages and fertility timing, and the changes over the last 30 years in married women's fertility timing and labor supply. Journal of Economic Literature Classification Numbers: J12, J13

marriage; fertility; returns to experience.

## 1. Introduction

Two of the most remarkable trends in family life of the last 40 years have been the decline of marriage and the rise in labor force participation of young women. These phenomena underscore the strength of the interactions between marriage and labor markets. Becker's seminal work on marriage (Becker (1973) and (1974)), suggests an approach to understanding such interactions: Becker argues that marriage and labor markets are definitively linked through the comparative advantages of spouses in market vs. non-market labor, particularly the production of children.

In a similar spirit, this paper analyses marital and labor supply decisions jointly with the evolution over time of the marriage "market". We argue that one of the key channels linking the labor and marriage markets is the decision of when to become a parent, and that this margin has important implications for both marital and labor supply patterns, as well as the evolution over time of earnings inequality across households. Using panel data for U.S. women, we show that neither the cross-sectional nor the time-series patterns are due to variation in the time women spend in education. We believe that these patterns reveal the interaction of two distinct economic incentives for fertility delay, one arising from the nature of marriage markets, the other from returns to experience in the labor market. To explore these interactions theoretically, we develop a dynamic model of family formation that links marriage decisions and labor supply via the production of children.

Our basic hypothesis is that cross-sectional relationships between household income and fertility and labor supply behavior are due to differences in the dynamic returns to fertility, and that these returns are determined in the marriage and labor markets. To the extent that having children consumes time, women may lower both their future labor time, their future wages, and their marriage possibilities. In a world where divorce is probable and information about future matches uncertain, even married women must consider the effect of motherhood and labor supply on their prospects for a possible future outside the marriage.

The strength of the empirical linkages between labor markets and fertility delay can be seen in the results of our analysis of U.S. women in the Panel Study of Income Dynamics (PSID). We find that women with higher wages have fewer kids and have them later; women in the highest wage quintile have 64% of their children at age 27 or older, compared to 42% for women in the lowest wage quintile. Even after controlling for years of education, measures of quality such as educational attainment and wages remain strongly associated with fertility delay. There has also been a significant change in both the level and the timing of births over time. Since the 1938 birth cohort of mothers, more recent cohorts have fewer kids and have them at later ages; the proportion of kids born to mothers age 27 or older has grown 44%. Simultaneously, the labor supply of married women age 20-26 has increased by 55%, from 923 hours per year for the 1938-47 cohort to 1428 for the 1958-67 cohort. Our analysis shows that these changes over time cannot be explained by changes in the length of education alone.

Turning to our model, the three key margins in child production are quality, quantity, and timing of children. In contrast to the previous literature on fertility dynamics, we allow for endogenous marital decisions, and solve for the marriage-market equilibrium. Although this inevitably entails considerable sacrifice in terms of the structure of the labor market and of the life-cycle, we feel that modeling the equilibrium is crucial for two reasons. First, the decisions in our model affect the evolution over time of the human-capital distribution, which in turn affects the marriage market equilibrium. And second, changes in women's labor market conditions have direct implications for marital decisions, because they change the bargaining power of wives relative to their husbands. To allow for this latter channel, we also assume that the decisions of married households solve a simple bargaining game between the spouses.

Our basic assumptions are well supported by previous research. Empirical studies suggest that the timing of fertility is strongly linked to human capital accumulation. The time a mother spends on child care and the number of young children she has substantially reduce her labor force participation, according to studies by Hotz and Miller (1988) and Eckstein and (1989). Lower and interrupted participation rates lead to lower human capital accumulation and lower wages for females, according to Altug and Miller (1998) and Gunderson (1989). Waldfogel (1998) finds that in 1994, mean wages for women with no children were 81.3% of mean wages for men, while mean wages for married mothers were only 76.5% of mean wages for men. Finally, the spread in child-bearing ages across education groups has been increasing; Rindfuss, Morgan and Offutt (1996) report that over the period 1963-1989 it was women with college degrees who shifted their child-bearing the most towards later ages, confirming a trend noticed earlier by Mare (1995) and Lewis and Ventura (1990).

Furthermore, empirical research suggests that the household decisions of married couples depend on the outside options of the spouses, which depend in turn on the states of the marriage and labor markets (see, for example, Chiappori, Fortin, and Lacroix (1998) and Rubalcava and Thomas (2000)).

To see the implications of our model for cross-sectional patterns of fertility timing, we parameterize the model to match calibration targets for the 1938-47 cohort of women in the PSID. These targets are chosen so as to pin down the key margins in our model, such as labor supply and marriage behavior, without building in the pattern of fertility timing of the model. In addition to the proportion of children born to women over 27, these targets include the total fertility rate, the income distribution across marital states, the aggregate marriage rate, and the share of income invested in children. As a result of this procedure, our calibrated model generates a steady-state equilibrium which reproduces the most relevant features of the data.

The calibrated model also allows us to run computational experiments aimed at understanding the changes in fertility and labor supply observed in the United States over the last few decades. We report the results of two such experiments. In the first, we raise the value of being married relative to staying single, to clarify the importance of including marriage in our model. In the second, we introduce a positive rate of return to labor-market experience for women, in the spirit of Blau and Khan (1997) and Olivetti (2001), who find significant increases in women's returns to experience since the 1970s.

The main results of the paper are as follows: 1) high-productivity women in our calibrated model choose fewer kids and delay fertility even in the absence of returns to experience in the labor-market. 2) increasing the gains from marriage results in more postponement of fertility, and 3) an increase in returns to labor-market experience for women also results in more fertility postponement, as well as a reduction in wage inequality among women. The first two results taken together indicate the importance of the incentives to fertility delay that arise from the marital matching process; higher-wage women are pickier about who they marry because delay is more likely to get them a better match than is the case for low-wage women. Since the third set of results mirror those observed in U.S. data, this suggests that the same force is at work in both cases: higher wages for women who work more when young constitute a persuasive argument for fertility delay. Overall, we infer from our results that while marriage-market returns are the principal force behind fertility timing, a significant part of the recent changes in both labor supply and fertility timing could be due to an increase in returns to labor experience for women.

Our research is most closely related to that of Conesa (1999) and Mullin and Wang (2001), who construct general-equilibrium models of the timing of fertility and human-capital accumulation. However these papers abstract from the dynamics of the marital matching process, which is the main force driving fertility delay, according to our paper. Other equilibrium family-structure models related to ours include Greenwood, Guner and Knowles (in press) and Regalia and Rios-Rull (1999), who consider choices of fertility and investment in children's human capital in the context of equilibrium marital instability, and Aiyagari, Greenwood and Guner (2000), who model the effect on income inequality of the interaction between optimal fertility decisions and parental decisions regarding marriage and divorce. None of the above papers considers the problem of fertility timing however. Our results are also complementary to those of Olivetti (2001), who models the labor-supply responses of women to shifts in the wage gap and returns to experience, taking demographics such as marital state and number of children as given. She finds that a simple wage shift does not account for the increase in labor supply of young married women, while the shift in returns to women's experience can, a finding analogous to our own regarding marriage and fertility timing.

In the next section, we present our empirical analysis. In the following section, we develop our model. We discuss calibration in Section 4. Discussion of our benchmark model and the results of our computational experiments are reported in Section 5. Our conclusions are listed in the final section.

## 2. Empirical Analysis

Empirically, two basic facts suggest the hypothesis that the timing channel plays an important role in the recent changes in labor market behavior and marital status. First, we know that women in low-income households tend to have children earlier than women in higher-income households. Second, there has been a significant change in the timing of births, especially since the 1970s. Women are now having children later than was the case 30 years ago. For white women, according to Hotz, Klerman and Willis (1997), the probability of a first birth at age 20 has fallen from 17% in 1960 to 7% in the late 1980s. Rindfuss, Morgan and Offutt (1996) show that between 1973 and 1988, the age specific fertility rates declined by 7% for women between ages 20 and 24, while increasing about 33% for those between ages 30 and 34. Indeed, Morgan (1996) points out that delayed child bearing is becoming a more visible feature of the modern American fertility pattern.

In this section we present an empirical description of labor supply and family decisions by income, education level and birth cohort of the parents, based on a simple analysis of the PSID from 1968 to 1999. The goal of the analysis is to show how fertility and timing of births are related to wages, education and birth cohort of the mother.

Before proceeding to the main analysis, we first give a simple view of what we mean by the timing of births. We construct a representative sample of births, which we call the 'child-birth sample' by taking all the child births and adoptions from the PSID Childbirth and Adoption History File. This file is based on interviews with members of PSID households in1985-1999, and contains all the births and adoptions to each member of the panel, dating back to 1910. As in the analysis to follow, we restrict attention to those children whose mothers were born between 1938 and 1967. We divide all births into 'early' and 'late', according to whether the mother was younger or older than 26 years when the child was born. [1]

Table I shows that the fraction of children born late was about 0.39 for those children whose mother was in the birth cohort of 1938-47, and that this number grew to 0.49 for the children of the 1948-57 mothers and to at least 0.56 for the 1958-67 mothers.[2] This is a significant change in fertility behavior, on the order of the much-better known change in the quantity of children per mother that occurred over the same cohorts. Furthermore, the youngest mothers in our sample were 32 years old in 1999, so their fertility is not yet complete; our results therefore tend to understate the degree to which the most recent cohort of women has postponed fertility. This is also reflected in the increase in the average age of mothers at childbirth, from 24 years in the earliest cohort, to nearly 27 years in the

[1] This age was chosen so that for our baseline cohort of 1928-37 about 1/3 of the births occurred in the 'late' interval. The results are qualitatively similar if the cut-off age is chosen anywhere up to age 30.

[2] Children are weighted by their mother's individual core weight for the year in which the mothers born in the middle of the 10 year interval reach the age of 25 years.

latest.[3]

In the analysis to follow, we take advantage of the panel structure of the PSID to relate these changes to women's wages, income and education. Because not all of these variables are available for all the mothers of the children in the above sample, our data set will be smaller than would be the case if we were to take the mothers of the above children. To maximize sample size, our sample is drawn from the entire PSID, rather than just the cross-sectional core sample of the PSID, and then reweighted appropriately to represent a random sample of U.S. women. Our basic women's sample is composed of all women from the 1938-1967 birth cohorts who are also present in the Childbirth and Adoption History File, and have a positive sampling weight; this yields a total sample size of 3837 women.

Our wage-data sample is a subset of the women's sample, and consists of all women for whom there is at least one observation of with at least 100 labor hours per year. Wage variables are constructed by dividing women's labor income by their total hours worked, for each year in which they worked more than 100 hours. The labor-income variable we use includes wages and salaries, as well as business income, tips and commissions. Hourly wages less than \$5 or more than \$100 are recorded as missing.[4] Lifetime wages are defined as averages over all years. Restricting attention to those women for whom wage data is available for ages 20-26 reduces the sample size to 2136 women.

The birth histories are compiled from the Childbirth and Adoption History File 1985-1999, and from the PSID individual data set (1968-1992), which contains birth-year variables for the first through 5th children born before 1992. We use these to compute the age of the mother at the birth of each child. We compute the proportion of "late" children of each mother as the fraction of her children born after she reached age 27; for women with no children, we set this proportion equal to missing.

In Table IIa, we present a basic statistical description of women's birth histories by cohort for the wage-data sample. As we go from the oldest cohort to the youngest, the table shows a decline in fertility from 2.6 to 2.0 and an increase of nearly two years in the average age at which women have their first and second children: women from more

[3] Observations here are weighted by the core sample weight of the mother; thus mothers with more children end up with a higher weight in the sample, holding constant their core weight.

[4] All dollar amounts in this paper are deflated to 1997 currency, using the CPI. For 1994-1999, the wages are drawn from the PSID 1994-1999 Hours of Work and Wage Files, which are constructed from a broader range of variables, including self-reported wages.

recent cohorts have fewer children and have them later in life. The fraction of women who remained childless before age 27 has increased 88% over the same cohort range. While the change in fertility is uncertain because the youngest may still have more children in the future, the postponement of fertility is unambiguous. Furthermore, the average number of children born after the mother has reached age 27 has already grown to exceed that of the older cohorts who have virtually completed fertility. Finally, the proportion of children born after the mother reached age 27 rose from 0.36 to 0.51, very much as in the larger child-birth sample discussed above. Taken together, the picture is clearly a very strong move away from motherhood while women are in their 20s. One component of this change is an decrease in the number of children demanded, and the second is a shift in child-bearing to the 30s.

The next table repeats the above analysis by mother's wage quintile, rather than by birth cohort. The wage measure is the average over ages 30-40, as this is assumed to be more closely related to lifetime labor income than the wage observed in the earlier period. Table IIb shows that women in the lowest wage quintile have more children, and have them much earlier than do women in the top wage quintile. Thus fertility is 2.45 for quintile 1, compared to 1.78 for quintile 5, a differential of about 38%. The age at which women have their first child rises over the wage distribution from an average age of 23 for the lowest quintile, to 26.7 years for the highest. The share of women who have no children before age 27 actually doubles, from 0.31 for the first quintile to 0.625 for the richest quintile. The fraction of children born after the mother reaches age 27 increases from 0.42 to 0.64 across the income distribution, though there is a dip in the second quintile to 0.33. However the overall pattern is one of much lower fertility and much later child-bearing for higher-income women.[5]

It is quite plausible that both of these patterns of fertility timing, the changes over cohorts and over wage quintiles, are driven by differences in education. This hypothesis seems to be supported by Tables IIIa and IIIb, which show that education and marriage patterns closely track the fertility timing patterns. Thus the percentage of women who attended college doubles over the cohorts, while the shares of high-school and college grad-

[5] Note that the number of observations reported in the table represents the number of records in the data, not the weights assigned to each respondent. Hence the lowest quintile has many more observations, as the PSID oversampled poor households.

uates increase from 70% to 83%, and from 11% to 19%, respectively.[6] The share of women who did not marry by ages 27 or 37 both tripled, which makes the divorce rate growth, from 12% to 19% of women divorced by age 27, even more significant that it may appear at first glance.

Across the wage distribution, the same patterns hold: the fraction of women with bachelor's degrees increases from 9% to 39% of women at the top quintile, while non-marriage by age 27 increases from 24% to 29%. The divorce rate however is much lower for the top wage quintiles than for the bottom, suggesting a positive association between marital stability and women's human capital.

To assess the relative importance for fertility timing of changes in education attainment vs changes in fertility behavior given education, we conduct a simple experiment. In Table IV, we ask what would have happened to fertility timing under the following two counter-factual conditions: 1) suppose that fertility behavior had remained constant, and that the education choices of the 1950's cohort had evolved to match that of the 1960's cohort; 2) suppose that education choices had remained the same, but fertility behavior had evolved to match that of the 1960's. The first part of the table gives the actual proportion of kids born after age 27 by mother's education. The second part gives the timing statistics under each of the counter-factual scenarios. The proportion of kids born late is much higher for the second scenario than for the first. If only the education distribution had shifted over time, the proportion of late children would have grown from 37% to 41%, while if only the behavior of each group had changed, the proportion would have risen to 48%. In other words, 70% of the change in the late proportion can be attributed to changes in the fertility behavior of women, taking education as given.

Another way to see this is to consider the regression estimates in Tables V and VI. In Table V, it is clear that log wages (lifetime averages) are strongly associated with later fertility, even when conditioning on the total number of kids. It is also clear that this effect is much stronger for the youngest cohort than it is for the older cohorts; the coefficient on log wage more than doubles, growing from 0.17 for the oldest cohort to 0.39 for the youngest. Thus it seems likely that the effect of wages on fertility delay has strongly increased over time.

[6] These statistics ignore high-school completion after age 21, and college attendance after age 30. A substantial fraction of women in the earlier cohorts appear to return to school after raising children.

It is possible that this effect of wages only reflects the facts that women are much less likely to have children while in school, and that high-wage women stay in school much later than do low-wage women. Ideally, adding education to the above regression would clarify this point, but the results can be hard to interpret and parameter instability may arise from multicollinearity between wages, attainment and years of education. This can be seen in Table VI, where we add various measures of education to the equation. It is clear from the results that even after controlling for the number of years of education, there is still a strong association between fertility delay and measures of human capital. The wage effect is naturally quite a bit smaller, and indeed only remains significant at the .05 level for the youngest cohort. However college attendance, bachelor's degree and high-school graduate are all strongly associated with fertility delay for the middle cohort, and for the oldest cohort only college attendance fails to delay fertility. Since this latter effect is estimated while controlling for the bachelor's degree, the natural interpretation is that women of the oldest cohort were likely to interrupt their college career in order to have children.

Turning to the labor market, we explore how female labor supply depends on marital status, and how this dependence has changed over the three ten-year cohorts from 1928 to 1958. Marital status is divided into three categories: "single", which is taken to mean never married, "married", which means living with a spouse, and "divorced", which means previously married. Marital information is derived from 1985-99 PSID Marital History File, which lists dates for legal marriages and divorces and from the married-pairs variable in the family data, which includes domestic partners who are not legally married. Widows are excluded from the data.

Table VII shows that young married women work much less than single women but that this difference is largely erased by age 27 for the youngest two cohorts. Over time, the labor supply of married women aged 20-26 has increased tremendously: from an average of 923 hours for the 1938-47 cohort to 1428 hours for the youngest cohort. As observed in the introduction, this has been commented upon in earlier research, such as Olivetti (2001), and is usually taken to reflect a decline in the pattern of young married women leaving the labor force temporarily to raise children. Wages of single women tend to be higher than those of married women at young ages, but married women catch up later. We interpret this as reflecting both timing of marriage (high-wage women marry later) and the selection out of the labor force among married women (high-wage married women tend to have higher non-labor income and hence work less while young).

Table VIII shows the same data for men. The main point of this table is that none of the labor supply patterns we observed for women are present for men. Single men tend to work less than married, which is the opposite of the case for women. There has been no trend, either up or down in the labor supply of young married men, although older married men now work about 10% more on average than they did in the older cohort. Wages for single men tend to be lower than for married men, but the differences in family income across marital status are much smaller than was the case for women, reflecting both higher wages and higher labor supply of men relative to women.

Our empirical analysis of a representative sample of the U.S. population confirms both the cross-sectional and time-series patterns alluded to in the introduction. Women's wages play a key role in both the quantity and timing of children, and the time trend for recent birth cohorts has been towards women giving birth at later ages. These phenomena cannot be explained by women's education decisions; cross-sectional fertility differences match up better with household income than with mother's education, and the shift in timing patterns over cohorts is greater within than it is across education classes. The labor supply of young women has increased tremendously over the birth cohorts in our sample, partly because women are staying single longer, and partly because married women now work more hours. The significance of these statistics is not only that they confirm and quantify the phenomena that we would like to model, they also provide targets that we will use below to discipline our model specification and assess its performance.

# 3. Model

## 3.1. Economic Environment

The economy is populated by people who live for five periods, two periods as children and three periods as adults. Adults differ in their sex, productivity, marital status, employment and child bearing histories. Women can have children in the first two periods of their adult life. The children are attached to their mother throughout their two-period childhood and they make no economic decisions. Adults care about consumption, human capital investment in their children, and leisure.

Each period there is a marriage market where each single agent meets an agent of the same generation and the opposite sex. Married couples decide whether or not to stay married. If they divorce they are considered single and match immediately in the marriage market.

Each period, one and two-period old married couples and single women decide how many kids, $k \in \{0, 1, ..., K\}$, to have. Children impose a fixed time cost for their parents. This cost depends on the age of the child and on the gender of the parent. Let $k_1$ represent the number of kids who are one-period old and $k_2$ represent the number of kids who are two-periods old. The total number of kids in a household is given by $k = k_1 + k_2$. Only two-period old women can have children of different ages. When there is no confusion we use $k$ to represent the number of kids of any age.

Let $x$ denote the productivity (wage) of a female, and $z$ the productivity (wage) of a male; we assume that these are random draws from finite sets:

$$x \in \mathcal{X} \equiv \{x_1, \ldots, x_N\} \text{ and } z \in \mathcal{Z} \equiv \{z_1, \ldots, z_N\}.$$

Each period the oldest generation of children become young adults, replacing the oldest generation of adults. The productivity of a first-period adult depends on the total human capital investment he or she receives during childhood. The productivity of a second-period adult depends on his or her initial productivity and labor supply in the first period. Similarly, the productivity of a third-period adult depends on his or her productivity and labor supply in the second period. The fact that future productivity depends on current labor supply decisions is key to the hypothesis that a change in the returns to labor market experience for women has led to a shift in the timing of births.

The utility function for females is represented by

$$F(c, h, k_1, k_2, 1 - l - t - \chi_f(k_1, k_2), \gamma),$$

where $c$ is consumption, $h$ is human capital investment in children, $l$ is labor supply, $t$ is child care, $\gamma$ is a marriage match quality shock, and $\chi_f(k_1, k_2)$ is the fixed time cost of having $k_1$ one-period old and $k_2$ two-period old children at home. Similarly, for males, the utility function is represented by

$$M(c, h, k_1, k_2, 1 - n - \chi_m(k_1, k_2), \gamma),$$

where $n$ is labor supply. For a single male, utility from human capital investment in children, $h$, is set to zero.

The total income of a household is represented by $Y(x, z, l, n)$, and per-member consumption by $c = \Psi(p, k)\left[Y(x, z, l, n) - g\right]$, where $p$ is the number of adult members in a household, $k$ is the number of children, and $g$ is the goods spent on kids.

Agents observe the match quality $\gamma$ before they decide whether to accept or reject a match. Let $\gamma \in \left\{\gamma_{1,}...., \gamma_M\right\}$, and assume that the realizations are independently and identically distributed with density function $\Gamma(\gamma_j)$. Human capital investment per child is represented by $h = H(g, t, k_1, k_2)$.

At the end of childhood, each child will have received a total human capital investment of $\mathfrak{h} = h_1 + h_2$, where $h_1$ and $h_2$ represent the human capital investment received when kids are one and two periods old, respectively. Initial productivity is drawn according to

$$\Pr\left[x = x_i\right] = \Xi\left[x = x_i|\mathfrak{h}\right], \text{ and } \Pr\left[z = z_i\right] = \Theta\left[z = z_i|\mathfrak{h}\right].$$

In the second and third periods, the productivity levels evolve according to

$$X(x_j|x_i, l_{-1}) = \Pr\left[x' = x_j|x = x_i, l_{-1}\right],$$

where $l_{-1}$ is the last period's labor supply. Similarly,

$$Z(z_j|z_i, n_{-1}) = \Pr\left[z' = z_j|z = z_i, n_{-1}\right].$$

Note that the dependence of the distribution on labor supply allows for returns to experience in the form of higher future productivity.

### 3.2. The Equilibrium

In order to define the equilibrium for this economy, it is necessary to list the problems agents solve at each point in time, and define the decision rules that are optimal under our assumptions about decision-making. We begin with the last period, and use the value functions defined there to represent the problems of younger agents. At the beginning of each period, single people meet in a marriage market. If a couple chooses to marry, they decide how many kids to have, how much to work, and how much to invest in their children. In all periods, we assume that the decision rules of married couples are given by the Nash solution to the fixed-threat bargaining problem, where agents have equal bargaining power.

The outside options in this problem are given by the continuation values of their next best options, whether that is remaining single or taking a new draw from the marriage market.

### 3.2.1. Third Period

Three-period old women have either no kids at home, or kids that were born last period. The value function for a single woman with productivity $x$ and $k$ two-periods old and 0 one-period old kids is defined by a simple maximization problem:

$$G_3(x,0,k) = \max_{l,t,g} \left\{ F(c,h,0,k,1-l-t-\chi_f(0,k)) \right\} \qquad P(3a)$$

subject to

$$c = \Psi(p,k)\left[xl - g\right],$$

$$h = H(g,t,0,k).$$

Let the human capital investment decision for a three-period old single woman be given by

$$h = H_3^s(g_3^s(x,0,k), t_3^s(x,0,k), 0, k),$$

where $g_3^s(x,0,k)$ and $t_3^s(x,0,k)$ are solutions to P(3a). Similarly, let

$$B_3(z) = \max_n \left\{ M(zn,0,0,0,1-n) \right\}, \qquad P(3b)$$

be the value of single life for a three-period old man.

We refer to three-period old newly-matched couples as new marriages. A three-period newly married couple can only have children who are now two periods old. The education decision rules, $g_3^{nm}(x,z,0,k,\gamma)$ and $t_3^{nm}(x,z,0,k,\gamma)$, and labor-supply decision rules, $l_3^{nm}(x,z,0,k,\gamma)$ and $n_3^{nm}(x,z,0,k,\gamma)$ of the newly-married couple solve:

$$\max_{l,n,t,g} \left[F(c,h,0,k,1-l-t-\chi_f(0,k)) - G_3(x,0,k)\right]\left[M(c,h,0,k,1-n-\chi_m(0,k)) - B_3(z)\right]$$

subject to

$$c = \Psi(2,k)\left[xl + zn - g\right], \qquad P(3n)$$

$$h = H(g,t,0,k).$$

Denote the resulting human capital investment decision of a three-period old newly married couple by

$$h = H_3^{nm}(g_3^{nm}(x,z,0,k,\gamma), t_3^{nm}(x,z,0,k,\gamma), 0, k).$$

Let the values of being newly married be $W_3^n(x,z,0,k,\gamma)$ for a woman, and $V_3^n(x,z,0,k,\gamma)$ for a man. These are simply the values of the utility functions evaluated at the decision rules that maximize the Nash bargaining product. Given these values, let $I_3^n(x,z,0,k,\gamma)$ be the indicator function for the marriage decision of a newly matched, three-period old couple of type $(x,z,0,k,\gamma)$,

$$I_3^n(x,z,0,k,\gamma) = \begin{cases} 1, \ W_3^n(x,z,0,k,\gamma) \geq G_3(x,0,k) \text{ and} \\ \qquad V_3^n(x,z,0,k,\gamma) \geq B_3(z) \\ 0, \ \text{otherwise} \end{cases}. \qquad P(3n')$$

Some agents enter the third period already married. As before, such a couple can only have children who are now two-periods old. For each agent, the outside option is to take a new draw from the marriage market; denote the value of this option $EW_3^{dr}(x,k)$ for women, and $EV_3^{dr}(z)$ for men. They are explicitly defined in Appendix A. Then for a couple with $k$ kids and a match quality $\gamma$, the optimal decision rules, $g_3^{om}(x,z,0,k,\gamma)$, $t_3^{om}(x,z,0,k,\gamma)$, $l_3^{om}(x,z,0,k,\gamma)$, and $n_3^{om}(x,z,0,k,\gamma)$ solve:

$$\max_{l,n,t,g} \left[F(c,h,0,k,1-l-t-\chi_f(0,k)) - EW_3^{dr}(x,k)\right]$$

$$\left[M(c,h,0,k,1-n-\chi_m(0,k)) - EV_3^{dr}(z)\right], \qquad P(3o)$$

subject to

$$c = \Psi(2,k)\left[xl + zn - g\right],$$

$$h = H(g,t,0,k).$$

Again denote the human capital investment by a three-period old, already-married couple, by

$$h = H_3^{om}(g_3^{om}(x,z,0,k,\gamma), t_3^{om}(x,z,0,k,\gamma), 0, k).$$

Let $W_3^o(x,z,0,k,\gamma)$ be the wife's value of continuing in the marriage and $V_3^o(x,z,0,k,\gamma)$ be that of the husband, resulting from the optimal decision rules. The indicator function,

$I_3^o(x,z,0,k,\gamma)$, for continuing the marriage is then given by

$$I_3^o(x,z,0,k,\gamma) = \begin{cases} 1, \; W_3^o(x,z,0,k,\gamma) \geq EW_3^{dr}(x,k) \\ \text{and } V_3^o(x,z,0,k,\gamma) \geq EV_3^{dr}(z) \\ 0, \; \text{otherwise} \end{cases}. \qquad P(3o')$$

### 3.2.2. Second Period

The second period decision process differs from the third-period decision process in that there is no fertility decision for single women and married couples. The value of being a two-period old single woman of type-$x$, who has $k_2$ two-period old kids is

$$G_2(x,k_2) = \max_{k,l,t,g}\{F(c,h,k,k_2,1-l-t-\chi_f(k,k_2))+\beta\sum_i EW_3^{dr}(x_i,k)X(x_i \mid x,l)\} \qquad P(2a)$$

subject to

$$c = \Psi(1,k+k_2)\left[xl-g\right],$$

$$h = H(g,t,k,k_2).$$

Let the decisions that solve this problem be denoted by $g_2^s(x,k_2)$, $t_2^s(x,k_2)$, $K_2^s(x,k_2)$, and $l_2^s(x,k_2)$. The per-child investment in human capital made by a two-period old single woman is then given by

$$h = H_2^s(g_2^s(x,k_2), t_2^s(x,k_2), K_2^s(x,k_2), k_2).$$

For single men, we define $B_2(z)$ in the obvious way:

$$B_2(z) = \max_n\{M(zn,0,0,0,1-n)+\beta\sum_j EV_3^{dr}(z_j)Z(z_j \mid z,n)\}. \qquad P(2b)$$

The decision rules for a newly-married 2nd-period couple in state $(x,z,k_2,\gamma)$ are given by the Nash solution to the bargaining game $P\,(2n)$ below, with outside options $B_2(z)$ and $G_2(x,k_2)$. We denote the decision rules for fertility, investment and labor supply by $K_2^{nm}(x,z,k_2,\gamma)$, $g_2^{nm}(z,x,k_2,\gamma)$, $t_2^{nm}(z,x,k_2,\gamma)$, $n_2^{nm}(x,z,k_2,\gamma)$, and $l_2^{nm}(x,z,k_2,\gamma)$, and the associated values of husband and wife as $V_2^n(x,z,k_2,\gamma)$ and $W_2^n(x,z,k_2,\gamma)$, respectively. These decision rules solve:

$$\max_{l,t,n,g,k}[F(c,h,k,k_2,1-l-t-\chi_f(k,k_2))+\beta EW_3^{con}(\cdot \mid x,z,k_2,\gamma)-G_2(x,k_2)]$$

$$[M(c,h,k,k_2,1-n-\chi_m(k,k_2))+\beta EV_3^{con}(\cdot\mid x,z,k_2,\gamma)-B_2(z)], \qquad P(2n)$$

subject to

$$c=\Psi(2,k+k_2)\left[xl+zn-g\right],$$

$$h=H(g,t,k,k_2).$$

Here $EW_3^{con}(\cdot\mid x,z,k_2,\gamma)$ and $EV_3^{con}(\cdot\mid x,z,k_2,\gamma)$ are expected third period continuation values of being married in the state-$(x,z,k_2,\gamma)$ in the second period for females and males, respectively. Their explicit definitions are again left for Appendix A. The utility of being married today also includes the possible gains from remaining married to your spouse next period, or getting divorced and taking a draw from next period's marriage market. Since this is a new marriage, the threat point only includes the possibility of remaining single in the second period. The associated indicator function for marriage is given by

$$I_2^n(x,z,k_2,\gamma)=\begin{cases}1, & W_2^n(x,z,k_2,\gamma)\geq G_2(x,k_2) \text{ and } \\ & V_2^n(x,z,k_2,\gamma)\geq B_2(z) \\ 0, & \text{otherwise}\end{cases}. \qquad P(2n')$$

The outside options for already-married couples will depend on the expected value of going back to the marriage market. Suppose that the expected values of taking a draw in the second period marriage market for men and women are given by $EV_2^{dr}(z)$ and $EW_2^{dr}(x,k_2)$, (see again Appendix A). Then for already-married couples in state $(x,z,k_2,\gamma)$, the decision rules $K_2^{om}(x,z,k_2,\gamma)$, $l_2^{om}(x,z,k_2,\gamma)$, $t_2^{om}(x,z,k_2,\gamma)$, $n_2^{om}(x,z,k_2,\gamma)$, and $g_2^{om}(x,z,k_2,\gamma)$ are the solutions to problem $P(2o)$:

$$\max_{k,l,t,n,g}[F(c,h,k,k_2,1-l-t-\chi_f(k,k_2))+\beta EW_3^{con}(\cdot\mid x,z,k_2,\gamma)-EW_2^{dr}(x,k_2)]$$

$$[M(c,h,k,k_2,1-n-\chi_m(k,k_2))+\beta EV_3^{con}(\cdot\mid x,z,k_2,\gamma)-EV_2^{dr}(z)], \qquad P(2o)$$

subject to

$$c=\Psi(2,k+k_2)\left[xl+zn-g\right],$$

$$h=H(g,t,k,k_2).$$

Let the value of continuing to be married in the second period that results from the decision rules that solve this problem be given by $W_2^o(x,z,k_2,\gamma)$ for the wife and by $V_2^o(x,z,k_2,\gamma)$ for the husband.

For a two-period old couple that considers divorce, we have the following indicator function,

$$I_2^o(x,z,k_2,\gamma) = \begin{cases} 1, \ W_2^o(x,z,k_2,\gamma) \geq EW_2^{dr}(x,k_2) \\ \text{and } V_2^o(x,z,k_2,\gamma) \geq EV_2^{dr}(z) \\ 0, \ \text{otherwise} \end{cases} . \qquad P(2o')$$

#### 3.2.3. First Period

In the first period, the decision process is simplified because there are no already-married couples at the beginning of the first period. The value of being a one-period old single woman of type-$x$ with $k$ one-period old kids, is given by

$$G_1(x) = \max_{k,l,t,g}\{F(c,h,k,0,1-l-t-\chi_f(k,0)) + \beta\sum_i EW_2^{dr}(x_i,k)X(x_i|x,l)\}. \qquad P(1a)$$

Let $K_1^s(x)$ be the optimal fertility choice of the first period single woman with productivity $x$. Let a one-period old single woman make the following human capital investment in her children:

$$h = H_1^s(g_1^s(x), t_1^s(x), K_1^s(x), 0).$$

We can similarly define $B_1(z)$ for one-period old single men, and $W_1^n(x,z,\gamma)$ and $V_1^n(x,z,\gamma)$ for one-period old, newly-married couples, and their corresponding fertility decisions, $K_1^{nm}(x,z,\gamma)$. Note that all marriages in period one are new marriages. The marriage decisions for the matches between one-period old single women and one-period old single men are given by

$$I_1^n(x,z,\gamma) = \begin{cases} 1, \ W_1^n(x,z,\gamma) \geq G_1(x) \text{ and} \\ \quad V_1^n(x,z,\gamma) \geq B_1(z) \\ 0, \ \text{otherwise} \end{cases} . \qquad P(1n')$$

#### 3.2.4. Definition

A stationary equilibrium is a collection of value functions, household decision rules, marital decision rules and matching probabilities such that all decision rules are optimal, taking the matching probabilities and decisions of other agents as given, and such that the value functions and matching probabilities are generated by the decision rules.

**Definition 1.** *A stationary matching equilibrium can be represented by a set of child quantity and quality allocation rules,* $K_1^{nm}(x,z,\gamma)$, $K_2^{nm}(x,z,k,\gamma)$, $K_2^{om}(x,z,k,\gamma)$, $K_1^s(x)$,

$K_2^s(x,k)$, $H_3^{nm}(g_3^{nm}, t_3^{nm}, 0, k)$, $H_3^{om}(g_3^{om}, t_3^{om}, 0, k)$, $H_3^s(g_3^s, t_3^s, 0, k)$, $H_2^{nm}(g_2^{nm}, t_2^{nm}, K_2^{nm}, k)$, $H_2^{om}(g_2^{om}, t_2^{om}, K_2^{om}, k)$, $H_2^s(g_2^s, t_2^s, K_2^s, k)$, $H_1^{nm}(g_1^{nm}, t_1^{nm}, K_1^{nm}, 0)$, and $H_1^s(g_1^s, t_1^s, K^s, 0)$, *a set of accept/reject decision rules,* $I_1^n(x,z,\gamma)$, $I_2^n(x,z,k,\gamma)$, $I_3^n(x,z,0,k,\gamma)$, $I_2^o(x,z,k,\gamma)$, $I_3^o(x,z,0,k,\gamma)$, *and a set of matching probabilities,* $\Phi_1(x)$, $\Phi_2(x,k)$, $\Phi_3(x,k)$, $\Omega_1(z)$, $\Omega_2(z)$,*and* $\Omega_3(z)$ *such that:*

1. *The household decision rules are optimal taking as given the marital decision rules and the matching probabilities, i.e. they solve P(3a), P(3b), P(3n), P(3o), P(2a), P(2b), P(2n), P(2o), and P(1a) defined above (as well as corresponding problems for one-year-old single men and one year old newly married couples that are not explicitly defined).*

2. *The marital decision rules for a given sex are optimal, taking as given the marital decision rules of the other sex, the household decision rules and the matching probabilities, i.e. they solve P(3n′), P(3o′), P(2n′), P(2o′) and P(1n′) defined above.*

3. *The matching probabilities,* $\Phi_1(x)$, $\Phi_2(x,k)$, $\Phi_3(x,k)$, $\Omega_1(z)$, $\Omega_2(z)$, *and* $\Omega_3(z)$ *are the fixed points of the mappings implied by the marital and household decision rules.*

### 3.3. Computation

Given the measures of each type in the marriage market, in each period, $\Omega_1(z)$, $\Phi_1(x)$, $\Omega_2(z)$, $\Phi_2(x,k)$, $\Omega_3(z)$, and $\Phi_3(x,k)$, we solve the model working backwards from period three. For married couples, this requires finding the Nash solution to the bargaining game where the threat points are the values of life as single. It is well-known that the Nash solution to the bargaining game maximizes the product of the net gains of the participants. Instead of solving the couple's bargaining problem directly, we maximize the weighted sums of the spouse's utility from marriage, and then choose the weights so that the solution maximizes the product of the gains from marriage. Since the Nash solution is a selection from the set of Pareto-optimal allocations, such a weight must exist if the problem is well-defined. Furthermore, provided that concavity of the product is satisfied, which is the case in our model, then the weight that equates the two problems is given by a simple first-order condition.[7]

[7] Consider an allocation resulting from maximizing a weighted sum of utilities of the husband and wife, $\rho H + (1-\rho)W$. When $\rho = \frac{F-G}{(M-B)+(F-G)}$, the solution to the weighted Pareto problem corresponds to the

Clearly, successful computation depends on the concavity of the objective functions of the weighted Pareto problems. In the first and the second periods these objective functions contain future continuation utility, as future productivity depends on current labor. The concavity of the objective function with respect to labor is maintained through appropriate restrictions on the functional forms that link future productivity and current labor. We need restrictions on the continuation values because when a married couple decides how much each should work, even though one may be better off by working more and accumulating more human capital, it is not clear that they are always better off if their partner works more. If the partner works more and accumulates more human capital, he or she has a greater incentive to leave the current partner and look for a better one. Hence, from the perspective of men and women, the continuation values are not simple functions of current labor supply decisions. Once we have computed the decisions, we then update $\Omega$ and $\Phi$. The solution is a fixed point of the $\Omega$ and $\Phi$ distributions.

## 4. Calibration

In this section we describe the functional forms and parameterization of our benchmark model. The purpose of calibrating the model is to restrict attention to a region of the parameter space where the average behavior of agents in the model resembles that observed in U.S. data, at least along the dimensions that are most relevant for our analysis. Since we want to use the model to explore the interaction between child-raising and female labor supply, we concentrate on matching statistics directly related to average fertility and labor supply, conditional on marital status, as well as the distribution of the population over marital states. Our basic strategy is to fix the parameters that can be mapped directly to published estimates, and then choose the remaining "free" parameters so that the steady-state of the model matches an equal number of statistics from the U.S. data. Where possible, we take these statistics from published sources, however in some cases we report our own statistics, computed from the PSID samples discussed earlier.

The productivity level grids $(\mathcal{X}_t, \mathcal{Z}_t)$ have 7 grid points in the first period $(t = 1)$, 9 in the second $(t = 2)$, and 11 in the third $(t = 3)$. We set each model period to 10 years.

Nash-bargaining solution with equal bargaining power, where $G$ and $B$ represents the outside options of the wife and the husband, respectively. This can be demonstrated by comparing the first-order conditions associated with the two problems.

We consider the first two periods of the model as representing two sub periods of a female's fecund lifetime. As we indicate in our empirical analysis one way to think about these sub periods is as ages 16 to 26, and 27 to 36. In calibrating the model, however, we will be more freely interpreting the first period as representing the 20s and the second period the 30s of the life-cycle. We set the discount factor, $\beta$, to 0.676, which is the standard annual value of 0.96 compounded to match our longer periods. The choices of functional forms and the other parameters are described below.

### 4.1. Parameters set directly from existing estimates

The effect on per-capita consumption of adding more members to the family is assumed to be given by the following function:

$$\Psi(p,k) = \frac{1}{(p+bk)^{\sigma}}.$$

The parameters $b, \sigma$, are set to the midpoints of the intervals provided by Cutler and Katz (1992), who report ranges of estimates for these parameters, based on their analysis of the U.S. poverty line and other available estimates.

We assume that the fixed time cost of children is linear in the number of one and two period old children, and given by:

$$\chi_f(k_1,k_2) = \chi_f^1 k_1 + \chi_f^2 k_2, \quad \chi_m(k_1,k_2) = \chi_m^1 k_1 + \chi_m^2 k_2,$$

where $\chi_g^i$ is the fixed time cost of an $i$-period old kid for gender $g$. For women, we can set these parameters directly from the results of Hotz and Miller (1988), who report that a newborn requires 660 hours of parental time per year.[8] This requirement declines geometrically at a rate of 12% per year. If people have 16 hours of non-sleeping time, in its first year a newborn takes up about 11.3 percent of a woman's potential work and leisure time. Using the fact that a period is ten years and that there is 12% depreciation, we can set $\chi_f^1 = .0736$ and $\chi_f^2 = .0257$.[9] For men, direct estimates are not available, but we assume the cost in father's time is proportional to that of the mothers. Using time use data

[8] One can imagine that over time improvements in child care technology will allow women to spend less time with kids and more time in the labor market.

[9] Hotz and Miller (1988) do not differentiate between the fixed time cost and the time for nurture. Robinson (1987) reports separate estimates for physical and non-physical time costs of kids. His estimates for fixed time cost of children is about 3.5% of non-sleeping time per child.

Robinson and Godbey (1997) find that in 1985, men were spending about half as much time as women in total family care (homework, shopping/services, and child care). Hill (1985) also reports that married men spend about 40% of the time married women spend in household work, and about half of the time married women spend in shopping/services and child care. Hence, we set the fixed time cost for men at half of the values for women, $\chi_m^1 = 0.0368$, and $\chi_m^2 = 0.0128$.

### 4.2. Parameters chosen to match model to data

To set the remaining parameters of the model, we choose a set of targets from the U.S. data, and pick a collection of parameters such that analogous statistics from the model's steady state match these targets. As is standard in the literature, we choose the number of targets equal to the number of free parameters. The list of targets, along with the corresponding parameters and the model statistics, is given in Table IX.

We assume that marriage quality can take on one of two values in a given period. These values are the same for the first two adult periods, and are given by $\gamma_1$ and $\gamma_2$; for the final period, they differ and are given by $\gamma_1^o$ and $\gamma_2^o$.[10] The probabilities, $\Gamma(\gamma_1)$ and $\Gamma(\gamma_2) = 1 - \Gamma(\gamma_1)$, of these realizations are assumed independent of previous realizations and identical in each period. Since marriage quality determines marriage and divorce rates in our model, we set these parameters to match the period-specific marriage statistics from previous studies. Based on data published by US Census Bureau, our targets include: the percent of women aged 25-29 over the period 1969-79 who were married (83%), the percent of males in the 35-39 age group over the same period who had not married (7.4%), and average percentage of US women who are married between ages 20 and 54 (78%).[11] From the US Census Bureau (1999), we also target the average fraction of females who remarry between ages 30 and 49 (67%). Finally, given estimates from Schoen and Weinick (1993), we target the percent of women between 1970 and 1980 who were never married (8.2%).

[10] Since old couples do not have children, their gains from marriage are much smaller in our model, and hence marriage quality must be increased on average to keep divorce rates realistic.

[11] The data on Marital Status of population is based on several issues of US Census Bureau publication *Marital Status and Living Arrangements* (series P-20). The current issues can be downloaded at: http://www.census.gov/population/www/socdemo/ms-la.html

The production function for children's education is assumed to be given by

$$H(g,t,k_1,k_2) = \left(\frac{g}{k_1^{\psi} + {k_2}^{\psi}}\right)^{\alpha} \left(\frac{t}{k_1^{\psi} + {k_2}^{\psi}}\right)^{1-\alpha}.$$

We set $\alpha = 0.38$ and $\psi = .3$, in order to match the aggregate fraction of goods that parents spend on their kids (14% according to Olson (1983)) and the fraction of kids born in the second model period (36% of children are born to mothers over 27, according to Table IIa).[12]

Childhood education in turn determines the probability distribution over initial adult productivity. Given a lifetime human capital investment $\mathfrak{h} \equiv h_1 + h_2$, the conditional means of log wages are given by:

$$\mu_x(\mathfrak{h}) = E\left[\log(x)|\mathfrak{h}\right] = \mu_z(\mathfrak{h}) = E\left[\log(z)|\mathfrak{h}\right] = log(\lambda_1 \mathfrak{h}^{\lambda_2}).$$

The standard deviation around this conditional mean is given by $\sigma_0$. We assume that the effect of human capital investment on children is symmetric between males and females. We further assume that initial productivity levels $(x, z)$ are distributed log-normally and approximated using our grid points for the initial model period for males and females. We take as targets the means and standard deviations from the 1988 PSID, restricted to full-time non-farm employees. Thus the targets are the mean log wages of men (2.3), the mean log wages for women (2.0), and the standard deviations of log wages (0.55 for both men and women). The corresponding parameters are $\lambda_1 = 10.5$, $\lambda_2 = 0.5$, and $\sigma_0 = 0.45$.

We assume that the utility functions have the following forms

$$F(c,h,k_1,k_2,1-l-t-\chi_f(k_1,k_2)) = \frac{c^{\nu}}{\nu} + w\frac{k^{\xi}}{\xi}\frac{h^{\vartheta}}{\vartheta} + \delta\frac{(1-l-t-\chi_f(k_1,k_2))^{\varsigma}}{\varsigma} - \gamma,$$

for females, and

$$M(c,h,k_1,k_2,1-n-\chi_m(k_1,k_2)) = \frac{c^{\nu}}{\nu} + w\frac{k^{\xi}}{\xi}\frac{h^{\vartheta}}{\vartheta} + \delta\frac{(1-n-\chi_m(k_1,k_2))^{\varsigma}}{\varsigma} - \gamma,$$

for males. This implies 6 more free parameters, which we restrict on the basis of fertility behavior and labor supply. Assuming each agent has a time endowment of 5000 hours per

[12] Aiyagari, Greenwood, and Guner (2000) and Greenwood, Guner, and Knowles (2000) use human capital production functions that are similar to the one used here. Restuccia and Urrutia (2001) use a human capital function where the only input is goods spent on children and the spending is subject to decreasing returns. While these papers attempt to analyze different question, they all are able generate a high degree of persistence across generations.

year, then Table VIII showed that, in the birth cohort 1938-47, married males aged 20-26 spent about 43% of their time working. Table VII shows that statistic to be about 15% for married females. We use these statistics, and the ratio of single women's income to married women's household income, to pin down the parameters $\delta = 3.6$, $\zeta = 0.05$ and $\nu = 0.5$. Table VII shows that in the birth cohort 1938-47 the total family income of single females is about 49% of married ones for younger women and drops to around 44% for women in their 30's.[13]

The parameters that govern utility for children are set to match the following targets: the total fertility rate for women between 15 and 40 years old (2.4, in 1970, according to Ventura et. al. (1998)), the percent of children born to single women (10%, between 1970 and 1980, according to Ventura and Bacharach (2000)), the fraction of kids living in 2-parent families (82%, between 1969 and 1979, according to U.S. Census Bureau data).[14] Finally, we allow each female to have at most $K = 2$ new children in any given period.

Although published estimates of the returns to labor-market experience exist, there is no consensus in the literature regarding how to treat the problems arising from self-selection into work or the endogeneity of the number of hours worked. It is clear however that labor-market experience does raise wages, and that for women this effect became much stronger in the 1970s than it had been previously. Moffitt (1984) finds that an additional year of work experience raises wages for men by a little more than 4%, and Blau and Kahn (1997) find that an additional year of full time experience, in 1988, increases log-female wages by .0289 and male wages by .0458. However these studies do not take selectivity bias into account. More recently, Olivetti (2001) estimates the return to experience for men and women, and shows that there has been a significant rise in the returns to experience, particularly for females, for whom wage growth between ages 20-29 to 30-39 was not significantly different from zero in the 1970s.

We assume that all wage growth is due to the returns to experience, as represented by a function that maps current productivity levels and current labor supply decisions into the next period's productivity levels. To minimize the need for new parameters, we assume that depending on current labor supply decisions, productivity can either go up one level,

[13] For men, the differential is 53% for the young cohort in their 20's, and 44% for older men.

[14] The fraction of kids living with married couples is based on US Census Bureau data on the Living Arrangements of Children under 18, which is available at http://www.census.gov/population/www/socdemo/hh-fam.html

go down one level, or stay the same. For each sex, this process is characterized by two parameters, $a_s$ and $\phi_s$, as follows:

$$\Pr[x_{i-1}|x_i, l] = (1 - a_f)(1 - l^{\phi_f}), \;\; \Pr[z_{i-1}|z_i, n] = (1 - a_m)(1 - n^{\phi m}),$$

$$\Pr[x_i|x_i, l] = a_f(1 - l^{\phi_f}), \;\; \Pr[z_i|z_i, n] = a_m(1 - n^{\phi_m}),$$

and

$$\Pr[x_{i+1}|x_i, l] = l^{\phi_f}, \;\; \Pr[z_{i+1}|z_i, n] = n^{\phi_m}.$$

In our benchmark economy, we set these two parameters to match the observed wage and labor-supply growth. For males, we choose $a_m = 0.6$ and $\phi_m = 0.45$. This gives a wage growth rate for males between first two model periods of about 27% (which is the average value we calculate for males between ages 20-29 and 30-39 using PSID data between 1969 and 1979). In the benchmark, the average labor supply of married men between first two periods is about constant (which matches the data on labor supply for the birth cohort 1938-47 in Table VIII). Olivetti (2001), using PSID data for 1973, shows that the wage growth for married females between ages 20-29 and 30-39 was negative. Using the PSID data between 1969 and 1979, we also find that the wage growth for all females between ages 20-29 and 30-39 was close to zero. Hence, for females we assume that there is no wage growth in our benchmark economy.

## 5. Inequality and Fertility Timing

In this section we analyze the interactions between wage inequality and the timing of fertility. We show that the marriage market plays a central role in determining the timing of fertility, as well as in the propagation of inequality across generations.

The main result of our benchmark model is that women's productivity (wages) delays fertility even when the labor-market returns to work experience are zero. This is evident from Table X, where we report fertility patterns by the marital status and productivity of the mothers.[15] Each cell reports the total number of kids and the fraction of kids born in

[15] The marital status and productivity levels correspond to the second model period. Hence, single mothers are those who have never been married or those who experienced a divorce but did not get remarried. New marriages are those formed in the second period, while old marriages are the intact marriages from the first period.

the second model period. Three important patterns are evident: 1) The completed-fertility rate is declining in the productivity level of the mothers. Women who are in the top half of the wage distribution have on average 2.1 kids whereas those in the bottom half have 2.7. 2) The proportion of the children born in the mother's first adult period is declining in the mother's wages. 3) Single women delay fertility more than married women, and women in stable marriages delay fertility the least.

The fact that women's fertility is declining in their education level is well-known (see Rindfuss, Morgan and Offutt (1996) and Matthews and Ventura (1997) for some recent evidence; and Browning (1992) and Hotz, Klerman and Willis (1997) for reviews of literature). In our model, this is driven by the time costs of both fertility and investment in human capital. Children are time-intensive, and thus more costly for women with high productivity.

In our benchmark model, women do not receive a return to labor-market experience in the form of higher wages, because we have set the experience effect on wages equal to zero for women. However more productive women tend to have children later than do less productive women. Thus, the lowest-productivity mothers who are newly married in the second period have about 74% of their children in the first period, the corresponding figure for the highest productivity level is 15%. The same figures are 78% and 50% for women who are in an intact marriage, and 45% and 28% for women who are single in the second period. We believe that this pattern is due to the fact that women with high productivity in our model gain more from fertility delay via the marriage market.

The third pattern, that single women postpone their childbearing more than married women, supports this interpretation. The fact that single women postpone their childbearing more than married women is a result of the fact that having children alone is costly for women. Women who are single in the first period tend to wait for the second period marriage market. Once the second period marriage market is cleared, however, they have their children. The same is also true for marriages that are more likely to end in divorce in the first period. Such marriages result in fewer kids in the first period than those that are more likely to remain intact.[16] Therefore, there is a return to delay from the marriage market.

[16] In fact this effect of divorce on childbearing is observable in U.S. data, according to estimates by Lillard and Waite (1993)).

Not surprisingly, women who have been continuously married (in other words, in a stable marriage) have the lowest fraction of kids born in the second period. The same force can also explain why high productivity women delay their childbearing more than low productivity women. While in an environment with returns to experience one can expect higher productivity women to postpone their childbearing decisions more than low productivity women, in our benchmark economy there is no dynamic return to labor-market experience for women, as they face a flat age-earnings profile. The returns from the marriage market, however, are not the same for high and low productivity women. Low productivity women have much less of a chance of marrying a high type in the future marriage market and hence less incentive to wait for a better match before having kids. Similarly, high type women are more likely to dump their low productivity partners from the first period and look for a more suitable mate.[17]

As further evidence of the effect in our model of the marriage market on the timing of births, we also run the following simple experiment: suppose the match quality levels for the last period of the model are now given by $\gamma_1^o = 0$ and $\gamma_2^o = 1.2$. In other words, we improve the match quality for the last period. Not surprisingly, this increases people's chances to get married in the last model period, and aggregate marriage rate rises to 84% from 78%. More importantly, on average, about 37% of the kids are now born in the second model period (instead of 36%). Hence, better marriage prospects simply lead to later births as we expect.

The human capital of children in the model depends on both the marital status of the parents and the timing of fertility. The effect of marital status is due to larger investments of both goods and mother's time, which is driven by the fact that the child's education now benefits two parents rather than just the mother, raising the return on mother's time in child-raising relative to market labor. On average a child with a single mother receives about one-third of the human capital investment received by a child in a married couple household.[18] Empirical support for this sort of interaction is discussed in McLanahan and Sandefur (1994). In the benchmark economy, children that are born in the second period

[17] As a robustness check, we ran some experiments with lower fertility rates for single women, by imposing a utility cost (or stigma) for having an out-of-wedlock birth. Our basic result regarding the shift in the timing of births with the introduction of returns to experience for women did not change.

[18] See Greenwood, Guner and Knowles (2001) for a more detailed discussion of the role of human capital investment in producing intergenerational persistence of income in such models.

receive about 13% more human capital investment than those born in the first period. These children receive more investment in our model for two reasons. First, women who have children later tend to be higher productivity and thus have both higher household incomes and fewer children. Second, the wage growth of the fathers increases household income, so that there are more resources for investment in the later-born children.

### 5.1. Changes in the Return to Experience

An interesting application of our model is to explore the effect on fertility and marriage behavior of increasing the returns to women's labor-market experience, which were set to zero in the benchmark model. This change is consistent with other evidence, such as Olivetti (2001) and Blau and Kahn (1997) who indicate the return to experience has grown much faster for women than for men since the 1970s. In particular, we assume that now women face the same labor-experience process as men, but it is parameterized so as generate a wage-growth rate for women that is close to what we observe in the PSID between 1980 and 1992 (based on our calculations using the PSID, from ages 20-29 to 30-39, wages for women grow on average about 12% during this period).

To match this growth rate, we now set the parameters $a_f = 0.62$ and $\phi_f = 0.6$ in the woman's function for returns to experience. The effect of this change on wage growth is depicted in Figure 1, where we show wage growth as a function of labor supply. Women who spent 10% of their time working in the first period experience wage growth of 3%, but those who worked for 60% of the period experience a wage growth of close to 30%.

The results of this experiment are shown in Table XI. The change in the returns to experience for women causes a further delay in the timing of births. Now about 38% of children are born when their mother is over 30 years, instead of the 36% in the benchmark case. It makes sense to question if the shift in the model resembles what we see in the data for later cohorts. As the data in Table IIa indicates, for the birth cohort of 1948-57, about 44% of the births occurred to women older than 30 years. Hence, we are able to explain some of changes in the timing behavior by changes in the returns to experience for women. Along with the increase in the delay of childbearing, total fertility falls from 2.4 to 2.25.

The aggregate marriage rate falls from 78% to 75%. The aggregate fraction of married people, however, does not tell the whole story. What is happening is that more women choose to remain single and accumulate human capital in the first two periods (i.e. they refuse to marry men with low productivity). The marriage rates in the third period are the same in this experiment as they are in the benchmark. The pattern of a delay in marriage without a significant change in the aggregate number of people who will eventually get married is consistent with recent evidence on US marriage patterns documented by Goldstein and Kenney (2001) who state that "the major change in marriage patterns has been a shift to older ages of marriage with only a small declines in eventual levels of marriage," (page 517).

Since the timing of births is the key link between labor and marriage markets in our model, we provide a more detailed look at the labor supply behavior in Table XII. The data is based on Tables VII and VIII. The first column is the labor supply numbers from our benchmark economy, and the first two rows are the numbers that are directly targeted by our parameters. The benchmark economy produces, however, reasonable labor supply behavior for other marital status and age groups, which is very encouraging.[19] The labor supply numbers for women are higher when we have positive returns to experience for women. This is not surprising as women work more to take advantage of returns to experience. Note that as more women work and choose to remain single in the first period, the relationship between labor supply and age also more closely resembles what we observe in the data. Finally, this change results in a more equal income distribution. Now female-headed households' labor income is about 51% of that of married couples for the first model period (as opposed to 45%).

What about the effect on children? There are three channels through which a change in returns to women's experience can affect investment in children. First, it can directly affect time and resource investment decisions. The direct effect in this experiment is minimal. Second, changes in the marriage market can affect the number of children born to single mothers. In our experiment, the fraction of all kids who live with single mothers is unchanged, however the fraction who live with young single mothers rises (10% to 12%). Children born to single mothers continue to receive around a third of the human capital investment of those born to married couples. And lastly, a shift in fertility timing changes the number of children born in the second period relative to the first. With returns

[19] The singles in the second period of our model, however, look a little different than singles in the data. The key force behind this discrepancy is the role of marriage market in our model. The marriage market selects more productive people into marriages, and the resulting singles pool consists mainly of low productivity people.

to experience for women, more kids are born in the second period, and they receive more human capital investment than those born in the first period of their mothers' lives. Overall, total human capital investment falls just under 4%, so the single mother effect dominates the shift in timing.

### 5.1.1. Discussion

The key factor that causes the shift in the timing of births is the changing return to experience for women. It is important to contrast this channel with the return to age in order to understand why women delay their childbearing decision here. If, on one hand, the growth in wages was mainly a result of the return to age, then women would experience a higher wage tomorrow independent of today's labor supply. This leads women to have kids sooner rather than later.[20] On the other hand, depreciation of wages by age, or a negative return to experience, would create a force for later childbearing. When we increase the return to experience for women, we get a slightly negative return to age: if a woman does not supply any labor when she is young, she experiences about a 10% decline in her wages next period. This deprecation is much less than, for example, numbers estimated by Olivetti (2001), who finds that a woman with zero labor supply between ages 20 and 29, loses about 50% of her human capital by age 30. Hence, our results are not driven by an implausibly large negative return to age, and on average women experience wage growth close to the data. Furthermore, the fact that the actual experience matters most for the wage growth is also consistent with recent analysis of the effect of fertility and labor turnover on employment and wages by Erosa, Fuster, and Restuccia (2002).

## 6. Conclusion

The goal of this paper is to understand the economic forces that cause women with high lifetime labor income to have children later in life than women with lower labor income. We argue that this phenomenon is interesting not only for understanding wage inequality over the lifetime, but also, via fertility and investment in children's education, for the evolution of the income distribution over time. Our basic hypothesis is that cross-sectional differences

[20] Indeed, using the current model, one can generate a decline in the fraction of kids that is born in the second model period, if all wage growth for females is due to returns to age.

in fertility behavior and labor supply behavior are due to differences in the dynamic returns to fertility. Because both fertility and labor-supply decisions are strongly linked to women's marital status, we argue that a deep understanding of these patterns requires a dynamic model of marital status that incorporates both fertility timing and labor supply.

The main result of our calibrated, benchmark model is that the steady-state equilibrium replicates the key qualitative features of fertility behavior in the data: fertility rates are declining in family income and lower-wage women have children earlier than do higher-wage women. In addition, we find that increasing the gains from marriage leads to further delays in fertility, confirming that marriage-market incentives are indeed responsible, in our model, for the cross-sectional pattern of fertility timing. The mechanism behind this is that for low-wage women the incentive to delay fertility is not very strong, because high-wage men are less likely to marry them, and should such a marriage occur, low-wage women get a much lower share of the surplus than would a high-wage woman. Therefore the gains to fertility delay are much smaller for low-wage women, and so they have their children earlier.

Finally, we explore the effect of allowing women's wages to respond to work experience, which we take to be analogous to the increases over the last 30 years in the returns to experience for women, as reported by Blau and Kahn (1997) and Olivetti (2001). We find that increasing the effect of labor-market experience on women's wages results in higher labor supply for young women, and a further delay in the timing of fertility; the proportion of children born to mothers over the age 30 rises 5%, compared to a 13% increase in the data. Total fertility rates fall by about 7%, and the proportion of the population ever-married falls 4%. Since all of these changes correspond to changes that actually occurred in the U.S over the same time period, we feel our results indicate that these changes were due, to a significant extent, to increases in the labor-market incentives for fertility delay.

Our results suggest that women in the more recent US birth cohorts perceived that their future wages were more responsive to their labor experience than was the case for the older cohorts. The causes of this change are outside the scope of this research, but are consistent with the intense campaign waged in the 1970's against sex-discrimination not only with respect to wages but also occupational choice and career advancement.

## A. Decision Rules

The expected values of having a new draw from the marriage market in the third period are given by,

$$EW_3^{dr}(x,k) = E_{z,\gamma}\left[W_3^n(x,z,0,k,\gamma)I_3^n(x,z,0,k,\gamma) + G_3(x,0,k)(1 - I_3^n(x,z,0,k,\gamma))\right]$$

$$= \sum_i \sum_j [W_3^n(x,z_i,0,k,\gamma_j)I_3^n(x,z_i,0,k,\gamma_j) + G_3(x,0,k)(1 - I_3^n(x,z_i,0,k,\gamma_j))]\Omega_3(z_i)\Gamma(\gamma_j),$$

for females and

$$EV_3^{dr}(z) = E_{x,k,\gamma}\left[V_3^n(x,z,0,k,\gamma)I_3^n(x,z,0,k,\gamma) + B_3(z)(1 - I_3^n(x,z,0,k,\gamma))\right]$$

$$= \sum_i \sum_k \sum_j [V_3^n(x_i,z,0,k,\gamma_j)I_3^n(x_i,z,0,k,\gamma_j) + B_3(z)(1 - I_3^n(x_i,z,0,k,\gamma_j))]\Phi_3(x_i,k)\Gamma(\gamma_j),$$

for males, where $\Phi_3(x,k)$ is the probability of meeting a three-period old single woman of type-$x$, with $k$ two-period old kids, in the third period marriage market, and $\Omega_3(z)$ is the probability of meeting a three-period old single man of type-$z$, in the third period marriage market.

These continuation values for people who are married in the second period are simply defined as

$$EW_3^{con}(\cdot \mid x,z,k_2,\gamma) = \sum_i \sum_j \sum_m \max\{W_3^o(x_i,z_j,0,k,\gamma_m)I_3^o(x_i,z_j,0,k,\gamma_m), \\ EW_3^{dr}(x_i,k)\}X(x_i|x,l)Z(z_j|z,n)\Gamma(\gamma_m),$$

and

$$EW_3^{con}(\cdot \mid x,z,k_2,\gamma) = \sum_i \sum_j \sum_m \max\{V_3^o(x_i,z_j,0,k,\gamma_m)I_3^o(x_i,z_j,0,k,\gamma_m), \\ EV_3^{dr}(z_j)\}X(x_i|x,l)Z(z_j|z,n)\Gamma(\gamma_m).$$

Finally, the values of having a new draw from the marriage market in the second period are given by

$$EW_2^{dr}(x,k_2) = E_{z,\gamma}[W_2^n(x,z,k_2,\gamma)I_2^n(x,z,k_2,\gamma) + G_2(x,k_2)(1 - I_2^n(x,z,k_2,\gamma))] =$$

$$\sum_i \sum_m \{W_2^n(x,z_i,k_2,\gamma_m)I_2^n(x,z_i,k_2,\gamma_m) + \\ G_2(x,k_2)(1 - I_2^n(x,z_i,k_2,\gamma_m))\}\Omega_2(z_i)\Gamma(\gamma_m),$$

and

$$EV_2^{dr}(z) = E_{x,k_2,\gamma}[V_2^n(x,z,k_2,\gamma)I_2^n(x,z,k_2,\gamma) + B_2(z)(1 - I_2^n(x,z,k_2,\gamma))] =$$

$$\sum_i \sum_{k_2} \sum_m \{V_2^n(x_i,z,k_2,\gamma_m)I_2^n(x_i,z,k_2,\gamma_m)+$$

$$B_2(z)(1 - I_2^n(x_i,z,k_2,\gamma_m))\}\Phi_2(x_i,k_2)\Gamma(\gamma_m).$$

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