

Fertility and Female Employment: A Different View of the Last 50 Years

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Abstract

Over the period from 1964 to 2003, married female employment almost doubled from 40 per cent in 1964 to 71 per cent in 2003. Disaggregated by age and education, changes were most pronounced during childbearing ages and increasing in education levels. At the same time, age at birth of first child as well as life-cycle wage profiles have increased the most for highly educated women. Given those facts, our purpose is that of "testing" if theories of the determinants of female labor supply are robust to a life-cycle representation of the fertility and labor supply choice, and, in the affirmative case, how much of the data from the last fifty years they capture. To this end, we build a quantitative life-cycle model of female labor force participation and child related choices with experience accumulation. First, we calibrate the model to the 1940 cohort's life-cycle participation, wages and distribution of completed fertility. Then, we investigate how much of the observed changes in behavior between cohorts born in 1940 and 1960 can be explained by our theoretical model and by two exogenous factors: (i) reduction of gender gap in wage levels, (ii) a decrease in the price of consumer durables useful in home production. To do this we use the microeconomic data for the 1940 to 1960 cohorts, as recorded by the CPS as well as Census data. We find that through our mechanism the effect of changes in the exogenous gender wage gap as well as improvements in the home technology, have significant effects on female labor supply but that these effects are smaller than previously reported, typically affect participation at later ages more than early in life and that, thereby, neither can account for the whole change in married female labor supply.

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1 Introduction

One of the most salient economic changes of last century and, in particular the second half of the latter, is the progressive and sustained entering of married women into the labor force. In 1964, only 40 percent of married women were part of the labor force, while this number increased to 71 percent in 2003.¹ The literature that studies the determinants of the increase in women's labor supply is very large. Proposed explanations span from changes in market technology favoring women over men, improvements in home technology, introduction of the pill and changes in social norms. Using data from the Current Population Survey (CPS), we find that for women born between 1940 and 1960, changes in employment have been most pronounced when young, which roughly corresponds to 'childbearing ages'. For example, before age 36 employment rates increased by 31 percentage points per year compared to only 16 percentage points between ages 36 and 50. Since those cohorts are also very different in their fertility behavior, we believe that examining the implications of proposed theories in light of the life-cycle and in connection with fertility is important.

The goal of this paper is to quantitatively assess two popular theories, namely the 'Household Revolution' (Greenwood et al. (2004)) and the 'Gender Wage Gap' (Jones et al. (2003)) theories² by introducing two additional dimensions into the analysis of married women's labor market participation decision, namely participation dynamics along the life-cycle and (heterogeneous) child related choices pertaining to the number of children, timing of births and child care arrangements. We show that under reasonable conditions motivated by data, though quantitatively important, both theories predict a larger increase in female participation when old than when young.

Given our goal, we have to construct a quite involved mathematical model that we briefly lay out next. Following the seminal work of Becker (1991), economists have used a model of specialization between husbands and wives to describe how the household nexus works and to analyze women's decision to join the labor force. Under fairly mild assumptions, men tend to specialize in market production, while women tend to divide their time between home and market production in this setting.

Starting with his basic mechanism, we first reinterpret the home good as children who are costly in terms of time as well as goods with partial substitutability. This is motivated by the fact that women who have more children are much less likely to work (and work fewer hours) than women with few children. The latter fact suggests a significant time trade-off between child rearing and market work. Second, we embed this static framework in a discrete choice dynamic life-cycle model with experience accumulation and preference heterogeneity. Finally, child related choices pertaining to the number of children, timing of births and child care arrangements, are made alongside the participation

¹See the two survey articles by Killingsworth and Heckman (1986) and Altonji and Blank (1999).

²... and possibly others in the future, e.g. returns to experience (Olivetti (2005)), child care availability (Attanasio et al. (2004))

decision.

Using moments estimation, we calibrate the parameters of our model to match the life-cycle participation and wage profiles as well as the distribution of completed fertility of women born in 1940. We then confront this calibration with several cross-sections motivating the modeling choices and show that they are closely predicted. That is, we generate (1) the fact that women with fewer children over their life-time, on average, have them earlier; (2) the decreasing pattern in participation by number of children (at different ages) thanks to the time trade-off between number of children and market work and, (3) the decreasing pattern in wages by number of children (at different ages), which follows from the previous two items and experience accumulation affecting wage levels.

Now, consider the qualitative implications for participation and fertility of a decrease in the exogenous gender wage gap and an improvement in the home technology. To make comparison possible between papers, as mentioned above, we reinterpret the number of children in our model as home (durable) consumption good in theirs. A decrease in the 'exogenous gender wage gap'³ increases the shadow price of consumption of the home good (i.e. children in our case) and as a result a positive fraction of women join the labor force. Assuming that time and goods inputs are not perfectly substitutable in the production of children while consumption and children are substitutable in utility, our model predicts an increase in participation, typically a decrease in fertility and an increase in timing of births. In Jones et al. (2003), a decrease in the gender wage gap has the same qualitative implications for hours worked by women and consumption of the home good. These changes occur through a similar economic channel as in our model, namely the higher incentive to accumulate human capital. However, the human capital decision in our model, while explicitly involving experience accumulation, disregards the education decision as well as any other kind of human capital investment.⁴

In Greenwood et al. (2004), the fraction of households that adopt the labor-saving technology at home increases as the price of consumer durables falls. As a result, time is freed up from home and the fraction of women working increases. Our technology for the production of children is similar to theirs for the home good production: each child requires a fixed amount of both market goods and mother's time and we allow for some substitutability between mother's time and market goods. In our setting, however, this 'adoption decision' comes with the participation decision: women who decide to work have to pay an extra goods cost; those who decide not to work have to pay some extra time cost. A decrease in the goods cost has then similar effects as in Greenwood et al. (2004): it frees up time previously allocated to the home technology; it draws a positive

³By exogenous gender wage gap, we mean the gap that exists after controlling for experience and education.

⁴In Buttet and Schoonbroodt (2005), we perform a simple accounting exercise that suggests that about 25 percent of the overall increase in female labor supply can be accounted for by shifts in the educational distribution. Education being just a different type of human capital investment, we do not address this effect of the gender wage gap so far.

fraction of women into the labor force and fertility levels typically increase.⁵

Finally, we perform two quantitative experiments to investigate how much of the observed changes in behavior between cohorts born in 1940 and 1960 can be explained by our theoretical model and by the two exogenous factors, i.e. reduction in the exogenous gender gap and a decrease in the price of consumer durables useful in home production. We first 'measure' the change in the exogenous gender wage gap by looking at wages for single females who have not changed their participation behavior much (and therefore accumulated experience). This measure is close to the one estimated in Jones et al. (2003). According to this measure, the wage gap has decreased by 2 to 4 percent between women born in 1940 versus 1960. For the price in home durables, we use the price decrease in Greenwood et al. (2004) which for our model implies that women born in 1940 faced a cost of children 5 times higher than those born in 1960.

So far we have calibrated and experimented only for College educated women and results are preliminary. From the first experiment, changes in participation after age 36 are reproduced at 100 percent. However, the change in the exogenous gender wage gap only captures 25 percent of changes in employment when young. Also on average, completed fertility is not affected by this change and age at birth of first child only increases at the second decimal. For the second experiment, we also capture a substantial part of the increase in employment after age 36, namely 60 percent, but again, only 25 percent of the change before age 36. However, in this experiment, fertility increases by 0.3 children and age at first birth slightly decreases.

The intuition for the differential changes in participation along the life-cycle is the following. Since the exogenous change happens at all ages, there is a first order positive effect on participation, which would produce a parallel shift along the life-cycle. In addition to that, however, there is a second effect since women with higher accumulated experience are also more likely to work. At the beginning of working life, only the first effect applies. Given this, at later ages women have on average accumulated more work experience. Hence, the second effect adds on to the first. Therefore we predict larger changes when old than when young.

Our model fails to match one important moment from the data, namely the average age at birth of first child. It is consistently lower in our model than it is in the data. This should not cause too much concern though since in our model everyone gets married at age 23. In fact age at birth of first child, conditional on having been married by age 25 is matched very closely. Therefore, allowing women to marry at different points of their life (after 23) will increase the average age at birth of first child. This would require formulating a theory of why people get married and how the marriage market is affected by changes in the economic/social environment. This avenue for future research seems promising as the age at marriage increased dramatically after 1960. This period

⁵Note, however, that we do not allow agents to borrow. This implies that women cannot save early on in life by working (before freeing up time) and save to buy the new technology to produce children later and thereby free up time. They can only postpone fertility.

of time also coincides with the introduction of the pill and the liberalization of sexual mores (see Goldin and Katz (2002) and Greenwood et Guner (2005)).

The remainder of the paper is organized as follows. In Section 2, we briefly review the existing literature. Section 3 describes changes in life-cycle employment, fertility and timing of births for 1940 to 1960 birth cohorts, while Section 4 uses motivational facts within cohorts to convey some intuition about the construction of the model. In Section 5, we present the model. We calibrate the model to match moments of the 1940 cohort in Section 6. In Section 7, we perform the quantitative experiments. Finally, we conclude in Section 8 and lay out directions for future work.

2 A Brief Review of the Literature

The literature that studies the determinants of the increase in women's labor supply is very large. Proposed explanations span from changes in market technology favoring women over men (Jones et al. (2003), improvements in home technology (Greenwood et al. (2004)), the introduction of the pill (Goldin and Katz (2002)), or changes in social norms (Greenwood et Guner (2005)), to name only a few.

Following the seminal work of Becker (1991), economists traditionally use a model of specialization between husbands and wives to describe how the household nexus works and to analyze women's decision to join the labor force.⁶ Simply put, a household is made of two economic agents (typically one man, one woman) deciding how to optimally allocate their resources for the production (and consumption) of home and market goods. Under some mild assumptions on technology and preferences, the outcome of the specialization model is partial or full specialization, that is, men allocate all of their time endowment to the market technology (and possibly leisure), while women devote a non-negative fraction of their time to the home technology, and allocate the rest of their time between market and leisure. If either the relative rate of return on the market technology increases more rapidly for women compared to men, or following a positive innovation in the home technology, women will decide to allocate more time to market activities. That is, women's participation in labor markets increases. In our paper, we interpret the number of children as consumption of a home durable good.

Eckstein and Wolpin (1989) nest the specialization theory of Becker within a life-cycle model and show that the importance of accumulated experience on future participation decisions of women. Olivetti (2005) studies the change in life-cycle profile of hours worked by married women between 1970 and 1990 and shows that changes in returns to experience can account for a significant part of the latter. Attanasio et al. (2004) document change in life-cycle participation for three cohorts of married women born in 1930, 1940, and 1950. Modelling

⁶See also Chiappori (1999) and Chiappori et al. (2002).

of women’s participation and savings decisions over the life-cycle, they investigate which changes in the main determinants of women’s participation can account for the large increase in women’s participation when young. They find that changes in the cost of children relative to life-time earnings are the most relevant change quantitatively. However, none of these papers studies the joint decisions of women’s labor supply and fertility. In a recent paper, Erosa et al. (2005) document that the wage gap between men and women increases over the life-cycle and this increase can be traced to the impact of children. Using a quantitative model of fertility, labor supply, and human capital accumulation decisions over the life-cycle, they show that fertility accounts for most of the increase in the gender wage gap over the life cycle.

Finally, Jones et al. (2003) build a dynamic general equilibrium version of Becker’s specialization model and investigate what fraction of the increase in average hours worked by married women can be accounted for by exogenous changes in the gender wage gap for the period between 1950 and 1990. They find that a modest reduction in the gender wage gap of only 6 percent can account for almost a hundred percent of the increase in average hours worked by married women between 1950 and 1990, while improvements in the home technology generally have a small impact on married women’s hours worked. Another recent paper by Greenwood et al. (2004) embeds household production theory in an OLG framework with exogenous growth and studies what fraction of the increase in women’s participation rate can be attributed to the introduction of labor-saving consumer durables at home (the “Household revolution”). Surprisingly enough, the second paper finds that technological progress in the household sector accounts for more than 50 percent of the increase in participation of married women, while the decrease in the gender wage gap accounts for less than 20 percent of it. These are the two mechanisms this paper is closest to.

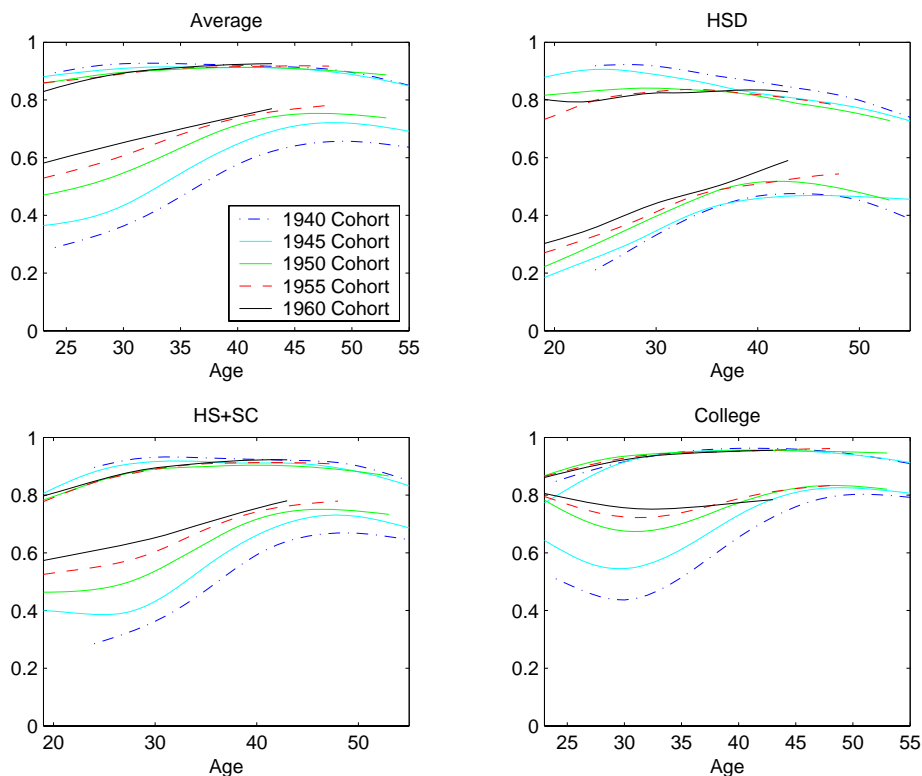
3 Changes in Life-cycle Employment, Fertility and Timing of Births: 1940 to 1960 Birth Cohorts

In this section, we present the changes in life-cycle labor supply and fertility across cohorts born between 1940 and 1960. We use data from the Current Population Survey (CPS) between 1964 to 2003 and from the Census to document these changes. Increases in female employment have been most pronounced for *young* women (i.e. before age 36). This pattern is robust across education groups but changes are larger for highly educated women. Since changes have been most pronounced during ‘childbearing ages’, we document changes in child related choices. While our main interest is in the changing employment patterns, we will confront the models predictions in terms of fertility and timing of births as well. Fertility levels decreased by almost 1 child on average (the 1940 cohort being the last Baby Boom cohort), changes being concentrated among High

School graduates and a shift in the educational distribution. Age at birth of first child, on the other hand, increased the most for College educated women.

In Figure 1, we present life-cycle profiles of employment rates for white, married (men and) women born between 1940 and 1960. For each year between 1964 and 2003, we count as employed, anyone who was at work the week preceding the interview or has a job but was not at work last week due to illness, vacations, etc... Panel A shows overall rates, while Panels B through D show rates by education level. We see that while employment rates for men are high and roughly constant by age, education and across cohorts (which is why we assume that men always work in our model below), female life-cycle employment rate patterns and changes differ considerably by age and across education groups.

Figure 1: Employment of Married Men and Women



The increase in employment rates of married women across cohorts is most pronounced before and during 'childbearing ages' at all education levels. Changes have been most pronounced for High School and College graduates. Table 1 summarizes the changes in employment depicted in Figure 1. These are the changes of interest in our quantitative experiments below.

Further, note that *within cohorts* employment rates are mostly increasing in age for High School drop outs and High School graduates, while College

Table 1: Changes in Employment Rates of Married Women across Cohorts and by Education: 1940 to 1960 Birth Cohorts

Age group → Education level ↓	Age 23-50 ^{a,b}	Age 23-35 ^c	Age 36-50 ^c
Average	0.22	0.31	0.16
HSD	0.09	0.12	0.10
HS+SC	0.21	0.30	0.16
College	0.18	0.31	0.09

^a Age 23-43 for the 1960 Cohort.

^b For each cohort and education group, we calculate life-time employment as the sum of employment rates over the life-cycle. That is, for each education group $j \in \{HSD, HS, COLL\}$, and cohort $c \in \{1940, 1945, 1950, 1955, 1960\}$ we define the "average" employment over the life-time as:

$$P_{ct,j} = \frac{1}{38} \sum_{a=23}^{50} p_{ct,j}(a) \quad (1)$$

and we report changes across cohorts, that is, $P_{ct+5,j} - P_{ct,j}$.

^c Similarly,

$$P_{ct,j}^{23,35} = \frac{1}{13} \sum_{a=23}^{35} p_{ct,j}(a), \quad P_{ct,j}^{36,50} = \frac{1}{15} \sum_{a=36}^{50} p_{ct,j}(a) \quad (2)$$

educated women tend to work more early on, then 'drop out' of the labor force and finally, similarly to lower education groups, progressively join the labor force after age 30. This fact suggests that child related choices are important in the decision to participate in labor markets, since low participation levels roughly correspond to 'childbearing ages'.⁷ We therefore analyze changes in completed fertility as well as timing of births by education.

In Table 2, we show the two measures of fertility by education level for cohorts of women born between 1940 and 1950. Fertility levels are decreasing in education and have changed the most for High School but somewhat less for College graduates (precisely those groups where the increase in employment was the largest). However, in Buttet and Schoonbroodt (2005), we perform a simple

⁷In the next Section, we analyze employment by number of children to stress the importance of modeling employment and child related choices jointly. There we also show the relevance of age at birth of first child in relation to experience.

Table 2: Changes in Fertility of Married Women across Cohorts and by Education: 1940 to 1960 Birth Cohorts

Fertility measure → Birth cohort → Education level ↓	<i>CEB</i> ^{a,c}		<i>NCHH</i> ^{b,c}		
	1940	1950	1940	1950	1960
Average	2.8	2.1	2.3	1.9	1.9
HSD	3.4	2.0	2.8	2.3	2.2
HS+SC	2.8	2.1	2.3	1.9	1.9
College	2.3	1.8	2.0	1.7	1.8

^a Children ever born

^b Number of own children in the household

^c We use Census data to obtain information on completed fertility because it is not readily available in the CPS (children are reported as 'other relatives' or not at all). However, we are only able to obtain 'completed fertility' (i.e. Children ever Born) for cohorts of women born between 1940 and 1950 (but not for the 1955 and 1960 cohorts) because this information is no longer available in the 2000 Census. In the calibration and experiments we use 'number of own children in the household' at age 40 as a proxy for completed fertility. In the future, we plan to use PSID data to find the missing information for the 1955 and 1960 cohort.

accounting exercise which suggests that changes in fertility distribution holding employment by number of children constant can account for no more than 10 to 30 percent of increases in employment, depending on education group. In the next section we show that employment by number of children at any given age accounts for the remainder.

Changes in timing of births, on the other hand, are surprisingly large. In Table 3, we present the average age of mother at birth of first child at age 40 by education from Census data. Age at birth of first child has increased for all education levels. Interestingly, these changes are more pronounced for more educated women. Between cohorts born in 1940 and 1960, age at birth of first child increased by 3 years for College educated women, compared to a modest 0.7 years for High School Drop Outs. These patterns, once again, mirror those in employment. That is, those groups for whom employment has changed the most are also those for whom age at birth of first child has increased the most. We confront the model's predictions to these changes as well.

Table 3: Average Age of Mother at Birth of First Child by Education: 1940 to 1960 Birth Cohorts

Birth cohort → Education level ↓	1940	1950	1960
HSD	22.9	22.9	23.6
HS + SC	23.7	24.5	25.7
College	26.3	28.4	29.2

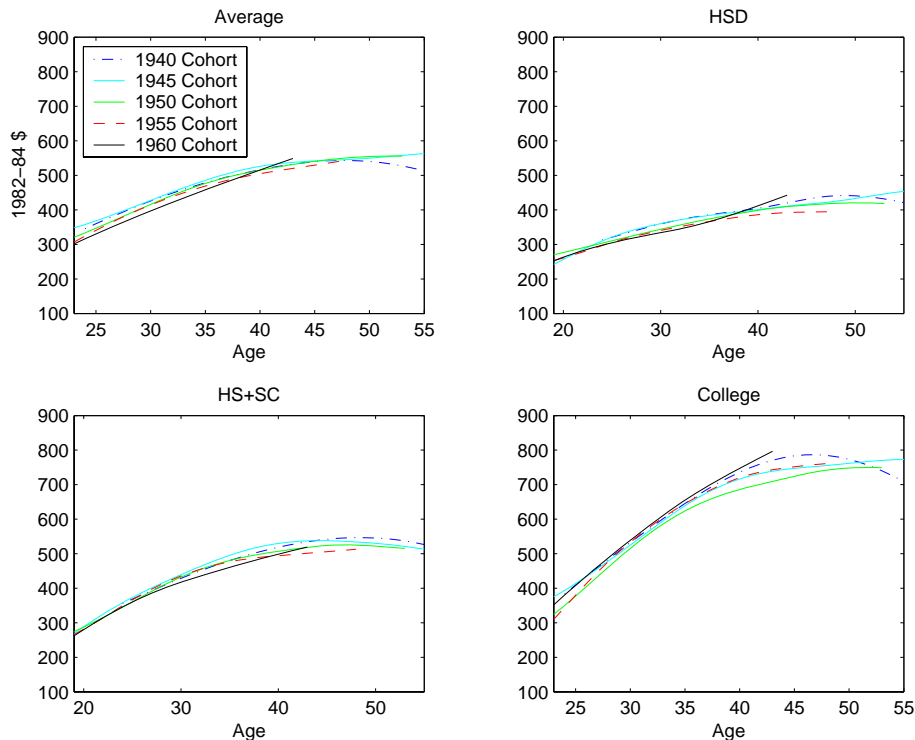
4 Intuition for the Model and Motivational Facts within Cohorts

Recall that the goal of this paper is to quantitatively assess the 'Household Revolution' and the 'Gender Wage Gap' theories⁸ by introducing two additional dimensions into the analysis of married women's labor market participation decision, namely participation dynamics along the life-cycle and heterogeneous child related choices (pertaining to the number of children, timing of births and child care arrangements). To accomplish this, we have to build a quite involved mathematical object. Not only do we view these decisions as discrete and therefore need several sources of heterogeneity to reproduce interior participation rates and distributions of number and timing of births, but we also have to make many specific choices for computational tractability. In this section, we present life-cycle wages as well as several cross sections, namely age at birth of first child by NCHH at age 40 and, employment and wages by NCHH at different ages, to motivate the specific modeling choices.

First, male weekly wages are increasing over the life-cycle - over and above TFP growth (see Figure 2). Moreover, for married women average wage profiles have steepened across cohorts (see Figure 3). Since employment rates of men have been high and unchanged for married men, while married female employment rates when young (and therefore average accumulated experience at later ages) have increased, these facts suggests that experience accumulation is important. This has been stressed a lot in the labor literature (e.g. Eckstein and Wolpin (1989)) and more recently by Olivetti (2005). We therefore explicitly model wages as an increasing function of the number of years of experience. However, returns to experience are not age dependent in our formulation. For example, a woman who has accumulated five years of experience at age 30 earns the same wage as a woman with 5 years of experience at age 45. Olivetti (2005)

⁸... and possibly others in the future, e.g. returns to experience (Olivetti (2005)), child care availability (Attanasio et al. (2004))

Figure 2: Real Weekly Wage of Married Men - Detrended by TFP



uses her own estimates of changes in returns to experience allowing for age dependence. She finds that marginal returns to experience decrease in age, but that the upward shift between the 1970s and 1990s is roughly parallel by age. We are currently working on a version of the model that allows for age dependence in payoffs from accumulated experience. Allowing for age dependent *accumulation* of human capital through experience becomes computationally untractable because the current level of human capital depends on the age it was accumulated which makes it dependent on the whole path of labor supply decisions and not just the number of years of work experience.

Second, we cross age at birth of first child with NCHH. Table 4 shows that women who have more children over their lifetime have their first one earlier. Furthermore, the variance in age at birth of first child is very high, especially for women with low completed fertility levels. This again is robust across education levels. We therefore introduce utility from children in such a way that it increases in the number of children but decreases in age at birth of first child (since children are a durable good providing utility from birth to the last period of the parents life). Besides educational attainment, identified by wage levels and returns to experience, households differ in their preference for children as well as leisure. It follows that women with a higher preference for children have

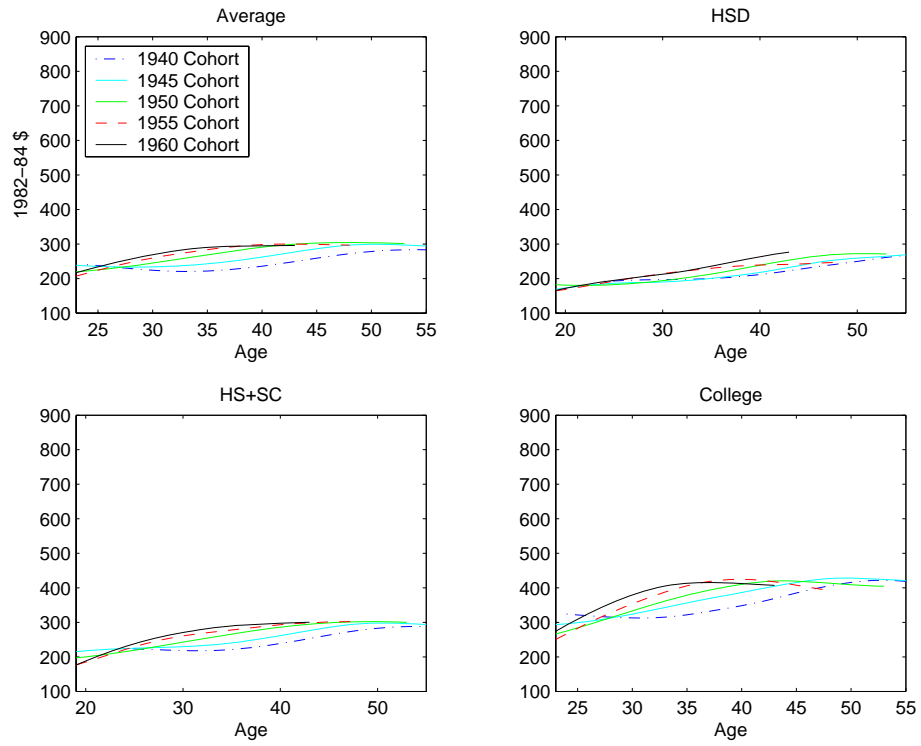
Table 4: Average Age of Mother at Birth of First Child by NCHH at age 40 and Education (Standard Deviation)

NCHH ^a	1	2	3	4+
1940:				
Aggregate	25.7	24.2	23.0	22.3
College	28.4(5.0)	26.4(3.3)	25.2(2.3)	24.6(2.0)
HS + SC	25.6(4.7)	24.0(3.4)	22.9(2.7)	22.2(2.3)
HSD	25.0(4.8)	23.2(3.5)	22.3(3.3)	21.6(2.5)
1950:				
Aggregate	26.9	25.5	24.2	23.2
College	30.7(5.3)	28.3(3.7)	26.7(3.0)	25.5(2.5)
HS + SC	26.1(5.1)	24.5(4.0)	23.5(3.2)	22.7(3.0)
HSD	25.0(5.0)	23.0(4.2)	22.2(3.5)	21.5(2.8)
1960:				
Aggregate	28.3	26.8	25.2	24.1
College	32.0(5.3)	29.4(3.8)	27.7(3.3)	26.3(2.8)
HS + SC	27.4(5.5)	25.9(4.3)	24.4(3.6)	23.5(3.2)
HSD	25.4(4.9)	23.9(4.8)	22.5(3.8)	21.9(3.7)

^a Number of own children in the household at age 40

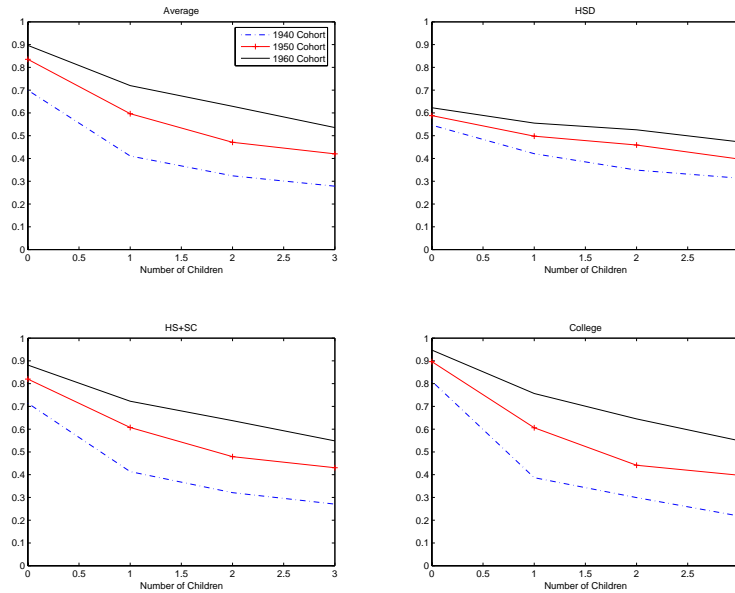
more children but also tend to have them earlier. Temporary wage shocks together with leisure heterogeneity generate the high variance in age at birth of first child by number of children. For example, even if women have a high preference for children, they may postpone fertility because of a particularly good wage shock today, especially if they don't care much about leisure.

Figure 3: Real Weekly Wage of Married Women - Detrended by TFP



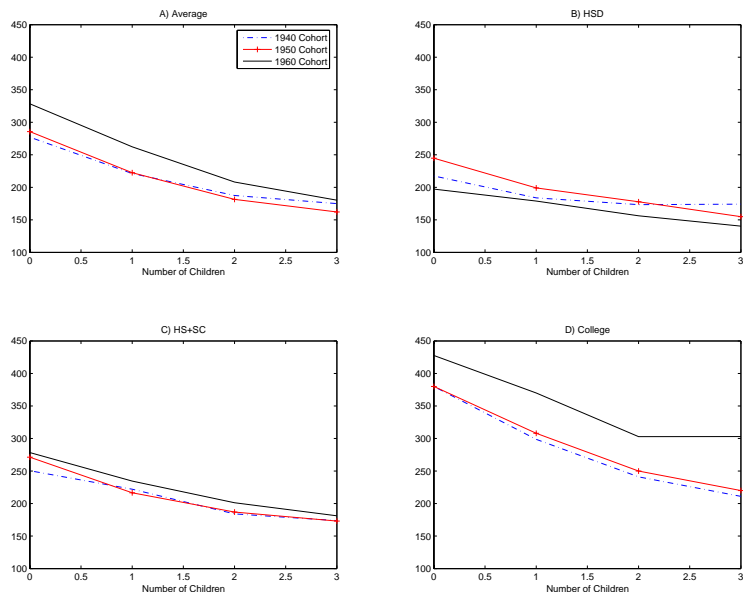
Third, we use the fact that employment rates are decreasing in the number of children in the household to motivate our time cost structure for children. Figure 4 shows that employment rates are decreasing in the number of children in the household for every cohort and every education group. Though not reported here, the former effect is particularly pronounced for women with young children but less strong at later ages. We therefore assume that children are costly in terms of time especially when young. This is consistent with Hotz and Miller (1988) who find that time inputs in children decrease with children’s age.

Figure 4: Women’s Employment by Number of Children at Age 30



Finally, wages by number of children are decreasing at any given age (see Figure 5). This suggests that, on average, women with many children have exited the labor market for a longer time, thereby accumulating less experience - hence the lower wage. However, the slope decreases as women get older. We therefore force women to drop out the very period they decide to have a child. This induces women who have more children to accumulate less experience. However, this effect fades away as women progressively join the labor force again after childbearing ages and the experience gap (in percentage terms) decreases. Together with preference heterogeneities and temporary wage shocks, this assumption also generates smooth participation rates over the life-cycle that increase at later ages through the endogenous distribution in timing of births.

Figure 5: Wage by Number of Children Across Cohorts - Age 30



5 The Model

In this section, we describe a discrete choice model of women’s participation and fertility decisions over the life-cycle within the household nexus. For simplicity, we omit the important issues of how families are formed and how they dissolve. That is, the life-time of a household is fixed and equal to T . Moreover, we assume that women are fertile for the first $T_f < T$ periods of their life.

Demographics: A household is composed of a man, a woman, and possibly some children. Each household is indexed by the following ”permanent” triplet, (S, ν, γ) , where S denotes women’s completed education, ν , her preference for children, and γ , her preference for leisure. We assume that women’s productivity depends on the number of years of work experience and increases with education. Moreover, in each period, women’s productivity is hit with a contemporaneous wage shock, ϵ_t , sampled from a fixed distribution. We chose the support and distributions for these heterogeneities to match life-cycle participation and wage profiles as well as fertility distributions reported in the previous section.

Preferences: Households care about joint consumption, c_t , women’s leisure

time, l_t , and the number of children, n_t , with period- t utility:

$$U^{(\gamma, \nu)}(c_t, l_t, n_t) = \frac{c_t^{1-\sigma_c}}{1-\sigma_c} + \gamma \frac{l_t^{1-\sigma_l}}{1-\sigma_l} + \nu \frac{(\psi + n_t)^{1-\sigma_n}}{1-\sigma_n} \quad (3)$$

Optimization Problem: We model participation and fertility decisions of women as discrete choices, that is $(p_{ft}, q_t) \in \{0, 1\}^2$. Men participate in labor markets in each period and matching is perfectly assortative in income. That is, men married to women with education S earn weekly wages, w_{mt}^S , with $w_{mt}^{S'} > w_{mt}^S$ whenever $S' > S$. In each period $t \in \{1, \dots, T\}$, women receive a sequence of wage offers, $\{w_{fr}^S(h_{fr}, \epsilon_r)\}_{r=t}^T$, which depends on their education, accumulated human capital, h_{fr} , and a productivity shock, ϵ_r . Given these wage offers and the wage of their husband, households choose a life-time sequence of consumption plan, $\{c_r\}_{r=t}^T$, wife's employment $\{p_{fr}\}_{r=t}^T$, and whether to have an additional child, $\{q_r\}_{r=t}^T$, to maximize the expected discounted flow of utility subject to a sequence of budget and time constraints and the laws of motion for wife's human capital and children. The expected discounted life-time utility of the household of type (S, γ, ν) at time t is given by:

$$E_{t-1} \sum_{r=t}^T \delta^{r-1} U^{(\gamma, \nu)}(c_r, l_r, n_r) \quad (4)$$

where $\delta \in (0, 1)$ denotes the time discount factor.

At each time $r \geq t$, the budget and time constraints of households with women's education S are given by:

$$\begin{aligned} c_r + g_k(\mathbf{N}_r, p_{fr}) &\leq w_{mr}^S + w_{fr}^S p_{fr} \\ l_r + p_{fr} t_w + t_k(\mathbf{N}_r, p_{fr}) &= 1 \\ p_{fr} &\in \{0, 1\} \\ q_r &\in \{0, 1\} \quad \text{for } r \leq T_f \\ q_r = 0 &\quad \text{if } p_{fr} = 1, \quad n_{r-1} = n_{max}, \quad \text{or } r > T_f \end{aligned} \quad (5)$$

where t_w denotes the length of the work week⁹ and \mathbf{N}_r is a vector of dimension $(1 + n_{max})$, where n_{max} denotes maximum feasible number of children. \mathbf{N}_r represents the number and birth date of children at time r . That is, $\mathbf{N}_r = (n_{r-1} + q_r, (a_{sr})_{r=1}^{n_{max}})$, where a_{sr} is the date of birth of child s ; if child s is not born, $a_{sr} = 0$. We assume that women who have a child in period $t \leq T_f$ have to spend at least one year with their child and cannot work during that time. That is, we rule out $(p_{ft}, q_t) = (1, 1)$ as a possible choice. Finally, the functions $g_k(\mathbf{N}_r, p_{fr})$ and $t_k(\mathbf{N}_r, p_{fr})$ denote the goods and time cost of

⁹Women make employment decisions only at the *extensive* margin. In particular, we do not allow them to choose how many hours to work when they participate. See Jones et al. (2003) or Caucutt et al. (2002) for a model where women make labor supply decision at the *intensive* margin.

children at time r .

Costs of Children: We adopt a parsimonious functional form for costs of children which allows for some substitution between goods and time costs.¹⁰ We assume that children are costly until age T_c and that time costs decrease with age of children. Specifically, we follow Hotz and Miller (1988) and write:

$$\begin{aligned} g_k(\mathbf{N}_t, p_{ft}) &= (g_1 + g_2 p_{ft}) n_t w_{mt}^S \\ t_k(\mathbf{N}_t, p_{ft}) &= \sum_{i=1}^{n_{max}} \rho^{t-a_i} (t_1 + t_2(1 - p_{ft})) \end{aligned} \quad (6)$$

with $g_i \in (0, 1)$, $t_i \in (0, 1)$, and $\rho \in (0, 1)$. Therefore, goods costs include a base cost, $g_1 n_t$, (expressed as a fraction of husband's income at time t) as well as an additional cost whenever the woman works, $g_2 n_t$. Examples of costs incurred when the woman works include market-provided child-care services, baby-sitting etc. Time costs decrease at rate ρ when children grow and women who do not work spend some extra time raising their children, $t_2 \sum_{i=1}^{n_{max}} \rho^{t-a_i}$.

Wages: The specification of wages plays an important role in our analysis. One important question when specifying life-cycle wages is whether returns to experience decrease with the level of accumulated experience or whether these returns decrease with age, independently of the level of experience.¹¹ In our baseline model, we assume that human capital is the number of years of experience accumulated so far, returns to experience decrease in the level of experience, h_{fr} , and that the return to that experience is increasing in education. This implies that the opportunity cost of children is very high for educated women and for women at the beginning of their life since all subsequent wages will be lower if they drop out of the labor force to have a child today.¹² We assume that time- t wage offers for women with education S are determined by the following Mincerian equation:

$$\log(w_{ft}^S) = \beta_0^S + \beta_1^S h_{ft} + \beta_2^S h_{ft}^2 + \epsilon_t^S \quad (7)$$

where ϵ_t^S is i.i.d over time and drawn from a beta distribution with support $[\underline{\epsilon}^S, \bar{\epsilon}^S]$ and parameters $(a_\epsilon^S, b_\epsilon^S)$. The law of motion for human capital accumulation is given by:

$$h_{ft+1} = h_{ft} + p_{ft} \quad (8)$$

¹⁰See Hotz and Miller (1988) for an estimate of time and goods costs of raising children. We review several formulations used in the literature in the Appendix.

¹¹Attanasio et al. (2004) and Olivetti (2005) assume that returns to human capital decrease with age but not the level of human capital. As it is the tradition in the labor literature, Eckstein and Wolpin (1989) and van der Klaauw (1996) assume that returns to human capital decrease with the level of human capital.

¹²The latter effect is even stronger with age dependent returns to experience because early years of forgone experience cannot be recovered later. We also ignore depreciation of human capital in the baseline formulation. We are currently working on a computationally tractable age dependent version of returns to experience. See Appendix for a review of wage formulations in the literature using life-cycle models.

Dynamic Program: We now write the maximization problem of the household as a dynamic program. The individual state of a household of type (S, γ, ν) consists of the following vector $(h_f, \mathbf{N}, \epsilon)$ where h_f denotes women's accumulated human capital, \mathbf{N} a vector summarizing the total number of children born and their age, and ϵ a productivity shock. Let $V_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}, \epsilon)$ be the maximum expected life-time utility of a household of type (S, γ, ν) in state $(h_f, \mathbf{N}, \epsilon)$ discounted back to period t . To make notation more readable, we omit the household type in what follows. During their fertile years, that is for period $t \leq T_f$, women must choose whether to participate in labor markets, and, if not, whether to have an extra child. The dynamic program for household of type (S, γ, ν) is given by:

$$\forall t \in \{1, \dots, T_f\},$$

$$V_t(h_f, \mathbf{N}, \epsilon) = \max_{(p_{ft}, q_t) \in \{(1,0), (0,1), (0,0)\}} U(c, l, n + q_t) + \delta E_t V_{t+1}(h'_f, \mathbf{N}') \quad (9)$$

subject to the budget and time constraints,

$$\begin{aligned} c + g_k(\mathbf{N}', p_{ft}) &\leq w_{mt}^S + w_f^S(h_f, \epsilon)p_{ft} \\ l_f + p_{ft}t_w + t_k(\mathbf{N}', p_{ft}) &= 1 \end{aligned} \quad (10)$$

the human capital accumulation function,

$$h'_f = h_f + p_{ft} \quad (11)$$

the earnings equation,

$$\log(w_f^S(h_f, \epsilon)) = \beta_0^S + \beta_1^S h_f + \beta_2^S h_f^2 + \epsilon \quad (12)$$

and the law of motion for children, \mathbf{N} ,

$$\begin{aligned} \mathbf{N}' &= \mathbf{N} \quad \text{if } q_t = 0 \\ \mathbf{N}' &= \mathbf{N} + (q_t, b_1, \dots, b_{n_{max}}) \quad \text{if } q_t = 1 \end{aligned} \quad (13)$$

where $b_{it} = t$ for $i = n + q_t$ and $b_{it} = 0$ for $i \neq n + q_t$. Once women are no longer fertile, that is for periods $t > T_f$, they only make decision about participation. Their dynamic program is given by:

$$\forall t \in \{T_f + 1, \dots, T\},$$

$$V_t(h_f, \mathbf{N}, \epsilon) = \max_{p_{ft} \in \{0,1\}} U(c, l, n) + \delta E_t V_{t+1}(h'_f, \mathbf{N}) \quad (14)$$

subject the budget constraint,

$$\begin{aligned} c + g_k(\mathbf{N}, p_{ft}) &\leq w_{mt}^S + w_f^S(h_f, \epsilon)p_{ft} \\ l_f + p_{ft}t_w + t_k(\mathbf{N}, p_{ft}) &= 1 \end{aligned} \quad (15)$$

and equations (11) and (12). Finally, we assume that agents have no bequest motives towards their children and that women start with 0 years of work experience. Therefore, the terminal condition is $V_{T+1} = 0$ for all possible individual states and $h_1 = 0$ for all household types.

Solution of dynamic program: We solve the above dynamic program using a standard backward induction procedure. We show that, for each household type, there exists a threshold productivity function, $\epsilon_t^*(h_f, \mathbf{N}; S, \gamma, \nu)$, such that women work if and only if $\epsilon_t \geq \epsilon_t^*(h_f, \mathbf{N}; S, \gamma, \nu)$. In the Appendix, we explain how we use the threshold productivity functions to calculate the expected value functions $E_t V_{t+1}$. The solution to the above dynamic program is a sequence of functions defined on the set of all possible individual states $(h_f, \mathbf{N}, \epsilon)$:

1. Value functions: $\{V_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}, \epsilon)\}_{t=1}^T$
2. Employment decision functions: $\{p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}, \epsilon)\}_{t=1}^T$
3. Fertility decision functions: $\{q_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}, \epsilon)\}_{t=1}^{T_f}$

Given the employment decision functions, we calculate participation and wage among households of type (S, γ, ν) with characteristics (h_f, \mathbf{N}) as:

$$p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) = \int_{\epsilon_t^*(h_f, \mathbf{N}; S, \gamma, \nu)} dB(\epsilon; a_\epsilon^S, b_\epsilon^S) \quad (16)$$

If $p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) > 0$ then,

$$w_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) = \frac{\int_{\epsilon_t^*(h_f, \mathbf{N}; S, \gamma, \nu)} e^{[\beta_0^S + \beta_1^S h_f + \beta_2^S h_f^2 + \epsilon]} dB(\epsilon; a_\epsilon^S, b_\epsilon^S)}{p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N})} \quad (17)$$

where $B(\epsilon; a_\epsilon^S, b_\epsilon^S)$ denotes the cumulative beta distribution of productivity shocks with given parameters a_ϵ^S and b_ϵ^S . Next, we define $\mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N})$ as being the measure of women of type (S, γ, ν) who have accumulated h_f years of work experience at the beginning of period $t \leq T$ and whose fertility characteristics are summarized by the vector \mathbf{N} . Given our assumption that women have to drop in the period where they have their children, the law of motion for $\mu_t(h_f, \mathbf{N})$ when women are fertile, that is for $t \leq T_f$, is given by:

- for $h_f = 0$: $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f, \mathbf{N})(1 - p_{ft}(h_f, \mathbf{N}))(1 - q_t(h_f, \mathbf{N})) + \mu_t(h_f, \mathbf{N} - 1)(1 - p_{ft}(h_f, \mathbf{N} - 1))q_t(h_f, \mathbf{N} - 1)$
- for $h_f = t - n$: $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f - 1, \mathbf{N})p_{ft}(h_f - 1, \mathbf{N})$
- for $h_f \in \{1, \dots, t - n - 1\}$:
 $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f, \mathbf{N})(1 - p_{ft}(h_f, \mathbf{N}))(1 - q_t(h_f, \mathbf{N})) + \mu_t(h_f - 1, \mathbf{N})p_{ft}(h_f - 1, \mathbf{N}) + \mu_t(h_f, \mathbf{N} - 1)(1 - p_{ft}(h_f, \mathbf{N} - 1))q_t(h_f, \mathbf{N} - 1)$

In the previous expression, we abused notation slightly and denote by $N - 1$ fertility characteristics of women who will have fertility characteristics \mathbf{N} in period $t + 1$ and who have a child in period t . Note also that since women have to drop in the period where they have their children, the maximum number of years of work experience accumulated up to the beginning of period t by a woman who has n children is equal to $t - n$. Moreover, given (S, γ, ν) and $(h_f, \mathbf{N} - 1)$, among those women whose $\epsilon_t < \epsilon_t^*(h_f, \mathbf{N}; S, \gamma, \nu)$, either all have a child or none, i.e. $q_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}, \epsilon) \in \{0, 1\}$.

Once women have completed their fertility, that is for $t > T_f$, the measures $\mu_t(h_f, \mathbf{N})$ evolve as follows:

- for $h_f = 0$: $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f, \mathbf{N})(1 - p_{ft}(h_f, \mathbf{N}))$
- for $h_f = t - n$: $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f - 1, \mathbf{N})p_{ft}(h_f - 1, \mathbf{N})$
- for $h_f \in \{1, \dots, t - n - 1\}$:
 $\mu_{t+1}(h_f, \mathbf{N}) = \mu_t(h_f, \mathbf{N})(1 - p_{ft}(h_f, \mathbf{N})) + \mu_t(h_f - 1, \mathbf{N})p_{ft}(h_f - 1, \mathbf{N})$

Aggregation: We now use the objects defined above to calculate average employment, wages, fertility levels, and timing of birth by education and for the aggregate. We assume that distributions of education, preference for leisure and for children are independent and denote by $f(a)$ their joint distribution with $a = (S, \gamma, \nu)$. These distributions are exogenous to the model and will be calibrated to match life-cycle participation and wages as well as fertility distributions. We first calculate the average employment of married women by education, $P_{ft}(S)$, and for the aggregate, P_{ft} . At any time $t \in \{1, 2, \dots, T\}$, we have:

$$P_{ft}(S) = \frac{\sum_{(\gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}{\sum_{(\gamma, \nu)h_f \mathbf{N}} \sum \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}$$

and

$$P_{ft} = \frac{\sum_{(S, \gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}{\sum_{(S, \gamma, \nu)h_f \mathbf{N}} \sum \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}.$$

Second, the average wage of married women by education, $W_{ft}(S)$, and for the aggregate, W_{ft} , is given by:

$$W_{ft}(S) = \frac{\sum_{(\gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) w_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}{\sum_{(\gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}$$

and

$$W_{ft} = \frac{\sum_{(S, \gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) w_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}{\sum_{(S, \gamma, \nu)h_f \mathbf{N}} \sum p_{ft}^{(S, \gamma, \nu)}(h_f, \mathbf{N}) \mu_t^{(S, \gamma, \nu)}(h_f, \mathbf{N}) f(S, \gamma, \nu)}.$$

Third, we denote by $m_i(S)$ the fraction of women with education S who have $i \in \{0, 1, \dots, n_{max}\}$ children in their life with $\sum_{i=0}^{n_{max}} m_i(S) = 1$ for all S . We have:

$$m_i(S) = \frac{\sum_{(\gamma, \nu)} \sum_{h_f} \sum_{N_i} \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_i) f(S, \gamma, \nu)}{\sum_{(\gamma, \nu)} f(S, \gamma, \nu)}$$

where N_i denotes all possible combinations for birthdate of children for women who have i children in their life. Similarly, we denote by m_i the fraction of women who have $i \in \{0, 1, \dots, n_{max}\}$ children in their life with $\sum_{i=0}^{n_{max}} m_i = 1$. We have $m_i = \sum_{(S, \gamma, \nu)} \sum_{h_f} \sum_{N_i} \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_i) f(S, \gamma, \nu)$. Given the last two distributions, we can easily calculate completed fertility of married women by education, $n(S) = \sum_{i=0}^{n_{max}} m_i(S) i$, and for the aggregate $n = \sum_{i=0}^{n_{max}} m_i i$.

Finally, we calculate the average age at birth of first child by number of children for the aggregate and by education. Let $a_i(S)$ denote the age at birth of first child among women who have i children in their life-time and with education S . We have:

$$a_i(S) = \frac{\sum_{(\gamma, \nu)} \sum_{h_f} \sum_j \sum_{N_{ij}} j \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_{ij}) f(S, \gamma, \nu)}{\sum_{(\gamma, \nu)} \sum_{h_f} \sum_j \sum_{N_{ij}} \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_{ij}) f(S, \gamma, \nu)}$$

where N_{ij} denotes all possible combinations for birthdate of children for women who have i children in their life and have their first children in period j . Similarly, the average age at birth of first child among women who have i children in their life-time, a_i , is determined by:

$$a_i = \frac{\sum_{(S, \gamma, \nu)} \sum_{h_f} \sum_j \sum_{N_{ij}} j \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_{ij}) f(S, \gamma, \nu)}{\sum_{(S, \gamma, \nu)} \sum_{h_f} \sum_j \sum_{N_{ij}} \mu_{T_f}^{(S, \gamma, \nu)}(h_f, N_{ij}) f(S, \gamma, \nu)}.$$

The model we just described is too complex to derive interesting quantitative results analytically. In the next section, we use a simulated method of moments to calibrate the model to match the life-cycle participation and wages of married women of the 1940 cohort as well as their completed fertility distributions and age at birth of first child. We then simulate a calibrated version of the model to assess the effects of a decrease in gender wage gap and improvement of the home technology on life-cycle decisions of women.

6 Calibration of the baseline model: 1940 cohort

Preliminary and Incomplete

We calibrate the model to match the life-cycle employment and wages of married women of the 1940 cohort as well as their completed fertility. That is, we chose parameters to minimize the distance between data moments and the corresponding model moments. So far we calibrated to the data for College educated women only. One period in our model is equal to one calendar year. We assume that women finish college at age 22, are fertile between the age 23 to 40, that is $T_f = 18$, and live until age 50, i.e. $T = 28$. From data, we chose the following moments: life-cycle participation rates between age 23 to 50, $\{p_{ft}^d\}_{t=23}^{50}$, women's wages, $\{w_{ft}^d\}_{t=23}^{50}$, husband's wages, $\{w_{ht}^d\}_{t=23}^{50}$, and the distribution of completed fertility $\{m_i^d\}_{i=0}^4$. We denote by χ the vector of parameters to be set or estimated. It includes parameters for preferences $(\sigma_c, \sigma_l, \sigma_k, \psi)$, the discount factor, δ , the work week length t_w , costs of children $(g_1, g_2, t_1, t_2, \rho)$, women's wage coefficients $(\beta_0, \beta_1, \beta_2)$, distribution of preferences for leisure, $(\underline{\gamma}, \bar{\gamma}, a_\gamma, b_\gamma)$, distribution of preferences for children, $(\underline{\nu}, \bar{\nu}, a_\nu, b_\nu)$, distribution of productivity shock $(\underline{\epsilon}, \bar{\epsilon}, a_\epsilon, b_\epsilon)$, and husbands wages $\{w_{ht}\}_{t=1}^T$.¹³

We use various outside sources and data to pin down some parameters. First, since husbands's wages are exogenous in our model, we read them directly from data, that is, $w_{ht} = w_{ht}^d$ for all $t \in \{1, \dots, T\}$. Second, the real business literature assumes a value of 0.98 for the discount factor (see Cooley et al. (1995)). Since CPS data are collected annually rather than quarterly, we set the discount factor, δ , to be equal to $0.92 = 0.98^4$. Third, we calibrate the work week length, t_w . From time use data (see Hill and Stafford (1980)) individuals sleep on average 8 hours a night and devote 2 hours to eating, which leaves 98 hours (7×14) to allocate to work, child care, and leisure in a week. We assume that the length of the workweek is 40 hours. Therefore, $t_w = \frac{40}{98} = 0.42$.¹⁴ Fourth, we use a study by Hotz and Miller (1988) to determine cost of children parameters, $(g_1, g_2, t_1, t_2, \rho)$. Hotz and Miller (1988) estimate time and goods costs of children and find that maternal time input decreases with the age of children. We take their estimates and set $\rho = 0.89$, $t_1 = 0.2$, and $t_2 = 0.04$. Moreover, Bernal (2004) estimates goods costs of children, including child care costs. She finds that, depending on child care arrangements, these costs vary a lot. Accordingly, we fix $g_1 = 0.09$ and $g_2 = 0.02$ in our baseline model. Finally, we set $(\underline{\gamma}, \bar{\gamma})$, $(\underline{\nu}, \bar{\nu})$, and $(\underline{\epsilon}, \bar{\epsilon})$, so that the support of preferences distribution and productivity shocks is wide enough (see Table 5 below).¹⁵

We chose the remaining 13 parameters to minimize the distance squared between the moments from the model and their data counterpart. Therefore, our system is over-identified since we match 59 moments (28 years of employment rates, 28 years of average wages and average fertility) using 13 parameters. The

¹³Remember that we assumed that preferences for leisure, γ , preferences for leisure, ν , and productivity shock, ϵ_t , are distributed according to a beta distribution. Therefore, we need four numbers to characterize these distributions: two to fix the support, and two more to determine the other moments of the distribution. For example, we denote by $[\underline{\gamma}, \bar{\gamma}]$ the support for preferences for leisure and its distribution parameters by (a_γ, b_γ) .

¹⁴Greenwood et al. (2004) do not consider eating time and estimate t_w to be equal to 0.36.

¹⁵Following Tauchen (1986), we use a discrete approximation of the beta distribution with 50 points.

estimated values for parameters, $\hat{\chi}$, for our baseline model is determined by the solution to the following equation:

$$\hat{\chi} = \underset{\chi}{\operatorname{argmin}} \left\{ \sum_{t=1}^T [(p_{ft}(\chi) - p_{ft}^d)^2 + (w_{ft}(\chi) - w_{ft}^d)^2] + \sum_{i=0}^5 (m_i(\chi) - m_i^d)^2 \right\} \quad (18)$$

and is summarized in Table 5 below. Notice that our estimates for women’s wage equations are comparable to those found previously in the literature, e.g. Eckstein and Wolpin (1989) or Eckstein and Nagypal (2004).

Table 5: Baseline Parameter Estimates

$\sigma_c = 1.50$	$g_1 = 0.09$	$\beta_0 = 5.2720$	$\underline{\epsilon} = -0.9$	$\underline{\gamma} = 0.022$	$\underline{\nu} = 18.32$
$\sigma_l = 1.66$	$g_2 = 0.02$	$\beta_1 = 0.0195$	$\bar{\epsilon} = 0.9$	$\bar{\gamma} = 0.031$	$\bar{\nu} = 48.61$
$\sigma_k = 1.95$	$t_1 = 0.1$	$\beta_2 = -0.0026$	$a_\epsilon = 3.06$	$a_\gamma = 7.43$	$a_\nu = 3.37$
$\psi = 63.30$	$t_2 = 0.04$	$t_w = 0.42$	$b_\epsilon = 4.94$	$b_\gamma = 2.62$	$b_\nu = 4.10$
$\delta = 0.92$	$\rho = 0.89$				

In Figure 6, we show life-cycle employment and wages as well as distribution of fertility and age at birth of first child comparing model and data.

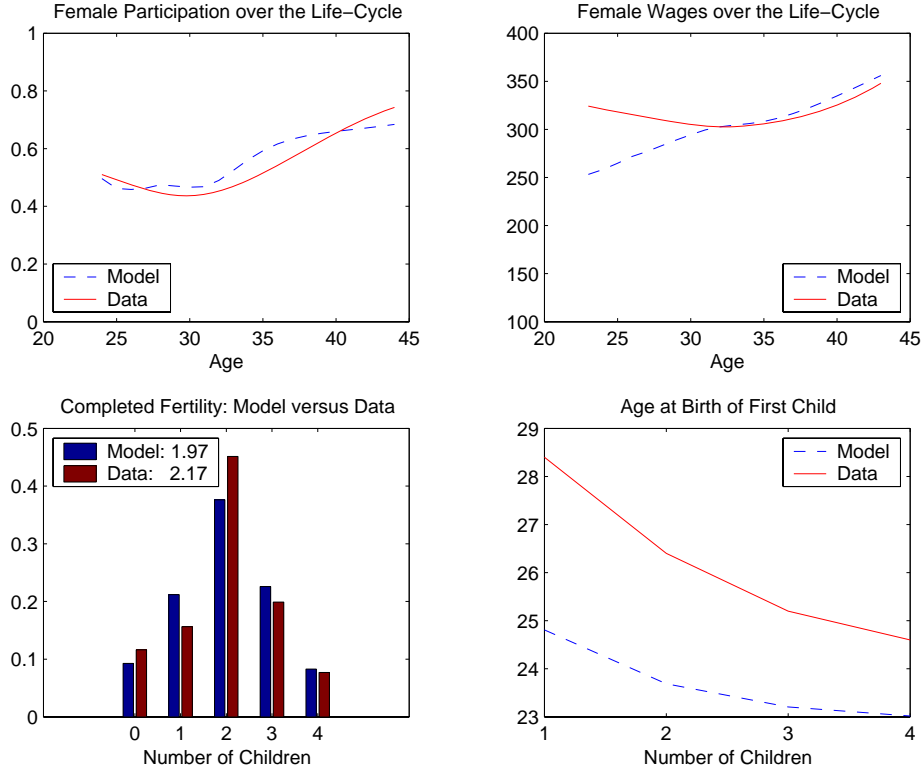
In terms of participation and distribution of completed fertility, the model fits nicely with data. Notice that even if the distribution of completed fertility is not exactly on, the average fertility level is very close to that in the data. Wages are too low at the beginning but fit nicely after age 30.

Our model fails to match one important moment from the data, namely the average age at birth of first child. It is consistently lower in our model than it is in the data. We believe this happens because all women get married at age 23 in our model. Since age at birth of first child and age at marriage are highly correlated in the data, allowing women to marry at different points of their life (after 23) will increase the average age at birth of first child. This would require formulating a theory of why people get married and how the marriage market is affected by changes in the economic/social environment.

Finally, the model reproduces the qualitative patterns of the cross sections presented in Section 4. Both wages and participation by number of children are decreasing. However, the model predicts a slope less steep than the one observed in the data. As can be seen in the left bottom panel of Figure 6, age at birth of first child is decreasing in completed fertility.

In the next section, we simulate a calibrated version of the model and assess the impact of a decrease in the exogenous gender wage gap and decreased child care costs on life-cycle decisions of married women.

Figure 6: Calibration Results



7 Changes in married female employment and fertility: experiments

Throughout the paper, we emphasize that changes in participation between the 1940 and 1960 cohorts of married women were the largest before age 36. We now compare predictions of the model to the data. For each cohort $c \in \{1940, 1960\}$, we calculate the "average" participation for three age groups $A \in \{(23, \dots, 45), (23, \dots, 35), (36, \dots, 45)\}$ in the data, denoted by $P_c^d(A)$. We then calculate those averages (1) from the baseline calibration, which are to be compared to the 1940 cohort, $P_{1940}^{base}(A)$, (2) after decreasing the gender wage gap (experiment 1), $P_{1960}^{exp1}(A)$, and (3) after decreasing child care costs (experiment 1), $P_{1960}^{exp2}(A)$. The formulas are given by:

$$\begin{aligned}
 P_c^d(A) &= \frac{1}{card(A)} \sum_A p_c^d(a), & P_{1940}^{base}(A) &= \frac{1}{card(A)} \sum_A p_{1940}^{base}(a), \\
 P_{1960}^{exp1}(A) &= \frac{1}{card(A)} \sum_A p_{1960}^{exp1}(a), & P_{1960}^{exp2}(A) &= \frac{1}{card(A)} \sum_A p_{1960}^{exp2}(a),
 \end{aligned} \tag{19}$$

where $p_c^i(a)$ denotes participation rates of cohort c at age $a \in A$ predicted by the baseline model, after experiment 1, 2 and in the data. In Tables 6 and 7, we report changes in participation between the 1940 and 1960 cohort both in the data and in the model by:

$$\begin{aligned}\Delta P^d(A) &= P_{1960}^d(A) - P_{1940}^d(A), \\ \Delta P^{exp1}(A) &= P_{1960}^{exp1}(A) - P_{1940}^{base}(A), \\ \Delta P^{exp2}(A) &= P_{1960}^{exp2}(A) - P_{1940}^{base}(A)\end{aligned}\tag{20}$$

7.1 Experiment 1: a drop in the gender wage gap

7.1.1 Approximating using singles

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Contrary to married women, single women have not changed their participation behavior (nor hours worked (see Jones et al. (2003))) across cohorts born between 1940 and 1960 in any significant way. Therefore one can argue that their wages are exempt from changes in accumulated experience. We have performed several measures of the singles' wage gap to men's wages by education, age and controlling for hours worked and, basically find that it has decreased uniformly across these groups. We therefore feel comfortable to use their time series of the exogenous gender wage gap in the experiment below.

7.1.2 The experiment

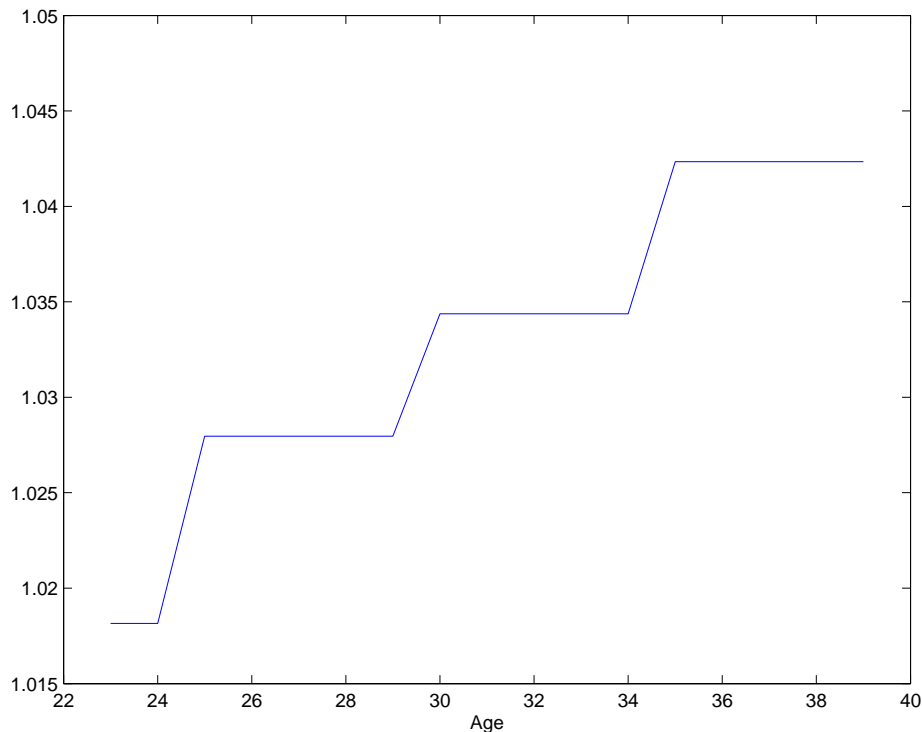
In Jones et al. (2003) a drop in the exogenous gender wage gap of 6% from 1950 to 2000 induces the entire increase in married female hours worked. We use their time series to infer how the wage equation (estimated before) changes from the 1940 to the 1960 cohort. That is, we assume that the 1940 cohort was facing the wage gap from 1963 to 1980 (age 23 to 40), while the 1960 cohort faced the lower wage gap from 1983 to 2000 (age 23 to 40). For example, let $w_{ft} = (1 - \tau_t)w_{mt}$ and $w_{mt+20} = w_{mt}$, then $w_{ft+20} = \frac{(1 - \tau_{t+20})}{(1 - \tau_t)}w_{ft}$. The induced index, $\frac{(1 - \tau_{t+20})}{(1 - \tau_t)}$, by which we multiply wages for the 1960 cohort ranges from 1.02 to 1.04 and is plotted in Figure 7.

As reported in Table 6, we find that changes in the gender wage gap capture slightly less than half of the increase in life-time participation, about one fourth of the increase before age 36 and slightly overshoot after age 36.

A closer look through Figure 8, which shows results from this experiment for life-cycle participation and wages, the distribution of completed fertility and age at birth of first child, reveals the main channel through which the wage gap change is affecting life-cycle participation in our model. First, notice that the average wage at age 23 is unchanged. Recall that we assume that all women start with experience $h_f = 0$. Therefore, at age 23 within any (γ, ν) type for

¹⁶see Buttet and Schoonbroodt (2005) for a detailed description of the facts about single women summarized here.

Figure 7: Time series of the change in gender wage gap index



which $\epsilon^* \in (\underline{\epsilon}, \bar{\epsilon})$ exists (i.e. participation is positive), the reservation wage does not change, because no preference or cost fundamentals have changed. However, it now takes a lower temporary shock, ϵ_{23} , for a woman to decide to work. That is, ϵ_{23}^* decreases, the average accepted wage stays constant and participation increases for every type - and therefore overall. As life goes on, the change in participation becomes larger and larger. This is due to the increase in accumulated experience: by the same rationale as before, ϵ_t^* decreases more and more.

Now let us turn to the fertility variables. Fertility levels as well as age at birth of first child are roughly unchanged. How is this compatible with increased participation since women have to drop out the year they have a child? It results from the fact that within (γ, ν) type, most women have their children at the same time, i.e. little heterogeneity in fertility decisions is strictly related to temporary shocks. Therefore an increase in the wage gap can only have a very limited effect of fertility levels and timing. All the change in participation comes from women who are not having a child this period. The change is larger, the fewer children the woman has accumulated so far since participation induces an extra goods cost to be borne. That is ϵ^* decreases by more the fewer children the women has so far.

Table 6: Changes in Participation: Model versus Data - Experiment 1

	Data	Model
Age 23-45	0.21	0.09
23-35	0.29	0.07
36-45	0.11	0.12

Two remarks are in order. First, while in Jones et al. (2003) human capital may include any kind of investment (e.g. education, experience, unobserved investments) in our model the only human capital investment is experience. The education decision as well as unobservable human capital investments are absent from our model. We cannot assess the importance of unobserved human capital. However, for education a simple accounting exercise shows that 8 percentage points of the overall 31 percent change in married women’s participation can be accounted for by higher levels of education, when participation by education level is held fixed.¹⁷ Moreover, average years of schooling has increased among College educated women themselves.¹⁸ We have not calibrated to other education groups so far and endogenizing the schooling choice is beyond the scope of this paper.

Finally, due to increased accumulated experience, wage profiles increase slightly faster after age 36.

7.2 Experiment 2: reduction in child care costs

In Greenwood et al. (2004) the cost of adopting the new technology drops from 18 percent of the efficiency wage in 1963 to 3.5 percent in 1983. They allow their agents to borrow and lend, which we prohibit. We therefore spread the cost of children over the first 23 years of their life and perform the experiment where g_2 drops to one fifth for the 1960 cohort of what it was for the 1940 cohort.

Table 7: Changes in Participation: Model versus Data - Experiment 2

	Data	Model
Age 23-45	0.21	0.06
23-35	0.29	0.05
36-45	0.11	0.07

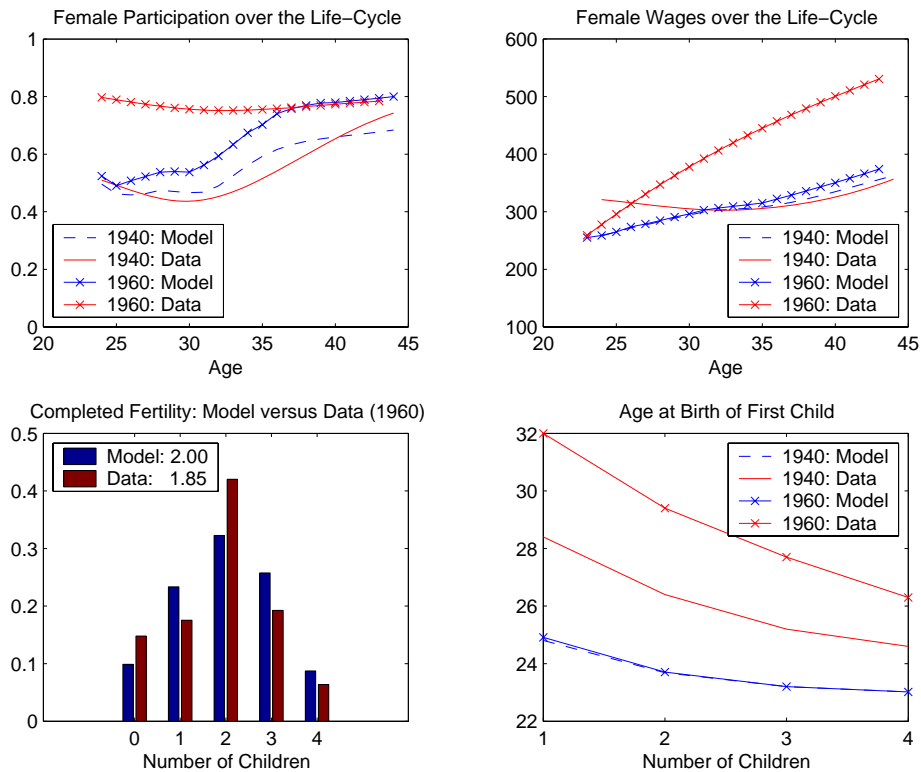
As reported in Table 7, we find that changes in child care costs capture about one third of the increase in life-time participation, about one sixth of the increase before age 36 and three fourth of the change after age 36.

Again, Figure 9 shows results from this experiment for life-cycle participation and wages, the distribution of completed fertility and age at birth of first child. The reservation wage argument from the first experiment can be made again.

¹⁷See Buttet and Schoonbroodt (2005) for details.

¹⁸See Goldin and Katz (2002)

Figure 8: Experiment 1: changes in gender wage gap



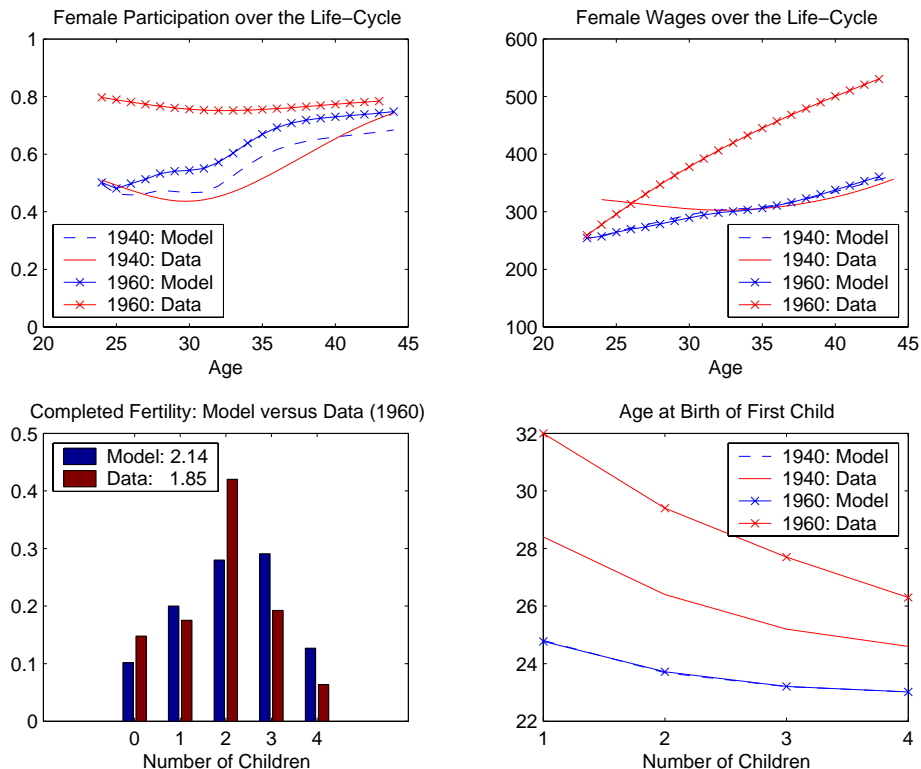
However, only the ϵ^* of women who have had children in the past decreases. This explains why participation at age 23 is unchanged.

In terms of fertility, the effect of a decrease in g_2 differs from the decrease in the gender wage gap in the following sense: while the gender wage gap makes leisure and children (due to the drop out requirement) more expensive, a decrease in child care costs makes children more affordable and the option of working right after childbearing more attractive (the additional time cost is unchanged but providing that time through the market is now relatively more affordable). Therefore, in this example fertility levels actually increase a little bit. Average timing is unchanged once again. Also, there is no perceptible change in wage profiles.

8 Concluding Remarks and Extensions

In this paper, we addressed changes in employment, fertility, and wages of women born between 1940 and 1960. We first documented that levels and

Figure 9: Experiment 2: reduction in child care costs



changes in these variables were very different across ages and education: changes were most pronounced at early ages and high education levels. In order to quantitatively assess the importance of existing theories along the life-cycle and in relation to fertility, we built a life-cycle model of married women's participation and child related decisions where specific choices are motivated by several cross-sectional facts, though limited by computational tractability. All in all, though, we trust the model in being able to give reliable results in the quantitative experiments we perform. There are, however, several lines along which we are currently further improving the model:

1. *Substitute heterogeneity in preference for leisure (γ) with permanent wage heterogeneity (β_0).* This has two advantages. First, we can match the distribution of observed wages to the model, while preference for leisure is not even observable when people decide to work. Second, all variability in wages in the model currently comes from i.i.d. shocks every period. If we were to match the wage distribution (over and above the average), this would basically imply that a secretary could become a doctor next year and drop back to being a secretary the year after. Ideally, we would want

to model shocks as partially correlated along the life-cycle. Given the large state space, however, this would be a large computational burden.

2. *Change the wage function to allow for age dependent payoffs from experience.* We are currently working on the following specification:

$$\log(w_{fa}) = \beta_0 + (\beta_1 + \beta_2(a - S))h_{fa} + \epsilon_t \quad (21)$$

where a denotes age. First, note that this specification is just a quadratic in h , if the person works all the time ($h_a = (a - S)$) which fits the male profile quite well. Second, from Olivetti (2005)'s estimates, returns to experience appear to *be* negatively age dependent. Third, negative age dependence in returns to experience (i.e. $\beta_2 < 0$) will increase the opportunity cost of dropping out when young, since once foregone, those returns can never be recovered. Finally, note that while with age and experience level dependent *wages* as shown here, many employment paths along the life-cycle lead to the same state h later in life, with age dependent *accumulation* of human capital, the number of possible states increases exponentially. Given the large state space and number of periods, this becomes an almost insurmountable computational problem.

3. *Change the utility function to allow for more complementarity between consumption, children and leisure.*

Once these changes have been implemented, we intend to perform at least two further experiments:

1. Once the wage equation has been changed, we can use Olivetti (2005)'s estimates of changes in returns to experience and assess their quantitative importance in our setting with endogenous fertility and timing of births.
2. Once the utility specification has been changed, we want to perform several experiments changing preferences. We are aware of the difficulties of this kind of exercise. First, it is hard to know what changing preferences may mean. Second, it is difficult to find a discipline since clearly, preferences are not 'measurable' per se. However, we still think that these experiments can be informative. That is if effects produce changes in line with the data along many dimensions, the experiments point into a direction of where to look for explanations. The 'discipline' we intend to impose is to change preferences for children in such a way that, given all changes in prices, changes in fertility are perfectly matched. Then compare the results in terms of participation, age at birth of first child, participation by number of children, and wages.

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9 Appendix

Important ingredients of our model include the functional form for costs of children, how women accumulate human capital, and how their wage is determined as a function of their human capital. In the two sections below, we review the review the literature on cost of children and human capital accumulation.

9.1 Costs of children in the literature:

- Hotz and Miller (1988):
 - goods: $\sum \psi_k b_{i,t-k}$
 - time: $\sum \gamma_k b_{i,t-k}$
 - The hypothesis that $(\gamma_k, \psi_k) = (\gamma_1 \delta^{k-1}, \psi_1)$ cannot be rejected (see unrestricted estimation results in Table II).
 - note 1: Espenshade (1984) find that goods costs rise with age of children.
 - note 2: Using time diaries, Hill and Stafford (1980) find that maternal time devoted to child care declines as the children age.
- Eckstein and Wolpin (1989):
 - goods vs time (indistinguishable): fixed cost of working $p_t b$, set to 0 in estimation, variable cost of working, i.e. depending on number and age of children, $p_t \sum \alpha_{4j} N_{tj}$, goods cost independent of employment decision, $\sum \alpha_{4j} N_{tj}$, c_j set to 0 in estimation.
- Attanasio et al. (2004):
 - goods: utility function is equalized by e_t which depends on age and number of children.
 - time: Hotz and Miller (1988) in terms of functional form $G(a_t) = \theta \phi^{a_t-1}$, all children have the same age, price p translates time into goods, so that $F(a_t) = pG(a_t)$ is a fixed cost of working (because someone else has to spend the time for which they have to pay), no leisure cost of children, but utility cost of participating.
 - note 1: everybody exogenously has 2 children that are "twins" (same age)
 - note 2: basically, costs same as in Eckstein and Wolpin (1989) except that there is only 1 age group.

9.2 Human capital Accumulation

There are several issues when modeling life-cycle wages. First, some researchers assume that returns to experience are decreasing in the *level of human capital* (e.g. Eckstein and Wolpin (1989), van der Klaauw (1996)), while others assume that returns to experience are decreasing in *age* (e.g. Olivetti (2005), Attanasio et al. (2004)). Furthermore, some assume depreciation of human capital and some don't (e.g. Eckstein and Wolpin (1989)). Some assume that depreciation depends on past employment and some assume it doesn't (e.g. Olivetti (2005)). Employment dependent depreciation is assumed to be temporary by some (e.g. van der Klaauw (1996)), permanent by others (e.g. Mincer and Polachek (1974) and Mincer and Olfek (1982)) or both (e.g. Attanasio et al. (2004)).

Once we decide on how to model wages, there are also computational issues. For instance, having depreciation increases the number of values experience can take on, so we would probably have to use a grid and not calculate it for every possible path and value of human capital. Or reduce the number of periods.

9.2.1 Eckstein and Wolpin (1989)

$$\begin{aligned}
 \ln y_t^w &= \beta_1 + \beta_2 K_{t-1} + \beta_3 K_{t-1}^2 + \beta_4 S + \epsilon_t + u_t \\
 \epsilon_t &\sim N(0, \sigma_\epsilon^2) \\
 u_t &\sim N(0, \sigma_u^2) \\
 K_t &= K_{t-1} + p_t
 \end{aligned} \tag{22}$$

where ϵ_t is a temporary idiosyncratic shock and u_t is measurement error.

They find (p.384, Table IV): (using data on employment and wages to identify all ϵ_t^* , (β_i) and (σ_j) from NLSY mature women's cohort.)

$$\begin{aligned}
 \beta_1 &= -0.280 \\
 \beta_2 &= 0.024 \\
 \beta_3 &= -0.0002 \\
 \beta_4 &= 0.05 \\
 \sigma_\epsilon &= -0.280 \\
 \sigma_u &= -0.280
 \end{aligned}$$

They estimate the hourly wage function, then multiply the hourly wage by 2000 to get annual earnings. Thus the annual earnings function has $\beta_1' = \beta_1 + \ln 2000$. To calculate husband's expected (real) earnings, they run a logarithmic husband's earnings regression which contained a linear and a quadratic term in husband's age, an individual-specific constant and a schooling-age interaction.

9.2.2 Olivetti (2001)

Human capital accumulation function and wages:

$$\begin{aligned}
 \theta_{i,t+1} &= ((1 - \delta) + \eta(a_{it})n_{it}^\phi)\theta_{i,t}\epsilon_{i,t+1} \\
 \eta(a_{it}) &= \eta_0 + \eta_1 a_{it} + \eta_2 a_{it}^2
 \end{aligned} \tag{23}$$

Wages are human capital times the rental rate:

$$w_{i,t} = \theta_{i,t} R_t$$

$$\ln w_{i,t+1} = \ln w_{i,t} + \ln \frac{R_{t+1}}{R_t} + \ln((1 - \delta) + \eta(a_{it})n_{it}^\phi) + u_{i,t+1} + \nu_{i,t+1} \quad (24)$$

Fixing $\delta = 0.2$ and $\phi = 0.4$, she finds (for females using PSID data, see p.10):

For the 1970s:

$$\begin{aligned} \eta_0 &= 0.0114 \\ \eta_1 &= -1.19e - 04 \\ \eta_2 &= -6.29e - 07 \end{aligned}$$

For the 1990s:

$$\begin{aligned} \eta_0 &= 0.0143 \\ \eta_1 &= -1.89e - 04 \\ \eta_2 &= -7.43e - 07 \end{aligned}$$

We wanted to use this for our average and do the following:

$$\bar{w}_{t+1} = \bar{w}_t \frac{R_{t+1}}{R_t} ((1 - \delta) + \eta(a_t)\bar{n}_t^\phi) \quad (25)$$

or

$$\bar{w}_{t+1}^d = \bar{w}_t^d ((1 - \delta) + \eta(a_t)\bar{n}_t^\phi) \quad (26)$$

where \bar{w}_t ($\bar{w}_t^d = \frac{\bar{w}_t}{R_t}$) would be the average weekly wage (d meaning detrended) for 1950 cohort at time $t + 1$ since that's last years wages, R_t would be our wage index, a_t age of 1950 cohort at time $t - 20$ years (to follow her definition) and, \bar{n}_t annual hours for 1950 cohort at time t (i.e. multiply average weeks worked in $t + 1$ since that's last year's weeks, by average hours worked last week) to see how well it predicts future wages.

We used the human capital accumulation function and the assumption as to how it translates into wages. Using her parameters for η 's, ϕ and δ , and two different ways to calculate the wage index (all (age 23 to 65) workers' wages by year and, only male workers' wages) to get the following predicted versus observed wages for males and females. And they look promising, given that she uses PSID data and this is a prediction for CPS data for a particular cohort (1950) of married women.

9.2.3 Attanasio, Low and Sanchez-Marcos (2004)

$$\begin{aligned} \ln y_t &= \ln y_0 + h_t - \delta_T I(P_{t-1} = 0) + v_t + \epsilon_t \\ \epsilon_t &\sim N\left(-\frac{\sigma_\epsilon^2}{2}, \sigma_\epsilon^2\right) \\ v_t &= v_{t-1} + \xi_t, \xi_t \sim N\left(-\frac{\sigma_\xi^2}{2}, \sigma_\xi^2\right) \\ h_t &= h_{t-1} + (\eta_0 + \eta_1 t) I(P_{t-1} = 0) - \delta_P h_{t-1} I(P_{t-1} = 0) \end{aligned} \quad (27)$$

Like Olivetti, age dependent returns to experience, not level dependent (t is age). (See Table of baseline parameter values and deviations from those p. 28 to 34)

$\delta_T = 0$ in baseline, temporary depreciation due to drop out, as estimated by van der Klaauw (1996)

$\delta_P = 0.02$, permanent depreciation due to drop out

ξ_t permanent shock

ϵ_t temporary shock

$\eta_0 = 0.065 > 0$

$\eta_1 = -0.00108 < 0$