Changes in Women's Employment Across Cohorts: The Effect of Timing of Births and Gender Wage Differentials

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Abstract

This paper studies the quantitative effects of changes in fertility patterns and relative wages, on changes in employment of married women born between 1940 and 1960. We explore three channels linking these factors to employment decisions in a life-cycle model with experience accumulation. First, because child-rearing is intensive in women's time, employment at childbearing ages increases as fertility is reduced. Second, if women have children later, they reach the childbearing age with more experience, thereby increasing their incentive to remain employed when having children. Third, a decrease in the gender wage gap, ceteris paribus, makes working more attractive, which feeds back on employment decisions later in life because of experience accumulation. After calibrating the model to the life-cycle facts characterizing the 1940 cohort, we find that the decrease in fertility levels has a minor effect on employment. However, the change in the timing of births has a large effect on employment very early in life, while relative wage changes affect employment increasingly with age. When taken together, these changes account for almost 90 percent of the increase in employment of married women throughout the life-cycle.

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1 Introduction

It is well known that labor supply of married women increased dramatically over the course of the 20th century. A less studied fact is that, for women born between 1940 and 1960, this increase was most pronounced before age 40. In particular, for married women with a college degree, employment increased by 30 percentage points between age 23 and 36, compared to 12 percentage points thereafter.

Since these are the ages at which women tend to have children, one natural hypothesis is that changes in employment are related to changes in fertility patterns such as number and timing of births. On average, college educated women born in 1960 have 0.5 fewer children over their life-time and have their first child more than 3 years later than women born in 1940.

Furthermore, employment increased substantially conditional on the number of children. Because of this, we also consider changes in the relative wage structure of women to men. From our decomposition, both wage levels and returns to experience increased dramatically.

These facts lead to the following question: how much of the increase in married female employment over the life-cycle can be accounted for by the decrease and delay in fertility and by changes in structure of female wages? To perform this quantitative exercise, we proceed in four steps.

First, from CPS and Census data we document the life-cycle and cross-sectional facts of married women born in 1940. These are life-cycle employment and average wage profiles, employment and wages by number of children at age 30 and 40 and the distributions of completed fertility and age at birth of first child by completed fertility.

Second, we build a forty period life-cycle model of participation and child-care decisions of married women with experience accumulation. Using the distributions in fertility patterns, we calibrate this model to the facts about employment and wages characterizing the 1940 cohort. The large number of periods allows us to report detailed effects of exogenous changes on employment by age.

To gain some intuition about the effects of changes in timing of births in our model, consider two women. The first one has children around age 25, while the second one has them around age 30. In their twenties, the second woman is unambiguously more likely to work than the first since children are costly in mother's time. In their thirties, however, there are two conflicting effects. First, since the second woman has accumulated more experience, she is more likely to work. Second, she is less likely to work because she has younger children at home.

Next, an increase in wage levels or returns to experience increases the opportunity cost of staying at home. Because of this, women are more likely to work at any given age. This is a static effect. Moreover, since households are forward looking in our model, wage increases in the future make experience accumulation more attractive today. Due to these two effects, women tend to have accumulated more experience later on, which in turn magnifies the original effects as they get older.

Third, we document changes in fertility patterns from Census data and in the relative wage structure from CPS data. We find that, besides the well known decrease in fertility levels, the distribution of age at birth of first child has widened and shifted towards later ages. Next, to measure changes in the relative wage structure of women to men, we use single women born in 1940 and 1960 as a reference group. This group of women exhibits life-cycle employment patterns that are very similar to men's and have not changed across cohorts. Using their wage profiles, we can therefore disentangle changes in wages due to changes in experience from those due to changes in exogenous variables. Since no Panel data set goes back in time far enough to analyze the whole life-cycle of women born in 1940, this is a useful and novel way to estimate these changes.

Finally, we perform several experiments using the observed changes in the explanatory variables. The model predictions are then compared to the data for the 1960 cohort. We find that none of the exogenous factors alone accounts for more than 50 percent of the change in employment over the entire life-cycle. In fact, changes in fertility patterns are most relevant before age 30, where they account for about one third of the change. Here, changes in timing of births play a particularly important role. Furthermore, changes in wage levels are more relevant for the increase in employment between age 30 and 36 (about one third). Last but not least, changes in returns to experience account for almost half of the change in employment at all ages. It is therefore surprising that when all changes are implemented jointly, they can account for almost 90 percent of the observed change in employment, which is more than the sum of the effects in the separate experiments. The reason for this result is that there are dynamic interaction effects working through experience accumulation. That is, the effect of relative wage changes is larger for women with higher accumulated work experience. Since the delay in fertility increases average work experience, the incremental effect of exogenous wage improvements are larger in the joint experiment. Conversely, if women anticipate higher wages in the future, a delay in fertility induces even more women to work early on.

Our work extends and complements the existing literature as follows. Several explanations for the long-run average increase in female labor supply have been analyzed in the literature, e.g. falling prices of home appliances (Greenwood, Seshadri and Yorukoglu (2004)), gender-biased technological change favoring women (Galor and Weil (2000)), exogenous changes in the gender wage gap (Jones, Manuelli and McGrattan (2003)). These papers cannot address the age specific changes in employment observed in the data. Another set of papers deals with the life-cycle pattern of female labor supply. First, Olivetti (2005) argues that increased returns to experience account for most of the change in life-cycle patterns of hours worked. Second, in a three period model, Caucutt, Guner and Knowles (2002) also show that increased returns to experience have an effect on female labor supply and timing of births. Third, Attanasio, Low and Sanchez-Marcos (2004) indicate that changes in child care costs account for most of the changes in life-cycle profiles across cohorts born between 1930 and 1950. None of these papers takes fertility related distributions into account. To calibrate to annual life-cycle employment rates for the 1940 birth cohort, we use detailed distributions of completed fertility and age at birth of first child by completed fertility. Within our framework, we find that changes in those distributions are very important to account for the increase in married women's employment, especially for young women.

Given these results, one open question is why fertility patterns changed. In Buttet and Schoonbroodt (2005a), we extend the present model and endogenize number and timing of births. We study the effect of changes in the wage structure documented here on fertility decisions. Preliminary results show that they potentially account for a significant fraction of the decrease and delay in fertility.

The paper is organized as follows. In the next Section, we briefly review the literature. In Section 3 we document the facts for women born between 1940 and 1960. Section 4 presents the model. In Section 5, we describe the calibration while Section 6 contains experiments and results. We conclude in Section 7.

2 A Brief Review of the Literature

The literature that studies the determinants of the increase in married women's labor supply is very abundant. Proposed explanations span from improvements in market opportunities favoring women over men (see Jones, Manuelli and McGrattan (2003) for wage levels, Olivetti (2005) and Caucutt, Guner and Knowles (2002) for returns to experience, Galor and Weil (2000) for gender-biased technological change favoring women), improvements in home technology (Greenwood, Seshadri and Yorukoglu (2004)), the decrease in child-care costs (Attanasio, Low and Sanchez-Marcos (2004)), the introduction of the pill (Goldin and Katz (2002)), or changes in social norms (Fernandez, Fogli and Olivetti (2004)), to name only a few. This paper argues that to understand the large increase in married women's employment between cohorts born in 1940 and 1960, the decrease and in particular the delay in fertility are crucial, and complementary to explanations based on improvements in market opportunities.

The facts about female labor supply have previously been addressed by McGrattan and Rogerson (2000) who analyze hours worked by age and birth cohort. The extensive margin, namely changes in life-cycle employment rates by education, are described in Buttet (2005). Changes in relative wages of men and women have been thoroughly analyzed before (see, for example, Blau and Kahn (2000) and O'Neill (2003)).[1] However, using wages of single women to approximate the change in wage levels and returns to experience is new in this paper.

Closely related quantitative exercises addressing the increase in hours worked are Jones, Manuelli and McGrattan (2003),Olivetti (2005) and Caucutt, Guner and Knowles (2002). First, Jones, Manuelli and McGrattan (2003) build a general equilibrium model with human capital accumulation and find that, due to specialization within married couples, a small change in the exogenous gender wage gap can generate large changes in hours worked by married women. We model one of these human capital investments explicitly, namely experience accumulation, in a forty-period life-cycle model. Second, in a four-period model, Olivetti (2005) studies the change in life-cycle profile of hours worked by married women between the 1970s and the 1990s and shows that changes in returns to experience can account for a significant

[1] See also Goldin (1990) for a historical description of the female labor force and the gender wage gap in earnings and occupations in the U.S. since 1890.

part of the increase in hours worked. Third, Caucutt, Guner and Knowles (2002) build a three-period model with endogenous fertility, timing of births, marriage and divorce. They show that changes in returns to experience have a significant effect on timing of births and hours worked by married women. Even though fertility is exogenous in the present framework, the large scale life-cycle model allows us to (1) match the whole life-cycle profile of employment rates using detailed distributions of completed fertility and age at birth of first child and (2) to assess the effect of changes in the entire distribution of age at birth of first child by completed fertility on employment of married women when young.

Our model is mainly based on Eckstein and Wolpin (1989) who estimate returns to experience for married women in a partial equilibrium, forty period and discrete choice life-cycle model. Our contribution here is to model the heterogeneity in fertility levels and timing of births to replicate the life-cycle profile of employment rates in detail, and to perform quantitative experiments across cohorts.

Another recent paper by Greenwood, Seshadri and Yorukoglu (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. They find 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. They do not, however, model experience accumulation or any other kind of human capital investment explicitly. Attanasio, Low and Sanchez-Marcos (2004) document changes in life-cycle participation for three cohorts of married women born in 1930, 1940, and 1950. Modelling women's participation and savings decisions over the life-cycle, they find that changes in the cost of children relative to life-time earnings are the most relevant change quantitatively. However, the importance of heterogeneity in fertility levels and timing of births cannot be addressed. Finally, in a recent paper, Erosa, Fuster and Restuccia (2005) document that the wage gap between men and women increase over the life-cycle and that the relatively low attachment of women in labor market 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 (through its disincentive to work and invest in human capital on the job) accounts for most of the gender differences in labor supply and wages between age 20 and

40. However, they do not consider changes across cohorts.

3 Data

In this section, we document the following facts for married women born between 1940 and 1960.[2] First, we describe life-cycle profiles of employment for these cohorts. We find that changes are the largest at childbearing ages (ages 23 to 37) and more modest at later ages. This leads one naturally to the hypothesis that changes in employment are related to the decrease in fertility levels (0.5 children per woman). Given this hypothesis, we describe employment by number of children at age 30 and find that (1) within cohorts it is decreasing but (2) across cohort it increased for any given number of children. The second of these two facts suggests that the decrease in fertility levels can only account for part of the change in employment when young (movement along the curve). We go on to document two factors that are potentially responsible for the increase in participation conditional on the number of children. These two factors are the delay in fertility and changes in the relative wage structure of women to men.

To measure the delay in fertility, we use age of mother at birth of first child. We find that this increased by more than 3 years on average.

The change in relative wages of women to men has been widely documented in the literature (e.g. Blau and Kahn (2000)). One weakness with this literature is that, in the absence of panel data, it is difficult to disentangle changes in wages due to changes in experience (a choice variable) from those due to changes in exogenous variables (e.g. discrimination). This is particularly relevant for married women, whose participation profile and hence experience changed so dramatically. To overcome this problem, we use single women as a reference group to document the change in both wage levels and the returns to experience. Since their employment profiles are very high, similar to men's and did not change much across cohorts, these observed changes in wages are not due to changes in experience. We find that returns to experience increased dramatically, while changes in the gender wage gap (levels) are more modest.

[2]All raw data was downloaded from Integrated Public Use Microdata Series (2004) available at http://www.ipums.org. A description of the data set and variables used and constructed can be found in the Appendix. Note that we limit our analysis to college educated women, where changes were the most pronounced.

3.1 Life-Cycle Employment of Married Women

In Figure 1, we present life-cycle employment rates for three cohorts of married women born in 1940, 1950, and 1960 using CPS data.[3] Although employment profiles have shifted upward across cohorts, the magnitudes of increases in women's employment vary a lot by age. For early cohorts, employment rates are low during childbearing ages (around 50% between age 23 and 35 for 1940 cohort) and progressively increase over the life-cycle, while they are high throughout the life-cycle for women born in later cohorts (around 80% for women born in 1960). As a result, the increase in employment of married women is the largest when young and more modest at later ages. Between the 1940 and 1960 cohort, employment of married women increased on average by 31 percentage points between age 23 and 35, compared to only 12 percentage points between age 36 and 50 (See Table 1 below). This fact is the focus of our analysis.

Table 1: Changes in Employment Rates of Married Women Across Cohorts by Age Group - Annual Percentage Point Difference

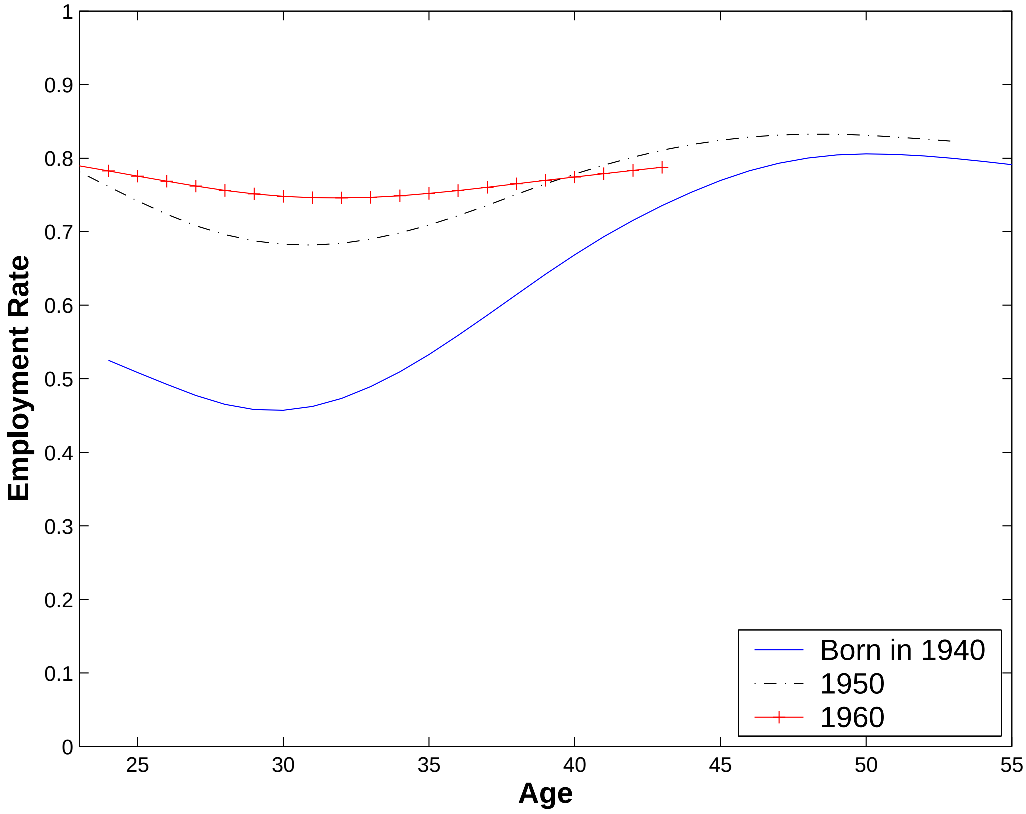
	Age 23-35	*Age 36-50*	*Age 23-50*
Annual Percentage Point Difference in Employment Rate: (1960 - 1940)	31	12	18

3.2 Employment by number of children

Two important facts come out of the above analysis: (1) employment rates of married women are typically the lowest at childbearing ages; and (2) increases in employment rates across cohorts have been the largest at childbearing

[3]Since we are interested in studying changes in life-cycle employment profiles across cohorts, and not so much fluctuations in employment due to business cycles, we take away the cyclical component from employment data by using the Hodrick-Prescott filter with smoothing parameter equal to 100 (see Ravn and Uhlig (1997)). See Appendix for a detailed description of this variable.

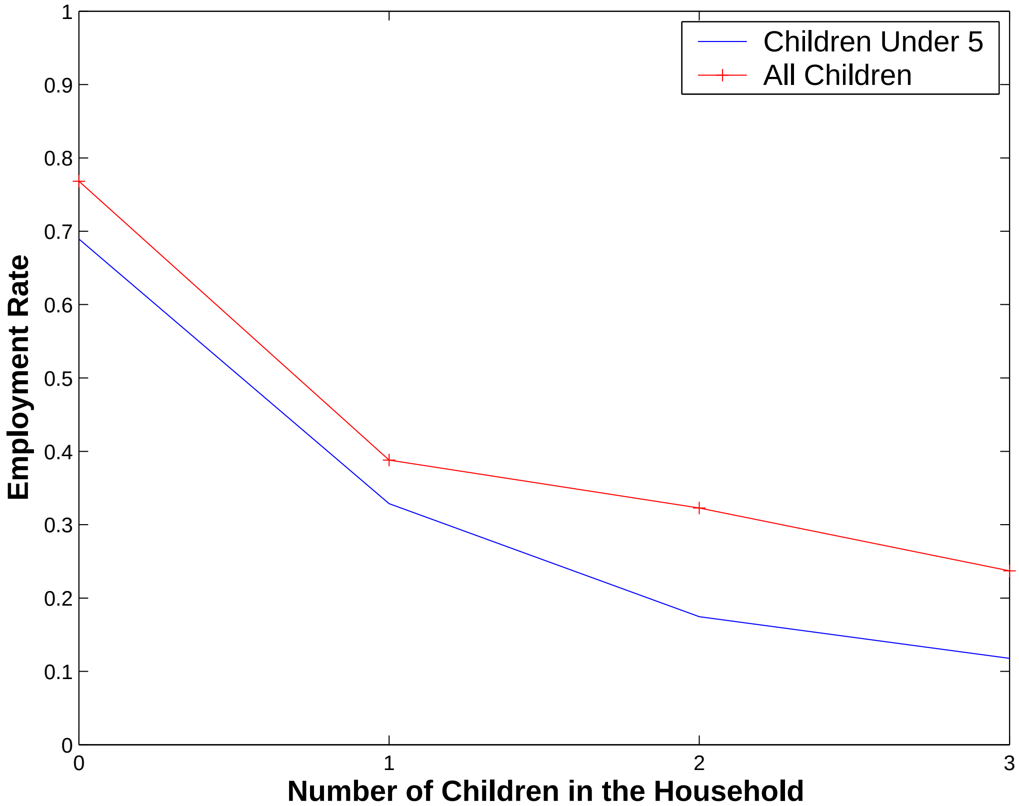
Figure 1: Life-Cycle Employment of Married Women by Cohort - College, White



ages. These two observations suggest that fertility is an important factor in a woman's decision of whether to work or not.

In Figure 2, we focus on married women born in 1940 and show employment rates at age 30 by number of children in the household, and by number of children age 5 and under. It is clear that women's employment is decreasing in the number of children and that this effect is stronger for the first child and when children are young. Therefore, holding this relationship constant, average employment at childbearing ages increases when women have fewer children. For college educated women born between 1940 and 1960, completed fertility decreased from 2.3 to 1.8 children per woman. Using this to perform a simple accounting exercise, we find that at most one third of the change in average employment at age 30 can come from a shift in the

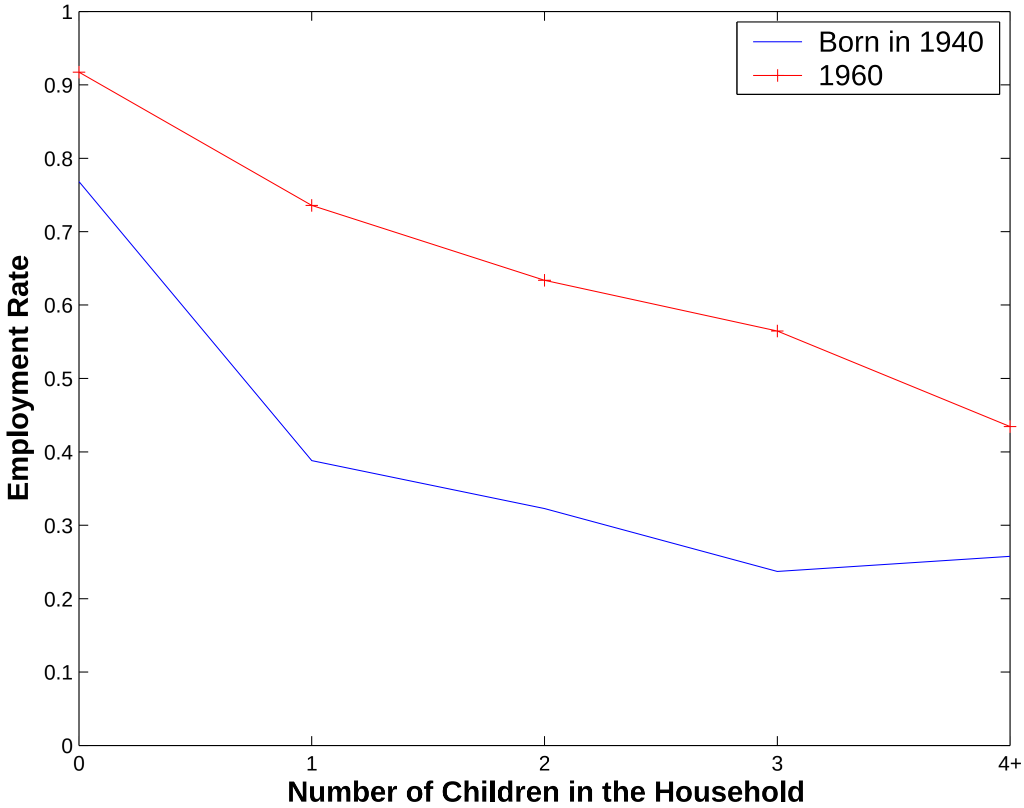
Figure 2: Employment of Married Women at Age 30 by Number of Children - 1940 Cohort (College, White)



distribution of number of children along this curve.

In addition, as shown in Figure 3 changes in employment conditional on the number of children across cohorts are close to the magnitudes observed on average. For women with at least one child, it amounts to about 30 percentage points. This fact suggests that a quantitatively successful exercise has to consider changes beyond fertility levels alone. In the remainder of this section, we focus on documenting two such variables. These are changes in the timing of births and changes in the structure of wages.

Figure 3: Changes in Employment Rates of Married Women at Age 30 by Number of Children Across Cohorts - College, White



3.3 Timing of Births

We use Census data for the years between 1980 and 2000 to describe age of mother at birth of first child, of married women born in 1940 and 1960. We consider women at age 40 assuming that fertility is close to completion at that age. We present summary statistics (average and standard deviation) of these two variables in Table 2 and plot the distribution of age at birth of first child in Figure 4.[4]

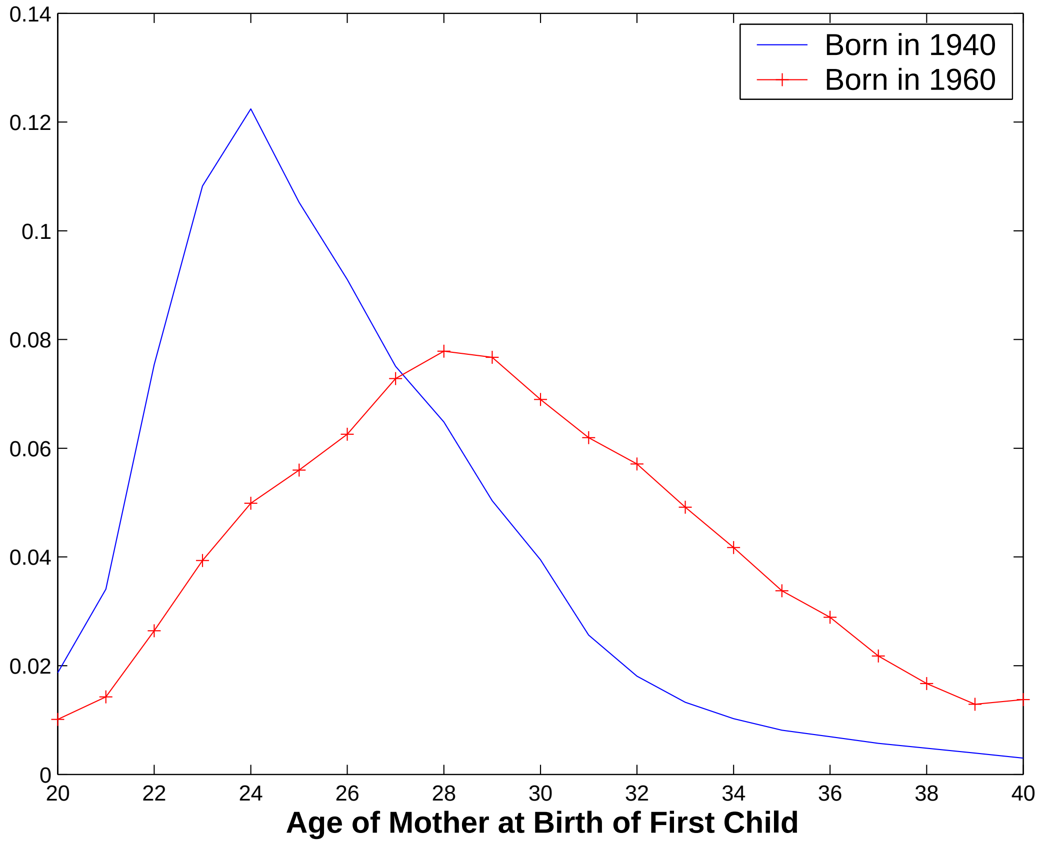
Between the 1940 and 1960 cohort, the average age of mother at birth of first child increased by more than three years. Moreover, the standard deviation of age at birth of first child has increased by almost 1 year.

[4]See Appendix for a detailed description of the data set.

Table 2: Completed Fertility and Timing of Births by Cohort - (Standard Deviation) - College, White

	Cohort 1940	Cohort 1960
Completed Fertility :	2.3 (1.22)	1.8 (1.12)
Age at Birth of First Child:	25.9 (3.72)	29.2 (4.56)

Figure 4: Timing of Births by Cohort - College, White



Why do we care about these dimensions of changes in timing of births? Consider a typical women born in 1940. Suppose she has two children over her life-time. From the data in Table 2, she has her first child at age 26. By the time she reaches age 30, she has two children under 5 in the household. From Figure 2 this implies that she only has a 17 percent chance of working. Now consider a typical woman born in 1960. Suppose she also has two children over her life-time, but starts at age 29. Thus, she typically only has one child by age 30. Holding employment rates by number of children at their 1940 values, she has a 32 percent chance of working (Figure 2).[5] In addition to the first effect, however, the woman born in 1960 is also more likely to have accumulated more work experience before childbearing, and therefore, is less likely to drop out of labor markets when having children. Finally, the increase in standard deviation of age at birth of first child provides another reason for the observed increase and flattening in average employment around childbearing ages: if married women have children at very different ages, a smaller fraction of women have children at any given age. Therefore the average employment rate tends to be higher as well.

3.4 Gender Wage Differentials

We use wage data from the CPS to describe changes in two measures of the gender gap in wages across cohorts. These measures are the gap in hourly wages between married men and women and the "pure" gender wage gap. By "pure" gender wage gap, we mean the part of the gender wage gap that is not due to differences in accumulated experience by gender.[6] Furthermore, we describe changes in the rate of return to work experience. The latter two measures will be used as inputs (exogenous changes) in the quantitative experiments below.

3.4.1 The "Pure" Gender Wage Gap

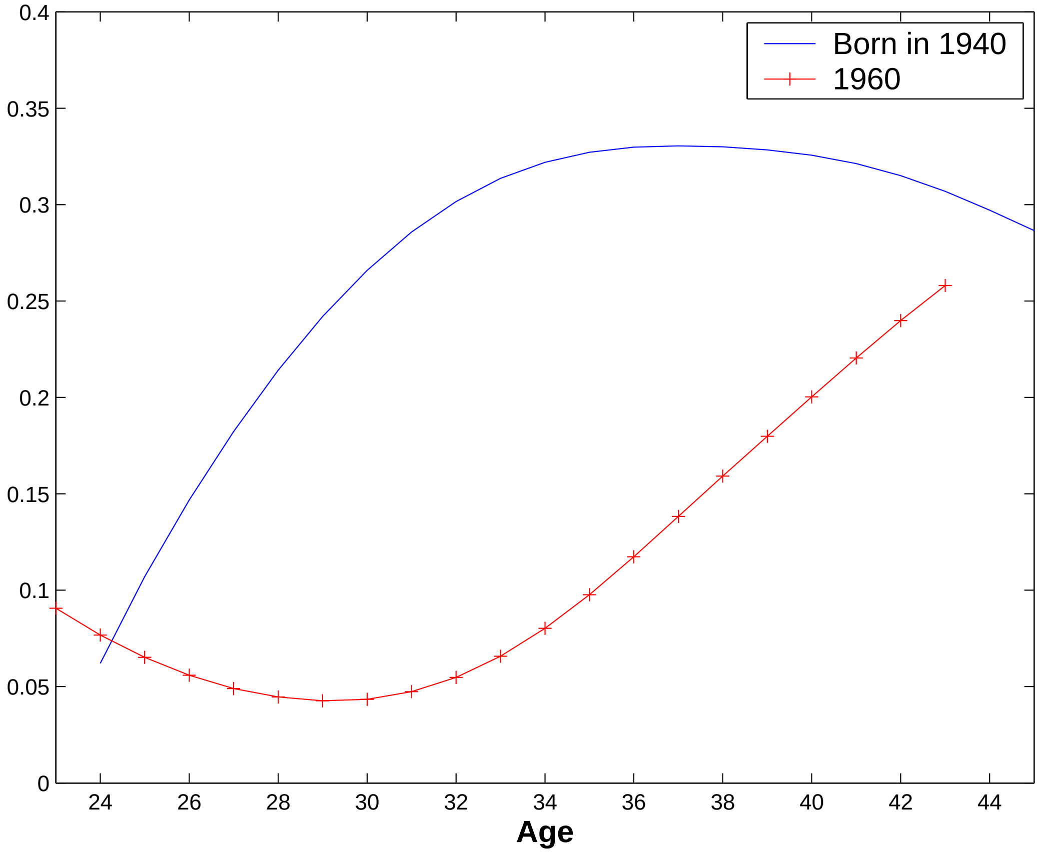
For the 1940 and 1960 cohorts, we first calculate the ratio of hourly wage of married women with a college degree to the hourly wage of their husbands

[5] This effect would be even stronger, if we were to consider women at age 28.

[6] Changes in the "pure" gender wage gap potentially include occupational shifts, sex specific changes in types of education, or discrimination, to name only a few. Disentangling those reasons is beyond the scope of the present paper.

over the life-cycle.[7] The gender wage gap, defined as one minus the average hourly wage ratio of married women to married men, increases over the life-cycle (see Figure 5). Moreover, it substantially decreased across cohorts by around 25 percentage points.

Figure 5: Ratio of Hourly Wages of Married Women with College Degree to their Husbands by Cohort - White



Changes in the relative wages between married women and their husbands are unlikely, however, to be an adequate measure of levels and changes of the "pure" wage gap for the following reason. Since employment of married women has changed dramatically across cohorts, it is not clear what fraction

[7] Since we have data until year 2003, we cannot calculate the average wage of men and women born in 1960 beyond age 43. See Appendix for a description of the hourly wage measure.

of changes in their wages come from increases in the average work experience versus changes in the wage structure. Therefore, we use single women as a reference group. Since for all cohorts of single women life-cycle employment rates are very high and similar to those of men, the average experience among working single women is less likely to be different from men's and also less likely to have changed across cohorts. For the 1940 and 1960 cohorts, we calculate the ratio of the hourly wage of single women to the hourly wage of married men (both with a college degree) over the life-cycle and present the results in Figure 6.[8] That is, our proxy of the "pure" gender wage gap faced by women born in $c \in \{1940, 1960\}$ at age t (between 23 and 45), $\tau_{c,t}$, is given by:

$$\tau_{c,t} = 1 - \frac{\bar{w}_{c,t}^{fem,singles}}{\bar{w}_{c,t}^{men,married}} \tag{1}$$

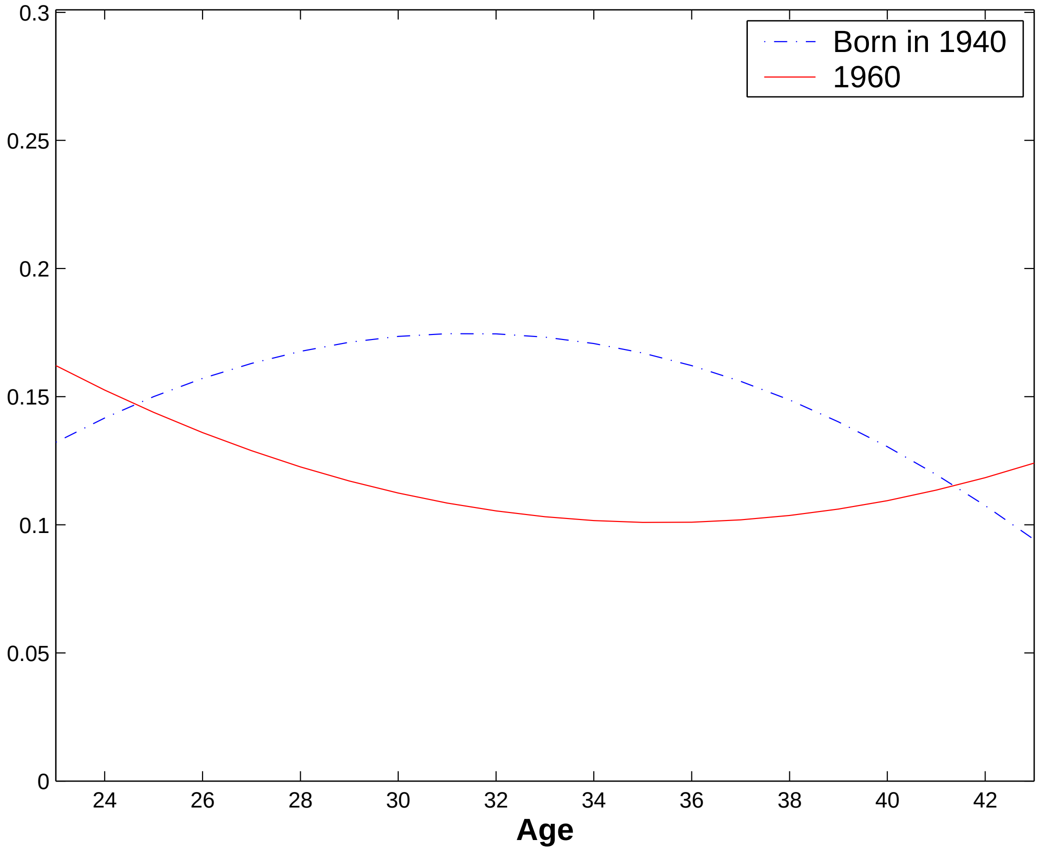
We retain three facts from the comparison of the two wage gaps. First, the "pure" gender wage gap is lower (i.e. the relative wage is higher) than the gender wage gap for married people. Second, it is roughly constant if not slightly decreasing over the life-cycle while it is increasing for married women. Third, across cohorts, the "pure" gender wage gap decreased by 8 percentage points (in contrast to 25 percentage points for married people). These three facts confirm that, on the one hand, the experience gap might be an important factor in accounting for the observed gender wage gap for married males and females across cohorts. But on the other hand, even holding experience "constant" (i.e. considering single women), the wage gap has decreased across cohorts. In the analysis below, following a decrease in the gender wage gap, employment increases at any given age and for any given number of children. However, this effect is magnified later on in life through experience accumulation.

3.4.2 Returns to Experience

The last exogenous measure we need is the rate of return to work experience and its change across cohorts. Choosing parameters $\beta_{0,c}, \beta_{1,c}, \beta_{2,c}$, we fit the average weekly wages of single women born in $c \in \{1940, 1960\}$ at age t

[8] Note that we abstract from the potential issue of self-selection into marriage. We also abstract from marriage bars which suggest that discrimination was larger against married women than it was for singles (see Goldin (1990)).

Figure 6: Changes in the “Pure” Gender Wage Ratio Across Cohorts - College, White



(between 23 and 45) from the following equation:

$$ln(\bar{w}_{c,t}^{fem,singles}) = ln(1 - \tau_{c,t}) + \beta_{0,c} + (\beta_{1,c} + \beta_{2,c}t)h_{c,t} \quad (2)$$

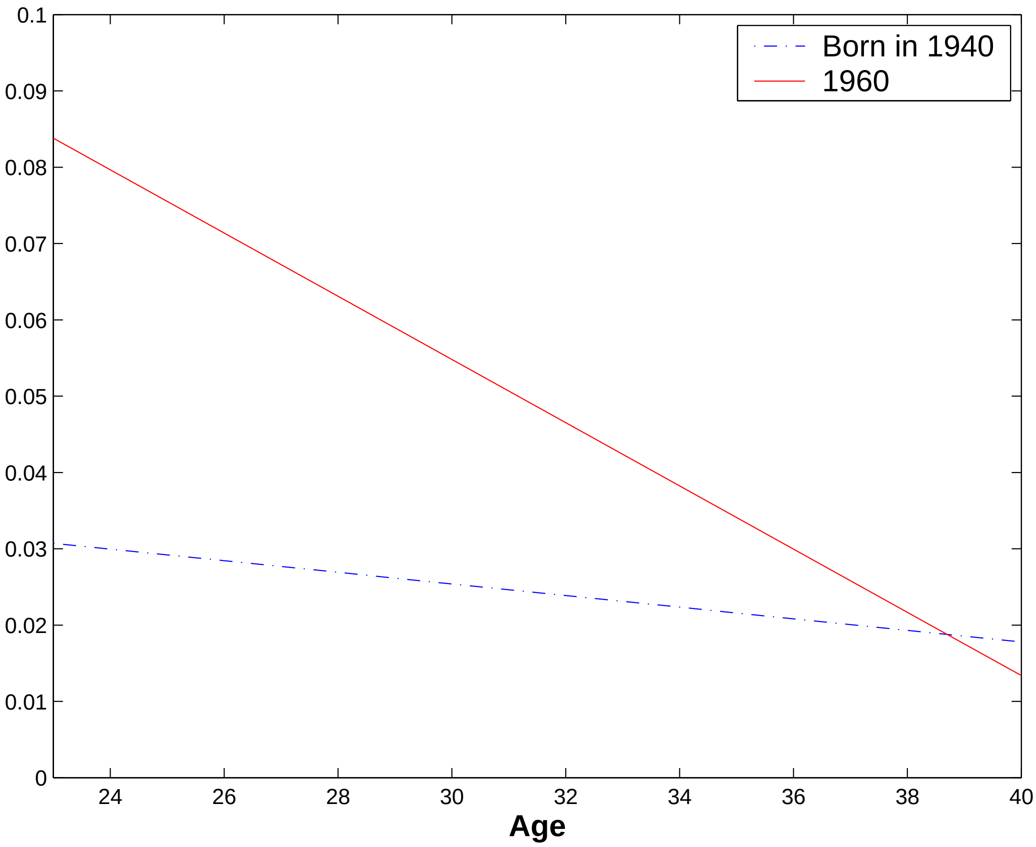
where $h_{c,t}$ denotes potential years of work experience for single women. Assuming that single women work every year and finish college at age 22, the former implies that $h_{c,t} = t - 22$. We calculate the returns to experience at age t for the 1940 and 1960 cohorts as

$$r_{c,t} = \beta_{1,c} + \beta_{2,c}t \quad (3)$$

and present the results in Figure 7. To avoid double counting we take our measure of the age and cohort specific “pure” gender wage gap, $\tau_{c,t}$, as given.

Returns to experience changed dramatically across cohorts. As plotted in Figure 7, changes in returns to experience are the largest when young. At age 24, they increased from 3 percent to 9 percent (the coefficient β_1 increased from $3.15e^{-2}$ for the 1940 cohort to $8.79e^{-2}$ for the 1960 cohort). At age 44, however, they remain roughly constant (β_2 decreased from $-7.61e^{-4}$ to $-4.15e^{-3}$). These changes in returns to experience have the following three effects on women's participation. First, from a purely static point of view, the incentive to work when young increased the most. Second, increased returns to experience in the future carry an investment motive today so that women are more likely to work to accumulate more work experience. Finally, due to higher experience accumulation when young, women are also more likely to work later in life.

Figure 7: Changes in the Returns to Experience Across Cohorts



4 The Model

In this section, we describe our model and derive its main qualitative properties.

4.1 The Household's Maximization Problem

Households are composed of a wife, a husband, and possibly some children. We assume that men and women live for T periods, while women are fertile for the first $T_f < T$ periods of their life.

Households are ex-ante heterogenous and differ in their completed fertility, f, the age at birth of first child, a, and their market ability, β_0. Women can have at most f_{max} children and the spacing of children is fixed and equal to 2 years. As a result, a woman who has f children in her life can start at the latest in period $a = T_f - 2(f-1)$.

Households derive utility from market consumption, c_t, leisure time, l_t, and the number of children born up to and including time t, n_t. The period-t utility is

$$U(c_t, l_t, n_t) = \alpha \ln(c_t) + (1-\alpha)\ln(\gamma n_t^{\lambda} + (1-\gamma) l_t^{\lambda})^{\frac{1}{\lambda}} \tag{4}$$

where $(\alpha, \gamma, \lambda) \in [0,1]^2 \times (-\infty, 1]$.

We model women's employment decisions as a discrete choice, $e_t \in \{0,1\}$. At each age $t \in \{1, 2, ..., T\}$, every women receives a wage offer, w_t, drawn from a known distribution. The mean of this distribution depends positively on market ability, β_0, and work experience accumulated up to period t, h_t. If the wage offer is accepted, $e_t = 1$, a woman devotes a fixed fraction of her time, $t_w \in (0,1)$, to market work. Women who work in the current period accumulate an additional year of work experience and, therefore, receive higher wage offers in the next period. The law of motion of work experience and the wage offer, respectively, are given by the following equations:

$$h_{t+1} = h_t + e_t \tag{5}$$

and

$$ln(w_t) = ln(1-\tau_t) + \beta_0 + (\beta_1 + \beta_2 t)h_t + \epsilon_t \tag{6}$$

where τ_t denotes the "pure" gender wage gap as defined in the data section and ϵ_t denotes a contemporaneous productivity shock. We assume that ϵ_t is normally distributed with mean 0 and standard deviation, σ_ϵ^2, and is i.i.d. over time.[9]

We model the child-care decisions of married women as a discrete choice, $q_t \in \{0, 1\}$. We assume that women who work have to use child-care services, $q_t = 1$, while women who do not work can choose either $q_t = 1$ or $q_t = 0$.

Finally, we do not model joint participation decisions between husbands and wives and assume that men work with certainty in each period.[10] We denote their (deterministic) wages in period t by w_{mt}.

We are now ready to describe the optimization problem of households of type $\Omega = (\beta_0, f, a)$. At each age $t \in \{1, 2, ..., T\}$, given the wage of their husband, w_{mt}, and their wage offer, $w_t(\beta_0, h_t, \epsilon_t)$, women choose employment, e_t, and whether to use child-care, q_t, to maximize the expected discounted utility subject to a sequence of budget and time constraints and the law of motion for human capital. The expected discounted life-time utility of women of type θ at time t is given by:

$$E_{t-1} \sum_{s=t}^{T} \delta^{s-1} U(c_s, l_s, n_s) \tag{7}$$

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

Moreover, in every period $s \geq t$, the budget and time constraints of women of type θ are given by:

$$\begin{aligned} & c_s + g(n_s, a, q_s) \leq w_{ms} + w_s(\beta_0, h_s, \epsilon_s)e_s \\ & l_s + e_s t_w + t(n_s, a, q_s) = 1 \\ & (e_s, q_s) \in \{0, 1\}^2, \\ & q_s = 1 \quad \text{if} \quad e_s = 1 \end{aligned} \tag{8}$$

where the parameter, t_w, denotes the length of the workweek. The time-invariant functions, $g(n_s, a, q_s)$ and $t(n_s, a, q_s)$, denote the goods and time cost of children at time s, respectively, which depend on the number of

[9] Notice that, the Mincer equation is a special case of the wage equation above. When women work in all periods, i.e. $h_t = t$, the wage offer equation is equal to: $ln(w_t) = \beta_0 + \beta_1 t + \beta_2 t^2 + \epsilon_t$. See Heckman, Lochner, Todd (2003) for a discussion of the theoretical foundations of the Mincer equation and empirical support for it.

[10] See Blundell, Chappiori, Magnac and Meghir (2005) for a model of joint participation decisions between husbands and wives and Eckstein and Wolpin (1989) for sequential participation decisions.

children in the household, their age and child-care choices. We write the functions $g(n_s, a, q_s)$ and $t(n_s, a, q_s)$ as:

$$
\begin{aligned}
g(n_s, a, q_s) &= \Big(g_1 \mathrm{N}_s(n_s, a)^\eta + g_2 q_s \sum_{i=1}^{\mathrm{N}_s(n_s,a)} \rho^{s-a_i}\Big) w_{mt} \\
t(n_s, a, q_s) &= (t_1 + t_2(1 - q_s)) \sum_{i=1}^{\mathrm{N}_s(n_s,a)} \rho^{s-a_i}, \\
&\text{with } (g_1, g_2, t_1, t_2, \rho, \eta) \in (0, 1)^6
\end{aligned}
\tag{9}
$$

where $\mathrm{N}_s(n_s, a)$ denotes the number of costly children in the household at time s and $a_i = a + 2(i - 1)$ denotes the age of the i^{th} child. We assume that children are costly in terms of time and goods until the age of 13. Notice that the goods cost of children includes a base cost, g_1, as well as an additional cost, g_2, when women use child-care. Since $\eta < 1$, there are economies of scale in the goods cost of children. The time costs of children decreases at rate, $\rho < 1$, when children grow. Women who do not use child-care spend some extra time raising their children, $t_2 \sum_{i=1}^{\mathrm{N}_s(n_s,a)} \rho^{s-a_i}$.[11]

Next, we write the previous optimization problem as a dynamic program. We denote by $V_t(h, \epsilon; \theta)$ the maximum expected life-time utility discounted back to period t of women of type, θ, who are in state (h, ϵ). For all $t \in \{1, ..., T\}$, the Bellman equation is

$$
V_t(h, \epsilon; \theta) = \max_{(e_t, q_t) \in (0,1)^2} \Big\{ U(c, l, n) + \delta E_t V_{t+1}\big(h + e_t, \epsilon'; \theta\big) \Big\} \tag{10}
$$

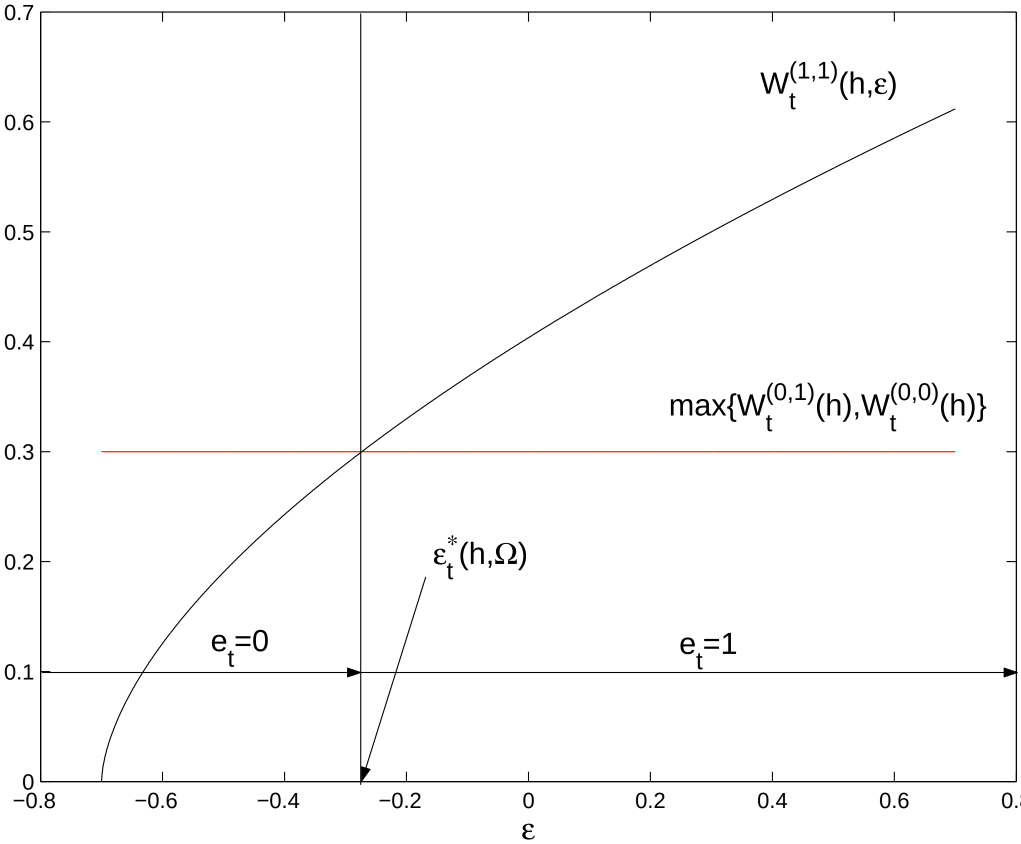
subject to the earnings equation and the budget and time constraints given in equations (6) and (8), respectively. We solve the dynamic program using a standard backward induction procedure. We define the indirect utility as:

$$
\begin{aligned}
W_t^{e_t, q_t}(h, \theta, \epsilon) = &U(w_{mt} + w_t(\beta_0, h, \epsilon)e_t - g(n_t, a, q_t), 1 - e_t t_w - t(n_t, a, q_t)) \\
&+ \delta E_t V_{t+1}\big(h + e_t, \epsilon', \theta\big)
\end{aligned}
\tag{11}
$$

[11]See Hotz and Miller (1988) who find that goods costs are independent of child's age, while time costs decrease with child's age.

Note that, because of the i.i.d. assumption, the contemporaneous productivity shock enters the expression in (11) only once, through the woman's wage offer, and only under choice $(e_t, q_t) = (1, 1)$. Thus, $W^{0,0}$ and $W^{0,1}$ are independent of ϵ_t, while $W^{1,1}$ is an increasing concave function of ϵ_t (see Figure 8).

Figure 8: Reservation shock, $\epsilon_t^*(h, \theta)$



In the Appendix, we show how we calculate the reservation productivity shock, $\epsilon^*(h, \theta)$, such that women of type, θ, who have accumulated h years of experience work this period if and only if $\epsilon_t \geq \epsilon_t^*(h, \theta)$. The reservation shock is defined such that women are indifferent between working and not-working:

$$W_t^{1,1}(h, \theta, \epsilon^*) = \max\{W_t^{0,0}(h, \theta), W_t^{0,1}(h, \theta)\} \tag{12}$$

We can also show that the reservation productivity shock decreases with

β_0, and h so that employment rates are higher for women with higher market ability and who have accumulated more work experience. Moreover, for our calibrated parameter values, we find that the reservation productivity shock increases with completed fertility, f, and the number of children in the household, $N_s(n_s, a)$. Finally, because of our choice of logarithmic utility and the assumption that the goods cost of children is proportional to husband's income, women's employment decisions only depends on their wage relative to that of their husband. The reservation shock is given by the following expression:

$$\epsilon_t^*(h, \theta) = \ln(B_t(h, \theta)) + \ln(w_{mt}) - \beta_0 - \beta_1(t)h \tag{13}$$

where $B(h, \theta)$ is a positive-valued function of h and θ, while the expected utility at time $t-1$ is equal to:

$$\begin{aligned} &E_{t-1}V_t(h, \theta) = \Phi\Big(\epsilon_t^*(h, \theta)\Big) \times \max\{W_t^{0,0}(h, \theta), W_t^{0,1}(h, \theta)\} \\ &+ \alpha \int_{\epsilon_t^*(h,\theta)} \ln\big(w_{mt} + w_t(\epsilon) - g(n_t, a, q_t)\big)\phi(\epsilon)d\epsilon + \Big(1 - \Phi\big(\epsilon_t^*(h, \theta)\big)\Big) \times \\ &\Big((1-\alpha)\ln\big(\gamma(1 - t_w - t(n_t, a, q_t))^\lambda + (1-\gamma)n_t^\lambda\big)^{\frac{1}{\lambda}} + \delta E_t V_{t+1}\big(h+1, \theta, \epsilon'\big)\Big) \end{aligned} \tag{14}$$

where Φ is the normal cumulative distribution with mean 0 and standard deviation σ_ϵ. Depending on the history of shocks, $\{\epsilon^t\}$, households of type θ may differ in the number of years of work experience. In the next subsection, we aggregate within types θ.

4.2 Construction of Aggregate Moments

4.2.1 Aggregation by type

We first calculate employment and wages for type $\theta = (\beta_0, f, a)$. Since we established in the analysis above that women work if and only if their productivity shock is higher than the reservation productivity, $\epsilon^*(h, \theta)$, the average employment and weekly wage for women of type θ is equal to:

$$p_t(h, \theta) = 1 - \Phi(\epsilon^*(h, \theta)) \tag{15}$$

and if $p_t(h, \theta) > 0$, then

$$w_t(h,\theta) = \frac{exp[\beta_0 + (\beta_1 + \beta_2 t)h] \int_{\epsilon^*(\theta)} exp[\epsilon]\phi(\epsilon)d\epsilon}{p_t(h,\theta)} \tag{16}$$

Second, we calculate the fraction of women, $\mu_t(h,\theta)$, of type θ who have accumulated h years of work experience at age t. In the first period, all women start with 0 years of work experience. Therefore,

$$\begin{aligned} \forall(\theta), \quad & \mu_1(0,\theta) = 1, \\ & \mu_1(h,\theta) = 0 \quad \text{whenever} \quad h > 0 \end{aligned} \tag{17}$$

We then define the measure, $\mu_t(h,\theta)$, recursively by the following formula:

$$\begin{aligned} & \bullet \text{ for } h = 0: \\ & \mu_{t+1}(h,\theta) = \mu_t(h,\theta)\big(1 - p_t(h,\theta)\big) \\ & \\ & \bullet \text{ for } h = t-1: \\ & \mu_{t+1}(h,\theta) = \mu_t(h-1,\theta)p_t(h-1,\theta) \\ & \\ & \bullet \text{ for } h \in \{1,...,t-2\}: \\ & \mu_{t+1}(h,\theta) = \mu_t(h,\theta)\big(1 - p_t(h,\theta)\big) \\ & \ + \mu_t(h-1,\theta)p_t(h-1,\theta) \end{aligned} \tag{18}$$

We are now ready to calculate life-cycle employment and wages, as well as employment and wages by number of children at different ages.

4.2.2 Aggregation over types

To describe the joint distribution of completed fertility and age of mother at birth of first child, we denote by $\chi(f)$ the marginal distribution of completed fertility with $f \in \{0, 1, ..., f_{max}\}$ and by $\varphi_f(a)$ the conditional distribution of age at birth of first child given completed fertility with $a \in \{1, 2, ..., T_f - 2(f-1)\}$. We also assume that market ability and age of mother at birth of first child are positively correlated. For any given age at birth of first child, a, the conditional distribution of market ability is a Beta distribution with support $[\beta_0(a), \overline{\beta}_0]$, and shape parameters (a_β, b_β). The lower bound of market ability depends on age at birth of first child in a linear way, with

$$\beta_0(a) = s_\beta \overline{\beta}_0 + (\underline{\beta}_0 - s_\beta \overline{\beta}_0)\frac{T_f - a}{T_f - 1} \quad \text{with} \quad \frac{\underline{\beta}_0}{\overline{\beta}_0} \leq s_\beta \leq 1 \tag{19}$$

Notice that market ability and age at birth of first child are independent when $s_\beta = \frac{\beta_0}{\overline{\overline{\beta}}_0}$.

The average employment and wage of married women at time t, P_t and W_t, respectively, is given by the following formula:

$$\forall t \in \{1, ..., T\},$$
$$P_t = \sum_{(h,f,a,\beta_0)} \chi(f)\varphi_f(a)b(\beta_0)\mu_t(h,\theta)p_t(h,\theta) \tag{20}$$

$$W_t = \sum_{(h,f,a,\beta_0)} \chi(f)\varphi_f(a)b(\beta_0)\mu_t(h,\theta)w_t(h,\theta) \tag{21}$$

Moreover, the employment and wage by number of children at age t, $P_{f,t}$ and $W_{f,t}$, respectively, is given by the following formula:

$$\forall t \in \{1, ..., T\}, \quad \forall f \in \{0, 1, ..., f_{max}\},$$
$$P_{n,t} = \sum_{(a,\beta_0,h)} \varphi_f(a)b(\beta_0)\mu_t(h,\theta)p_t(h,\theta) \tag{22}$$

$$W_{n,t} = \sum_{(a,\beta_0,h)} \varphi_f(a)b(\beta_0)\mu_t(h,\theta)w_t(h,\theta) \tag{23}$$

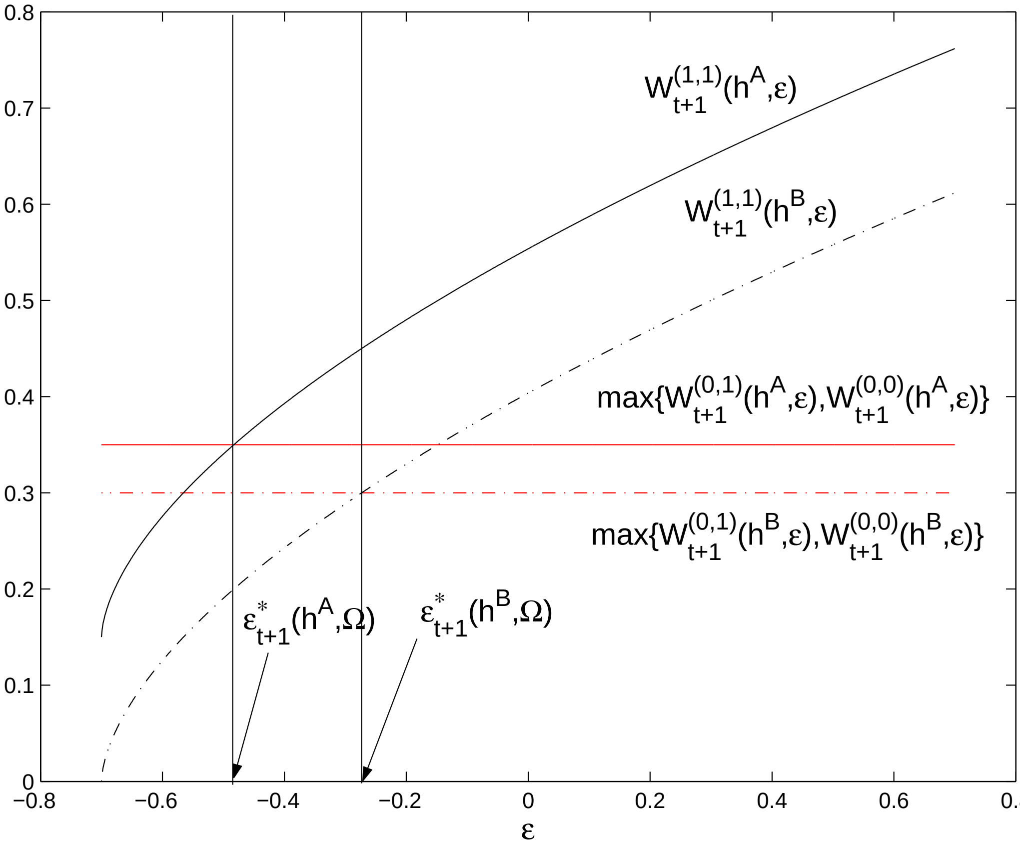
4.3 Qualitative results

4.3.1 Comparative statics within types (h) and across types (θ)

Suppose two women of type θ have had the same sequence of work decisions so far and therefore have the same number of years of work experience, $h_t^A = h_t^B$, and the same reservation shock this period (see Figure 8). Suppose, woman A receives a wage shock above the reservation shock, while woman B receives a shock below. Next period, we have $h_{t+1}^A = h_{t+1}^B + 1$. This affects their respective continuation values as well as the period utility if they decide to work (since the wage is increasing in the number of years of work experience). In fact, the indirect utility both, from working and not working, is higher for woman A than woman B (see Figure 9), but the difference in the former is larger than the difference in the latter. Hence woman A is more likely to work in the future.

By analogy, the same comparative statics apply for ability types, β_0, holding everything else the same. That is, high ability women are more

Figure 9: Comparative Statics - $h^A > h^B$



likely to work than low ability women, provided that their husbands earn the same. These findings will be used in the comparative dynamics results after the aggregation section.

Next, consider two women who have a different number of children over their life-time, $f^A < f^B$, but the same age at birth of first child, $a^A = a^B$. Here comparative statics depend on the relative magnitudes of time and goods costs. For sake of intuition, consider two extreme cases. Suppose we force households to choose $e_t = q_t$ and:

(1) $t_1 = t_2 = g_1 = 0$ and $g_2 > 0$

(2) $t_1 = g_1 = g_2 = 0$ and $t_2 > 0$

In case (1), children are costly if the woman works, while in case (2) they are costly if she doesn't work. Therefore, in case (1) (case (2)), women with fewer children are more (less) likely to work. In the data section above, we described employment by number of children in the household and found that it is decreasing. Calibrating to this fact, parameters adjust such that a version of case (1) applies. Therefore, under our parameters, the reservation shock is higher for women who have more children over their life-time. Thus, they are less likely to work.

Given this result, consider two women who differ in their age at birth of first child, i.e. $a^A > a^B$, but will have the same number of children over their life-time, $f^A = f^B$. Then for some periods, woman A will have fewer children than woman B. She will therefore be more likely to work, everything else the same. However, once she starts to have children herself, she will have younger children in the household than woman B. Since younger children are costlier ($\rho < 1$), she is less likely to work during those periods. After the aggregation section below, we explain how a delay in fertility also increases average work experience in a comparative dynamics exercise. In the next subsections, we explain how the model produces the mechanisms outlined in the introduction.

4.3.2 Effect of exogenous changes

Here we describe the qualitative effects of changes in fertility distributions and the wage structure.

Decrease and delay in fertility, ($\varphi_f(a)$,$\chi(f)$): From the comparative statics, a delay in fertility unambiguously increases employment early on. However, there are two counterbalancing effects for later ages: (1) women born in 1960 are more likely to work since they have accumulated more work experience, (2) they are less likely to work since eventually they will have younger (i.e. more costly) children. Note that the second effect is smaller the larger the decrease in fertility levels.

Effect of changes in relative wages, $(\tau_t^c, \beta_1+\beta_2 t)$: Using the comparative statics about h and β_0, it is clear that (1) employment increases following a decrease in either the "pure" gender wage gap, τ_t^c, or returns to experience, $(\beta_1 + \beta_2 t)$, (2) through the accumulation of experience over time, this effect is larger later in life.

Finally, in our calibration, it turns out that the impact of changes in gender wage differentials on women's employment increases with women's work experience. Therefore, when performing both changes at once, the increase in employment is larger than the sum of individual changes.

5 Calibration: 1940 Birth Cohort

In this section, we explain our calibration procedure and results. First, we describe our identification strategy. Second, we discuss our parameter values. Third, we present fitted and non-fitted predictions of the model.

5.1 Identification

In what follows, we describe parameter values taken from outside sources and lay out the calibration procedure through model simulation.

The model period is one year and we assume that households live for $T = 40$ periods. Since we consider women after they have graduated from college this corresponds to age 23 to 62. Women are fertile for $T_f = 18$ periods, i.e. age 23 to 40. Therefore age at birth of first child, a, belongs to the set $\{1, ...18 - 2(f - 1)\}$ depending on the level of completed fertility, $f \in \{0, 1, 2, 3, f_{max} = 4\}$.

5.1.1 Parameters taken from outside sources

Several parameters are determined directly from outside sources.

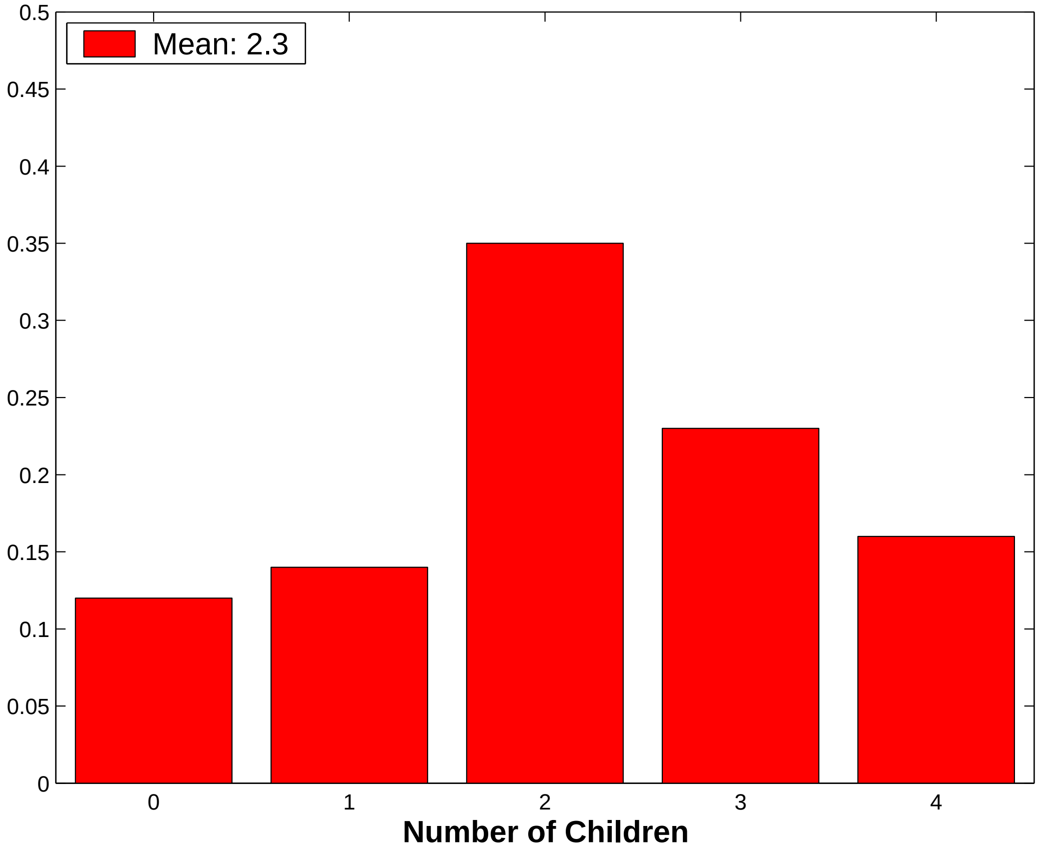
1. We take average life-cycle wages of men, married to our College educated women from CPS data.

2. We use the distributions of completed fertility as well as age at birth of first child by completed fertility from Census data (see Figures 10 and 11).

3. We use the wage equation including the age dependent "pure" wage gap obtained directly from data on single women (Figure 6). That is, let $\tau_t^{1940} = 1 - \frac{w_t^{1940,singles}}{w_{mt}^{1940}}$ and use the wage equation rewritten as:

$$ln(w_t) = ln(1 - \tau_t^{1940}) + \beta_0 + (\beta_1 + \beta_2 t)h_t + \epsilon_t \quad (24)$$

Figure 10: Completed Fertility - 1940 Cohort

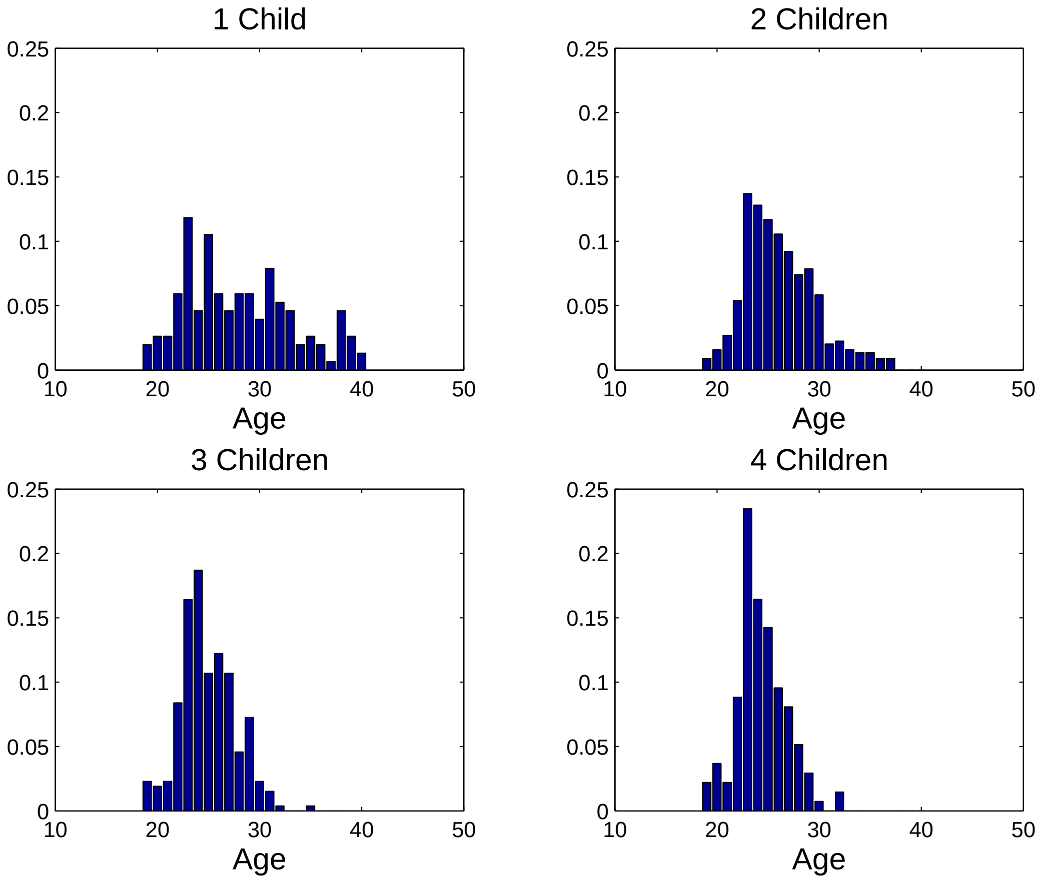


4. The discount factor, δ, is set to $\delta = 0.96$ to match an annual interest rate of roughly 4%.

5. The workweek length is taken from time use data. People use on average 8 hours a day for sleeping and 2 for eating which leaves 98 hours per week to devote to work, leisure,... (see Juster and Stafford (1991)). From CPS data, the average workweek length for married women (conditional on being employed) is 35 hours a week. Therefore, $t_w = 35/98 = 0.36$.

6. Hotz and Miller (1988) estimate that the time cost of children decreases at rate 0.89 with age of children. Accordingly, we fix, $\rho = 0.89$.

Figure 11: Timing of Births by Completed Fertility - 1940 Cohort



7. We use Guvenen (2005)'s estimates of the variance for productivity shocks of college men and fix $\sigma_\epsilon^2 = 0.047$.

8. We use the average observed weekly wage of the highest and lowest deciles of married women born in 1940 at age 23 to find $\underline{\beta}_0 = 4.75$ and $\overline{\beta}_0 = 6.25$.

5.1.2 Parameters determined through model simulation

This leaves us with 13 free **parameters** to estimate:

- 3 utility parameters, $(\alpha, \gamma, \lambda)$,

- 5 parameters for the costs of children, $(g_1, g_2, t_1, t_2, \eta)$,
- 2 parameters for the wage equation and distribution, (β_1, β_2),
- 3 parameters for the distribution of market ability, $(a_\beta, b_\beta, s_\beta)$.

We chose these parameters to minimize the squared percentage deviation between the **moments** from the model and their data counterpart. We use the following data moments:

- life-cycle employment rates, $\{e_t^D\}_{t=23}^{45}$ (23 moments),
- life-cycle average weekly wages, $\{w_t^D\}_{t=23}^{45}$ (23 moments),
- employment by number of children in the household at age 30, $\{e_{i30}^D\}_{i=0}^{3}$ (4 moments),
- and, weekly wages by number of children in the household at age 40[12], $\{w_{i40}^D\}_{i=0}^{4}$ (5 moments).

Formally, the vector $\psi = \{\sigma_c, \sigma_l, \gamma, g_1, g_2, t_1, t_2, \eta, \beta_1, \beta_2, a_\beta, b_\beta, s_\beta\}$ is chosen to solve the following equation:[13]

$$\hat{\psi} = \arg\min_{\psi\in\Psi} \left\{ \begin{array}{c} \sum_{t=1}^{28} \left[\left(\frac{e_{ft}(\psi) - e_{ft}^D}{e_{ft}^D} \right)^2 + \left(\frac{w_{ft}(\psi) - w_{ft}^D}{w_{ft}^D} \right)^2 \right] \\ + \sum_{i=0}^{3} \left(\frac{e_{i30}(\psi) - e_{i30}^D}{e_{i30}^D} \right)^2 + \sum_{i=0}^{4} \left(\frac{w_{i40}(\psi) - w_{i40}^D}{w_{i40}^D} \right)^2 \end{array} \right\} \tag{25}$$

Note that this system is over-identified since we have 55 moments (two of which are a liner combination of the cross-sections by number of children, namely the average employment rate at age 30,e_{30}^D, and the average weekly wage at age 40, w_{40}^D) to determine 13 parameters.

Even though all model moments depend on the entire set of parameters, we nevertheless think of certain parameters to be more related to a particular set of our target moments. These relationships are described next.

[12]Hourly wages are decreasing as well, since the difference in weekly hours by number of children is small and less than 2 hours per child.

[13]Since we work with synthetic cohorts, we do not know the conditional probabilities of transiting from employment to non-employment state. Therefore, we cannot weigh the loss function by the variance-covariance matrix, which implies that our estimates are consistent but not necessarily efficient.

First, the utility parameters as well as costs are closely related to the employment moments. In particular, employment by number of children determines the economies of scale (η), the relative magnitudes of substitutable goods and time costs (g_2 and t_2) and the elasticity of substitution between leisure and children in the utility function, (λ). First, more economies of scale (lower η) induce participation by number of children to be more convex. Second, the higher the child-care cost, g_2, relative to its time cost counterpart, t_2, the less likely women with many children are to work (participation by number of children steeper). Third, the more complementary children and leisure (lower λ), the more attractive is the option of staying home for women with many children.

Second, the main ingredient to match the smooth employment profile over the life-cycle are the detailed fertility and timing of births distributions coming directly from the data. In turn, the fixed per child goods and time costs (g_1 and t_1) determine the general level of employment.

Table 3: Age of Mother at Birth of First Child by Completed Fertility (Standard Deviation in Parenthesis) - White Married Women with College Degree

Completed Fertility:	1 child	2 children	3 children	4+ children
1940 Cohort:	28.4 (5.0)	26.4 (3.3)	25.2 (2.3)	24.6 (2.0)
1960 Cohort:	32.0 (5.3)	29.4 (3.8)	27.7 (3.3)	26.3 (2.8)

Finally, wage parameters are closely tied to wage related moments. First, life-cycle profiles are mostly determined by the distribution parameters for ability, a_β and b_β, (general level of observed wages) as well as returns to experience parameters, β_1 and β_2 (slope). Furthermore, the steepness of wages by number of children in the household closely relates to the correlation parameter between age at birth of first child and ability level, s_β. In fact, there are two reasons why wages by number of children are decreasing in our model. On the one hand, women who have more children tend to have accumulated less work experience by age 40. On the other hand, we assume that permanent market ability, β_0, is positively correlated with age at birth of first child, a, which is itself negatively correlated with completed fertility, f (see Table 3). Thus having more children implies lower ability on average. Hence, beyond the first effect through β_1, the higher s_{beta} the more steeply weekly wages decline with number of children.

5.2 Discussion of Parameters Values

In Table 4, we report our **calibrated parameter values**.

Table 4: Calibrated Parameters

Wage	$\beta_1 = 1.94e^{-2}$ $a_\beta = 4.24$	$\beta_2 = -2.04e^{-5}$ $b_\beta = 6.18$	$s_\beta = 0.97$
Cost of Children	$g_1 = 10.63e^{-2}$ $t_1 = 14.53e^{-2}$	$g_2 = 7.61e^{-2}$ $t_2 = 9.91e^{-2}$	$\eta = 0.98$
Utility	$\alpha = 0.38$	$\gamma = 0.87$	$\lambda = 0.49$

First, even though the wage parameters, β_1 and β_2, have the usual positive and negative sign, our estimates are smaller than estimates from traditional Mincer regressions (see, for example, Eckstein and Wolpin (1989), where $\beta_1 = 3.7e^{-2}$ and $\beta_2 = -5e^{-4}$). However, Eckstein and Wolpin (1989) show that simple wage regressions on female wages yield biased estimates because of selection and experience accumulation. They find that, when using a structural model of women's employment decisions, the coefficient on experience in the Mincer equation, β_1, is equal to $2.4e^{-2}$, while the coefficient on experience squared is equal to $-2e^{-4}$. Therefore, our estimates are only slightly lower than theirs and the remaining discrepancy is most likely due to the unusual shape of average wages of married women born in 1940.

Second, we compare our child cost parameters to those found in the literature. We find very modest economies of scale in the number of children, as $\eta = 0.98$. Previous findings are mixed. For example, Lazear and Micheal (1980) find large economies of scale, while Espenshade (1984) find that they are of the order of five percent for an additional child. Next, we compare time and goods costs to those in Hotz and Miller (1988) who use closely related functional forms, except for economies of scale and substitutability. They estimate that the time cost of a newborn amounts to 660 hours per year which corresponds to about 13 hours a week. That is about 13 percent of a woman's time after sleeping and eating hours have been subtracted. This compares well to $t_1 = 0.14$, but would not include t_2.[14] However, in their linear utility specification, their finding was calculated from the net utility loss from children. It is therefore to be expected that our estimate is higher. Also, their goods estimate, transformed into weekly 1982-84 dollars magnitudes, ranges from 16 to 100 dollars per child per week. Since husband's weekly wages range from 430 to 680 depending on age and goods costs ranging from 11 to 17 percent of the latter(depending on use of child care), our calibration lies in the upper range of Hotz and Miller (1988)'s estimates.[15]

Finally, we find children and leisure to be substitutable ($\lambda = 0.49$). The intuition behind this result is the following. We calculated the average leisure time of married women at age 30 by number of children for the 1940 cohort, $\bar{l}(n)$, as:

$$\bar{l}(n) = 1 - p_{n,30} t_w - \bar{t}(n) \tag{26}$$

where $p_{n,30}$ denotes women's employment rate at age 30 by number of children and $\bar{t}(n)$ is the average time cost of children. We find that average leisure is decreasing in the number of children because the average time cost of an additional child is larger than the decrease in employment (recall that women's employment by number of children decreases very steeply between 0 and 1 children but is, otherwise, very flat for women who have children).

5.3 Cohort 1940: Model versus data

The calibration results are presented in Figures 12 to 15. Since our system is over-identified, we cannot match all moments perfectly. Nevertheless, the

[14] Hill and Stafford (1980) analyzing time use data in 1976 find that women with some college education or more spend 550 minutes per child per week in child-care if they have one preschooler and 440 minutes per child per week if they have two (p.237). This corresponds to about 10 percent of a woman's total time after sleeping and eating hours have been subtracted. However, housework time can to some extent be viewed as time spent where watching children is possible at the same time.

[15] Note that it is very common to find wide ranges of goods cost estimates in the literature. See also Bernal (2004) who finds a comparable wide range for child-care expenditures.

model predictions fit the data quite well.

Figure 12: Calibrated Life-Cycle Employment of Married Women - 1940 Cohort

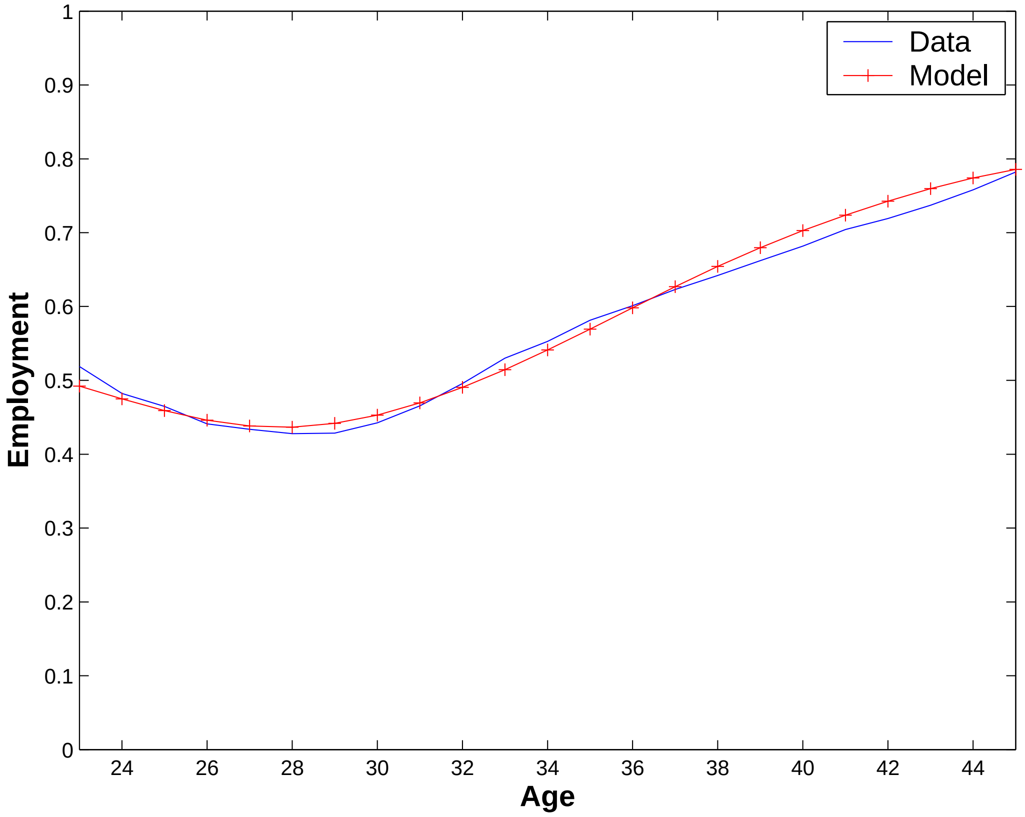


Figure 13: Calibrated Life-Cycle Weekly Wages of Married Women - 1940 Cohort

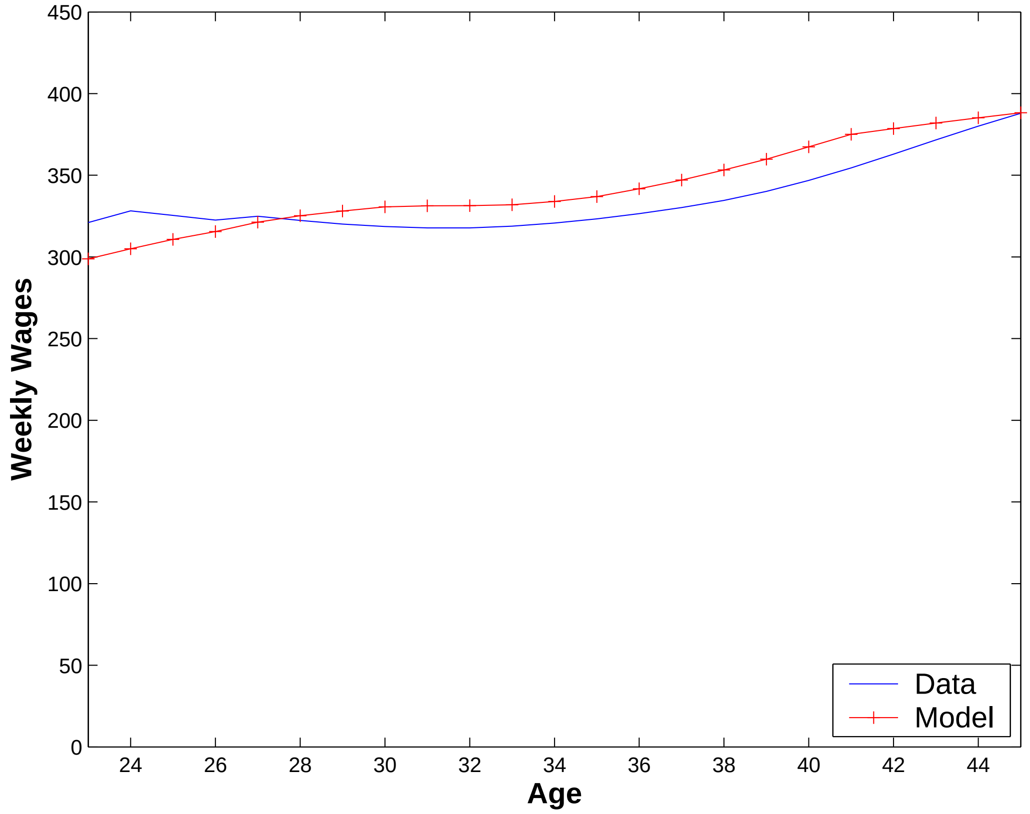


Figure 14: Calibrated Employment at Age 30 by Number of Children - 1940 Cohort

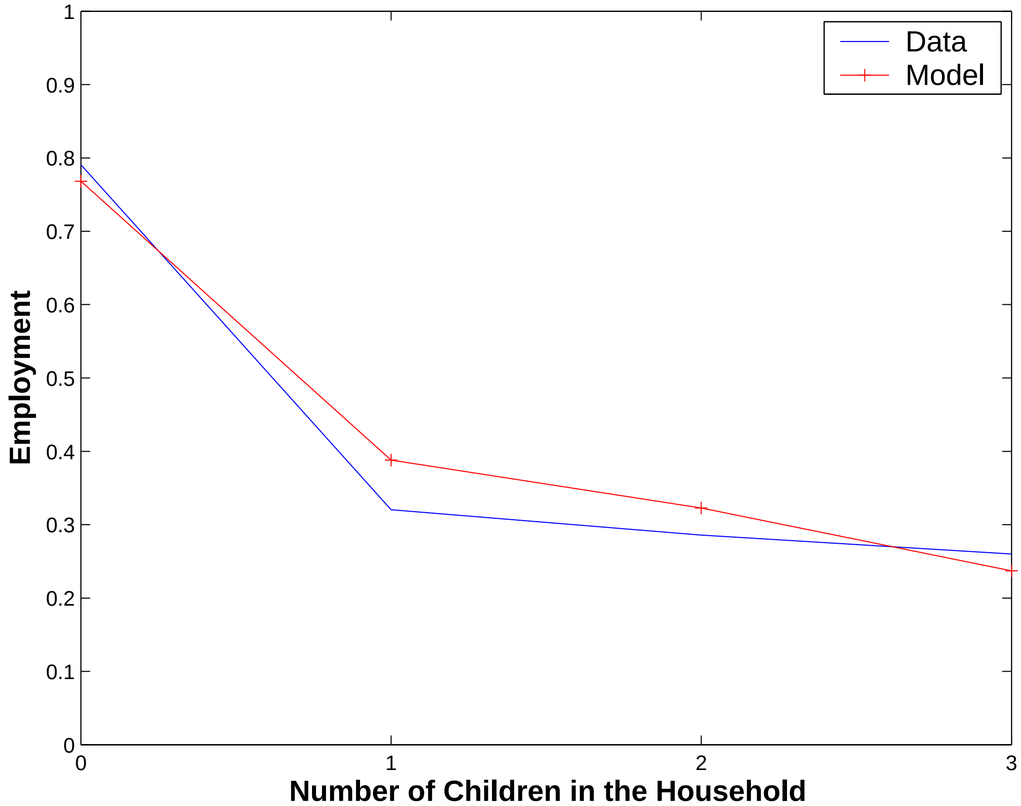
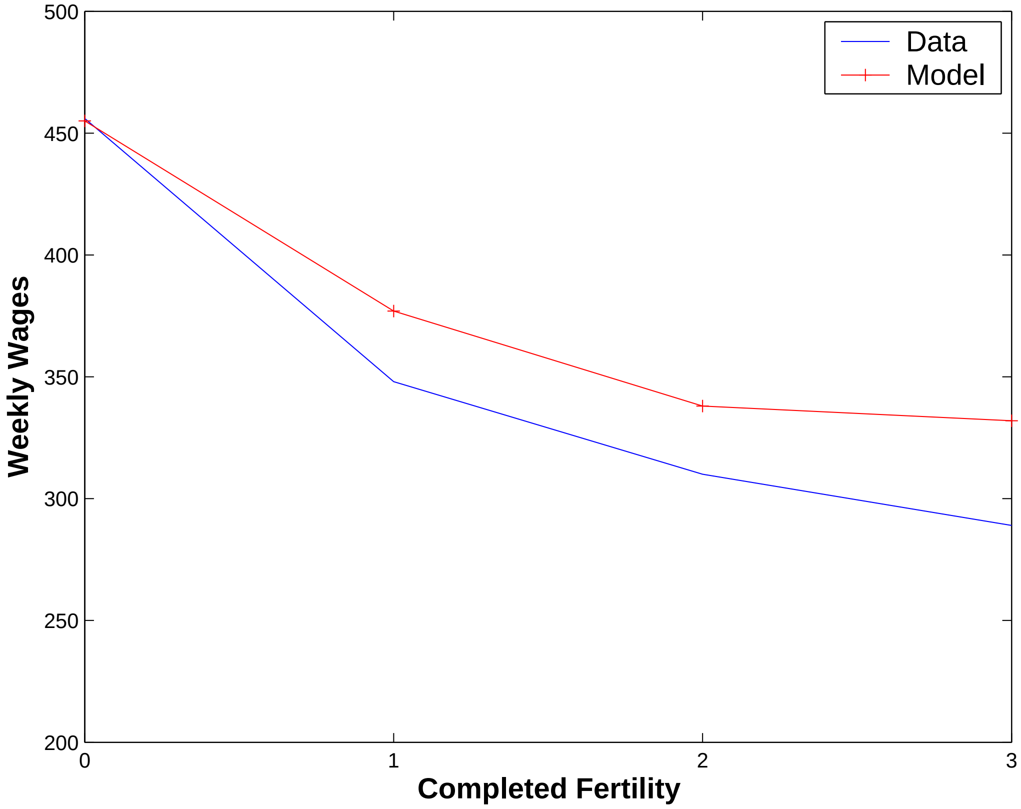
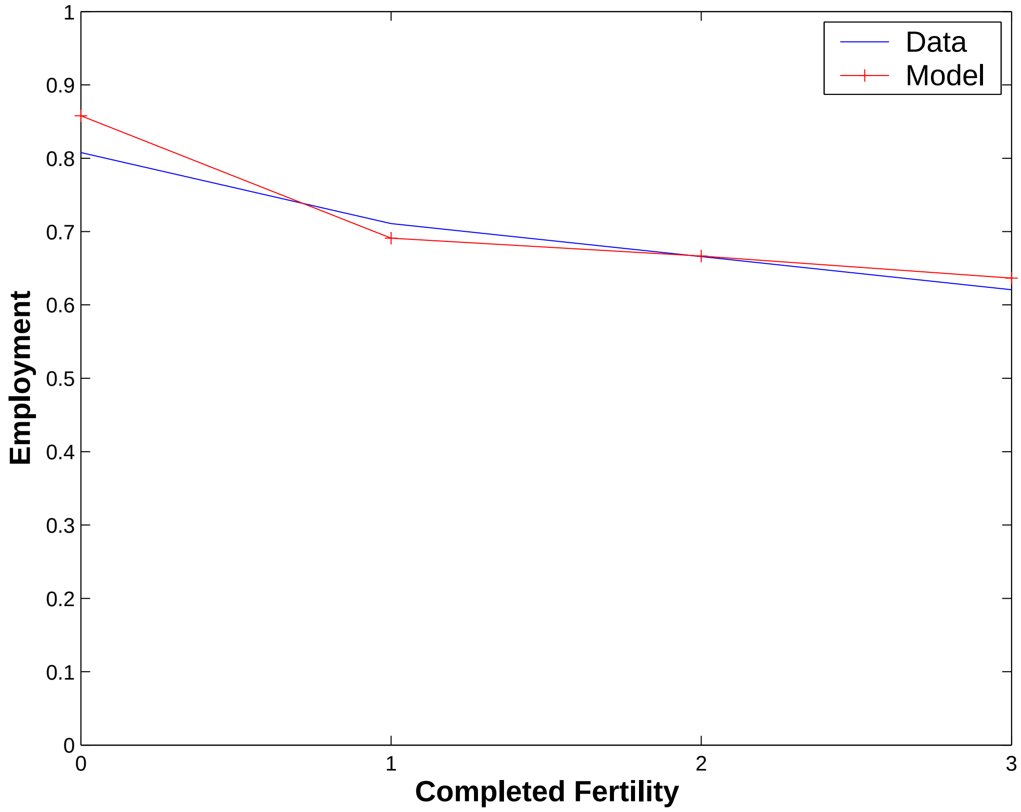


Figure 15: Calibrated Weekly Wage at Age 40 by Number of Children - 1940 Cohort



It is interesting to note that, even if we calibrate only to average employment at age 40, the model prediction for employment by number of children at age 40 fits the data well (see Figure 16).

Figure 16: Employment at Age 40 by Number of Children - 1940 Cohort



6 Experiments: 1960 Cohort

Here we report the results of the experiments outlined under our qualitative results in section 4.3.2. We compare model and data for 3 separate age groups, namely age 23 to 29, 30 to 36 and 36 to 43. First, we change fertility distributions from their 1940 to their 1960 values. Second, we hold fertility distributions at their 1940 values, but change female wage offers in levels using the estimates presented in Figure 6. Third, we hold wage levels and fertility distributions at their 1940 values and change returns to experience as shown in Figure 7. Finally, we change fertility distributions, wage levels and returns to experience simultaneously. While individual changes have strong effects on different age groups, when taken together these changes account for about 87 percent of the increase in employment for cohorts born between 1940 and 1960 throughout the life-cycle. This change is larger than the sum of individual changes.

6.1 Change in Fertility Levels and Timing of Births

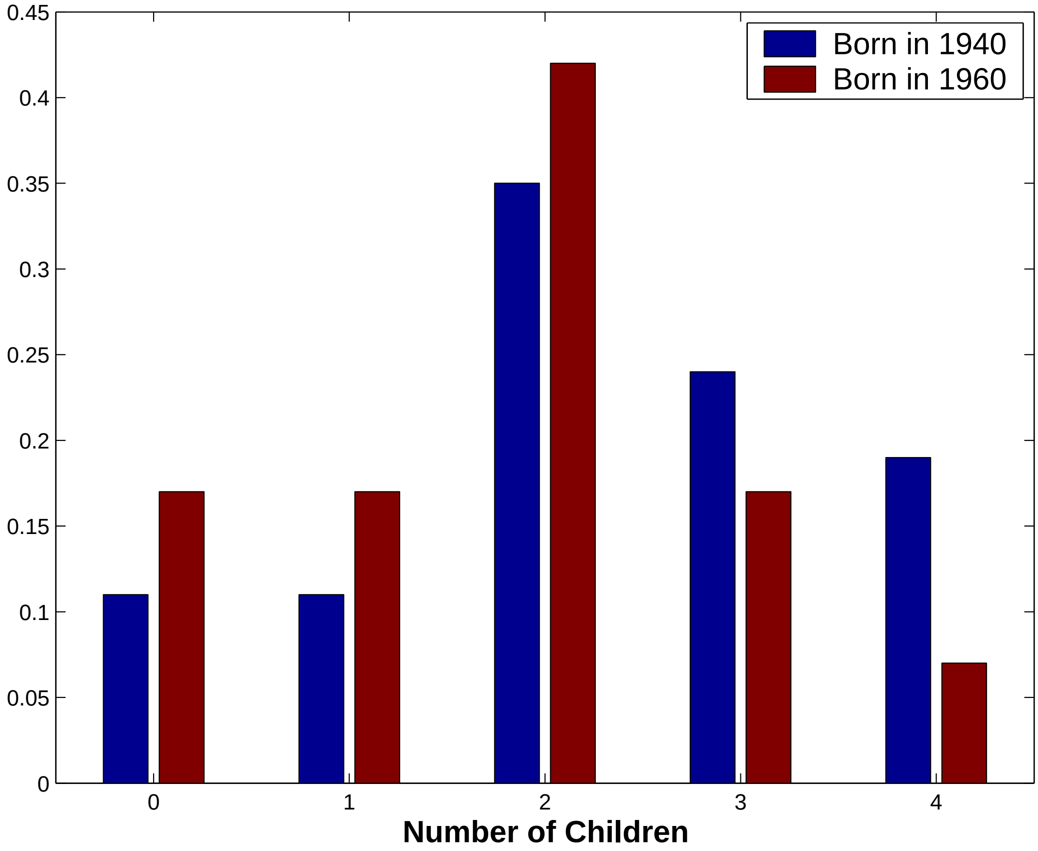
In this subsection, we describe the experiment that consists of changing distributions of fertility levels and age at birth of first child from their 1940 values to their 1960 values, holding all other determinants of female employment at their 1940 values.

We plot the distribution of age at birth of first child and completed fertility for the 1940 and 1960 cohorts in Figures 4, 17, and 18. In Table 5, we report the predictions of the model, plotted in Figure 19.

The effects of changes in completed fertility alone on women's employment are imperceptibly small. We therefore present the effect of changes in age at birth of first child by completed fertility together with the change in distribution of completed fertility. In line with the qualitative results in section 4.3.2., we find that the effect is unambiguously positive and large for the first age group. However, since many women born in 1960 have children after age 30, the effect is negative for the second age group and zero for the third.[16]

[16]Note, however, that age at birth of first child ($a \sim \varphi_f(a)$)is positively correlated with ability ($\beta_0 \sim B[\beta_0(a), \overline{\beta_0}]$) and negatively correlated with completed fertility (f). This implies that, when shifting the distribution of age at birth of first child (and/or completed fertility) to the right (left), the average ability level increases. To control for this effect,

Figure 17: Completed Fertility by Cohort - College



we hold the average ability level constant by scaling all ability levels as follows:

$$\beta_{0,1960} = \left[\frac{E_{1940}(\beta_0)}{E_{1960}(\beta_0)}\right]\beta_0 \tag{27}$$

where the expectation, E_c, is taken using age at birth of first child and completed fertility distributions of cohort c and the calibrated beta distribution, $B[\beta_0(a), \overline{\beta_0}]$. We find $\frac{E_{1940}(\beta_0)}{E_{1960}(\beta_0)} = 1.02$.

Figure 18: Timing of Births by Completed Fertility - 1960 Cohort

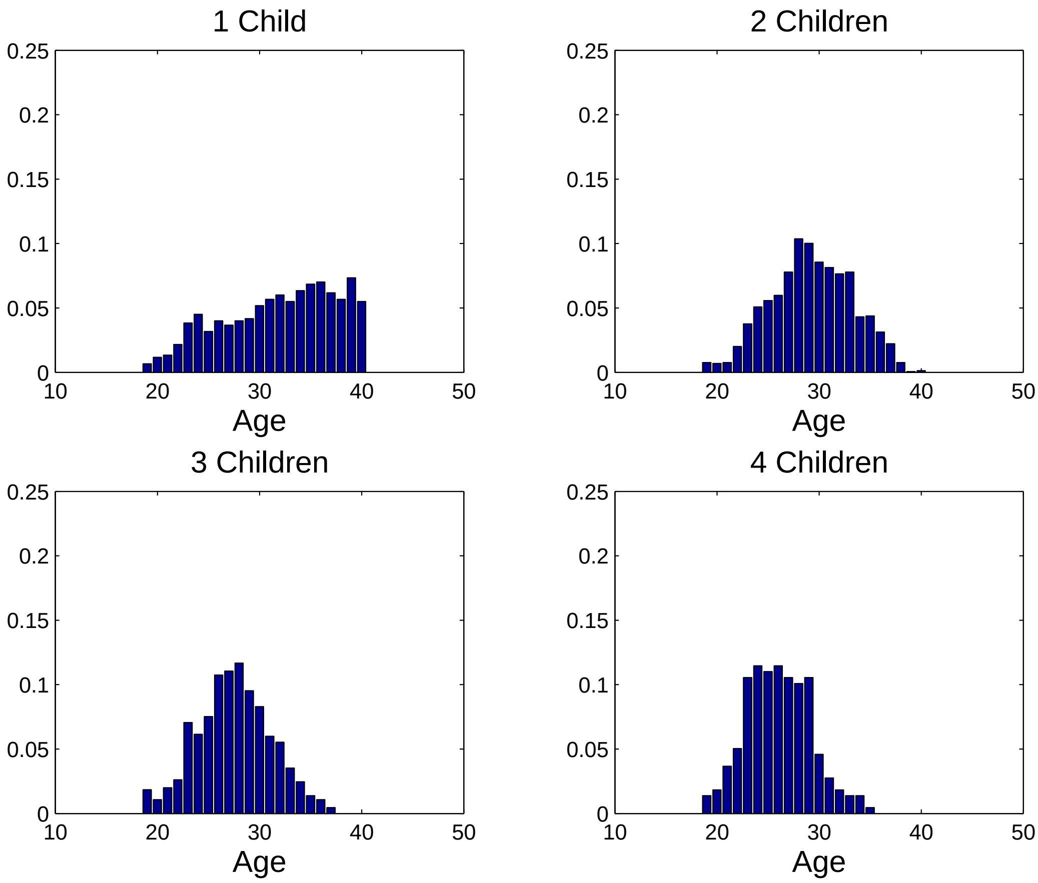
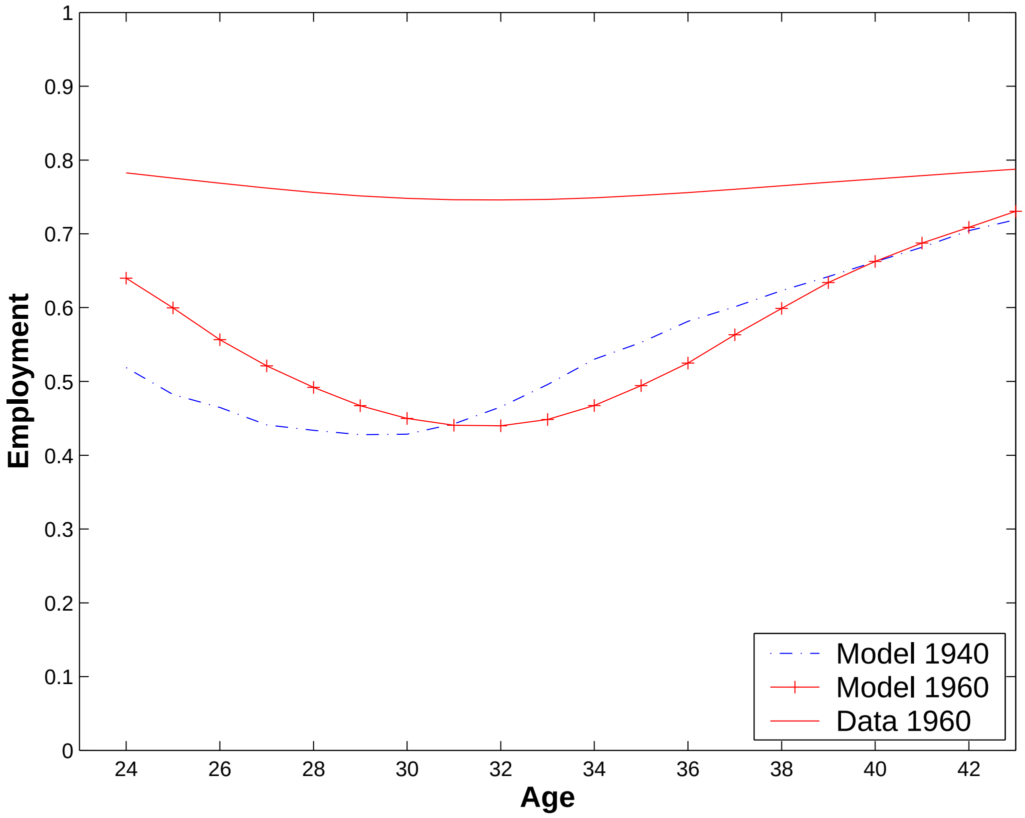


Table 5: Exogenous change: Completed fertility distribution and age at birth of first child by completed fertility distributions

Annual Percentage Point Difference in Employment Rate: (1960 - 1940)	*Age 23-29*	*Age 30-36*	*Age 36-43*
Model :	8	-3	0
Data :	30	27	12

Figure 19: Change fertility level and timing exogenously: Employment over the Life-Cycle



6.2 Changes in Wages

6.2.1 Change in the Gender Wage Gap

In this experiment, we hold everything to its 1940 value, except the "pure" life-cycle gender wage gap , $\tau_{c,t}$. That is, we simulate the model using,

$$ln(w_t) = ln(1 - \tau_{1960,t}) + \beta_0 + (\beta_1 + \beta_2 t)h_t + \epsilon_t \tag{28}$$

with $\tau_{1960,t}$ as depicted in Figure 6. Figure 20 and Table 6 show model predictions for this experiment.

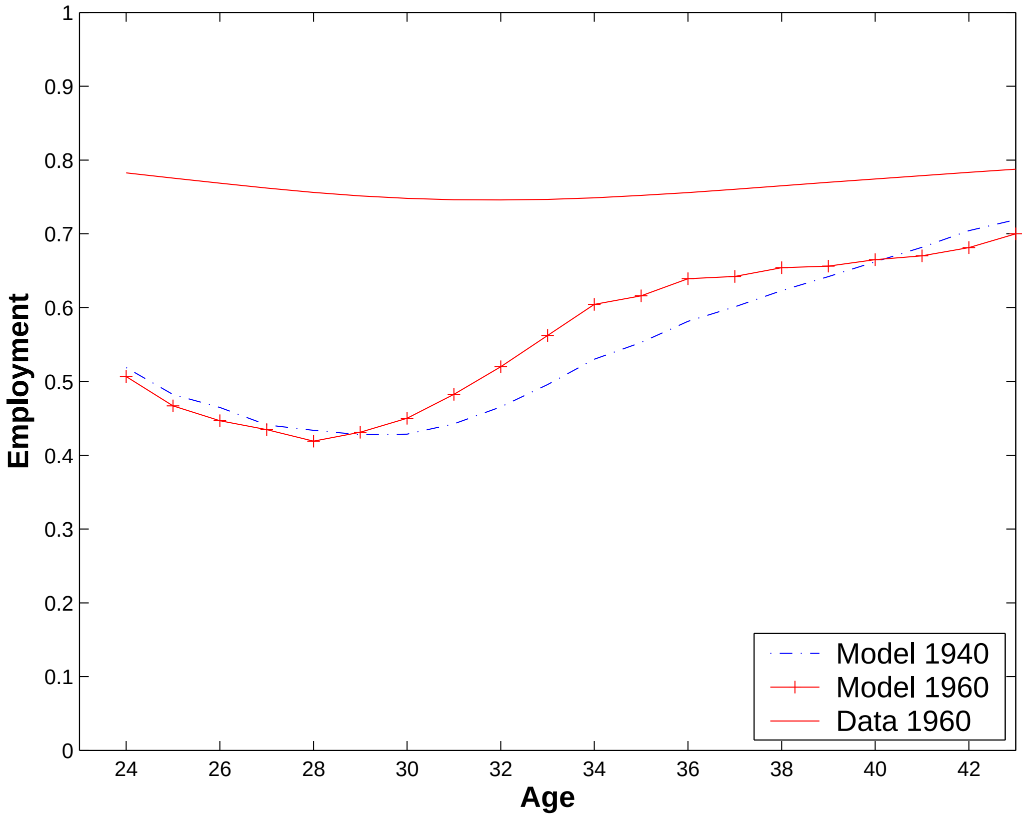
Changes in the gender wage gap have the largest effect between age 30 and 36. This closely mirrors the pattern of change in the "pure" gender wage gap itself, which decreases the most around age 33. In our framework, changes in wage levels don't seem to induce a strong investment motive to work early on, accumulate more experience which would pay off at ages where the wage gap has decreased. This is a result that has to be interpreted with caution, since there are no schooling or on the job investment in human capital opportunities in our model.[17]

Table 6: Exogenous change: "Pure" gender wage gap holding fertility distributions at values for 1940 cohort

Annual Percentage Point Difference in Employment Rate: (1960 - 1940)	*Age 23-29*	*Age 30-36*	*Age 36-43*
Model :	0	6	0
Data :	30	27	12

[17]See Jones, Manuelli and McGrattan (2003) for a more general concept of human capital accumulation and Buttet and Schoonbroodt (2005b) for explicit schooling choices of married women.

Figure 20: Change Gender Wage Gap Exogenously with Fertility Distributions of 1940 Cohort: Employment over the Life-Cycle



6.2.2 Change in Returns to Experience

In this experiment, we change returns to experience holding all other parameters to their 1940 values. That is, we simulate the model using,

$$ln(w_t) = ln(1 - \tau_{1940,t}) + \beta_0 + \frac{r_{1960,t}}{r_{1940,t}}(\beta_1 + \beta_2 t)h_t + \epsilon_t \qquad (29)$$

where $r_{c,t}$ was obtained as described in equation 2 and depicted in Figure 7. Figure 21 and Table 7 show model predictions for this experiment.

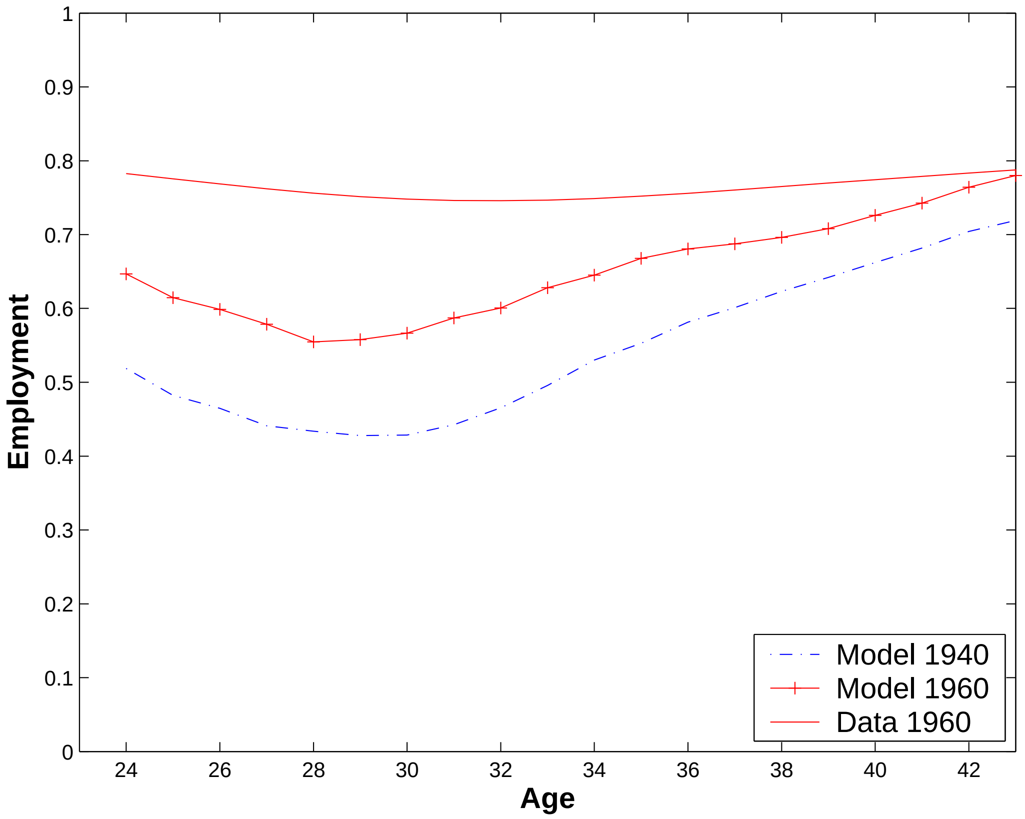
This experiment alone predicts more than one third of the large increase for the first two age groups (13 percentage point per year out of 30 and 12 out of 29, respectively). It predicts half of the change for the last cohort (6 out of 12). The reasons for this result are twofold. First, as estimated from singles, returns to experience increase more when young.[18] This induces many women to work when young. Second, increased returns to experience in the future carry an investment motive today so that women are more likely to work to accumulate more work experience. Finally, note that despite the decrease in returns to experience at age 40, women work more at and beyond this age. This comes from the increased average work experience in the population by the time this age is reached. While these changes are significant and qualitatively correct along the life-cycle (i.e. larger change when young), returns to experience alone are quantitatively still far from accounting for the whole change in married women's employment, especially when young.

Table 7: Exogenous change: Returns to experience holding fertility distributions at values for 1940 cohort

Annual Percentage Point Difference in Employment Rate: (1960 - 1940)	*Age 23-29*	*Age 30-36*	*Age 36-43*
Model :	13	12	6
Data :	30	27	12

[18] Olivetti (2005) finds a similar pattern between the 1970s and the 1990s.

Figure 21: Change Returns to Experience Gap Exogenously with Fertility Distributions of 1940 Cohort: Employment over the Life-Cycle



6.3 All Together

Finally, we feed all exogenous changes (fertility distributions and wage changes) at once. Figure 22 and Table 8 show model predictions for this experiment (line 1, Model).

Here, the model predicts about 87 percent of the overall change in employment. Moreover, due to interaction effects between fertility and wages, the results from this experiment produce larger changes than the sum of the three previously performed experiments beyond age 24.

Figure 22: Change Gender Wage Gap, Returns to Experience, and Fertility Distributions Exogenously: Employment over the Life-Cycle

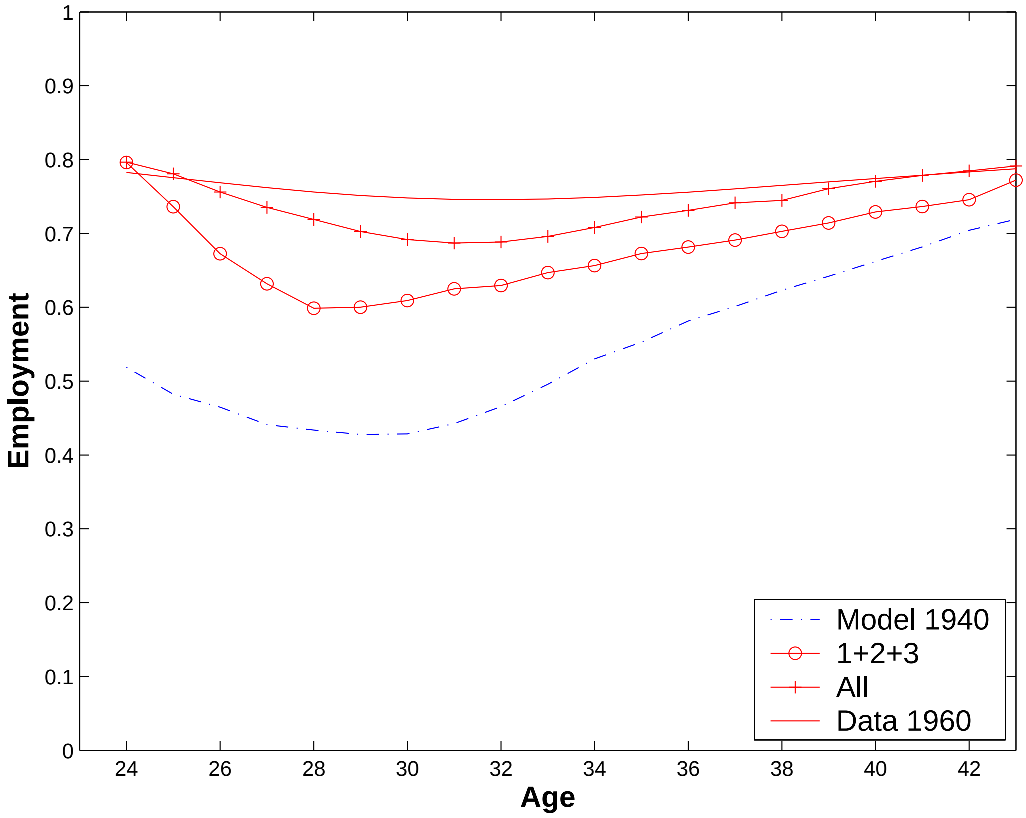
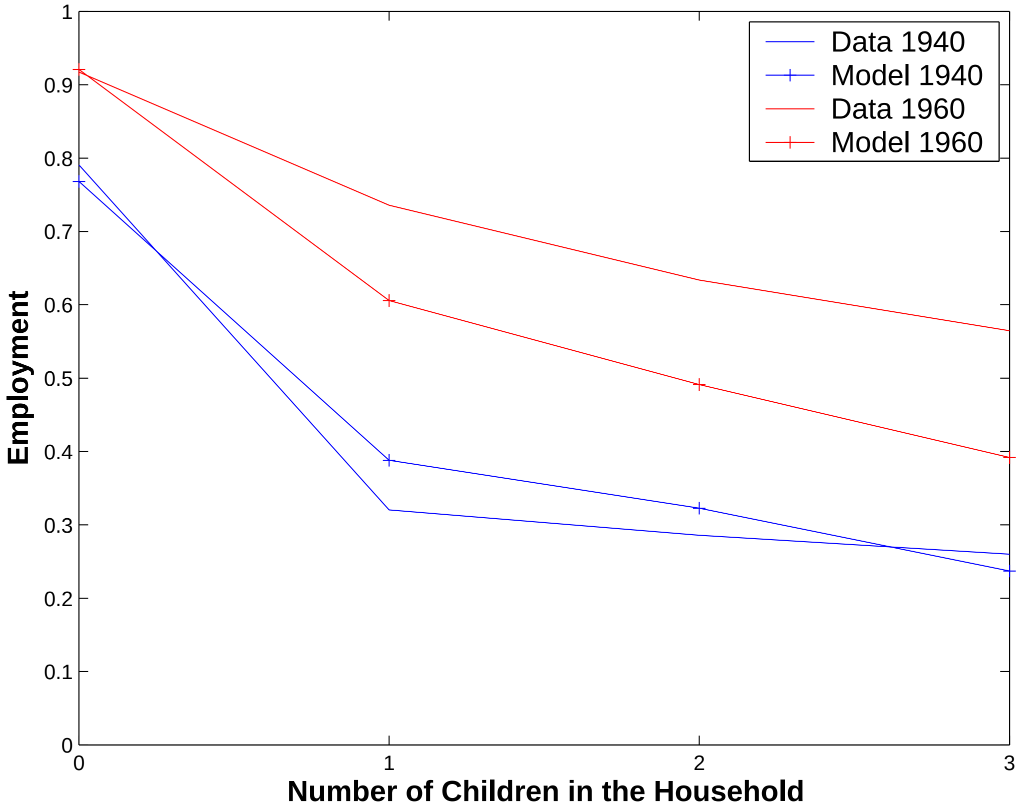


Table 8: Exogenous changes: Fertility distributions, gender wage gap, and returns to experience

Annual Percentage Point Difference in Employment Rate: (1960 - 1940)	*Age 23-29*	*Age 30-36*	*Age 36-43*
Model :	28	21	11
Sum :	21	15	6
Data :	30	27	12

Figure 23: Cross-section at Age 30



Finally, we compare model predictions to data for employment by number of children in the household at age 30 (see Figure 23). For women with zero children, we predict almost the entire change, while for women with one or more children in the household at age 30, we capture roughly 50 percent of the change. Thus, our model correctly predicts that women born in 1960 are more likely to work even when having children than those born in 1940. It may seem puzzling that the average increase is so large while we capture only about 50 percent of the increase in employment for one or more children. First, note that this corresponds to the age at which model and data are the furthest apart on average. Furthermore, there are two effects that contribute to the increase in female labor supply on average: a movement along the curve and a shift of the curve. To find an average employment rate of almost 70 percent, this suggests that a substantial fraction of women has zero children at age 30. Referring to Table 3, we see that at least 50 percent of women who have one or even two children over their life-time have them after age 30. This explains why despite the seeming failure to predict the entire increase in employment by number of children, most of the increase at age 30 on average comes from women who have zero children so far.

7 Concluding Remarks

We have presented data on employment, fertility and wages for cohorts of married women born between 1940 and 1960. After calibrating a life-cycle model of married female employment with experience accumulation, our experiments show that:

- Changes in fertility levels and, more importantly, **timing of births** are crucial to account for and understand changes in married women's employment.

- Together with **gender specific changes in wages**, they account for 87 percent of the increase in life-cycle employment.

One open question is: What caused the decrease and delay in fertility? Our current work in progress is to endogenize fertility and timing of births decisions to ask whether changes in wages can also account for the delay in fertility. Preliminary results show that the delay, though positive, is largely left unaccounted for.

Something else seems to have caused the delay in fertility. Several related questions come to mind: How is fertility related to the marriage decision? Was the change in fertility decisions simply due to cultural changes and changes in social norms? In what sense and can we attempt to measure these changes? The answers to these questions are closely intermingled and hard to disentangle from the question about why women tend to have children later and take care of them differently than they used to. They are however crucial to set up a useful model of fertility choices in terms of number and timing of births as well as child-care arrangements.

The other open question is why wage levels and returns to experience changed more for women than they did for men. Besides straight out discrimination, many other more readily quantifiable hypotheses can be considered. Changing occupational opportunities due to the rise in the service sector, changing educational investments pertaining more to women than men because of initial conditions are only a few avenues to be explored further.

8 Appendix

8.1 Data Sets and Definition of Variables

All raw data (Current Population Survey and Census) was obtained from Integrated Public Use Microdata Series (2004) available at http://www.ipums.org.

Current Population Survey (CPS), selection and sample sizes: We use data from the Current Population Survey (CPS) for the period between 1964 and 2003 to construct and analyze life-cycle employment rates and wages for cohorts of married women born between 1940 and 1960. For each year between 1964 to 2003, we gather the following information about individuals: their sex, race, age, marital status, education, whether they are in the labor force at the time of the survey, the number of weeks worked last year, the number of hours worked last week, and the total labor income earned last year. We select white women who are married. Moreover, we concentrate our analysis on women with a college degree since changes in life-cycle employment, wages and timing of births were the largest for this group.[19] Since we are mainly concerned with women's employment during the fertile part of their lives, we only look at employment and wages between age 20 and 50 (if available). These data cuts result in sample sizes ranging from 844 observations for the year 1964 to 3671 observations for the year 2003.

Census data, selection and sample sizes: We use Census data for the years 1970, 1980, 1990 and 2000 to describe fertility related variables of married women born between 1940 and 1960. We gather the following information about individuals: their race, marital status, education, whether they are in the labor force at the time of the survey, the number of weeks worked last year, the number of hours worked last week, the total labor income earned last year, the number of own children in the household, the number of own children in the household age 5 and under, the number of children ever born (if available) and the age at which they had their first child (if any). We select white women who are married and have a college degree. From this data, we construct a measure of completed fertility and age at birth of first child using women at age 40 (e.g. 1980 Census for 1940

[19]See Buttet (2005) for changes in life-cycle employment and fertility across cohorts for different education groups and for the average.

cohort). Furthermore, we calculate employment and weekly wages by number of children at age 30 and/or 40. These data cuts result in sample sizes ranging from 1,158 observations for the year 1970 (1940 cohort at age 30) to 3,865 observations for the year 2000 (1960 cohort at age 40).

Synthetic Cohorts: We construct cohorts using 3 birth year intervals. For example, to build the "1940 birth cohort at age 24", we consider married women of age 23 to 25 in the year 1964 of the CPS, "at age 25" married women of age 24 to 26 in the year 1965, etc. This keeps the annual number of observations large despite the many data cuts we use.

Employment: We count as employed, anyone who was at work during the week preceding the interview or has a job but was not at work last week due to illness, vacations, etc.

Weekly wage: The Current Population Survey (CPS) provides individual data on total labor income earned in the previous calendar year as well as weeks worked last year. Weekly wages then total labor income divided by weeks worked.

Hourly wage: The CPS does not provide a readily available measure for the hourly wage rate. We calculate an estimate of the average hourly wage of individuals as follows. For each individual who works, we divide his/her total labor income earned in the previous year by the total number of weeks he/she worked last year and the average number of hours worked by men/women in a typical week.[20]

8.2 Calculation of ϵ^* and $E_t V_{t+1}$

In this subsection, we explain our procedure to calculate the productivity threshold, $\epsilon_t^*(\theta, h)$, where $\theta = (\beta_0, f, a)$. We define the indirect utility from choice (e_t, q_t):

$$
\begin{aligned}
&\forall t \in \{1, ..., T\}, \quad W_t^{e_t,q_t}(\theta, h, \epsilon) = \\
&U(w_{mt} + w_t(\beta_0, h, \epsilon)e_t - g_n(f, a, q_t), 1 - e_t t_w - t_n(f, a, q_t), n_t) \\
&+ \delta E_t V_{t+1}\big(\theta, h + e_t, \epsilon'\big)
\end{aligned}
\tag{30}
$$

[20]See Eckstein and Nagypal (2004) and Card and DiNardo (2002) for a detailed discussion of the main issues involved with the calculation of hourly wage rates.

For convenience, we omit the permanent type, θ. Note that when women do not work, i.e. $e_t = 0$, the indirect utility does not depend on the productivity shock, ϵ_t. Therefore, let $W_t^0(h)$, be defined by:

$$W_t^0(h) = \max\{W_t^{0,1}(h,\cdot), W_t^{0,0}(h,\cdot)\} \tag{31}$$

The reservation productivity threshold, $\epsilon_t^*(h)$, is defined by:

$$W_t^{1,1}(h, \epsilon_t^*(h)) = W_t^0(h) \tag{32}$$

Let $\hat{q}_{0t}$ be the optimal child-care decision at time t when women do not work. Since the period-t utility is given by:

$$u(c_t, l_t, n_t) = \alpha \ln(c_t) + (1-\alpha) \ln \left(\gamma l_t^\rho + (1-\gamma) n_t^\rho\right)^{\frac{1}{\rho}} \tag{33}$$

the previous equation simplifies to:

$$\begin{aligned} &\alpha \ln(c_t^1(\epsilon_t^*)) + (1-\alpha) \ln \left(\gamma l_t^{1\rho} + (1-\gamma) n_t^\rho\right)^{\frac{1}{\rho}} + \delta E_t V_{t+1}\big(h+1, \epsilon'\big) \\ &= \alpha \ln(c_t^0) + (1-\alpha) \ln \left(\gamma l_t^{0\rho} + (1-\gamma) n_t^\rho\right)^{\frac{1}{\rho}} + \delta E_t V_{t+1}\big(h, \epsilon'\big) \end{aligned} \tag{34}$$

where

$$\begin{aligned} &c_t^1(\epsilon_t^*) = (1 - g_n(f,a,1)) w_{mt} + w_t(\beta_0, h, \epsilon_t^*(h)), \\ &c_t^0 = (1 - g_n(f,a,\hat{q}_{0t})) w_{mt}, \\ &l_t^1 = 1 - t_w - t_n(f,a,1), \\ &l_t^0 = 1 - t_n(f,a,\hat{q}_{0t}) \end{aligned} \tag{35}$$

Therefore,

$$\begin{aligned} &\alpha \ln \Big[\frac{c_t^1(\epsilon_t^*)}{c_t^0}\Big] = (1-\alpha) \ln \Big[\frac{\left(\gamma l_t^{1\rho} + (1-\gamma) n_t^\rho\right)^{\frac{1}{\rho}}}{\left(\gamma l_t^{0\rho} + (1-\gamma) n_t^\rho\right)^{\frac{1}{\rho}}}\Big] \\ &+ \delta E_t V_{t+1}\big(h, \epsilon'\big) - \delta E_t V_{t+1}\big(h+1, \epsilon'\big) \equiv A(h) \end{aligned} \tag{36}$$

The previous equation can be rewritten as:

$$c_t^1(\epsilon_t^*) = c_t^0 exp[\frac{A(h)}{\alpha}] \tag{37}$$

or, after rearranging,

$$\begin{aligned} w_t(\epsilon_t^*) &= \Big((1 - g_n(f,a,\hat{q}_{0t})) exp[\frac{A(h)}{\alpha}] - (1 - g_n(f,a,1))\Big) w_{mt} \\ &\equiv B(h) w_{mt} \end{aligned} \tag{38}$$

Women's wage equation is given by:

$$w_{ft}(\epsilon_t^*) = exp[\beta_0 + \beta_1(t)h] \times exp[\epsilon_t^*] \tag{39}$$

Therefore, when the right-hand side of equation (38) is positive, we have:

$$exp[\epsilon_t^*] = \frac{B(h)w_{mt}}{exp[\beta_0 + \beta_1(t)h]} \tag{40}$$

i.e.,

$$\epsilon_t^*(\theta, h) = \ln(B(\theta, h)) + \ln(w_{mt}) - \beta_0 - \beta_1(t)h \tag{41}$$

We can then calculate the expected utility for woman of type, θ, with work experience h:

$$\begin{aligned} & E_{t-1}V_t(\theta, h) = \Phi\Big(\epsilon_t^*(\theta, h)\Big) \times W_t^0(\theta, h) \\ & + \alpha \int_{\epsilon_t^*(\theta,h)} \ln(c_t^1(\epsilon))\phi(\epsilon)d\epsilon + \Big(1 - \Phi\big(\epsilon_t^*(\theta, h)\big)\Big)\times \\ & \Big((1-\alpha)\ln\big(\gamma l_t^{1\rho} + (1-\gamma)n_t^{\rho}\big)^{\frac{1}{\rho}} + \delta E_t V_{t+1}\big(\theta, h+1, \epsilon'\big)\Big) \end{aligned} \tag{42}$$

Finally, to calculate the integral on the computer, we linearize the second term around $\epsilon = 0$. That is,

$$\ln(c_t^1(\epsilon_t)) \approx \ln(c_t^1(0)) + \frac{exp[\beta_0 + \beta_1(t)h]\epsilon_t}{c_t^1(0)} \tag{43}$$

Therefore, women's utility in equation 42 is approximated by:

$$\begin{aligned} & E_{t-1}V_t(\theta, h) \approx \Phi\Big(\epsilon_t^*(\theta, h)\Big) \times W_t^0(\theta, h) \\ & + \frac{exp(\beta_0 + \beta_1(t)h)E(\epsilon|\epsilon > \epsilon^*)}{c_t^1(0)} + \Big(1 - \Phi\big(\epsilon_t^*(\theta, h)\big)\Big)\times \\ & \Big(\alpha\ln(c_t^1(0)) + (1-\alpha)\ln\big(\gamma l_t^{1\rho} + (1-\gamma)n_t^{\rho}\big)^{\frac{1}{\rho}} + \delta E_t V_{t+1}\big(\theta, h+1, \epsilon'\big)\Big) \end{aligned} \tag{44}$$

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