Cognitive Skills, Education, and Fertility Risk*

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Abstract

The paper studies the relationship between cognitive ability, education outcomes, wages, and fertility timing, focusing on how cognitive ability influences fertility decisions. First, the paper presents empirical evidence on the relationship between cognitive ability, early pregnancies, and pregnancy intention using NLSY79 data. Second, I build and estimate a life cycle model to quantify the importance of cognitive ability, wages, marriage, and education outcomes on women's fertility. To explain the data, the model needs heterogeneous contraception costs by ability, as the relation between cognitive ability with education opportunities and labor opportunity costs can not explain the relation of cognitive ability with fertility timing. Next, I use the model to analyze how decreasing contraception costs affect early pregnancies and women's educational outcomes. Finally, I study the mechanism behind the decline in teen pregnancies during the '90s.

JEL: J13, J16, J24, I21, D91

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1 Introduction

The decision of when to have children is one of the most crucial economic choices that individuals make, as it has significant implications for them and their descendants' welfare. Additionally, the consequences of fertility timing extend beyond the household level and have far-reaching social and economic effects as they shape human capital investment. In 2011, some 562,000 women younger than 20 became pregnant. About 553,000 of those pregnancies were among teenagers (i.e., 15–19 years old)[1]. Early pregnancies are associated with a multitude of adverse life outcomes for mothers and children. Particularly, young mothers experience low educational, occupational, and marital outcomes. These pregnancies are more prevalent among the most disadvantaged members of our society, who exhibit lower performance across multiple dimensions even before becoming pregnant, increasing intergenerational inequality. As a result, the study of fertility timing is a relevant topic in order to improve people's lives. In this paper, I focus on a specific aspect: the prevalence of early pregnancies among low cognitive abilities individuals and the mechanism through which cognitive ability shapes fertility.

Multiple studies have shown the link between cognitive ability and behavioral outcomes (Heckman et al., 2006; Cawley et al., 1996; Herrnstein and Murray, 2010). Simultaneously, education attainment and wages are key mechanisms for determining fertility (Becker, 1965; Rosenzweig and Schultz, 1989; Greenwood et al., 2000; Caucutt et al., 2002; Keane and Wolpin, 2010). My study contribution is quantify which fraction of the relation of cognitive ability and fertility is explained through education and labor cost and which fraction remains to be explained.

The study of the importance of education, wages, and labor market opportunities on fertility outcomes dates from the allocation of time theory (Becker, 1965), which argues that differences in opportunity costs by education shape fertility decisions. However, Rosenzweig and Schultz (1989); Musick et al. (2009) find that differences in opportunity cost are not able to account for fertility patterns across different education groups, and differences in proficiency at utilizing contraception effectively are necessary to explain part of the difference in fertility. In this paper, I extend these studies by incorporating cognitive ability into the

[1] https://www.guttmacher.org/report/us-teen-pregnancy-trends-2011

joint decisions of education, marriage, fertility, and wages to comprehend the role of cognitive skills in shaping fertility outcomes.

The economic and social repercussions of early pregnancies are numerous. Women who experience early first childbirth are more likely to be single mothers or enter into shotgun marriages, which have a higher probability of ending in divorce (Kozlov, 2021). As a result, their children are more likely to grow up in single-parent households, which is associated with poorer educational and economic outcomes (Kearney and Levine, 2017). Furthermore, mothers with early pregnancies tend to have worse economic and social outcomes (Amador, 2017; Foster et al., 2018; Levine and Painter, 2003). Additionally, these pregnancies are more prevalent among low-income women, which further reduces intergenerational mobility Seshadri and Zhou (2022).

In order to explore the relationship between cognitive skills and fertility, I use data from the National Longitudinal Survey of Youth 1979 (NLSY79), which offers comprehensive information on cognitive skills, women's fertility, and labor outcomes. To measure the impact of cognitive skill on fertility decisions, a static linear model is estimated at ages 14-17, 18-21, and 22-29 years old, treating ability as a latent variable in order to address measurement error and simultaneous causation bias (Hansen et al., 2004).

The results indicate that the significance of cognitive skills in determining the occurrence of the first childbirth diminishes as individuals age. However, the estimated model does not account for individuals' expectations about the future and how those expectations may influence the relationship between ability and fertility. For instance, in the case of teenagers, the coefficient capturing ability also contains the fact that high-ability women are more likely to pursue higher education, which could impact the cost and usage of contraception. Therefore, the previous analysis fails to disentangle whether cognitive skills become less influential with age or if the decreasing coefficient results from education and wage opportunities being realized.

In order to address the previous limitation and enable counterfactual analysis, I construct and estimate a life-cycle model incorporating endogenous fertility, education, and marriage decisions to jointly study the relationship between cognitive skills, wages, education, and fertility choices over the life cycle. In the model, differences in opportunity costs by ability and contraception costs by education are insufficient to explain the correlation between ability and fertility, making it necessary to incorporate ability directly in the fertility decision in order to explain the data.

Subsequently, the developed model is employed to examine the impact of early pregnancies on education outcomes and vice versa. Consistent with existing empirical evidence, the model indicates that improvements in contraception have a small effect on college attendance, which is consistent with the fact that women who experience teenage pregnancies already face significant challenges, making the cost of attending college prohibitively high, even without additional costs associated with raising a child. Finally, I use the model to discompose the mechanism behind the decline in teenage pregnancies in the United States during the 1990s. I found that this decline is explained by lower contraception costs and, to a lesser extent, by improvements in college access, which raises the opportunity cost of early pregnancies.

2 Literature

The paper is related to various branches of economic literature. Firstly, it relates to the literature on dynamic models with endogenous family formation and stochastic fertility choices pioneering by (Rosenzweig and Wolpin, 1993; Wolpin, 1984). Among the closest works is Keane and Wolpin (2010) study on the role of labor market opportunities, marriage market opportunities, and preference heterogeneity in school attendance, labor, marriage, fertility, and welfare participation. Regalia et al. (2011) who examine how changes in relative wages impact the number of single mothers. Caucutt et al. (2002) explore how child investment, marriage, and labor market outcomes influence women's fertility timing. Choi (2017) who study differences in childbearing and abortions across educational groups, finding that differences in fertility risk by education are necessary to explain the data. Filote et al. (2019) who study how the welfare state affects teenage childbearing behavior. Amador (2017) studies the effect of reducing contraception costs in contraception use, pregnancies, and education. Finally, Seshadri and Zhou (2022) analyzes how heterogeneity in fertility planning affects children's investment and shapes intergenerational mobility. The main contribution to this literature is modeling the effect of cognitive ability on contraception jointly with its effect on education outcomes and wages in order to measure the effect of cognitive ability on fertility.

This paper is also related to the empirical literature on the determinants of the relationship between education and childbearing. Some relevant studies are Rosenzweig and Schultz (1989), which find that education is associated with higher contraception efficiency due to better knowledge. Levine and Painter (2003); Hotz et al. (2005) suggests that the impact of early pregnancies on subsequent education outcomes is smaller than what cross-sectional data may imply, as those who experience early pregnancies are less likely to achieve higher education outcomes. Musick et al. (2009) find that the fertility gradient by education primarily arises from unintended childbearing rather than differences in opportunity costs. Bailey et al. (2023) conducted an RCT and found that eliminating the monetary cost of contraception methods increases the use of high-quality methods and could potentially reduce undesired births by 5.3%. The contribution is to use a structural model to analyze the relationship between early childbearing and education outcomes once we account for differences in cognitive skills and study how a decrease in contraception cost shapes fertility timing and educational outcomes.

Additionally, this paper is connected to the literature examining the impact of cognitive skills and education on various behavioral outcomes. (Heckman et al., 2006, 2018; Hai and Heckman, 2022) provide evidence that cognitive skills significantly reduce the likelihood of teenage childbirth, with individuals at the higher end of the ability distribution having nearly zero chances of unintended pregnancies. In particular, I contributed by studying the role of cognitive ability on pregnancy timing and teen pregnancies. Finally, this paper is related to the economic literature on teen pregnancies and the reason behind their decline in the last years; see Kearney and Levine (2012) for a review.

3 Empirical Evidence

In this section, I present empirical evidence on the impact of cognitive skills on fertility using data from the National Longitudinal Survey of Youth 1979 (NLSY79). Firstly, I describe the dataset and provide an overview of its key characteristics. Secondly, I present descriptive statistics that relate cognitive skills, early pregnancies, education, and marriage. Finally, I estimate a linear factor model at various ages to measure the influence of cognitive skills on fertility across the life cycle.

3.1 Data Description

The NLSY79 tracks a representative sample of American youth born between 1957 and 1964 aged 14 to 22 when initially interviewed in 1979. In this paper, a pregnancy is defined as a live birth. Therefore, childbirth and pregnancy are used interchangeably. The survey is significant for this study for three reasons. Firstly, cognitive skills were assessed in 1980 through ten intelligence tests known as the Armed Services Vocational Aptitude Battery (ASVAB). Secondly, the participants have been monitored for over 40 years, and the women in the sample have already completed their reproductive years. Lastly, the survey asked mothers whether their pregnancies were intended at the time of conception.

Using a subset of the ASVAB test, an approximate score of a general cognitive skills test known as the Armed Forces Qualifications Test (AFQT) was computed in 1980. This test is the standard measure utilized in the literature to approximate cognitive skills. The resulting scores were used to rank women according to cognitive skills percentiles. After dropping the observations with missing ASVAB values, a panel of 5,634 women was utilized for the analysis. Aditional information about the data distribution and cleaning is available in appendix A.

3.2 Descriptive Statistics

This subsection outlines the data characteristics that are the main focus of this paper. The objective of this study is to investigate the relationship between cognitive skills and fertility. Since pregnancies influence education costs, labor supply, and marital status, the analysis focuses on data characteristics that relate cognitive skill, childbirth timing, education, wages, and marital outcomes.

3.2.1 Cognitive Skills and Age at First Childbirth

Table 1 displays the joint distribution between age groups, cognitive skills quartiles, and childbirth outcomes conditional on not having childbirth in the previous age bin. For example, the interpretation of the first column, third row, is that half of the women in the first ability quartile who did not have childbirth before 22 years old had one between 22-29 years old.

Table 1. Joint Distribution First and Unwanted First Pregnancy by Age and Cognitive Skills

	Ability Quartile			
	First Quartile	Second Quartile	Third Quartile	Four Quartile
Age	Pregnancy Probability			
14-17	28%	16%	9%	3%
18-21	49%	38%	25%	16%
22-29	54%	53%	46%	45%

Notes: Women are bin by cognitive skills scores and age. Each age-ability bin only considers the sample of women without a childbirth before the initial age at the respective bin. The childbirth probability is calculated as the ratio of women with a childbirth at a particular age-ability bin over the total number of women in the respective bin.

We can see a positive correlation between cognitive skills and age at first birth that diminishes as women age. Between the ages of 14 and 17, 26% of women in the lowest cognitive skills quartile have their first childbirth, compared to only 3% of those in the highest quartile, indicating a ninefold difference in childbirth rates. However, as women age, this ratio decreases to 3 between ages 18-21 and 1.2 between ages 22-29.

3.2.2 Pregnancy Timing and Education

Table 2 shows the joint distribution of women's age at first childbirth and the highest educational level achieved. First, we observe that most pregnancies occur at ages when women are expected to have completed their final education level. For example, 82% of high school graduates had their first child after high school age, and 73% of college graduates had their first childbirth after college age.

Table 2. Conditional Distribution Age First Pregnancy by Education Outcomes

	Education Outcome		
Age at First Pregnancy	High School Dropout	High School Graduate	College Graduate
14-17	42%	14%	3%
18-21	32%	31%	8%
22-29	14%	28%	37%

Notes: The table shows the fraction of women that had their first childbirth at each respective age group by the highest education achievement reported in the sample. Each column sum 100.

The relationship between education outcomes and pregnancies is mutually causal. On the one hand, pregnancies are costly in terms of time and money, making women more likely to drop out or not pursue higher education, creating a link between early pregnancies and lower educational attainment. On the other hand, the opportunity cost of a pregnancy is lower for less educated women. As a result, we need a dynamic model to understand if women with early pregnancies have low educational attainment because they are young mothers or whether they have children at a young age because pursuing higher education is too costly.

3.2.3 Early Pregnancies and Marriage

Becker (1991) argues that out of wedlock children decrease the likelihood of the mother's future marriage by reducing her net resources and raising the cost of searching for a husband. Bronars and Grogger (1994) find that women with unplanned births were, on average, 13 percentage points less likely to be married while their children were young, and this differential narrowed only by 4 percentage points by the time their children were preteenagers.

I investigate the impact of out of wedlock pregnancy on the probability of marriage during mothers' lifetime and the quality of their husbands, measured by their income. I found that women with out of wedlock births have a similar probability of marriage during their lifetime as women without such births. In terms of wages, women from all education groups with out of wedlock pregnancies have husbands with lower wages.

Table 3. Probability of ever marriage single mother vs non single mothers

	High School Dropout	High School Graduate	College Graduate
Age at Pregnancy		Single Mothers	
14-17	77%	87%	92%
18-21	71%	85%	87%
22-29	64%	75%	85%
		Non Single Mothers	
	84%	84%	83%

Notes: The table shows the probability of ever marriage for women with and without out of wedlock childbirth. In the case of women with out of wedlock pregnancies, the probabilities are disaggregated by age at childbirth. The probability is defined as the number of women who married at some point over the survey over the number of women in the respective bin. "Ever Marriage" is defined as reporting at least one marriage during the survey.

Table 3 compares the probability of marriage for single mothers to non-single mothers. For single mothers, the marriage probability is analyzed conditional on their age at first childbirth. The marriage probability for single mothers increases with education and decreases with age at childbirth. For example, 87% of high school graduate single mothers between 14 and 17 years old married after birth compared to 75% of single mothers between 22-29 years old with the same education level. In addition, 71% of 18 to 21 years old high school dropout single mothers got married compared to 87% of college graduates. For non-single mothers, the fraction who married is around 83% for the three education groups. High school dropout is the only group in whom an out of wedlock pregnancy considerably decreases their marriage probability.

Table 4. Average Husband Wage by Education and Women Children at Marriage.

	High School Dropout		High School Graduate		College Graduate	
Age Fir. Preg.	Out-Wed.	No Out-Wed.	Out-Wed.	No Out-Wed.	Out-Wed.	No Out-Wed.
14-17	35089	34563				
18-21	35806	39064	44602	46000		
22-29	33622	35806	43719	55143	66025	73628

Notes: The table shows husbands' average yearly wage for women with and without an out of wedlock childbirth. Wages are deflated to 2016 prices. I only consider married women with husbands who make more than 2.5 dollars per hour and work more than 2000 hours a year.

Table 4 presents a comparison of husbands' yearly wages for women with and without out of wedlock childbirths after completing their highest level of education. The table provides information on the average income of husbands based on women's age at first childbirth, educational attainment, and the occurrence of an out of wedlock childbirth. Results show that women without out of wedlock childbirths have husbands with higher incomes. The highest penalty that we observe for high school dropout women is around \$2,000 yearly. High school graduates face an average penalty of \$11,000 yearly. Finally, in the case of college graduates, they face a penalty of around \$8,000 in annual husband income.

3.3 The Effect of Cognitive Skills on Fertility

In order to comprehend the effect of ability, we need to control for two important mechanisms that delay childbirth: education opportunities and forgone income. Both mechanisms increase the opportunity cost of having children early in life for high-skill individuals, which makes it difficult to separate the effect of ability given that individuals' decisions are affected by their forward-looking behavior, which is determined by future education and income. To address this, I estimate a static model at three different points in time: teens (14-17 years old), college age (18-21 years old), and young adults (22-29 years old). Between 18 and 21 years old, high school education outcomes are already realized for most agents; however, future income and college outcomes still affect the opportunity cost and, with them, fertility decisions. Between 22 and 29 years old, education is entirely realized for most individuals, and a significant proportion of income realizations has already been observed. In this form, I see how the effect of cognitive ability changes as the uncertainty about education outcomes and income disappears.

Another concern is that the dataset provides an intelligence test susceptible to measurement error and reverse causality bias as the test is affected by family background and formal education. As Heckman et al. (2006) argue *"we note that there is an important distinction between intelligence tests (i.e., IQ tests) and achievement tests. Although IQ is fairly well set by age 8, achievement tests have been demonstrated to be quite malleable"*. The simple least square model overpredicts the impact of ability tests and understates the contribution of formal education on different outcomes as it imputes the impact of family background and education on cognitive skills. I follow the method proposed by Cawley et al. (1996); Heckman et al. (2006); Hansen et al. (2004) to estimate cognitive skills as a latent variable correcting reverse causality bias and measurement error.

Additionally, I follow the same process to estimate the effect of cognitive skills on unintended childbirth to provide further evidence of its effects on women's fertility. In the NLSY79, women were asked whether they wanted to become pregnant before their first pregnancy. Then, I define an unintended pregnancy as when a woman does not want to get pregnant at the moment of the pregnancy.

The estimated linear model at each age is:

$$Y_i^{14-17} = \beta_0 + \alpha_\theta \theta_i + \beta_X X_i + \epsilon_i$$
$$Y_i^{18-21} = \beta_0 + \alpha_\theta \theta_i + \beta_{HS} HS_i + \beta_{CA} CA_i + \beta_X X_i + \epsilon_i$$
$$Y_i^{22-29} = \beta_0 + \alpha_\theta \theta_i + \beta_w w_i + \beta_{HS} HS_i + \beta_C C_i + \beta_X X_i + \epsilon_i$$

where Y_i^{age} represents the outcome for individual i at a specific age, such as having a child or having an unintended child. The latent variable, θ, represents cognitive skills, while HS, CA, and C are dummies for graduating high school, attending college, and graduating college, respectively. Additionally, w is the mean hourly wage during the period, and X includes demographic controls such as race, both parent education and broken home status at 14. To identify the latent variable θ, I use the following measurement system:

$$T_i = \beta_T X_{i,T} + \theta_i + \epsilon_{i,T}$$

the vector of cognitive skills measures is denoted by T, while X_T is a vector of controls for each measure, including race, both parents' education, broken home at 14, and years of completed education at the moment of the test. The model is estimated by maximizing a likelihood function, which assumes that F_θ follows a mixture of normal distributions.

Table 5 presents the results of the models, showing that cognitive skills significantly affect childbirth timing and intention, but the effect decreases with age as expected as the bias generated by future outcomes disappears. Specifically, the data indicates that higher cognitive skills decrease the probability of childbirth for teenagers and college age women but increase the probability for young adults. However, for the last group, the effects are not significant. Additionally, cognitive skills significantly reduce the probability of unintended pregnancies for all age groups, although the effect is not significant for young adults, which is consistent with the hypothesis that cognitive skill affects fertility timing.

Teenagers in the top cognitive quartile are 50% less likely to have childbirth and 17% less likely to have unintended childbirth than those in the bottom quartile. For 18-21 year old, the difference in childbirth and unintended childbirth rates between the top and bottom quartile is 13% and 11%, respectively. Finally, women between 22-29 years old in the top quartile are 3% more likely to have childbirth but 17% less likely to have unintended childbirth than those in the bottom quartile.

Education and income are important determinants of fertility timing. Higher wages and college education decrease the probability of childbirth and unintended childbirth. For women aged 18-21, attending college reduces the probability of having their first childbirth by 82% and reduces the probability of unintended first childbirth by 75%. For women aged 22-29, a college education reduces the probability of childbirth by 26% and the probability of unintended childbirth by 19%. The interquartile range of wages is associated with a 9% increase in the probability of having their first childbirth and a 10% decrease in unintended pregnancies. The fact that college attendance remains relevant even after controlling for wages supports that education affects fertility beyond the opportunity cost.

The preceding results provide supporting evidence that cognitive skills affect fertility. However, we cannot estimate the unbias effect of ability for younger women and disentangle which fraction of the decrease in the effect with age is caused by the upward bias disappearing as uncertainty disappears or the importance of ability on fertility changing with age. For this reason, in the following sections, I build and estimate a dynamic lifecycle model that quantifies the importance of cognitive skills in fertility decisions at different ages. Additionally, the model allows us to realize counterfactuals to understand how different policies and mechanisms affect women's fertility timing.

Table 5. Latent Factor Model: Pregnancies and Unintended Pregnancies

	(1)	(2)	(3)	(4)	(5)	(6)
	Preg.	Unint. Preg.	Preg.	Unint. Preg.	Preg.	Unint. Preg.
	14-17 yrs old	14-17 yrs old	18-21 yrs old	18-21 yrs old	22-29 yrs old	22-29 yrs old
Cog. Ab.	-.10***	-.03***	-.05***	-.02	.03	-.03
	(.01)	(.01)	(.02)	(.02)	(.03)	(.02)
HSG			.04**	.00		
			(.02)	(.01)		
Att. Coll.			-.23***	-.09***		
			(.02)	(.01)		
College					-.13***	-.02
					(.02)	(.02)
Wage					.05***	-.01
					(.01)	(.01)
Change in Probability						
$\Delta(d_{75} - d_{25})/\overline{Cog.Ab.}$	-50%	-17%	-13%	-11%	3%	-17%
HS			14%	-1%		
Att. Col.			-82%	-75%		
College					-26%	-19%
$\Delta(d_{75} - d_{25})/\overline{Wage}$					9%	-10%
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4270	3504	3710	2949	2556	1847

Standard Errors in Parentheses $\quad$ * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

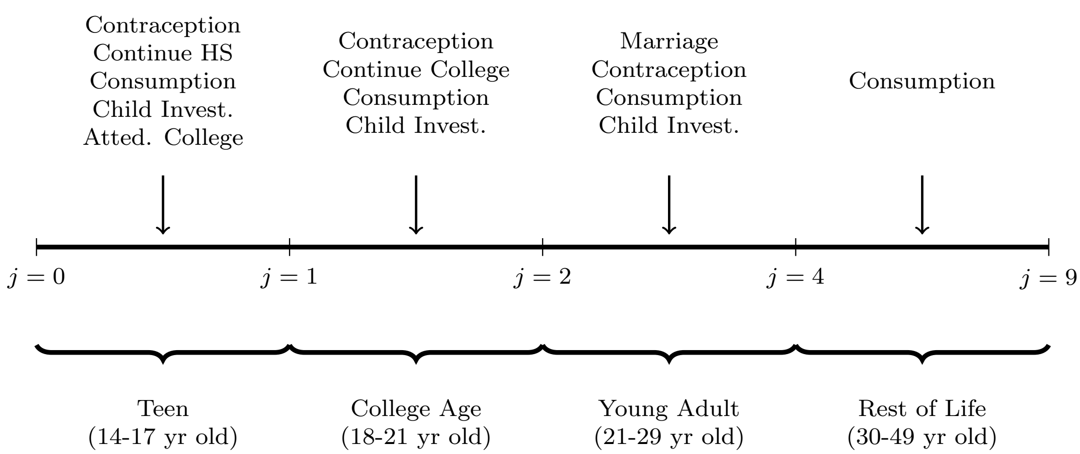
Notes: Wage and test scores are standardized with a mean zero. Controls include race, both parent education, and broken home at 14. $\Delta(d_{75} - d_{25})/Y$ is the interquartile range divided by the mean for a particular variable. Each age group only considers women without childbirth at the initial age of each group.

4 Model

In this section, I present the life cycle model that I use to quantify the effect of cognitive skills on fertility. The model addresses the dynamic concerns arising from individuals being forward-looking, where childbearing affects future opportunities, and contraception choice depends on labor, marriage, and educational prospects. Additionally, it allows us to measure the effects on fertility of changes in contraception costs and education opportunities.

4.1 Environment and Timing

Figure 1. Women Attending College Life Cycle



Notes: The figure describes women's life cycle. The women's life cycle is divided into four stages: i) teen, ii) college age, iii) young adult, and iv) rest of life. Above the timeline, we can see women's decisions every period during each age.

Time is discrete, and women live a finite number of periods. The women's life cycle is divided into nine periods, each spanning four years, as illustrated in Figure 1. All women start as 14-year-old teenagers with varying levels of cognitive skills a and remain fertile until the age of 29. In the sample, 70% of first childbirth occurred between the ages of 14 and 29. During each fertile period, women make decisions regarding contraception, and if a child is born, they decide on the investment in the child. If she is in high school or college, she decides whether to continue or drop out and work as a high school graduate after determining their fertility outcomes. This decision precedes any investment in the child. Thus, opting to participate in the labor market augments the immediate resources available for child investment at the cost of lower educational achievement for the mother. During each fertile period, when women are not attending school, they can meet a potential husband and choose to marry if the utility of being married is higher than that of being single. Husbands' only contribution is a wage, and women decide the allocation of household resources. After their fertile years, individuals do not make any choices and only consume their income.

In this economy, each woman can only have one child who lives only during the period that the child was born. During that period, mothers can invest money to increase the child's human capital, and the utility of having a child is increasing in the child's human capital. As a result, children are a once-in-a-lifetime investment opportunity. The optimal age for having a child is when parents have higher resources, which incentivizes women in the model to postpone pregnancies. However, waiting is costly, given the cost of contraception. The model includes a reduced form for child investment to incentivize high-income individuals to postpone parenthood. The investment function is consistent with the fact that child investment is increasing in income, but it does not model child investment realistically, as this is beyond the scope of the paper. The model does not include assets, income uncertainty, or divorce to maintain tractability.

To capture the multi-dimensional nature of contraception, I include in the contraception cost both monetary and non-monetary components, such as physical, psychological, and social costs, associated with avoiding childbirth, rather than focusing on specific contraceptive methods. In addition, contraception is imperfect, which always makes the probability of unintended childbirth positive. By including the costs of contraception and the potential for imperfect contraception, the model aims to capture the complexity of this decision, which is crucial in understanding how women's fertility choices respond to changing economic opportunities and contraception costs.

The model notation is as follows. The indirect utility function is denoted by V_t^j, where t represents the period, and j is the sub-period. The state variables include ability, education, current marital status, marital status at childbirth, and the period in which a child was born. Ability, $a \in [0, 1]$, is continuous. Education is represented by three states, $e \in HSD, HS, C$, where HSD represents high school drop-out, HS represents high school graduate, and C

represents college graduate. Marital status is denoted by $m \in \{0, 1\}$, where 0 represents single, and 1 represents married. The variable $sm \in \{0, 1\}$ represents whether a woman had an out of wedlock childbirth. The variable $k_t \in \{0, 1, 2, 3, 4\}$ tracks the period in which a child was born. If a woman has never been a mother, this state variable is zero. The decision variables are consumption $c \in [0, \infty)$, child monetary investment $i \in [0, \infty)$, and the amount of contraception $s \in [0, \infty)$, all of which are continuous. In the following sections, I introduce each period and its respective sub-period in reverse order to simplify the exposition.

4.2 Rest of Life: Fifth to Ninth Period (30-49 Years Old)

The model focuses on ages 14 to 29, as these are the ages when fertility and education decisions are made. However, given that an important proportion of post-college earnings are realized after 30, I also incorporate the age range of 30 to 49 into the model. During these periods, agents consume their household income and do not make any choices, so each period comprises only one sub-period. Agents live until 49 years old due to data constraints, as I explain in the wage estimation section 5.2. Women are characterized by their age t, ability a, education e, marital status m, single motherhood sm, and maternal age at birth k_t. Therefore, a woman's utility at the beginning of each period is determined by the following Bellman equation:

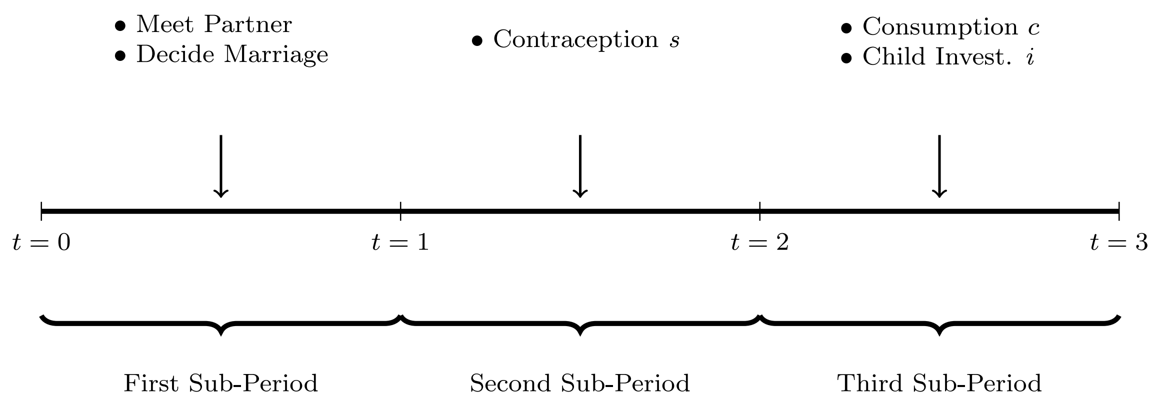
$$
\begin{aligned}
V_t(a, e, m, sm, k_t) &= \max_c \; u(c) + \beta V_{t+1}(a, e, m, sm, k_t) \\
\phi_c(m, k_t) \cdot c &= \; w(t, a, e, m, sm, k_t) + 1_{m=1} w^h(t, e, sm, k_t)
\end{aligned}
$$

where $\phi_c(m, k_t)$ maps consumption expenditures and family composition into effective consumption. The women's wage $w(t, a, e, m, sm, k_t)$ is a function of several variables, including age, ability, education, marital status, single motherhood, and her age at childbirth. The indicator function $1_{m=1}$ is used to determine if the woman is married. Finally, the husband's wage $w^h(t, e, sm, k_t)$ is a function that depends on age, the woman's education, single motherhood, and the age at which she became a mother.

4.3 Young Adult: Third and Fourth Period (22-29 Years Old)

During these periods, women make three sequential decisions, with each decision occurring in a sub-period. Figure 2 illustrates the decision timing within the period. In the first sub-period, single women meet potential husbands and decide to marry or remain single. In the second sub-period, women without previous children decide on contraception. Finally, in the last sub-period, women consume and invest in their children, depending on whether a child is born.

Figure 2. No Child, Single Women Between 22-30 Years Old



Notes: The figure describes the decision timing for young adult women (22-29 years old). Each period is divided into three sub-periods, and a decision is made on each: i) marriage, ii)contraception, and iii) consumption-investment.

4.3.1 Third Sub-Period: Consumption and Child Investment

In this sub-period, women must make decisions regarding both consumption and child investment, but this depends on whether they have a child within the period. If a child is born, they must decide on how much to invest in the child's human capital, in addition to their own consumption. The corresponding Bellman equation for this case is:

$$V_t^3(a, e, m, sm, k_t = t) = \max_{c,i} \; u(c) + V(i)^k + \beta V_{t+1}^1(a, e, m, sm, k_t = t)$$

$$\phi_c(m, k_t) \cdot c = \; w(t, a, e, m, sm, k_t) + 1_{m=1} w^h(t, e, sm, k_t) - i$$

where $V^k(i)$ is the utility that the child provides to the mother, which is increasing in the monetary investment i. The woman's wage is denoted by $w(t, a, e, m, sm, k_t)$, and $w^h(t, e, sm, k_t)$ represents the husband's wage if the woman is married. On the other hand, if the woman does not have a child during the period, her Bellman equation only includes the consumption choice:

$$V_t^3(a, e, m, sm, k_t) = \max_c \; u(c) + 1_{t=4 \text{ \& } k_t=0} \cdot \mu_{nk}(e) + \beta V_{t+1}^1(a, e, m, sm, k_t)$$
$$\phi_c(m, k_t) \cdot c = \; w(t, a, e, m, sm, k_t) + 1_{m=1} w^h(t, e, sm, k_t)$$

where $\mu_{nk}(e)$ is a utility value assigned in the last fertile period to women who never had a child during their fertile life ($1_{t=4 \text{ \& } k_t=0}$). The previous value is necessary to match that in the data 30% of women do not have a child at 30 years old.

4.3.2 Second Sub-Period: Contraception

During the second sub-period, women who did not have a child in previous periods decide on the amount of contraception s. The Bellman equation in this sub-period is as follows:

$$V_t^2(a, e, m, sm, k_t) = \max_s \; p(t, a, e, s) \cdot V_t^3(a, e, m, sm, k_t = t)$$
$$+\big(1 - p(t, a, e, s)\big) \cdot V_t^3(a, e, m, sm, k_t = 0) - \phi_s s$$

where ϕ_s is the utility cost associated with contraception, and $p(t, a, e, s)$ is the probability of having a childbirth, which is decreasing in the amount of contraception. If a woman has already had a child, she does not make a decision on contraception, and her utility at the beginning of the sub-period is $V_t^2(a, e, m, sm, k_t) = V_t^3(a, e, m, sm, k_t)$.

4.3.3 First Sub-Period: Marriage

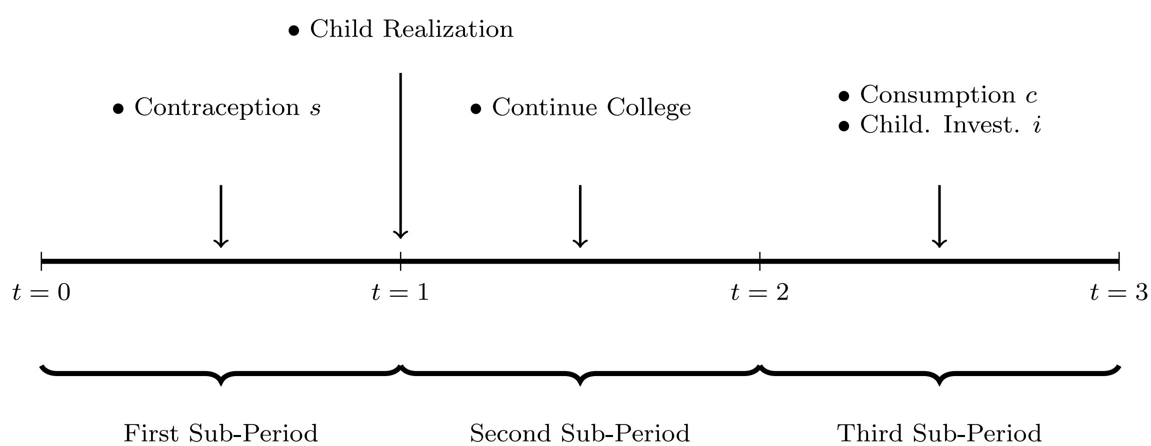
In the first sub-period, single women meet a potential husband with probability $\mu(e, t)$, which depends on the women's education achievement e and age t. If a woman meets a potential husband, she decides whether to marry or remain single. The woman will choose to marry if the utility of marriage is greater than remaining single. The Bellman equation in this sub-period is given by:

$$
\begin{aligned}
V_t^1(a, e, m = 0, sm, k_t) = \mu(e, t) \cdot \max\{V_t^2(a, coll, m = 1, sm, k_t), V_t^2(a, e, m = 0, sm, k_t)\} \\
+\big(1 - \mu(e, t)\big) \cdot V_t^2(a, e, m = 0, sm, k_t)
\end{aligned}
$$

Since the model does not account for divorces, women who are married do not make any marital decisions in the subsequent periods, and their utility is defined as $V_t^1(a, e, m = 1, sm, k_t) = V_t^2(a, e, m = 1, sm, k_t)$.

4.4 College Age: Second Period (18-21 Years Old)

Figure 3. Attending College (18-21 Years Old)



Notes: The figure describes the decision timing for women attending college. Each period has three sub-periods, and a decision is made on each: i) contraception, ii) continuing college, and iii) consumption-investment.

This period focuses on the decision of whether to attend college or join the labor market. In the case of not attending college, they have the same decision sequence as in subsection 4.3. If they decide to attend college, they make three sequential decisions. First, they decide on contraception. Second, after observing their childbirth outcome, they decide whether to continue attending college or dropout. When having a child during college, women face a double penalty: the cost of continuing college increases by $\kappa_{\mathrm{k,C}}$, and college students have limited monetary resources to invest in their child. Women who continue with their college education receive an allowance, denoted as w_c. College dropouts move to the last sub-period with the wages of high school graduates. Finally, in the third sub-period, women decide on consumption and child investment when having a child.

4.4.1 Third Sub-Period College Age: Consumption and Child Investment

The sub-period in which women attend college or work as high school graduates is the focus of this subsection. Women in college make consumption and child investment decisions. The Bellman equation for this sub-period is as follows:

$$V_2^{3,G}(a, k_t) = \max_{c,i} u(c) - \kappa_{\mathrm{k,C}} + V^k(i) + \beta V_3^1(a, e = \mathrm{C}, m, sm, k_t)$$

$$\phi_c(k) \cdot c = w_c - i$$

where the value function of continuing college is denoted by $V^{3,G}$ and the cost of attending college with a child is $\kappa_{\mathrm{k,C}}$. For women who dropped out of college in the previous sub-period, their problem is denoted by $V^{3,CD}$, and they face the consumption-investment problem of a high school graduate. Their Bellman equation is $V_2^{3,CD}(a, k_t) = V_2^3(a, e = \mathrm{HS}, m = 0, sm, k_t)$.

4.4.2 Second Sub-Period College Age: Continue College

During this sub-period, women who are attending college must decide whether to continue their education. This decision is made after they have observed their childbirth outcome. Their problem can be formulated as follows:

$$V_2^2(a, coll_a = 1, k_t) = \max_{i \in \{G,CD\}} \{V_2^{3,G}(a, k_t) + \sigma_{Coll}\epsilon_i, V_2^{3,CD}(a, k_t) + \sigma_{Coll}\epsilon_i\}$$

where $V^{3,G}$ and $V^{3,CD}$ represent continue college or drop out, respectively. The shock ϵ_i

is i.i.d. and follows a Type I extreme value distribution, and σ_{Coll} is the scale parameter.

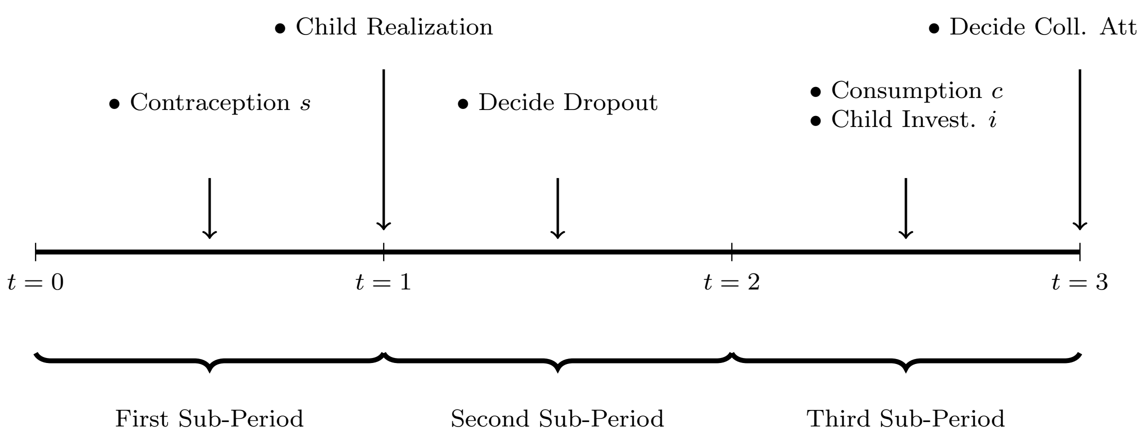
4.4.3 First Sub-Period College Age: Contraception

During the first sub-period, college women make a decision about the amount of contraception they choose to use. This decision is similar to the one they made in previous periods. As a result, the utility function at the beginning of this sub-period is given by:

$$
\begin{aligned}
V_2^1(a, coll_a = 1, k_t = 2) = \max_s \; & p(t, a, e = coll_a, s) \cdot V_2^1(a, coll_a = 1, k_t) \\
& + \big(1 - p(t, a, e = coll_a, s)\big) \cdot V_2^1(a, coll_a = 1, k_t = 0) - \phi(s)s
\end{aligned}
$$

4.5 Teen: First Period (14-17 Years Old)

Figure 4. Teens (14-17 Years Old)



Notes: The figure describes the decision timing for teens. Each period has three sub-periods, and a decision is made on each: i) contraception, ii) continuing high school, and iii) consumption-investment. At the end of the third period, teens that finish high school decide on college attendance.

The decision-making process for women aged 14-17 is as follows. At the beginning of the period, all attend high school and decide on contraception. After observing their fertility outcome in the second sub-period, they decide whether to continue high school. Those who choose to stay in school receive an allowance w_{HS} in the third sub-period. Those who drop out of high school work as high school dropouts. Finally, women who continue high school decide whether to attend college at the end of the third period.

4.5.1 Third Sub-Period Teen: Consumption, Child Investment, and College Attendance

At the end of the period, women who have graduated from high school face the decision of whether to attend college. The Bellman equation for this decision problem is given by:

$$V_1^{CD}(a, e = \text{hs}, sm, k_t) =$$
$$\max_{i \in \{C,NC\}} \{V_2^1(a, coll_a = 1, k_t) - \kappa_c(a, k_t) + \sigma_{CD}\epsilon_i, V_2^1(a, e = HS, m = 0, sm, k_t) + \sigma_{CD}\epsilon_i\}$$

where ϵ_i is an i.i.d. extreme value shock drawn from a Type I extreme value distribution, and σ_{CD} is the scale parameter. The psych cost $\kappa_c(a, k_t)$ of attending college depends on the woman's ability and whether she has a child. In the case of women attending high school with a child, the Bellman equation is:

$$V_1^{3,HSG}(a, HS_a = 1, sm = 1, k_t = 1) = \max_{c,i} \; u(c) + \kappa_{HS}$$
$$+V^k(i) + \beta V_1^{CD}(a, e = \text{HS}, sm, k_t)$$
$$\phi_c(k) \cdot c = w_{HS} - i$$

where κ_{HS} is the utility cost of attending high school with a child, w_{HS} is the parents' allowance, and V_1^{CD} is the value of deciding college attendance. When attending high school without a child, women consume their allowance w_{HS}.

Women who drop out of high school face the consumption-investment problem of a high school dropout. They also decide on the investment amount if they have a child during the period. As a result, their Bellman equation is given by:

$$V_1^{3,HSD}(a, e = HSD, sm = 1, k_t = 1) = \max_{c,i} u(c) + V^k(i)$$
$$+\beta V_2^1(a, e = HSD, m = 0, sm = 1, k_t = 1)$$
$$\phi_c(k) \cdot c = w(t, a, HSD, k_t = 1) - i$$

where $w(t, a, HSD, k_t = 1)$ is the wage of a high school dropout. In the case of dropping out without a child, women consume their wages.

4.5.2 Second Sub-Period Teen: Continue High School

Once a teenager has observed her fertility outcome, she must decide whether to continue in high school. The decision depends on whether the value of graduating from high school is greater than the value of dropping out.

$$V_1^2(a, sm, k_t) = \max_{i \in HSD, HSD} \{V_1^{3,HSG} + \sigma_{HS}\epsilon_i, V_1^{3,HSD} + \sigma_{HS}\epsilon_i\}$$

where ϵ_i is an i.i.d. extreme value shock drew from a Type I extreme value distribution, and σ_{HS} is the scale parameter.

4.5.3 First Sub-Period Teen: Contraception

In the first sub-period, all women attend high school, and their ability is the only heterogeneity among them. The decision in this stage is the amount of contraception, which is the same decision as in the other periods. The corresponding Bellman equation is:

$$V_1^1(a) = \max_s \ p(1, a, s) \cdot V_2^1(a, sm, k_t = 1)$$
$$+\big(1 - p(1, a, s)\big) \cdot V_2^1(a, sm, k_t = 0) - \phi(s)s$$

The amount of contraception used by teens depends on their ability, as reflected in the contraception technology $p(1, a, s)$, and the difference in the value of continuing to the next sub-period with and without a child, as given by $\left(V_2^1(a, sm, k_t = 1) - V_2^1(a, sm, k_t = 0)\right)$.

4.6 Functional Forms and Parameters

The functional forms in the model are chosen to allow it to replicate the data. The model has 32 unknown parameters and an income process, whose estimation will be discussed in section 5.

4.6.1 Preferences (3)

Consumption (1)

Women's utility over consumption is modeled with constant relative risk aversion preferences $\left(u(c) = \frac{c^{1-\gamma}}{1-\gamma}\right)$. This parameterization is motivated by the idea that parents smooth consumption over their children, as discussed in Regalia et al. (2011). However, if the curvature is above one, high-income women would find children to be less costly, which is counterfactual since they tend to postpone motherhood. Therefore, the literature assumes that the level of risk aversion is below one.

Parent Child Utility (2)

The utility that parents derive from having a child is represented by $V^k(i) = \omega_1 i^{\omega_2}$, where ω_1 is a scale parameter that maps investment to utility units, and ω_2 determines the curvature at which child investment increases parent utility. To ensure an interior solution to the children's investment problem, it is assumed that ω_2 is below one.

4.6.2 Fertility (10)

In order to model the probability of having a child, this paper uses a modified logistic function to bound the probability at one, as done in Seshadri and Zhou (2022); Choi (2017). However, since the childbirth probability in this paper depends on both contraception s and ability a, a constant elasticity of substitution (CES) production function is used to aggregate both inputs. The childbirth probability also varies with age t and education e. Thus, the probability of having a child is given by:

$$p(t,a,e,s) = \frac{2\exp(-\lambda_{e,t}(\lambda_a \cdot (\underline{a}+a)^\rho + (1-\lambda_a)\cdot s^\rho)^{\frac{1}{\rho}})}{1+\exp(-\lambda_{e,t}(\lambda_a \cdot (\underline{a}+a)^\rho + (1-\lambda_a)\cdot s^\rho)^{\frac{1}{\rho}})} \tag{1}$$

The fertility decisions in the model are determined by five parameters: $\lambda_{e,t}$, λ_a, $\underline{\mathrm{a}}$, ρ, and $\phi(s)$. Since $\phi(s)$ and $\lambda_{e,t}$ determine the cost of contraception, $\phi(s)$ is normalized to 1. $\lambda_{e,t}$ determinate the difference in efficiency by education and age, λ_a determines the share of ability in the contraception function, $\underline{a}$ is a minimum level of ability, while ρ gives the elasticity of substitution in the contraception technology.

4.6.3 Marriage Market (7)

The probability of women meeting a potential husband and marrying is determined by the parameter $\mu(e,t)$, which is a function of a woman's education and age.

4.6.4 College Attendance and Graduation (6)

College attendance is determined by the psych cost of attending college, which is given by $\kappa_c(a,k_t) = \frac{\xi_c}{a^{\omega_c}} + 1_{k_t=1} \cdot \kappa_{kb}$. Here, ξ_c is the psych cost of attending college, while ω_c determines how the psych cost decreases with cognitive ability. Women who continue college while having a child during that period face an additional cost κ_C. The extreme value shock scale parameters for attending and continuing college are given by σ_{Coll} and σ_{CD}, respectively.

4.6.5 High School Graduation (2)

The decision of whether to graduate from high school depends on the continuation values, which include the costs associated with attending high school with a child. In particular, the cost of attending high school with a child is represented by the parameter κ_{HS}, while the extreme value shock scale parameter that captures the unobserved in the decision-making process is denoted by σ_{HS}.

5 Model Estimation

The model parameters can be categorized into three groups: first, those parameters that are taken from the literature; second, the wage process, which is estimated exogenously to the model; and third, the parameters that are estimated within the model using the simulated method of moments, conditioned on the previous two groups of parameters.

5.1 Exogenous Parameter

Table 6 presents the exogenous parameters used in the model, which are taken from the literature. These parameters include the discount factor, relative risk aversion, and economies of scale in consumption.

Table 6. Exogenous Parameters

Parameter	Interpretation	Value	Source
		Preferences	
β	Discount Factor	.96	Regalia et al. (2011)
γ	Relative Risk Aversion	.43	Regalia et al. (2011)
ϕ_s	Contraception Cost	1.00	Normalization
		Household Parameters	
$\phi_c(m, k)$	Economies of Scale in Consump.	$\{.5, .7\}$	OECD

Notes: Model parameters that take values from previous results in the literature.

5.2 Wages Profiles

Women's and husbands' wage profiles are crucial in the model as they determine the opportunity cost of early and out of wedlock pregnancies. In the model, women's wages are determined by age, education, marital status, age at childbirth, and cognitive skills. Husbands' wages depend on the wife's education, marital status at childbirth, and age at birth. Since the NLSY79 individuals are currently in their early fifties, wage profiles are estimated using OLS for individuals aged 14 to 49. While not including wages after their fifties may understate the value of college or the child penalty, later wages are discounted heavily in the model's fertility decisions. Details about the wage process estimation and results are available in appendix B.

The main characteristics of the estimated profiles are that early pregnancies have a negative impact on women's wages across all education groups, with the wage penalty increasing as cognitive skills increase. Women who marry after experiencing out of wedlock childbirth have husbands with lower wages, with the steepest husband wage drop observed among college educated individuals. As a result, there is a higher cost of early motherhood for high-ability women who are more likely to attend college and have a college-graduate spouse.

5.3 Endogenous Parameters

The remaining 32 unknown parameters are estimated with 38 data moments using the Simulated Method of Moments. These parameters govern the responses of individuals to the key determinants of fertility in the model: ability, education, wages, and marriage. Thus, the model is estimated by selecting moments in the data that reflect the relationship between cognitive ability, education, marital status, and fertility outcomes.

Table 7 presents the estimation results. The share of ability in contraception is estimated at 0.79, which is important in explaining the differences in pregnancies by ability, as discussed in section 6.2. The estimated additional cost of graduating from high school with a child is a tenth of the extra cost during college. The added cost of graduating from college with a child is three times the college psych cost for an individual of mean ability.

Table 7. Parameters estimated through the indirect method of moments

Contraception Technology and Child Return Parameters		
Parameter	Value	Interpretation
α_a (1)	0.79	Ability Share Contr. Tech.
$\underline{a}$ (1)	0.22	Minimum Ability Contr. Tech.
ρ (1)	0.15	Elasticity of Substitution Contr. Tech.
$\lambda_{e,t}$ (7)	Table C1	Scale Parameter by Ability and Education
ω^1_{ch} ω^2_{ch} (2)	3.34, 0.52	Child Return
Marriage Parameters		
Parameter	Value	Interpretation
$\mu(e,t)$ (5)	Table C2	Probability Meeting a Husband
Education Parameters		
Parameter	Value	Interpretation
ξ_c ω_c (2)	$-19, 1.15$	College Psych Cost
$\kappa_{HS}, \kappa_{kb}, \kappa_C$ (3)	$-17, -62, -163$	Cost Child Dif. Edu. Stages
$\mu_{nk}(e)$ (3)	96, 108, 74	Terminal Value no Child
w_{HS}, w_C (2)	US$40K, US$14K	Teen and Coll. Allowance
σ_{HS}, σ_{CD}, σ_C (3)	138, 42, 17	EV Shock HS, Attend Coll., Grad Coll.

Notes: Model parameters that are estimated using the Simulated Method of Moments.

6 Results

This section discusses the model results. First, I discuss the goodness-of-fit of the model with the data. Second, I show the importance of ability in order to explain the model. Finally, I quantify the differences in contraception costs by education and ability, using equivalent consumption as the unit of measurement.

6.1 Model Fit

This subsection compares the fit of the model to the empirical data used to estimate its parameters. Overall, the model performs well given its simplicity and the use of 38 moments to estimate 32 parameters. For ease of presentation, the moments are grouped into three categories: those that link ability to pregnancies, those that relate to educational outcomes, and those that relate to marital outcomes.

6.1.1 Cognitive Skills and Pregnancies

Table 8. Fit Model Pregnancy and Ability

	Ability Quartile			
	First Quartile	Second Quartile	Third Quartile	Four Quartile
Age	Pregnancy Probability | No Prev. Preg.			
14-17	27%	13%	7%	4%
	(28%)	(16%)	(9%)	(3%)
18-21	59%	36%	21%	16%
	(49%)	(38%)	(25%)	(16%)
22-29	76%	56%	43%	29%
	(54%)	(53%)	(46%)	(45%)

Notes: The table shows moments relating cognitive skills with age at first childbirth. Values without parenthesis are moments generated by the model, and values in parenthesis are the data analogous.

Table 8 presents the moments that compare cognitive skills with childbirth timing. These moments are the fractions of women who had their first child between 14-17, 18-21, and 22-29 years old by cognitive skills quartiles, conditional on being childless at the beginning of each age interval. Between 14-17 and 18-21 years old, the model can replicate the positive correlation between ability and childbirth, and the fraction of pregnancies is similar to the data for most quartiles. On the other hand, the model generates a stronger positive relationship between ability and pregnancies than in the data for women between 22-29 years old.

6.1.2 Education Outcomes

Table 9. Education Outcomes and Pregnancy Moments

Moments	Data	Model
Drop out High School | No Pregnancy (<18)	0.07	0.06
Drop out High School | Pregnancy (<18)	0.29	0.31
Attend College | No Pregnancy (<18)	0.41	0.36
Attend College | Pregnancy (<18)	0.08	0.08
Attend College | Ability Q1	0.12	0.10
Attend College | Ability Q2	0.25	0.34
Attend College | Ability Q3	0.41	0.44
Attend College | Ability Q4	0.67	0.44
Graduate College | No Pregnancy (<22)	0.63	0.54
Graduate College | Pregnancy (<22)	0.29	0.28

Notes: The table shows moments relating age at first childbirth with education outcomes.

The model successfully captures the link between cognitive skills, childbirth, and education attainment. Table 9 reveals that the model generates a similar proportion of high school dropouts and college attendees as in the data. Although the model generates a lower college attendance rate for the top quartile of ability than in the data, it reproduces the right attendance rate for the lowest ability quartile, which is particularly important due to the high number of teen pregnancies in this group. The weakest relationship between ability and college attendance is explained by the lack of financial constraints and the unmodeled relationship between ability and parental income. Conditionally, on this simplification, the model fits the relationship between ability and college attendance well. Finally, the model produces a gap in college graduation between women with and without children during college comparable to the data.

6.1.3 Marital Outcomes

Moving on to moments related to contraception and marriage choices conditional on education and age, we have total pregnancies, single motherhood, and fraction married. Table 10 summarizes the model's performance in matching these moments with the empirical data. Overall, the model is able to capture the key features of these outcomes, with total pregnancies, single motherhood, and fraction married all falling within the range of the corresponding empirical data. However, there is one important discrepancy: the model significantly over-predicts the number of married women among college graduates.

Table 10. Fit Marital Outcomes and Pregnancies by Education Group

Moments	Data	Model	Moments	Data	Model
Married 18-21 yr. old | HSD, NPP	0.55	0.43	Sing. Mom 22-29 yr. old | HS, NPP	0.14	0.14
Married 18-21 yr. old | HS, NPP	0.53	0.46	Sing. Mom 22-29 yr. old | Coll, NPP	0.06	0.06
Married 22-29 yr. old | HSD, NPP	0.67	0.62	Preg. 18-21 yr. old | HSD, NPP	0.54	0.59
Married 22-29 yr. old | HS, NPP	0.68	0.69	Preg. 18-21 yr. old | HS, NPP	0.36	0.40
Married 22-29 yr. old | Coll, NPP	0.66	0.95	Preg. 18-21 yr. old | Att. Coll, NPP.	0.13	0.13
Sing. Mom 18-21 yr. old | HSD, NPP	0.33	0.34	Preg. 22-29 yr. old | HSD, NPP	0.52	0.57
Sing. Mom 18-21 yr. old | HS, NPP	0.22	0.20	Preg. 22-29 yr. old | HS, NPP	0.51	0.46
Sing. Mom 22-29 yr. old | HSD, NPP	0.26	0.20	Preg. 22-29 yr. old | Coll, NPP	0.41	0.43

Notes: The table shows moments relating age at childbirth with martial outcomes by education. All moments are conditional on no pregnancies before the respective age (NPP).

6.2 Mechanisms Decomposition and the Importance of Ability

In this section, I analyze how the model performs when cognitive skills only affects fertility decisions through education and wage opportunity cost. First, I estimate the model with homogeneous contraception technology in education and ability, which I call the "Baseline Model". In this case, the only heterogeneity in contraception is by age, with $\lambda_{1t}^{HSD} = \lambda_{1t}^{HS} = \lambda_{1t}^{Coll}, \lambda^a = 0$, and $\rho = 0$. Next, I make contraception depend on education, and finally, I make it depend on both education and ability, with $\lambda^a \geq 0$ and $\rho \in \mathbb{R}$. Each model is estimated separately, and the fit with the data is assessed using the sum of squared errors normalized by the data moment (SSE):

$$\text{SSE} = \sum \Big(\frac{m_i - m_i(\hat{\theta})}{m_i}\Big)^2$$

where m_i is the data moments and $m_i(\hat{\theta})$ is the model moments for the parametrization θ.

The paper studies whether cognitive skills affect childbirth timing beyond education, wages, and marriage opportunities. Therefore, analyzing how the model performs when cognitive skills are not considered in the contraception technology provides insight into the importance of cognitive skills in fertility decisions. As in the previous section, I group the moments into three categories: Cognitive Skills and Pregnancies, Education, and Marital Moments. The top of table 11 shows the total SSE and the correlation between ability and age at first childbirth for each different version of the model. The bottom displays the percentual improvement in the model fit when each mechanism is added ($1 - \frac{\text{SSE}_1}{\text{SSE}_0}$). The complete set of moments for each model specification is shown in table D1.

Table 11. Decomposing the Model Fit

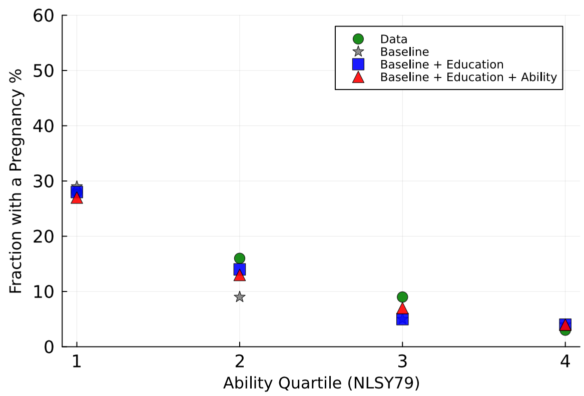
	(1) Baseline	(2) Baseline + Educ. Het.	(3) Baseline + Educ. Het. + Ab. Cont.
Total SSE	5.11	3.68	1.25
Pregnancies and Ability Moments SSE	1.45	0.57	0.50
Education Moments SSE	1.37	1.68	0.37
Marital Moments SSE	2.28	1.43	0.38
Fit Improvement ($1 - \frac{\text{SSE}_1}{\text{SSE}_0}$)		+ Educ. Het.	+ Ab. Cont.
Total Fit		28%	66%
Pregnancies and Ability Moments		61%	12%
Education Moments		-23%	78%
Marital Moments		76%	73%
Corr(P_{14-17}, Ability) Data=-0.26	-0.27	-0.27	-0.26
Corr(P_{18-21}, Ability) Data=-0.27	0.02	-0.10	-0.24
Corr(P_{22-29}, Ability) Data=-0.07	0.00	0.07	-0.29
Corr(P_{14-29}, Ability) Data=-0.24	-0.16	-0.21	-0.41

Notes: The table shows the sum of square moments (SSE) for each set of moments and the respective fit improvement at adding a layer of heterogeneity to the model. Corr(P_J, Ability) is the correlation between age at first childbirth and ability generated in the model at different ages.

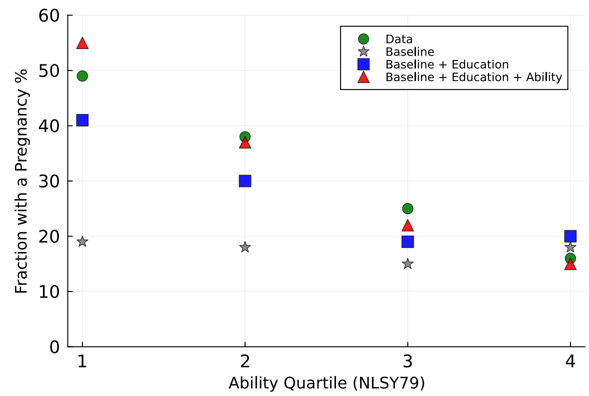
Table 11 shows the impact of introducing education-based heterogeneity to the "Baseline Model", resulting in an improvement of 28% in the overall model fit. The moments connecting ability and pregnancies improve by 61%. However, this comes at the expense of a 23% reduction in model performance for the education moments. Finally, the inclusion of ability into the contraception technology improves the total model fit by 66%, simultaneously fitting the three sets of moments with the data. In particular, the improvement comes from 12% in the moments associated with pregnancies and abilities, 78% in education-related moments, and 73% in the marital moments.

Figure 5. Fraction of Pregnancies by Age and Cognitive Skills Quartile

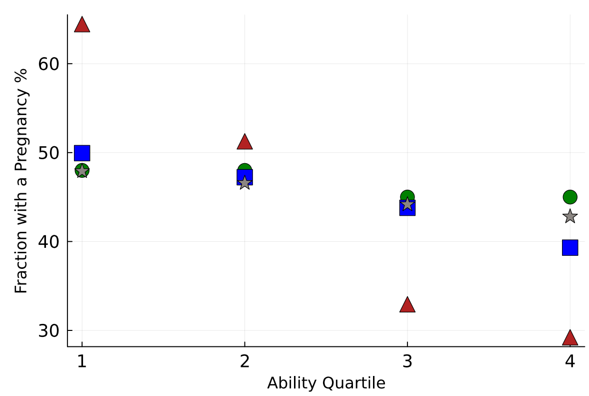
(a) First Period: Pregnancy between 14-17 years old



(b) Second Period: Pregnancy between 18-21 years old



(c) Third Period: Pregnancy between 22-29 years old



Notes: The upper left figure shows the fraction of women with teen childbirth (14-17 years old) by ability quartile in the data and each model. Second, the upper right figure shows the fraction of women with pregnancies at college age (18-21 years old). Finally, the bottom figure shows the fraction of women with pregnancies between 28-29 years old. Dots are the data, triangles are the model with heterogeneity by education and ability, squares are the model with heterogeneity by education, and stars are the baseline model.

Figure 5 compares the different fits with the data between ability and age at first childbirth across different ages for each model. The "Baseline Model" accurately reproduces the negative relationship between ability and age only among teenagers. With the introduction of education, a negative correlation arises during college years, though weaker than observed in the data (-0.10 compared to -0.27). Lastly, incorporating ability into contraception allows replicating the ability-age relation for teenage and college age women during their first childbirth. However, the model overpredicts the correlation for the 22-29 age group (-0.41 compared to -0.29).

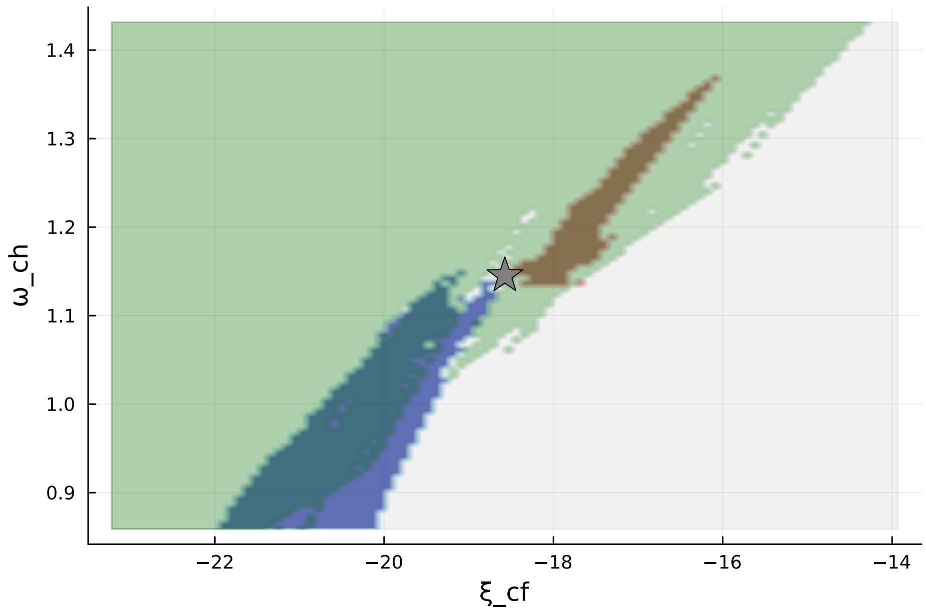
6.3 The Importance of Cognitive Skills

In order to show the need to incorporate the cognitive ability to explain the relationship with age at first childbirth in the data, I simulate the moments around the estimated parameterization $\hat{\theta}$ following the "Boundary Analysis" methodology proposed by Laibson et al. (2023). If the relationship between pregnancies and ability is explained through the fact that high-ability women have pregnancies later due to their college attendance and their higher wage opportunity cost, the model should be capable of fitting the data through the parameters that determine the relation between ability and college. These parameters are the psychological cost (ξ_c), and the rate at which ability reduces college costs ω_c^1.

Let us define $\chi = (\xi_c, \omega_c^1)$, $q_{ab}(\hat{\chi}, \hat{\omega})$ denote the contribution of moments relating ability to pregnancies, $q_{edu}(\hat{\chi}, \hat{\omega})$ represent the contribution of moments related to education, and $q_{mar}(\hat{\chi}, \hat{\omega})$ the moments related to marriage outcomes to the sum of square errors. In Figure 6, the colored areas depict the regions where the contributions decrease, indicating a better model fit with the corresponding set of moments. The red area represents the moments relating ability to pregnancies, the blue area represents the moments related to education, and the green area the moments related to marriage outcomes.

We observe that the blue and red regions do not overlap, implying that improvements in the set of moments related to education come at the expense of the ability moments and vice versa. This result is consistent with the previous section's finding that we need to create contrafactual educational outcomes to explain the data relationship between ability and fertility through education and wage opportunity cost. As a result, in the model, the relationship between cognitive skills and age at first childbirth can not be fully explained by the relationship between cognitive skills, education, and wages.

Figure 6. Boundary Analysis

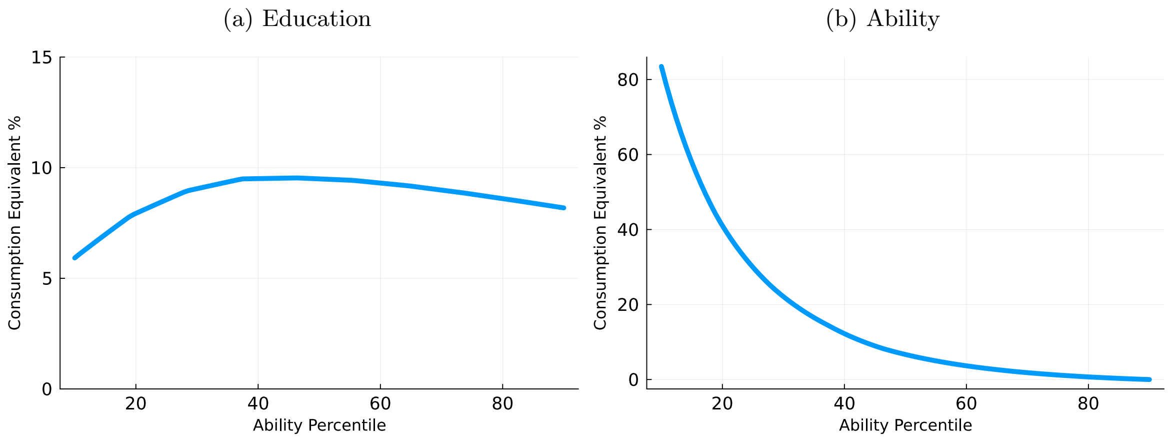


Notes: In the figure, the blue area represents the space where the fit of the ability moments improves, as indicated by $q_{ab}(\chi, \hat{\theta}) < q_{ab}(\hat{\chi}, \hat{\theta})$. The red area corresponds to the region where the fit of the education moments improves, denoted by $q_{edu}(\chi, \hat{\theta}) < q_{edu}(\hat{\chi}, \hat{\theta})$. Finally, the green area corresponds to the region where the fit of the marital outcomes moments improves, denoted by $q_{mar}(\chi, \hat{\theta}) < q_{mar}(\hat{\chi}, \hat{\theta})$. The star shows the point in the space where the parametrization $\hat{\theta}$ estimated in the previous section is located.

6.4 Contraception Costs as Consumption Equivalent

In this subsection, I analyze the consumption value of lower contraception costs by education and cognitive skills. Specifically, I estimate the value in lifetime consumption resulting from the difference in contraception costs between high school and college graduates. Then, I quantify the value in terms of consumption of contraception costs differences between individuals with high and low cognitive skills implied by the model.

Figure 7. Equivalent Consumption by Ability Percentiles



Notes: The left figure shows the change in lifetime consumption required to make women indifferent between having their estimated contraception cost and the contraception cost of a college graduate. The right figure shows the increase in lifetime consumption required to make a teenager indifferent between using the amount of contraception necessary to have the same childbirth probability as a teen in the top ability decile and her current choice.

To measure the difference in contraception cost by education, Figure 7a displays the increase in women's lifetime consumption if all education groups have the same contraception cost as college graduates. The results show that equalizing contraception cost by education groups is equivalent to an increase of 6% in lifetime consumption for women in the first ability decile, while it is around 8% for women in the top decile. The benefit of reducing the contraception cost by education is an inverse U-shape. For lower ability groups, the consumption equivalent increases as the benefits of delayed childbirth increase in ability; however, as ability increases, it is more likely to attend college, so the contraception cost remains the same for most women in those deciles.

Figure 7b quantifies the difference in contraception cost by teenagers' ability. It does so by calculating the increase in lifetime consumption necessary to make a teenager indifferent between using the amount of contraception necessary to have the same childbirth probability as a teenager in the top ability decile and her current choice. This exercise shows that a teenager in the ten percentile would need an increase of 80% in their lifetime consumption to be indifferent between their current contraception choice and the amount of contraception necessary to have the same pregnancy probability as an individual in the percentile ninety.

This result highlights how costly contraception is for low-ability individuals in the model.

7 Teen Pregnancies and Education Outcomes

In this section, I address two questions. First, I use the model to investigate whether teen pregnancies cause low educational achievement or if it is the other way around, where low-ability women leave education early and become pregnant given their low opportunity cost of having children early. Second, I examine the impact of a hypothetical policy on reducing contraception costs on the level of college educated women on educational outcomes, marriage, and pregnancies.

I find that teen pregnancies do not cause the poor educational outcomes observed in low-ability women. These women do not attend college because it is too costly, even without a child. Therefore, policies aimed at reducing teen pregnancies may not necessarily lead to increased educational achievement. In the case that we reduce the contraception cost to the level of college graduates, we observe a small change in education attainment, but we see a significant reduction in early pregnancy, single motherhood, and marriage.

7.1 Do Teen Pregnancies Lead to Lower Academic Performance or Vice-versa?

Single motherhood and teen childbirth are critical policy concerns, as women in these situations are often significantly disadvantaged in many economic and social dimensions. They have lower levels of educational attainment, reduced labor force participation, and face greater economic insecurity. Additionally, the impact of mistiming in children's outcomes is persistent over time, affecting multiple economic dimensions such as human capital accumulation, intergenerational inequality, and family formation.

While there is evidence linking early pregnancies to poor educational outcomes, previous research has suggested that this correlation may overstate the effect of the child on the mother's outcomes. For instance, Hotz et al. (2005), using miscarriages as an instrumental variable, found that teenage pregnancies had an insignificant effect on high school graduation at age 28. Similarly, Levine and Painter (2003) used propensity score matching to deal with endogeneity and found that only half of the correlation between teenage childbirth and low educational attainment was causal. They also found that teenage childbirth decreased college attendance by 20%, half of what is suggested by simple regression analysis. To further assess this question, I conduct three counterfactual analyses using the model.

1. High ability for contraception: All women are in the top ability percentile for contraception purposes.
2. High ability for education and wages: All women have the same college cost and income profile as women in the top ability percentile.
3. High ability for contraception, education, and wages: All women are in the top ability percentile for contraception, college cost, and wages.

The results of the counterfactual analysis are presented in table 14. In the first column, we examine the effect of reducing contraception costs for low-ability women to the level of high-ability women. Consistent with previous empirical studies, reducing contraception costs has little effect on college attendance. The model shows that giving low-ability women the same contraception cost as high-ability women increases college attendance by only 6%, as teen mothers are concentrated in the lowest ability quartiles, and attending college is too costly even without a child. However, reducing contraception costs leads to a substantial decline in teen pregnancies, with a 90% reduction in teen pregnancies and a 57% reduction in pregnancies before age 22. Furthermore, as discussed in subsection 6.4, reducing contraception costs significantly increases low-ability women's welfare.

Table 12. Counterfactual Results

Moments	(1) Same Cont. Ab.	(2) Same Ab. Edu. + Same Ab. Wage	(3) Same Cont. Ab. + Same Ab. Edu. + Same Ab. Wage
Attend Coll	6%	32%	42%
Preg < 18 Years Old	-90%	-10%	-90%
Preg 18 − 22 Years Old	-57%	-35%	-61%

Notes: The table shows the change in college attendance, pregnancies before 18 years old, and pregnancies before 22 years old of three different policies: i) all women have are high ability for contraception, ii) all women are high ability for education and labor, and iii) all women are high ability for contraception, education, and labor.

In the second column of the table, we see the effect of reducing the psych cost of attending college for low-ability individuals while keeping the contraception cost fixed. The results show that this policy change increases college attendance by 32% and reduces teen pregnancies by 10%. The previous result suggests that increasing college attendance decreases teen pregnancies, but their effect is relatively small compared to a decrease in contraception costs. Finally, the third column of the table shows the effect of reducing both contraception and the psych cost of college attendance, increase college attendance by 42%, and reduces teen pregnancies by 90%.

In the model, policies that affect contraception costs can significantly decrease teen pregnancies, especially among low-ability individuals, leading to substantial welfare improvements, as shown in Figure 7. However, it is important to note that this alone is insufficient to improve low-ability individuals' educational outcomes, as reducing contraception costs has a small effect on educational outcomes. On the other hand, policies that increase college access reduce pregnancies, but their effect is small relative to reducing contraception costs.

7.2 The Effects of Reduce Contraception Cost

In this subsection, I examine the impact of a policy that reduces the cost of contraception for all women to the level of a college graduate on educational outcomes, marriage, and pregnancies. Specifically, I set the contraception cost $\lambda_{e,t}$ for high school dropouts and high school graduates between the ages of 18-21 to the same level as college attendees and between 22-29 to the level of college graduates allowing to quantify the effects of equalizing contraception costs across education levels.

Reducing the cost of contraception for all women to the level of college graduates is found to have a significant impact on educational outcomes, marriage, and pregnancies. The model predicts a decrease in pregnancies across all age groups, with a 12% decrease in teenage pregnancies, a 16% decrease in pregnancies before age 22, and a 7% decrease in pregnancies before age 29. The decrease in teenage childbirth is driven by the expectation of future outcomes, given that the cost of contraception between ages 14-17 remains the same. However, the decrease in contraception costs also increases high school dropouts and reduces college graduation, given that one reason to achieve higher educational outcomes is to reduce contraception costs.

We observe a decrease in single mothers, with a 49% decrease among high school dropouts and a 23% decrease among high school graduates aged 18-21. Among those aged 22-29, the number of single mothers almost disappears for high school dropouts and high school graduates, while it remains constant for college graduates, as their contraception costs remain unchanged. Finally, the number of marriages remains constant for high school graduates and college graduates but declines by 20% and 5% for high school dropouts between 18-21 and 22-29, respectively. In the case of high school graduates, this decline is 26% and 32%. Finally, college graduates' marriages remain almost constant. In the model, marriages serve as insurance in case of childbirth; then, as pregnancies decrease, they also decrease.

Table 13. Reduce Contraception Costs

Moments	Data	Coll. Cost	Moments	Data	Coll. Cost
Preg. < 18 yr. old	0.11	-12%	Pregnancy 18-21 yrs. old | HSD, NPP	0.47	-97%
Preg. < 22 yr. old	0.40	-16%	Pregnancy 18-21 yrs. old | HS, NPP	0.40	-91%
Preg. < 29 yr. old	0.64	-7%	Pregnancy 18-21 yrs. old | Attend Coll, NPP	0.17	-1%
Drop HS | No Preg	0.06	147%	Single Mom 22-29 yrs. old | HSD, NPP	0.18	-98%
Drop HS | Preg	0.27	-20%	Single Mom 22-29 yrs. old | HS, NPP	0.10	-95%
Attend Coll, NPP | No Preg	0.38	-9%	Single Mom 22-29 yrs. old | Coll, NPP	0.02	-32%
Attend Coll, NPP | Preg	0.08	15%	Married 22-29 yrs. old | HSD, NPP	0.50	-5%
Grad. Coll., NPP | No Preg	0.51	-11%	Married 22-29 yrs. old | HS, NPP	0.68	-32%
Grad. Coll., NPP | Preg	0.38	47%	Married 22-29 yrs. old | Coll, NPP	0.64	1%
Married 18-21 yrs. old | HSD, NPP	0.35	-20%	Pregnancy 22-29 yrs. old | HSD, NPP	0.48	-97%
Married 18-21 yrs. old | HS, NPP	0.34	-26%	Pregnancy 22-29 yrs. old | HS, NPP	0.37	-91%
Single Mom 18-21 yrs. old | HSD, NPP	0.36	-49%	Pregnancy 22-29 yrs. old | Coll, NPP	0.49	12%
Single Mom 18-21 yrs. old | HS, NPP	0.24	-23%			

Notes: The table shows the changes in different model moments of decreasing the contraception cost to the level of a college graduate for all education groups. The moments are conditional on not having previous pregnancies (NPP).

8 The Decline in Teen Pregnancies During the '90s

Between 1990 and 2005, there was a decrease of 32% in teen births in the United States (Santelli and Melnikas, 2010). To comprehend the reasons behind this trend, I utilized the previously developed model and re-estimated it using data from the NLSY97 survey. Individuals in this survey were born between 1980 and 1984 and were teenagers during the 1990s and early 2000s. The model indicates that the decline in pregnancies is linked to a significant reduction in contraception costs across all ages, particularly for teenagers. Additionally, the psych cost of attending college decreased, which has increased incentives for avoiding early pregnancies, particularly for low-ability women.

Table D1 presents the data moments concerning childbirth timing, education, and marriage in both cohorts. Consistent with previous studies, there is a substantial decline in pregnancies between them. Moreover, this decrease is observable in all cognitive skills groups. In addition, women without a history of teen childbirth showed a substantial increase in college attendance, from 41% to 69%. The trend of higher education attainment was consistent across all cognitive skills levels, with college attendance increasing from 36% to 66%. Moreover, marriage rates among women under 30 decreased across all education levels, especially among high school dropouts. Finally, the data shows a similar fraction of single motherhood among women aged 18 and older across all education groups, with only a significant increase between college educated women between 22-29 years old.

To estimate the model using NLSY97 data, I adopt the same preference parameters from the literature used in section 5.1. Then, I estimate the income process and other parameters using the same methodology and data moments as section 5.2. More details about the estimation result are in appendix D. In the remaining part of this section, I present the estimation results and highlight the differences observed in this young cohort compared to the previous one. To assess the significance of each factor, I modify the parameters that determine each model mechanism separately, beginning with the NLSY79 estimation and progressing to the NLSY97. I implement this by modifying one set of parameters at a time in the order outlined below:

1. NLSY97 Wage Process.
2. Child Return (ω_1, ω_2).
3. College Cost (ξ_c, ω_c).
4. Contraception Cost $(\lambda_{e,t}, \lambda_a, \rho)$.
5. Other Factors.

Table 14. Factor Contribution

Moments	NLSY79	(1) Wages	(2) Child Return	(3) College Access	(4) Contraception	(5) Other Factors
Teen Pregnancies (Level)	12.5%	12.2%	12.1%	11.0%	5.6%	5.8%
Teen Pregnancies (Δ%)		5%	1%	16%	80%	-2%
Attend Coll (Level)	32.8%	31.7%	31.9%	43.1%	40.7%	64.2%
Attend Coll (Δ%)		-4%	1%	36%	-8%	75%
Fit (SSE)	1.3	27.8	24.3	20.1	12.3	1.2

Notes: The table shows the change in college attendance and teen pregnancies explained by each factor: i) Wages, ii) Child Return, iii) College Cost, iv) Contraception Cost, and v) Other Factors.

Table 14 provides a summary of the contribution of the main factors in the reduction in teen pregnancies. The results indicate that most of the reduction in teen pregnancies is due to a decrease in contraception cost (80%) followed by the improvement in college access (16%). In the case of the increase in college attendance, 36% is attributed to college access improvements. As highlighted in subsection 7.1, the decrease in contraception costs has a minor effect on the college attendance rate, and improvement in college access reduces teen pregnancies. However, their effects are small relative to decreases in contraception costs.

9 Conclusion

The paper contributes to the literature on the role of cognitive skills in fertility timing by empirically and quantitatively exploring its effects. The findings suggest that cognitive skills is an important determinant of fertility timing beyond the differences in time opportunity cost and fertility risk by education. The dynamic life-cycle model developed and estimated in this paper provides a framework to evaluate the welfare gains of improvements in contraception cost by ability and analyze the effects of policies targeting contraception cost and cognitive skills.

The model results show that early pregnancies are caused by high contraception costs and not low time opportunity costs. As a result, improving contraception costs is welfare-improving, especially for low-ability individuals. However, policies aimed solely at reducing contraception costs have a small impact on educational outcomes, as higher education costs are often too high for low-ability individuals, even without the added cost of a child.

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A Data

Appendix Table A1. National Longitudinal Survey of Youth 1979 Sample Size Summary

	Low Ability			High Ability			
Age First Pregnancy	High School Drop.	High School	College	High School Drop.	High School	College	Total
14-17	205	372	16	14	145	24	776
18-21	168	819	60	15	594	80	1736
22-29	50	394	50	1	477	387	1359
No child at 30	52	443	79	10	581	598	1763
Total	475	2028	205	40	1797	1089	5634

Notes: Sample size by bins. Observations are bin by mother's age at first childbirth, higher education achieved during the survey, and whether she is below or above the mean AFQT. The sample includes all NLSY79 women surveyed without missing AFQT scores and childbirth information.

In this study, I utilize data sourced from the National Longitudinal Survey of Youth (NLSY) which can be accessed at https://www.nlsinfo.org/content/getting-started/accessing-data. The primary analysis focuses on the NLSY79 cohort, while examining the decline in teenage pregnancies during the 1990s involves the NLSY97 cohort.

To focus of the empirical analysis and model estimation are women's first childbirth that occurs prior to the age of 30, as nearly 70% of the sampled women have their first childbirth before this age threshold. Women are categorized into three distinct age groups based on their age at their first childbirth. The first group comprises women who were in high school (aged 14 to 17) during their first childbirth. The second group consists of women who were of college age (18 to 21 years old) when they experienced their first birth. Finally, the third group encompasses young adults aged between 22 and 29 years who gave birth for the first time during this period.

Table A1 presents the number of observations by age at first childbirth, ability, and education. The classification of individuals into high or low ability is based on whether they score above or below the sample mean. The relationship between ability and education outcomes is evident, as very few high-ability women drop out of high school, while a small percentage of low-ability women graduate from college.

B Wages Process

Women's and husbands' wage profiles are crucial in the model as they determine the opportunity cost of early and out of wedlock pregnancies. Women's wages are determined by age, education, marital status, age at childbirth, and ability, while husbands' wages depend on the wife's education, marital status at childbirth, and the wife's age at birth. Given that the individuals from the NLSY79 dataset are in their early fifties, wage profiles are estimated based on data collected from ages 14 to 49 years old. The wage estimation process employs Ordinary Least Squares (OLS) regression. The impact of the first childbirth is assessed using dummy variables that indicate the age group in which women had their initial child (14-17, 18-21, 22-25, or 26-29 years old).

While not including wages after their fifties may understate the value of college or the child penalty, later wages are discounted heavily in the model's fertility decisions. The wages are self-reported by the surveyed individuals in the NLSY79 and deflated to 2016 prices. I exclude individuals earning less than 2.5 per hour or working less than 2000 hours per year. Since 1994 the survey has been realized biannually as results wage are missed for years that the survey was not realized. In order to overcome this problem, I impute the wage as the average of the previous and the following year. We do not observe high school dropouts with out of wedlock childbirth who marry after 26 in our sample. Therefore, we assume that the penalty after 26 is similar to the penalty observed between 23-26 years old.

The estimated equations for women's and husbands' wages are as follows:

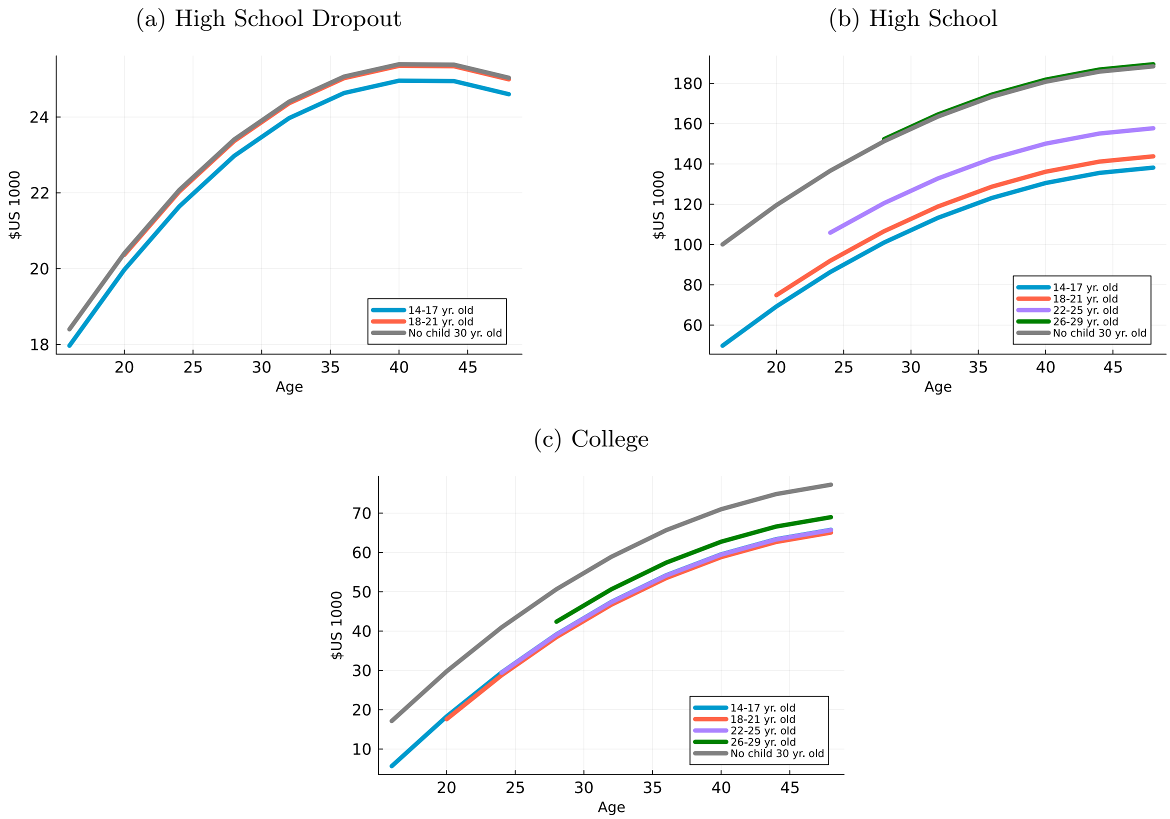
$$
\begin{gathered}
w_{i,t} = \alpha_0 + \alpha_t \cdot t + \alpha_{t^2} \cdot t^2 + \alpha_e e_i + \alpha_{\mathrm{HA}} \mathrm{HA}_i + \alpha_k k_i + \alpha_{et} \cdot e_i \cdot t + \\
\alpha_{et^2} \cdot e_i \cdot t^2 + \alpha_{e\mathrm{HA}} \cdot e_i \cdot \mathrm{HA}_i + \alpha_{k\mathrm{HA}} \cdot k_i \cdot \mathrm{HA}_i + \alpha_{e\mathrm{HA}} \cdot e_i \cdot \mathrm{HA}_i + \\
\alpha_{ek} \cdot e_i \cdot k_i + \alpha_{ek\mathrm{HA}} \cdot e_i \cdot k_i \cdot \mathrm{HA}_i + \alpha_m \cdot m_{i,t} + \epsilon_{i,t}
\end{gathered}
$$

$$
\begin{gathered}
w^h_{i,t} = \gamma_0 + \gamma_t \cdot t + \gamma_{t^2} \cdot t^2 + \gamma_m \cdot m_i + \gamma_{e^f t} \cdot e^f_i \cdot t + \\
\gamma_{e^f t^2} \cdot e^f_i \cdot t^2 + \gamma_{e^f m} \cdot e^f_i m_i + \epsilon_{i,t}
\end{gathered}
$$

where variables are the woman's wage w, the husband's wage w^h, the woman's age t, the individual i, the woman's education level e and e^f, a dummy variable HA indicating whether the individual scored above the mean on the cognitive skills test (AFQT), a dummy variable indicating the woman's age at first childbirth k, a dummy variable indicating whether the woman is married m, and a dummy variable indicating whether the woman was married at the time of childbirth m^f.

Early pregnancies have a negative impact on women's wages across all education groups, with the wage penalty increasing as ability levels rise. Women who marry after experiencing an out of wedlock childbirth have husbands with lower wages, and the size of the husband's wage penalty increases with the woman's age at childbirth. College educated women bear the highest wage penalty, resulting in a higher cost of early childbirth for high-ability women who are more likely to attend college and have a college graduate spouse.

Appendix Figure B1. Women Wage Profile by Education and Age First Childbirth

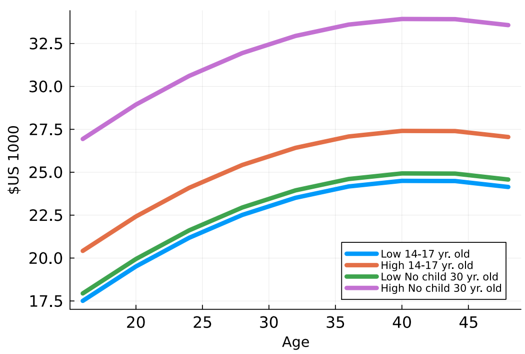


Notes: Wage profiles across age, education, and women's age at first child estimated as explained in section 5.2. Light blue lines show women with their first childbirth between 14-17 years old, red between 18-21, purple between 22-25, green between 26-29 years old, and grey no childbirth before 30 years old.

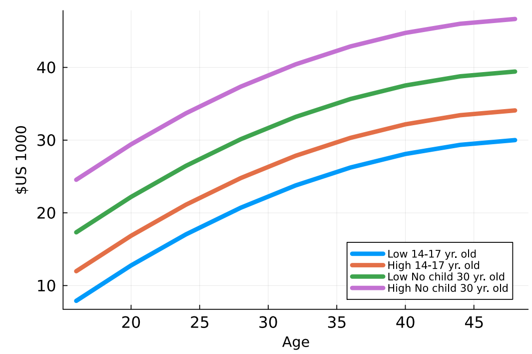
The figures showing women's wage profiles are breakdown by education and age at first childbirth. College educated women have the highest earnings, followed by high school graduates, and high school dropouts have the lowest wages. In figure B1a, the wage profiles for high school dropouts show that early childbirth has a small effect on earnings, with birth between 14-17 years old reducing wages by only \$1700. The wage profiles for high school graduates in figure B1b indicate that women who have children between 26-29 years old have the highest wages, with early childbirth carrying a substantial wage penalty. For example, each year, women with a child between 14-17 years old earn \$12,500 less than women with a first child between 26-29 years old. Finally, figure B1c shows the wage profiles for college women. We observe two wage paths for women who had a child before 26 and those who had a child after 26 or did not have one before 30. The first group earns around $11,500 less than the second. The child penalty for college and high school graduates is similar in monetary terms, but the relative magnitude is higher for high school graduates as they have lower wages.

Appendix Figure B2. Women Wage Profile by Education and Ability

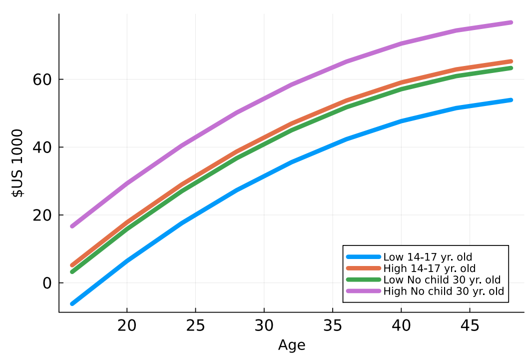
(a) High School Dropout



(b) High School



(c) College



Notes: Wage profiles across age, education, women's age at first child, and ability type estimated as explained in section 5.2. Light blue lines show low ability and red high ability teen mothers. Green lines show low ability and purple high ability women without a child at 30 years old.

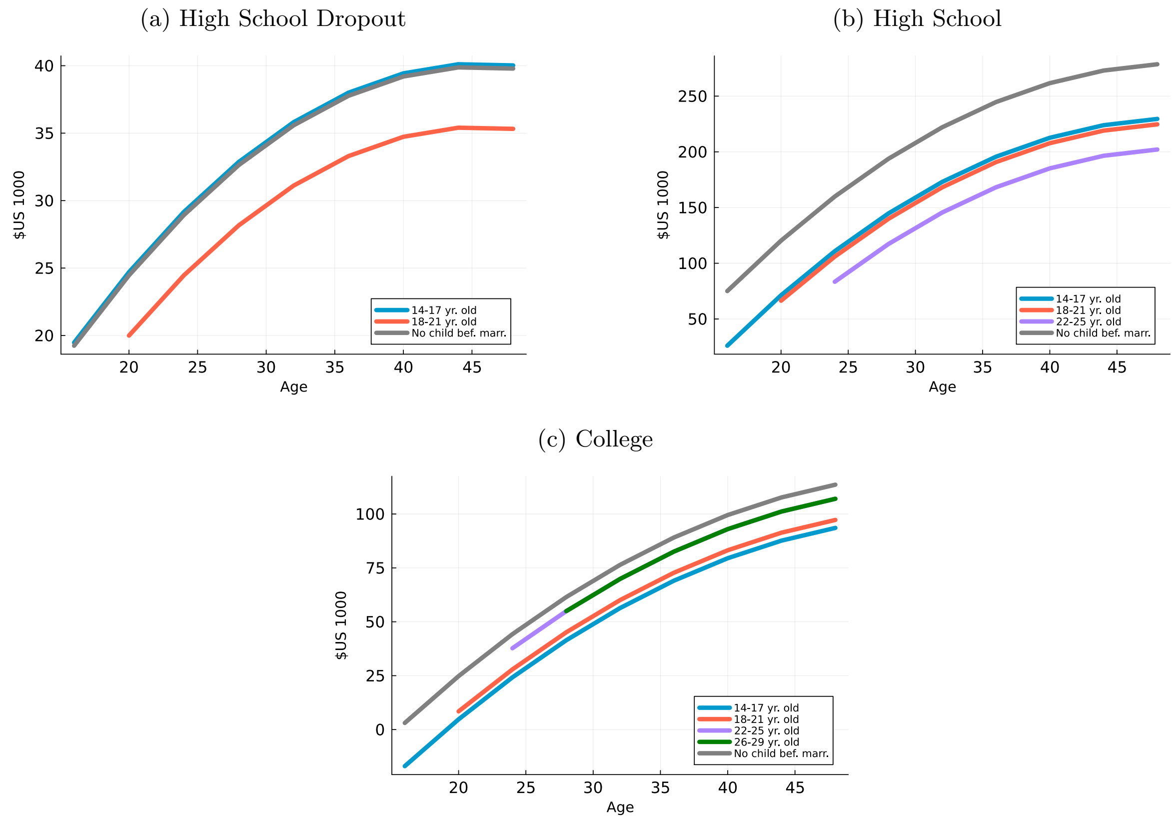
Figure B2 shows how cognitive skills affects women's wages by education level. The effect of ability on wage is increasing with education. I plotted four wage profiles for simplicity: high and low ability women with childbirth between 14-17 years old and high and low ability women without a child at 30. Cognitive ability increases wages in every education group.

Specifically, for high school dropouts (shown in Figure B2a), high ability women with childbirth between 14-17 years old earn $3,700 more yearly than low ability. High ability women without a child at 30 years old earn $9,000 more yearly than low ability. For high school graduates (shown in Figure B2b), the difference between high and low ability is $4,000 yearly for women with childbirth between 14-17 years old, and $7,000 yearly for women without childbirth at 30 years old. For college graduates (shown in Figure B3), high ability women with childbirth between 14-17 make $11,000 more yearly than low ability, and this difference is $13,000 for women without a child at 30 years old.

The penalty wage associated with early childbirth is increasing in ability. Low ability high school dropouts face an early childbirth penalty of $400 yearly, while high ability dropouts face a penalty of $6,500 yearly. Low ability high school graduates face an early childbirth penalty of $9,400 yearly, while high ability graduates face a penalty of $12,600 yearly. For college graduates, the penalty for low ability is $9,400 yearly, while high ability graduates face a penalty of $11,400 yearly.

The impact of early pregnancies on husbands' wages is an important element of the model, as it affects the opportunity cost of having children. Figure B3 presents husbands' wages by education, marital status at childbirth, and the mother's age at birth in the case of out of wedlock pregnancies. Single mothers have husbands with lower wages across all education groups, with the penalty increasing in age and education. The highest penalty is found among college educated women with out of wedlock pregnancies between 14 and 17 years old. High school dropouts are shown in Figure B3a, where the husbands' wages are reduced by $4,700 for an out of wedlock child between 18-21 years old. In Figure B3b, high school graduates have husbands with wages reduced by $12,200 between 14-21 years old and by $19,000 between 23-26 years. Finally, college graduates face the highest penalty, as they marry men earning $20,000 and $6,500 less if they have an out of wedlock childbirth between 14-25 and 26-29 years old, respectively.

Appendix Figure B3. Husband wage profile by marital status at birth and age first birth



Notes: Husband wage profiles across women's age, education, and women's age at first child estimated as explained in section 5.2. Light blue lines show women with an out of wedlock child between 14-17 years old, red between 18-21, purple between 22-25, green between 26-29 years old, and grey are women without childbirth before marriage.

C Estimated Parameters

In this appendix, we can observe the contraception cost parameter λ and the probability of meeting someone for each age and education group not displayed in the main text given space.

Appendix Table C1. Contraception Cost by Education and Age Group

Education / Age Group	13-17 yr. old	18-21 yr. old	22-29 yr. old
High School Dropout	3.39	1.22	1.34
High School Graduate	3.39	1.43	1.65
College	3.39	2.40	2.05

Notes: Estimated contraception cost λ by age and education.

Appendix Table C2. Probability Meeting a Husband

Education / Age Group	18-21 yr. old	22-29 yr. old
High School Dropout	0.40	0.13
High School Graduate	0.46	0.34
College		0.78

Notes: Estimated probability of meeting a men μ by age and education.

D Estimated Models Fit

This appendix shows the moments generated by each model specification compared with the actual data from the NLSY79 and NLSY97.

Appendix Table D1. Pregnancy and Wages

	NLSY79				NLSY97	
Moments	Data	Baseline + Educ. Het. + Ab. Cont.	Baseline + Educ. Hete.	Baseline	Data	Baseline + Educ. Het.
% Pregnancy AQ1 14-17 Yrs. Old	0.28	0.27	0.28	0.29	0.14	0.14
% Pregnancy AQ2 14-17 Yrs. Old	0.16	0.13	0.14	0.09	0.05	0.05
% Pregnancy AQ3 14-17 Yrs. Old	0.09	0.07	0.05	0.05	0.03	0.03
% Pregnancy 14-17 Yrs. Old	0.03	0.04	0.04	0.04	0.01	0.01
Drop HS | No Preg	0.07	0.06	0.07	0.09	0.06	0.06
Drop HS | Preg	0.29	0.31	0.07	0.04	0.37	0.37
Att. Coll. | No Preg	0.41	0.36	0.38	0.33	0.66	0.66
Att. Coll. | Preg	0.08	0.08	0.07	0.07	0.27	0.27
Att. Coll.| AQ1	0.12	0.10	0.00	0.12	0.34	0.34
Att. Coll.| AQ2	0.25	0.34	0.24	0.29	0.66	0.66
Att. Coll.| AQ3	0.41	0.44	0.54	0.40	0.76	0.76
Att. Coll.| AQ4	0.67	0.44	0.57	0.41	0.78	0.78
% Pregnancy AQ1 18-21 Yrs. Old	0.49	0.59	0.41	0.19	0.40	0.40
% Pregnancy AQ2 18-21 Yrs. Old	0.38	0.36	0.30	0.18	0.24	0.24
% Pregnancy AQ3 18-21 Yrs. Old	0.25	0.21	0.19	0.15	0.12	0.12
% Pregnancy AQ4 18-21 Yrs. Old	0.16	0.16	0.20	0.18	0.07	0.07
Graduate Coll. | No Preg	0.63	0.54	0.60	0.98	0.67	0.67
Graduate Coll. | Preg	0.29	0.28	0.33	0.34	0.20	0.20

Notes: The table shows the moments generated by the full model, the model with heterogeneity by education, and the baseline model. Moments are conditional on not having previous pregnancies (NPP).

Appendix Table D2. Pregnancy and Wages

	NLSY79				NLSY97	
Moments	Data	Baseline + Educ. Het. + Ab. Cont.	Baseline + Educ. Hete.	Baseline	Data	Baseline + Educ. Het. + Ab. Cont.
Married 18-21 Yrs. Old | HSD	0.55	0.43	0.37	0.46	0.22	0.22
Married 18-21 Yrs. Old | HS	0.53	0.46	0.45	0.47	0.20	0.20
Single Mom 18-21 Yrs. Old | HSD	0.33	0.34	0.34	0.40	0.32	0.32
Single Mom 18-21 Yrs. Old | HS	0.22	0.20	0.21	0.09	0.23	0.23
Pregnancy 18-21 Yrs. Old | HSD	0.54	0.59	0.49	0.54	0.42	0.42
Pregnancy 18-21 Yrs. Old |HS	0.36	0.40	0.42	0.17	0.29	0.29
Pregnancy 18-21 Yrs. Old | Att. Coll.	0.13	0.13	0.00	0.08	0.15	0.15
% Pregnancy AQ1 22-29 Yrs. Old	0.54	0.76	0.63	0.61	0.50	0.49
% Pregnancy AQ2 22-29 Yrs. Old	0.53	0.56	0.52	0.53	0.39	0.39
% Pregnancy AQ3 22-29 Yrs. Old	0.46	0.43	0.48	0.46	0.36	0.36
% Pregnancy AQ4 22-29 Yrs. Old	0.45	0.29	0.47	0.46	0.30	0.30
Single Mom 22-29 Yrs. Old | HSD	0.26	0.19	0.21	0.27	0.18	0.18
Single Mom 22-29 Yrs. Old | HS	0.14	0.14	0.12	0.17	0.16	0.16
Single Mom 22-29 Yrs. Old | Coll.	0.06	0.06	0.05	0.06	0.11	0.11
Married 22-29 Yrs. Old | HSD	0.67	0.62	0.61	0.76	0.35	0.35
Married 22-29 Yrs. Old | HS	0.68	0.69	0.50	0.46	0.35	0.35
Married 22-29 Yrs. Old | Coll.	0.66	0.95	0.59	0.71	0.49	0.49
Pregnancy 22-29 Yrs. Old | HSD	0.52	0.57	0.70	1.00	0.26	0.26
Pregnancy 22-29 Yrs. Old | HS	0.51	0.46	0.54	0.67	0.48	0.48
Pregnancy 22-29 Yrs. Old | Coll.	0.41	0.43	0.41	0.18	0.26	0.27

Notes: The table shows the moments generated by the full model, the model with heterogeneity by education, and the baseline model. Moments are conditional on not having previous pregnancies (NPP).

In this appendix, I compare the estimated parameters for the model using NLSY79 and NLSY97 data.

]Estimated Parameters NLSY79 vs. NLSY97

In this appendix, I compare the estimated parameters for the model using NLSY79 and

NLSY97 data.

Appendix Table E1. Contraception Technology and Education Parameters (NLSY79 vs. NLSY97)

Contraception Technology and Child Return Parameters			
Parameter	NLSY79	NLSY97	Interpretation
λ_a	0.79	0.14	Ability Share Contr. Tech.
$\underline{a}$	0.22	0.37	Minimum Ability Contr. Tech.
ρ	0.15	-1.92	Elasticity of Substitution Contr. Tech.
ω_1 ω_2	3.34 , 0.52	0.89, 0.77	Child Return
Education Parameters			
Parameter	NLSY79	NLSY97	Interpretation
ξ_c ω_c	$-19, 1.15$	-2, 1.26	College Psych Cost
$\kappa_{HS}, \kappa_{kb}, \kappa_{Coll.}$	$-17, -62, -163$	-49,-124, 0	Cost Child Dif. Edu. Stages
$\mu_{nk}(e)$	96, 108, 74	-37,-25, -120	Terminal Value no Child
w_{HS}, w_C	US$40K, US$14K	US$47K, US$11K	Teen and Coll. Allowance
σ_{HS}, σ_{CD}, σ_C	138, 42, 17	48, 77, 23	EV Shock HS, Attend Coll., Grad Coll.

Notes: Estimated contraception technology, education and child return parameter using NlSY79 and NLSY97, respectively.

Appendix Table E2. Contraception Cost by Education and Age Group (NLSY79 vs. NLSY97)

Education / Age Group	13-17 Yrs. Old		18-21 Yrs. Old		22-29 Yrs. Old	
	NLSY79	NLSY97	NLSY79	NLSY97	NLSY79	NLSY97
High School Dropout	3.39	2.27	1.22	0.97	1.34	8.97
High School Graduate	3.39	2.27	1.34	1.17	1.65	2.22
College	3.39	2.27	1.65	1.28	2.05	1.24

Notes: Estimated contraception cost λ by age and education using NlSY79 and NLSY97, respectively.

Appendix Table E3. Probability Meeting a Husband (NLSY79 vs. NLSY97)

Education / Age Group	18-21 Yrs. Old		22-29 Yrs. Old	
	NLSY79	NLSY97	NLSY79	NLSY97
High School Dropout	0.33	0.40	0.29	0.13
High School Graduate	0.48	0.46	0.31	0.34
College			0.78	0.27

Notes: Estimated probability of meeting a men μ by age and education using NlSY79 and NLSY97, respectively.