Education, Cognitive Ability and Fertility Risk*

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Abstract

The paper provides empirical evidence using NLSY79 data that cognitive ability affects pregnancy timing and intention. Then, I build and estimate a life cycle model to measure the difference in contraception efficiency by cognitive ability and education. Women in the top ability quartile are four times more efficient using contraception than those in the bottom. In addition, high school and college graduates have a 77% and 84% lower contraception costs than high school dropouts. Finally, I use the model to show that changes in ability can explain the effect of mandatory education reforms on teen and young adult pregnancies.

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1 Introduction

In 2020, 4% of total pregnancies were from women below 20 years, and 18% were from women between 20-24 years old (Osterman et al., 2022). In the U.S., 41% of pregnancies are unintended, and among teens aged 15 to 19 years old, the rate is 75% [1]. Only between 2015-2019, of 5,660,000 pregnancies annually, 2,590,000 pregnancies were unintended, and 886,000 ended in abortion[2]. Women that had their first child unintended are more likely to be single mothers, or enter in shot-gun marriage with higher divorce probability (Kozlov, 2021). As a result, unintended pregnancies are a relevant economic issue because children raised in single-parent houses perform worse in multiple educational and economic dimensions (Kearney and Levine, 2017). Moreover, mothers with early or unintended pregnancies have worse economic and social outcomes (Amador, 2017; Foster et al., 2018; Levine and Painter, 2003).

Unintended pregnancies and early pregnancies widely vary by women's education. For example, in 2008, high school dropout women had 3.5 times more unplanned pregnancies than college graduates (Finer and Zolna, 2014). Two prominent explanations are the allocation of time theory and the second is differences in contraception efficiency by education groups. The allocation of time theory (Becker, 1965) proposes that highly educated women have a higher opportunity cost of having children early in terms of labor and marriage opportunity. This theory has been explored in multiple studies showing its empirical relevance (Caucutt et al., 2002; Rosenzweig, 1999; Greenwood et al., 2000). The differences in contraception efficiency by education groups come from Rosenzweig and Schultz (1989), which found that college-educated individuals are more efficient at using contraception.

Musick et al. (2009) and Choi (2017) argue that different labor and marital market opportunity costs cannot fully explain the educational gap in unintended pregnancies. Additionally, Choi (2017) shows that combining both mechanisms can account for the difference in fertility timing across different education groups. However, he does not explain how attending college affects women's fertility risk.

In this paper, I show that differences in contraception efficiency by cognitive ability groups

[1]https://www.cdc.gov/reproductivehealth/contraception/unintendedpregnancy/index.htm
[2]https://www.guttmacher.org/fact-sheet/unintended-pregnancy-and-abortion-northern-america

explain part of the difference in fertility timing by education groups. First, I document a strong relationship between cognitive ability with pregnancy timing and intention beyond education achievement and wages. Second, I build a life cycle model with agents heterogeneous in cognitive ability who decide on education, contraception, marriage, consumption, and child investment. Third, I estimate the model using U.S. data to study how cognitive ability and education shape fertility, single mothers, and marriage. Finally, I show that a possible explanation behind the efficiency of policies that increases mandatory education on teen pregnancies is through changes in cognitive ability and higher contraception efficiency.

This work is related to several branches of economic literature. First, it relates to the literature on dynamic models with endogenous family formation and fertility choices. For example, Regalia et al. (2011) study how the change in relative wages affects the number of single mothers; Caucutt et al. (2002) study how child investment, marriage, and labor market outcomes shape women's fertility timing; Choi (2017) shows that to simultaneously account for the observed heterogeneity in births and abortion profiles across educational groups, differences in fertility risk by education are necessary; Filote et al. (2019) study how the welfare state affects teenage childbearing behavior through a parental investment model with risky sexual behavior; Kozlov (2021) study how unintended pregnancies affect marriage and divorce; or Seshadri and Zhou (2022) look how heterogeneity in fertility planning affects children's investment and shape intergenerational mobility.

Second, it is related to the empirical literature on education and fertility. For example, Rosenzweig and Schultz (1989) shows that contraception method efficiency increases with education, and Musick et al. (2009) found that the education gradient on fertility comes primarily from unintended childbearing, not differences in opportunity cost.

Finally, it relates to the literature on the return on cognitive, noncognitive ability, and education on behavioral outcomes. For example, Heckman et al. (2006) found that cognitive and noncognitive abilities decrease the probability of teenage pregnancy; at the top of the cognitive and noncognitive ability distribution, the likelihood of unintended pregnancy is close to zero. Heckman et al. (2018) found that increasing cognitive endowments positively affects education, wages, smoking, and health outcomes. Meanwhile, increasing noncognitive endowments primarily affects smoking and health outcomes. Additionally, education affects the present value of health and smoking. Hai and Heckman (2022) found that an extra year of schooling reduces smoking by 21%.

I provide two main contributions. First, I document a positive relationship between cognitive ability, fertility timing, and intention. Additionally, with age, the difference by ability in the number of pregnancies by ability disappears, but the difference in unplanned pregnancies remains. Second, I build and estimate a dynamic choice model with endogenous education, marriage, and fertility, in which contraception efficiency depends on cognitive ability. Then I estimate the model to quantify the importance of cognitive ability and education on women's fertility risk and timing.

To study the relationship between ability, early and unintended pregnancies, I use the National Longitudinal Survey of Youth 1979 (NLSY79) as it measures cognitive ability and women's fertility and labor outcomes until their late forties. Women in the lowest ability quartile are ten times more likely to have their first pregnancy between 14 and 17 years old than women in the top quartile (29% vs. 3%) and seven times more likely to report an unintended (14% vs. 2%). Meanwhile, the difference by ability in the probability of having their first pregnancy disappears with age; low-ability women remain 60% more likely to have an unintended pregnancy.

Then, I estimate a static linear regression model in which ability is a latent factor at different ages. Ability is measured as a latent factor as it is well now that using cognitive ability tests directly considerably upward bias the estimated effect of ability as capture part of the effect of formal education (Hansen et al., 2004). I found that with age, the importance of the cognitive ability to have a first pregnancy decreases and even changes signs. The magnitude of cognitive ability is quantitively significant, with its interdecile range effect two times the effect of graduating from college and 70% of the interdecile range effect of wage. Interestingly, even when between 22-29 years old, women in the top ability decile are 40% more likely to have their first pregnancy than the ones in the bottom; they are 15% less likely to have an unintended pregnancy. This finding is consistent with cognitive ability improving women's capacity to plan pregnancies.

Subsequently, I explain and estimate the model showing that it fits targeted and nontargeted crucial dimensions. Formal education and cognitive ability are quantitatively relevant to explain fertility. High school and college graduates have 77% and 84% lower contraception cost than high school dropouts. Additionally, teens in the top ability quartile are four times more efficient using contraception than those in the bottom. Most college graduates are high-ability individuals, so the probability of having an unintended pregnancy for college women is close to zero. Finally, I look at contraception costs by age. Contraception cost reaches its highest level between 18-21 years old and its lowest cost for young-adults college graduates (22-29 years old).

Finally, I show that the decreases in teen pregnancies caused by laws that increase mandatory schooling can be explained through the effect of extra education on cognitive ability, which decrease pregnancies given that increases contraception efficiency. This result provides a channel to explain how these reforms affect teen pregnancies and show their importance of them even when there is little evidence of positive effects on economic outcomes such as future income.

Accounting for heterogeneity in fertility risk by cognitive ability allows a better understanding of the relationship between pregnancies and academic outcomes. In particular, it provides a relevant channel through which these outcomes are related and delivers additional evidence about the multiple positive effects of policies that improve cognitive ability in children.

2 The Data

I use NLSY79 data to study cognitive ability's effect on unplanned pregnancies. The National Longitudinal Survey of Youth follows a representative sample of American youth born between 1957-64 who were 14-22 years old when first interviewed in 1979. The survey has three essential characteristics for the paper: First, in 1980, participants took a cognitive test allowing measure ability. Second, participants have been followed for more than 40 years, and women in the sample have already finished their reproductive life. Third, mothers in the survey were asked if the pregnancy was intended at the moment of conception.

In 1980, NLSY responded to ten intelligence tests referred to as the Armed Services Vocational Aptitude Battery (ASVAB). Using a sub-sample of the ASVAB test, it is possible to construct an approximate score of a general cognitive ability test known as the Armed

Forces Qualifications Test score (AFQT), a standard measure in the literature that allows me to rank women by cognitive ability.

2.1 Main Features of the Data

The paper focuses on the relationship between pregnancy timing and cognitive ability. As cognitive ability determines education outcomes and educational outcomes determine marriage, I would focus on the data moments relating ability with pregnancy timing, early pregnancies with education outcomes, and education outcomes with marital and pregnancy outcomes. I divide the women's fertility life into three and only consider women younger than 30 years old, as 90% of firstborn children are born before 30 years old. The first period is teens, between 14 and 17 years old. The second period is college age, between 18-21 years old. The third period is young adults between 22-29 years old.

2.2 Ability and Unintended Pregnancies

Table 1. Joint Distribution First and Unwanted First Pregnancy by Age and Ability

	Ability Quartile			
	First Quartile	Second Quartile	Third Quartile	Four Quartile
Age First Pregnancy	Pregnancy Probability			
14-17	29%	15%	9%	3%
18-21	55%	46%	31%	20%
22-29	50%	49%	45%	47%
Age First Pregnancy	Unwanted Pregnancy Probability			
14-17	14%	8%	5%	2%
18-21	20%	16%	10%	7%
22-29	11%	10%	8%	7%

Table 1 displays the joint distribution between age groups, ability quartiles, and pregnancy outcomes conditional on not having a pregnancy before. 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 a pregnancy before 22 years old had one between 22-29 years old.

The most relevant characteristic of the data is the positive relationship between ability and age at first pregnancy and the fact that the gap disappears for women that did not have a child in the early periods. Between 14 and 17 years old, twenty-nine percent of women in the bottom ability quartile had their first pregnancy; meanwhile, only 3% in the top cognitive quartile, or they are 10 times more pregnancies. As women grow, this ratio reduces to 2.75 between 18-21, and between 22-29 years old, it is just 1.06.

However, the gap in unintended pregnancies between women with high and low cognitive ability women do not disappear with age. At the bottom of table 1 we see the relationship between unintended pregnancies and ability. For 14 and 17 years old, the probability of unintended pregnancy is 7 times higher for the low-skill group. Between 18-21 years old is 2.9 times higher, and for 22-29 years old, it is 1.6 times higher.

2.3 Pregnancy Timing and Education

Table 2 shows the joint distribution of women's age at first pregnancy 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 percent of high school graduates had their first child after high school age, and seventy-three percent of college graduates had their first pregnancy 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	48%	18%	6%
18-21	40%	50%	21%
22-29	12%	32%	73%

As children are costly, a potential reason women do not achieve higher education levels after pregnancy is that children make them more likely to drop out of high school or college, causing the relationship between early pregnancies and low educational outcomes. Additionally, women with low cognitive ability attain lower education levels, which allows them to have children early, explaining the relationship between cognitive ability and pregnancy. For this reason, I use a dynamic model to account for how early pregnancy affects high school and college completion and how low cognitive ability increases education costs reducing the opportunity cost of children for low-ability women.

2.4 Early Pregnancies and Marriage

Table 3 compares marriage probabilities of single mothers to non-single mothers. At the top of table 3 we can see marriage probability for single mothers conditional on age at first pregnancy. The probability of marriage for single mothers increases with education and decreases with age. For example, 86% of high school graduate single mothers between 14 and 17 years old got married at some point in their life compared to 73% of single mothers between 22-29 years old with the same education level. Additionally, 73% of 18 to 21 years old high school dropout single mothers got married compared to 88% of college graduates. For non-single mothers, the fraction who married is around 83% for the three education groups. Out-of-wedlock pregnancies only decrease the probability of finding a husband for high school dropouts.

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%	86%	91%
18-21	73%	84%	88%
22-29	48%	73%	83%
		Non Single Mothers	
	82%	83%	83%

Another important dimension is the husband's wage. Table 4 compares husbands' wages of women whit and without a child at the wedding for women who marry after finishing their highest level of education. The table shows the husband's average yearly income by women's education, age at the first pregnancy, and if she had a child before marriage.

High school and college graduate women without a child before marriage have higher income spouses than women with a child at the moment of the pregnancy. In the case of high school dropouts, husband income does not differ considerably between women who marry with and without a child. Surprisingly, high school dropout women with an out-of-wedlock pregnancy between 22-29 years old had, on average, a higher income husband. However, this group has few observations, and the result is probably caused by a small sample. In the case of high school graduates with the first pregnancy between 18 and 21 years old, the penalty for an out-of-wedlock pregnancy is 4000 dollars a year; meanwhile, for the one that had the first child between 22 and 19 years old, the penalty is 11000 dollars. For college graduates the penalty is 18000 dollars.

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

	High School Dropout		High School Graduate		College Graduate	
Age Fir. Preg.	Child	No Child	Child	No Child	Child	No Child
14-17	36873	34546				
18-21	37473	41224	44785	48923		
22-29	43760	30448	47420	58889	63248	81521

Out-of-wedlock pregnancy affects the probability of finding a husband for high school dropouts; meanwhile, for high school and college graduates, the probability is similar, but an out-of-wedlock pregnancy is costly in terms of the husband's income.

2.5 The effect of cognitive ability on pregnancies

A major concern is that cognitive ability directly affects pregnancy timing and intention and is not the result of differences in family background, education, and time opportunity cost. To alleviate this concern, I estimate a static linear model at three moments of women's life cycle: teens (14-17 years old), college age (28-21 years old), and young adults (22-29 years old).

As I am using an intelligence test, measurement error and reverse causality are important concerns as they are 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 as they impute part of its impact on ability. I follow Cawley et al. (1996); Heckman et al. (2006); Hansen et al. (2004) to estimate ability as a latent variable and correct for the reverse causality bias and measurement error.

As agents are forward-looking, future education and income would affect teenager decision. As my static linear model does not capture the effect of future outcomes on current fertility decisions, I estimate the model at three points of time explained before. First, for teens, the effect of ability is upward bias, as is capturing future wages and marital opportunities. Some of the education outcomes are already realized in the case of women at college age, but still, there is a higher future income opportunity cost that bias the estimators. Finally, for young adults, education is completely realized, and we already observe an important fraction of the wage realizations allowing a better imputation of the effect of the ability, education, and wage on fertility.

The estimated linear model at each age is:

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

where Y_i^{age} is an outcome at a particular age (had a pregnancy and had an unintended pregnancy), θ is a latent measure of cognitive ability, HS is if graduate from high school, CA is a dummy for attending college, C is if graduate from college, w is the mean wage during that period and X are demographic controls (race, both parent education, and broken home at 14). The measurement system used to identify the latent ability measure α is:

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

where T is a vector of cognitive ability measures (math reasoning, numerical operations, and coding speed), X_T is a vector of control for each measure (race, mother education, broken home at 14, and years of completed education at the moment of the test). Finally, the linear model is estimated, maximizing a likelihood function assuming that F_θ follows a mixture of normal distributions.

Table 5 shows the model results. First we can observe that cognitive ability affects pregnancy timing and intention even after controlling for education and wages. In the case of a pregnancy higher ability decrease the probability for teens and women at college age. However, as high ability women wait until they are young adults high ability increase the probability of a pregnancy at this age. Consistent with the hypothesis that high ability women are better planning pregnancy cognitive ability decrease the probability of an unintended pregnancies for the three age groups however the effects is moderated for young adults.

Teenagers between 14-17 years old in the top cognitive decile are 76% less likely to have a pregnancy and 50% less likely to have an unintended pregnancy than teenagers in the bottom decile. For 18-21 years old women, the difference between the top and the bottom deciles is 40% for a pregnancy and 40% for an unwanted pregnancy. Finally, women between 22-29 years old in the top decile are 39% more likely to have a pregnancy but 7% less likely to have an unintended pregnancy than their pairs in the bottom.

Second, education and income are also relevant for fertility timing. Higher wages and college decrease the probability of pregnancy and unintended pregnancy. The interdecile range effect of ability is a third of the effect of attending college (18-21 yr. old), 2 times the effect of graduating from college (22-29 yr. old), and 70% of the interdecile range effect of wage (22-29 yr. old). In the case of unintended pregnancies, the interdecile range effect of ability is 42% of the effect of attending college (18-21 yr. old), 20% of the effect of graduating from college (22-29 yr. old), and 6% of the interdecile range effect of wage (22-29 yr. old). It is important to notice that in the case of wages, my results are upper-bound as mothers work fewer hours and have lower labor force attachment.

Graduating from high school does not affect pregnancies or unintended pregnancies once controlled by ability. However, attending college reduces the probability of pregnancy and unintended pregnancy to almost zero. In addition, graduating from college reduces pregnancy probability by 24% and unintended pregnancy by 36%. Finally, the wage is also a significant determinant of pregnancies and unintended pregnancies. Women in the top wage decile are 55% less likely to have a pregnancy and 125% less likely to have an unwanted pregnancy than the ones in the lower. The fact that college is relevant even after controlling for wage support the evidence that college affects fertility decisions beyond future wage. In appendix B, we can see the results of using the actual test scores without correct measurement error and reverse causality. Similar to Heckman et al. (2006), I found that using actual score generate upward bias estimators of the ability effect as they capture part of the education effect.

The previous results suggest the importance of cognitive ability in fertility beyond its correlation with education and income opportunity cost. However, to deal with the previously exposed concern, in the following sections, I build and estimate a dynamic model to quantify the importance of cognitive ability and formal education in fertility timing and intention.

Table 5. Latent Factor Model: Pregnancies and Unintended Pregnancies

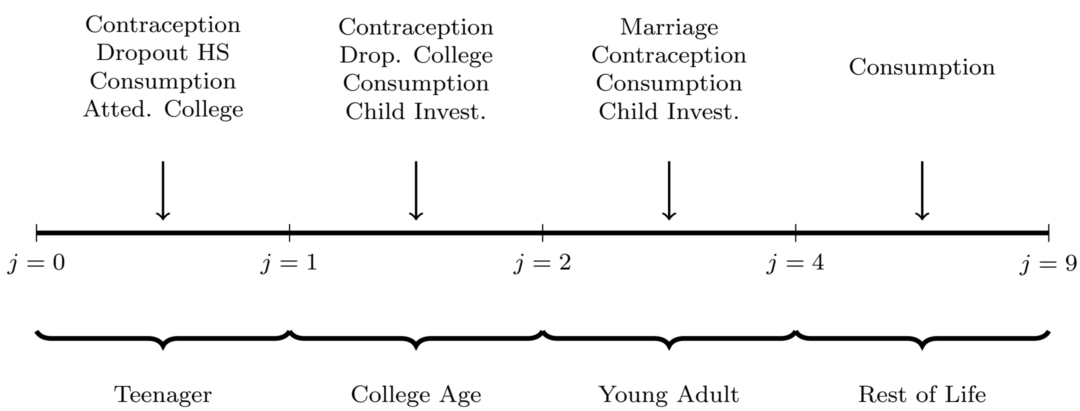
	(1)	(2)	(3)	(4)	(5)	(6)
	Preg.	Unint. Preg.	Preg.	Unint. Preg.	Preg.	Unint. Preg.
	14-17 yrs old	14-17 yrs old	18-21 yrs old	18-21 yrs old	22-29 yrs old	22-29 yrs old
Cog. Ab.	-.0815***	-.0704**	-.0319***	-.0291***	.0971***	-.0030
	(.0144)	(.0104)	(.0200)	(.0142)	(.0292)	(.0158)
Wage					-.0755***	-.0310***
					(.0120)	(.0065)
HSG			.0472	.0082		
			(.0177)	(.0123)		
Att. Coll.			-.2765***	-.0943***		
			(.0176)	(.0125)		
College					-.0770***	-.0203*
					(.0224)	(0122)
Change in Probability						
$\Delta(d_{10} - d_1)$ Cog. Ab.	-76%	-50%	-30%	-40%	39%	-7%
$\Delta(d_{10} - d_1)$ Wage					-55%	-125%
HS			16%	8%		
Att. Col.			-95%	-94%		
College					-24%	-36%
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3948	3948	3450	3450	2412	2412

Standard errors in parentheses , * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3 Model

To analyze the role of cognitive ability on unplanned pregnancies, I built a nine-period model in which each period represents four years of life. The timing of the model is depicted in figure 1. During the first four periods, women are fertile, deciding contraception and child investment when they have a child. In the remaining five periods, women do not make any decisions and consume their wages. In the first period, they are teenagers (14-17 years old); in the second, they are at college age (18-21 years old); the next two, they are young adults (22-29 years old), and in the last periods they consume until their death (22-29 years old). Women differ by ability, marital status, child, wage, and education. During each fertile period, women make different decisions like marital status, contraception use, education achievement, and child investment. Within each period, decisions are sequential, allowing us to divide them into sub-periods.

Figure 1. Women Attending College Life Cycle



In the model, each woman can only have one child who lives in only that period in which mothers can invest money to increase human capital. The child is a one-in-a-lifetime investment opportunity that is optimal when the mother has more resources. Contraception is costly and imperfect; women choose the optimal amount, but pregnancy can occur even when having a child is not optimal. On the other hand, without contraception, a child is born with probability one. Agents are altruistic to their children, and the utility received is increasing in children's monetary investment. Once married, there is no divorce.

The variables of the model and their notation are the following. The value of the problem at each moment is V_t^s, where t represents the period, and s is the sub-period. The state variables are ability, a continuous variable denoted by a. Education has three levels that agents can achieve $e \in \{HSD, HS, C\}$, where HSD is high school drop-out, HS is high school graduate, and C is college graduate. Marital status is denoted by $m \in \{0, 1\}$ where 0 is single, and 1 is married, $sm \in \{0, 1\}$ represents if the woman was a single mother or not. $k_t \in \{0, 1, 2, 3, 4\}$ keeps track of a child's birth period and is zero if she does not have a child. The decision variables are consumption c, child monetary investment i, and the contraception amount s. Finally, the exogenous variables are w and w^h, which are women's and husbands' wages when married. Now, I introduce the model backward to facilitate the exposition.

3.1 Fifth to Nine Period (30-49 years old)

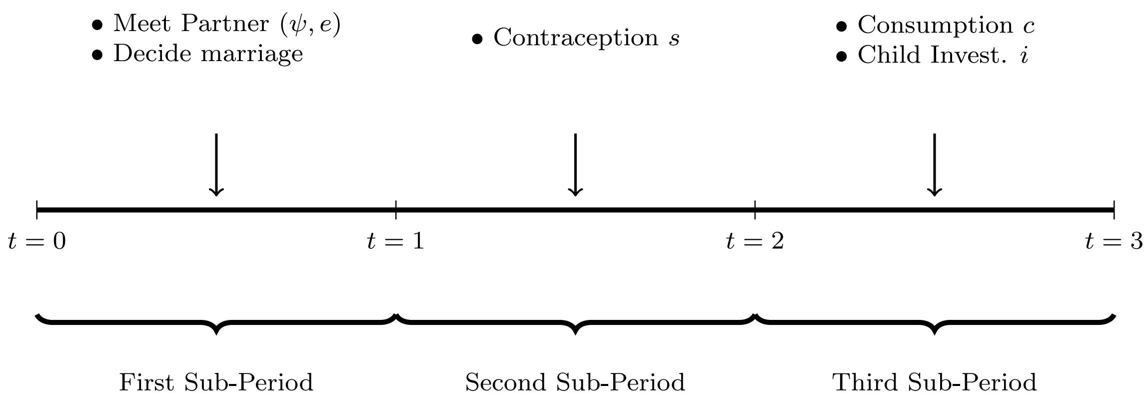
During these periods, women consume the household income and do not make any choices. Therefore, women's value function is the following:

$$V_t(a, e, m, sm, k_t) = \max_c \ u(c)$$
$$\phi_c(m, k_t) \cdot c = \ w(t, a, e, m, sm, k_t) + 1_{m=1} w^h(t, e, sm, k_t)$$

where $\phi_c(m, k_t)$ maps consumption expenditures and family composition into effective consumption depending on the number of members in the household. Women's wage w is a function of their age, ability, education, marital status, single motherhood, having a child, and maternal age at birth k_t. Husband wage w^h is a function that depends on age, the woman's education, if she was a single mother, and if they had a child at that period. The estimation of the wage process is discussed in section 4.1.

3.2 Third and Fourth Period (22-29 years old)

Figure 2. No child, Single Women between 22-30 yr. old



During this period, women make three decisions sequentially. Each decision will represent a sub-period. Figure 2 shows the decision timing of a single woman with no kids. In the first sub-period, single women meet a husband and decide on marriage after the matching shock is realized. In the second sub-period, women without previous children decide on contraception use, and in the last sub-period, they consume and invest in the children if a child is born.

3.2.1 Third Sub-Period: Consumption and Child Investment

Women's problems in this period depended on whether they have a child. If a woman has a child, she has to decide between investing in the child's or consumption. Then, she solved the following problem:

$$V_t^3(a, e, m, sm, k_t = t) = \max_{c,i} \; u(c) + V(i)^k + V_{t+1}(a, e, m, sm, k_t = t)$$
$$\phi_c(m, k_t) \cdot c = \; w(t, a, e, m, sm, k_t) + 1_{m=1} w^h(t, e, sm, k_t) - i$$

where $V^k(i)$ is the utility a child provides to her mother, which depends on monetary investment i. In the case of a woman with a child during a previous period, she only has to decide on consumption; then her problem is the following:

$$V_t^3(a,e,m,sm,k_t) = \max_c \; u(c) + V_{t+1}(a,e,m,sm,k_t)$$

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

Finally, a woman that never had a child, in period four faces a similar problem to a woman with a child in a previous period, except that they receive a utility $\mu_{nk}(e)$. The parameter is necessary to explain that 10% of women do not have a child before 30 years old. Then they face the following problem:

$$V_4^3(a,e,m,sm,k_t=0) = \max_c \; u(c) + \mu_{nk}(e) + V_5(a,e,m,sm,k_t=0)$$

$$\phi_c(m,k_t)\cdot c = \; w(4,a,e,m,sm,k_t) + 1_{m=1}w^h(4,e,sm,k_t)$$

3.2.2 Second Sub-period: Contraception

If a woman has not had a child a the beginning of period four, she has to decide the amount of contraception s; then she resolve the following problem:

$$\begin{aligned} V_t^2(a,k,e,m,s,k_t) = \max_s p(t,a,e,s)\cdot V_t^3(a,k,e,m,sm,k_t=t) \\ +(1-p(t,a,e,s))\cdot V_t^3(a,e,m,sm,k_t=0) - \phi_s s \end{aligned}$$

where s is the amount of contraception that has a utility cost of ϕ_s and $p(t,a,e,s)$ is the probability of having a pregnancy. The pregnancy probability is decreasing in the amount of contraception $\frac{\partial p(t,a,e,s)}{\partial s} < 0$, and at the same amount of contraception, higher ability implies lower pregnancy risk $\frac{\partial p(t,a,e,s)}{\partial a} < 0$. Finally, if the amount of contraception is 0, a child is born $p(t,a,e,s=0)=1$. In the model, women are only allowed to have one child. In the case of already had a child, they do not make any choice during this sub-period, then the value is:

$$V_t^2(a, k, e, m, sm, k_t) = V_t^3(a, k, e, m, sm, k_t)$$

3.2.3 First Sub-Period: Marriage

Single women meet a potential husband with probability $\mu(e, t)$, which depends on education achievement e and the period t. After meeting the matching quality shock $\psi(e) \sim N(0, \sigma_\psi(e))$ is realized and women get marriage if the utility of being married is higher than being single. Then the problem during this stage is the following:

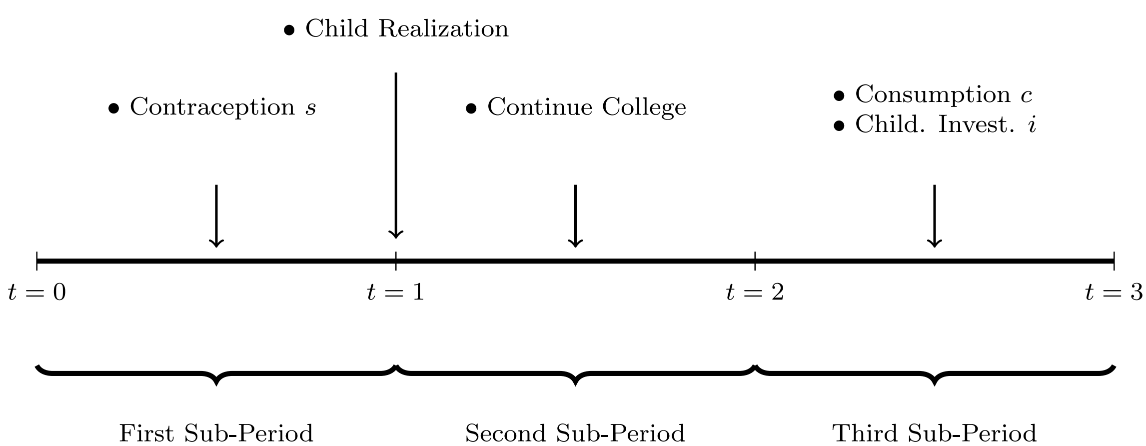
$$V_t^1(a, e, m = 0, sm, k_t) = \mu(e, t) \cdot \max\{V_t^2(a, coll, m = 1, sm, k_t) + \psi(e)$$
$$, V_t^2(a, e, m = 0, sm, k_t)\} + (1 - \mu(e, t)) \cdot V_t^2(a, e, m = 0, sm, k_t)$$

The model does not have divorces, so married women do not make decisions. So then, their value at the beginning of the period is:

$$V_t^1(a, e, m = 1, sm, k_t) = V_t^2(a, e, m = 1, sm, k_t)$$

3.3 Second Period (18-21 years old)

Figure 3. Attending College (18-21 years old)



During this period, women attended college or joined the labor market. Women attending college make three sequential decisions shown in figure 3. First, they decide on contraception. Second, they observe their pregnancy outcome and decide on continuing college. In the case of having a child during college, there is a double penalty. First, graduation cost increases, and second as a college student, she has few monetary resources to invest in the child. She receives a college student's wage if she decides to graduate during the second sub-period. Women who drop out of college move to the consumption-investment sub-period as high school graduates and receive the income of a high school graduate worker.

If a woman does not attend college, the decision sequence is the same as in figure 2. First, they meet a potential husband and decide on marriage. Second, she decides on contraception. Third, she receives a wage conditional on their education level (high school dropout or high school graduate), deciding on consumption and child investment if a child is born. As the decision problem of a woman not attending college is the same as in periods three and four, I will only characterize the problem of women attending college.

3.3.1 Third Sub-Period 18-21: Consumption and Child Investment decisions

In the third sub-period, a woman can continue attending college and graduate or drop out and work as a high school graduate. If a woman decides to graduate, she receives the wage of a college student and decides on consumption and child investment if she has a child. Then her problem is the following:

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

$$\phi_c(k) \cdot c = w(a, e = \text{attend-coll}, s, k_t) - i$$

where G denote the graduation period and $\kappa_{\mathrm{k,C}}$ is the cost of attending college with a child. If the woman drops out from college, her problem is denoted by CD, and she faces the consumption-investment problem of a high school graduate. Then, her value function in this sub-period is:

$$V_2^{3,CD}(a,k_t) = V_2^3(a, e = \text{HS}, m = 0, sm, k_t)$$

3.3.2 Second Sub-Period 18-21: Continue College

During this sub-period, a woman decides whether to continue college or drop out and continue as a high school graduate. The decision is realized after she observes her pregnancy outcomes. Then the problem is:

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

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

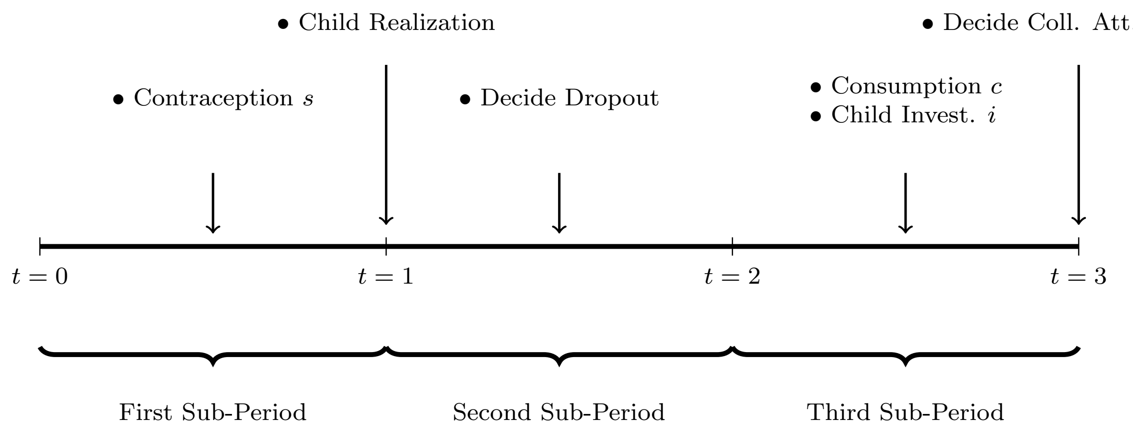
3.3.3 First Sub-Period 18-21: Contraception

Women in college choose contraception in the same way that in previous periods. Then, they solve the following problem:

$$V_2^1(a, coll_a = 1, k_t) = \max_s \; p(t,a,e = coll_a, s) \cdot V_2^1(a, coll_a = 1, k_t)$$
$$+(1 - p(t,a,e = coll_a, s)) \cdot V_2^1(a, coll_a = 1, k_t) - \phi(s)s$$

3.4 First Period (14-17 years)

Figure 4. Teenager (14-17yr. old)



Women between 14-17 years old face the following decisions. At the beginning of the period, all attend high school and decide on contraception. In the second part of the period, after observing the fertility outcome, they decide whether to continue high school. If a teenager continues high school, she consumes in the third period receiving an allowance. If she drops out from high school, she works in the third sub-period and receives the income of a high school dropout. Finally, women who continue high school decide whether to attend college at the end of the third period.

3.4.1 Third Sub-Period 14-17: Consumption, Child Investment, and College Attendance

At the end of the period, women who graduated from high school decide whether attend college. The decision problem is the following:

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

where ϵ_i is an i.i.d. extreme value shock drew from a Type I extreme value distribution, and σ_{CD} is the scale parameter. $\kappa_c(a, k_t)$ is the psych cost of attending college that depends on the woman's ability and if she has a child.

Women that attend high-school graduate and receive an allowance $w(\mathrm{HS}_a)$ from their parents. If they decided to drop out of high school in the previous sub-period, they work and receive the wage of a high school dropout. In the case of women that decide to graduate from high school and had a child in that sub-period, they solve the following problem:

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

where κ_{hs} is the utility cost of graduating from college with a child, $w(HS_a)$ is the parent's allowance and V_1^{CD} is the value of decide college attendance. If a women graduate from high school without a child, her problem is:

$$V_1^{3,HSG}(a, HS_a, k = 0, s = 0, k_t) = \max_{c} u(c) + \beta V_1^{CD}(a, e = \text{hs}, sm, k_t)$$
$$c = w(HS_a)$$

In the case of dropping out of high school, she receives the wage of a high school dropout, and if she has a child, she also decides on child investment. So then, her problem is:

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

where $w(hsd, a, k_t)$ is the wage of a high school dropout, and she continues next period as a high school dropout. For a teen that drops out of high school without a child, her problem is:

$$V_1^{3,HSD}(a, HS_a, sm = 0, k_t = 0) = \max_c \; u(c)$$
$$+\beta V_2^1(a, e = HSD, m = 0, sm = 0, k_t = 0)$$
$$c = w(HSD, a, k)$$

3.4.2 Second Sub-Period 14-17: Continue high school

After women observe their pregnancy outcome, they decide whether continue high school. Then, the problem is the following:

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

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

3.4.3 First Sub-Period 14-17: Contraception

In the first sub-period, all women attended high school and decide on contraception, then their solve the following problem:

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

3.5 Functional Forms and Parameters

I choose the functional forms described in this sub-section to take the model to the data. These functional forms originate 26 parameters which I will discuss their estimation in section 4.

3.5.1 Preferences (2)

Consumption Preferences:

Women have standard CRRA preferences in consumption:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \tag{1}$$

Parent Altruism:

The utility that parent perceive from a child is given by:

$$V(i) = \omega_0 + \omega_1 i^{\omega_2} \tag{2}$$

where ω_0, ω_1, and ω_2 determine the child's return and affect the choice of a husband as he brings monetary resources to invest in the child.

3.5.2 Fertility (12)

The parameter that determinate the fertility decision are $\lambda_{e,t}$, λ_h and $\phi(s)$. The probability of having a child is given by the following function that depends on age t, education e, and contraception s:

$$p(t,a,e,s) = \frac{2\exp(-\lambda_{e,t} \cdot a^{\lambda_a} s^{1-\lambda_a})}{1+\exp(-\lambda_{e,t} \cdot a^{\lambda_a} s^{1-\lambda_a})} \tag{3}$$

Given that $\phi(s)$ and $\lambda_{e,t}$ determinate the contraception cost, I normalize $\phi(s)$ to 1. λ_a determinate the share of ability in the contraception technology. The chosen functional form generates that if the amount of contraception is zero, a pregnancy will occur with probability one.

3.5.3 Marriage Market (7)

The marriage outcomes are determined by the probability of meeting someone $\mu(e,t)$ and the variance of the matching shock $\sigma_\psi(e)$ that depends on her education.

3.5.4 College Attendance and Graduation (6)

College attendance is determined by $\kappa_c(a, k_t) = \frac{\xi_c}{a^{\omega_c}} + 1_{k_t=1} \cdot \kappa_{kb}$ where ξ_c is the psych cost of attending college and κ_{kb} is the cost of attending college having a child. The intuition that psych cost decrease with cognitive ability comes from the fact that study is less painful for high-ability kids or at the same amounts of study hours, the learning is higher. College graduation depends on the continuation cost and the cost of having a child during college $\kappa_{k,\text{coll}}$. Finally, the extreme value shock scale parameters for attending and continuing college are given by σ_{coll} and σ_{CD}.

3.5.5 High School Graduation (2)

High school graduation depends on the continuation values and the cost of attending high school with a child $\kappa_{k,HS}$ and the extreme value shock scale parameter σ_{HS}.

4 Estimation

There are three sets of parameters in the model: those that I take from the literature, the wage process that is estimated exogenously to the model, and those that are estimated within the model using the simulated method of moments, conditional on the two previous sets.

Moments taken from the literature are shown in table 6. These moments are the discount factor, the relative risk aversion, and the 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
$w(t, e, a, m, sm, k)$	Wage Process		NLSY79

4.1 Wages Process

Wages are essential in the model because they determine the cost of early pregnancy in terms of resources to invest in the child and woman's consumption.

I allow women's wages to vary by age group, education, motherhood, age at pregnancy, and ability. The husband's wage depends on the women's education and if the woman had a child before marriage. I estimate the wage profile for women between 14-50 years old. Given data constraints, I chose this age interval as women surveyed in the NLSY79 data are currently in their early fifties. Not having wages after this age is a drawback. However, wages later in life are heavily discounted when fertility decisions are made in women's teens and twenties. I estimated the wage process using OLS for the reported annual wages in NLSY79, dropping individuals who make less than 2.5 dollars per hour and work less than 2000 hours a year. The estimated regression is the following:

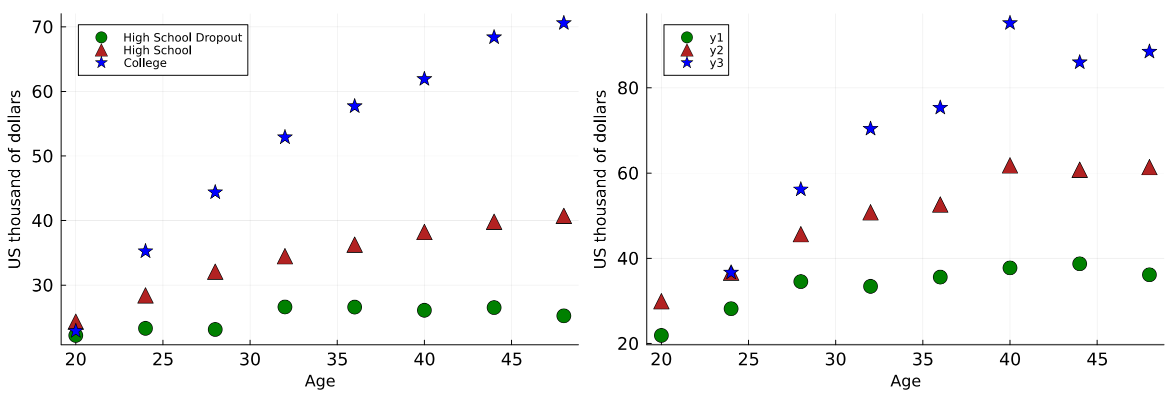
$$
\begin{aligned}
w_{i,t} = \alpha_0 + \alpha_e e_{i,t} + \alpha_e a_i + \alpha_{ea} e_{i,t} \cdot a_i + \alpha_k k_{i,t} + \alpha_{\text{P14-17XEdu}} \text{P14-17} e_{i,t} \\
+ \alpha_{\text{P18-21XEdu}} \text{P18-21} e_{i,t} + \alpha_X X_{i,t} + \epsilon_{i,t}
\end{aligned}
$$

where w is the wage at wife age group t, e is the education level (HSD,HS, C), a is cognitive ability measured by the AFQT test, k is dummy variable that indicates if a woman had a child, P14-17 is a dummy that captures if a woman had a pregnancy as a teen and P18-21 is a dummy that captures if the woman had a pregnancy at college age. In the case of the husband, the wage process is specified as follows:

$$
w^h_{i,t} = \gamma_0 + \gamma_e e^f_{i,t} + \gamma_{KBxEdu} \text{KB}_{i,t} e^f_{i,t} + \epsilon_{i,t}
$$

where e^f is the woman's education and KB^f is a dummy if the woman had a child before marrying.

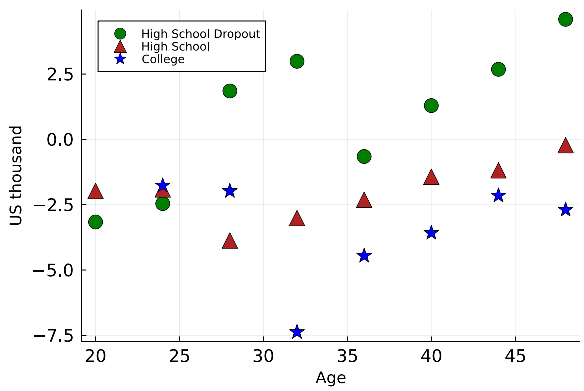
Figure 5a shows the women's average wage by education and age group. As expected, college women have higher earnings, followed by high school graduates and then by high school dropouts. The difference in wage between college and high school graduates is increasing in age and achieve \$30000 at the age bin 46-49 years old. Figure 5b shows the husband's wage where we can observe the same pattern. However, the difference between college and high school graduates' wages increases until bin 30-34 years old, after which it remains flat at around \$25000. In the model, a child is a one-lifetime investment opportunity that is optimal to postpone until women achieve their higher earnings and women are fertile only until 29 years old. The model does not capture how wages after 30 years old affect child investment and fertility timing. However, during women's twenties, the wage growth is higher as education increases, and at 26-29 years old, there is a considerable wage gap between education groups. As a result, I expect the model to capture an important part of how wage growth and disposable resources shape fertility timing for women with different educational achievements.



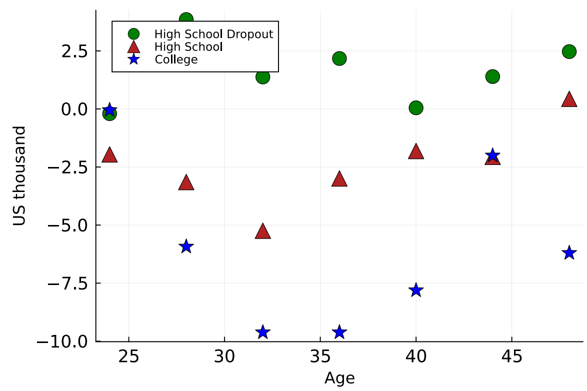
(a) Women (b) Husband

Figure 5. Mean Wage by Education and Age

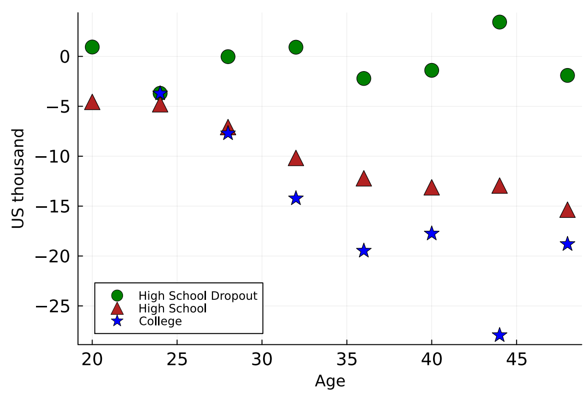
Figure 6a shows the wage penalty of a pregnancy before 14-18 years old. We observe that college and high-school teenage mothers have lower incomes than non-teenage mothers. The penalty is higher for high school graduates between 20-35 years old and 28-45 years old for college mothers. The maximum yearly penalty for high school mothers is 4000 dollars and 7500 for college mothers. In the case of high school dropouts, we can observe a penalty before 26, but teen mothers have higher incomes after that age than non-teenage mothers. Figure 6b shows the cost of pregnancy between 18-21 years old by education group. The penalty behavior is similar to teen pregnancies, but for college mothers, the persistence and size are higher, achieving around 10000 dollars per year in their thirties. Finally, figure 6c shows the effect of an out-of-wedlock pregnancy on the husband's income. Again, we can see that women college graduates suffer the highest penalty, followed by high school graduates. In the case of high school dropouts, the income of the husband that marries after or before the woman had her first child is similar. The penalty is persistent and relevant for college and high school graduates, achieving 15000 and 2000 dollars, respectively.



(a) Pregnancy between 14-17 yr. old



(b) Pregnancy between 18-21 yr. old



(c) Husband Out-of-Wedlock Pregnancy Penalty

Figure 6. Early Pregnancy and Wage Penalty

4.2 Endogenous Paramaters

Table 7. Parameters estimated through the indirect method of moments

Parameter	Value	Interpretation
Contraception Technology and Child Return		
Parameter	Value	Interpretation
λ_a (1)	.56	Ability Share Contr. Tech.
$\lambda_{e,t}$ (7)	Table 13	Scale Parameter by Ability and Education
ω_0 ω_1 ω_2 (3)	-207, 14, .87	Child Return
Marriage Outcomes		
Parameter	Value	Interpretation
$\sigma_\psi(e)$ (3)	36, 116, 71	Volatility Match Quality Shock
$\mu(e,t)$ (5)	Table 8	Probability Meeting a Husband
Education Outcomes		
Parameter	Value	Interpretation
$\kappa_{Coll.}$ ξ_c ω_c (3)	$-97, -2.86, 1.66$	College Psych Cost
κ_{HS}, κ_{kb} (2)	$-10, -1$	Cost Child Dif. Edu. Stages
$\mu_{nk}(e)$ (3)	128, 226, 248	Terminal Value no Child
$w(HS)$ (1)	US$21600	Teenager Allowance
σ_{HS}, σ_{CD}, σ_C (3)	79, 116, 58	EV Shock HS, Attend Coll., Grad Coll.

The model has 31 unknown parameters estimated through 34 data moments using Simulated Method of Moments. Table 7 shows the parameters' respective interpretations. The model aims to understand how ability, education, wage, and marriage shape contraception and age at first pregnancy. For this reason, I estimate the model using moments that relate cognitive ability, education, and marital outcomes with fertility timing.

The data moments are conditional on not having a child before that particular age. I do this because, in the model and the data, I focus on first pregnancies as these are the most costly and significant for women's outcomes. For example, the fraction of women who have their first pregnancy between 18-21 years old is conditional on not having a child before 18. In the following sub-section, I describe each data moment and discuss whether the model fits it. To simplify the explanation, I divide the moments into three categories: cognitive ability and pregnancy, education, and marital outcomes.

Table 8. Probability Meeting a Husband

Education / Age Group	18-21 yr. old	22-29 yr. old
High School Dropout	0.63	0.05
High School Graduate	0.72	0.18
College		0.30

In table 7 second column, we can observe the value of the estimated parameters. The estimated share of ability is 0.56, making ability a relevant input to planning fertility. Table 8 shows the probability of meeting a husband by age and education. High school dropouts' probability of meeting a husband after 22 years old is almost zero; for high school graduates between 18-21 to 22-29 years old, the probability falls to a third, and college graduates have the highest probability by education of meeting someone after 21 years old. The highest cost of pregnancy while studying is during college. The cost of teen pregnancy to attend college is low, so it is not a significant driver in the low college attendance of teen mothers. This result is surprising as women who had teen pregnancies and worked during college attendance periods do not provide child care, indicating that women with early pregnancies are not attending college even in the case of not having a pregnancy. The estimated parent allowance during high school is 21600 dollars. In section 5.1, I discuss how contraception costs vary by age and education.

4.2.1 Cognitive Ability and Pregnancies

Table 9. Fit Model Pregnancy and Ability

	Ability Quartile			
	First Quartile	Second Quartile	Third Quartile	Four Quartile
Age First Pregnancy	Pregnancy Probability | No Prev. Preg.			
14-17	29%	15%	9%	3%
	(46%)	(12%)	(9%)	(3%)
18-21	55%	46%	31%	20%
	(70%)	(37%)	(20%)	(16%)
22-29	50%	49%	45%	47%
	(68%)	(39%)	(39%)	(54%)

Values in parenthesis are model outcomes, and values without parenthesis are the data values.

The first set of moments used is the main data feature that the model aims to replicate, the relationship between cognitive ability and pregnancy. For this purpose, I use the probability of having a child for each cognitive ability quartile for the 14-17, 18-21, and 22-29 years old age intervals, conditionally on being childless at the moment of entering the respective age group. In Table 9, we can see that the model replicates the positive relationship between ability and pregnancy age. Also, as the data after 22 years, the pregnancy and ability relationship has a U-shape with higher rates in the bottom and top quartiles. However, the model generates a steeper slope than the observed in the data, overpredicting pregnancy rates for the lowest ability quartile.

4.2.2 Education Outcomes

Table 10. Education Outcomes and Pregnancy Moments

Moments	Data	Model
Drop out High School | No Pregnancy (<18)	0.06	0.06
Drop out High School | Pregnancy (<18)	0.28	0.27
Attend College | No Pregnancy (<18)	0.41	0.33
Attend College | Pregnancy (<18)	0.08	0.08
Graduate College | No Pregnancy (<22)	0.63	0.56
Graduate College | Pregnancy (<22)	0.30	0.32

The second set of moments is education attainment conditionally on having or not having a pregnancy. These are the empirical counterpart to the modeled decisions: high school dropout, attending college, and graduating. Table 10 shows that the model does a good job replicating women's educational outcomes conditional on motherhood status. Nevertheless, it underpredicts the probability of attending college conditional on not having a pregnancy.

4.2.3 Marital Outcomes

Table 11. Fit Marital Outcomes and Pregnancies by Education Group

Moments	Data	Model	Moments	Data	Model
Married 18-21 yr. old | HSD, NPP	0.51	0.53	Sing. Mom 22-29 yr. old | HS, NPP	0.15	0.13
Married 18-21 yr. old | HS, NPP	0.53	0.57	Sing. Mom 22-29 yr. old | Coll, NPP	0.07	0.07
Married 22-29 yr. old | HSD, NPP	0.61	0.55	Preg. 18-21 yr. old | HSD, NPP	0.62	0.66
Married 22-29 yr. old | HS, NPP	0.67	0.59	Preg. 18-21 yr. old | HS, NPP	0.48	0.76
Married 22-29 yr. old | Coll, NPP	0.68	0.58	Preg. 18-21 yr. old | Att. Coll, NPP.	0.16	0.19
Sing. Mom 18-21 yr. old | HSD, NPP	0.43	0.47	Preg. 22-29 yr. old | HSD, NPP	0.48	0.53
Sing. Mom 18-21 yr. old | HS, NPP	0.39	0.41	Preg. 22-29 yr. old | HS, NPP	0.48	0.47
Sing. Mom 22-29 yr. old | HSD, NPP	0.24	0.21	Preg. 22-29 yr. old | Coll, NPP	0.44	0.49

NPP = No Previous Pregnancy.

Finally, I look at the moments related to contraception and marriage choices conditional on education and age. These moments are total pregnancies, single motherhood, and fraction married. Table 11 shows the model fit. The model generally does a decent job, given its simplicity and the high number of data moments. The model is close to matching marriage, single mothers, and total pregnancies. The biggest model failure is in the number of high school graduates' total pregnancies, which the model considerably overpredicts.

4.3 Non Targeted Moments

Table 12. Non Targeted Moments

Moments	Data	Model	Moments	Data	Model
High School Grad. | Ability Q1	0.72	0.81	College Att. | Ability Q3	0.40	0.44
High School Grad. | Ability Q2	0.92	0.91	College Att. | Ability Q4	0.70	0.47
High School Grad. | Ability Q3	0.98	0.95	College Grad. | Ability Q1	0.04	0.01
High School Grad. | Ability Q4	1.00	0.94	College Grad. | Ability Q2	0.11	0.12
College Att. | Ability Q1	0.12	0.02	College Grad. | Ability Q3	0.22	0.22
College Att. | Ability Q2	0.25	0.23	College Grad. | Ability Q4	0.52	0.25

Since the calibration does not target educational outcomes by ability, I use high school, college attendance, and college graduation to evaluate the model's fit. Table 12 shows that the model captures the positive relation between ability and education outcomes. However, it cannot generate enough college attendance and graduation at the highest ability quartile.

5 Results

In this section, I present the main model results. First, I show the estimated contraception cost by education and age. Second, I decompose the contribution of ability and heterogeneous contraception cost by education. Third, I analyze how three important model margins work: i) the wage penalty of early pregnancy, ii) the wage penalty of out-of-wedlock pregnancy, and iii) the utility cost of having a child meanwhile studying.

5.1 Contraception Cost by Age and Education

Table 13. 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	1.64	0.92	1.19
High School Graduate	1.64	0.69	1.67
College	1.64	0.75	2.20

Table 13 shows the scale parameter of the contraception technology. This parameter determines the cost of using contraception by age and education group. Higher parameter values make the same amount of contraception conditional on ability more efficient, implying a lower probability of having a pregnancy. In the first period, women are teenagers having the same contraception cost. In the second period, we have three groups: high school dropouts, high school graduates, and college attendings. Finally, the groups in the last two fertile periods are high school dropouts, high school graduates, and college graduates.

We can see that high school graduates have a higher contraception cost than college graduates. This result is consistent with the estimated factor model in section 2.5 that formal education affects pregnancy beyond income and ability. Attending and graduating from college decrease the contraception cost, which reaches its highest level between 19 and 21 years old and declines with age. Figure 7 shows that between 22 and 29 years old High school and college graduates have 77% and 84% lower contraception costs than high school dropouts. We can also see that high school dropouts between 19 and 22 years old have a lower contraception cost than the other two same-age groups. The reason is that high school dropout individuals have the highest contraception cost as teenagers, given their low ability. So then, the ones who arrive at 18 years old without a child have the lowest contraception cost within this education group.

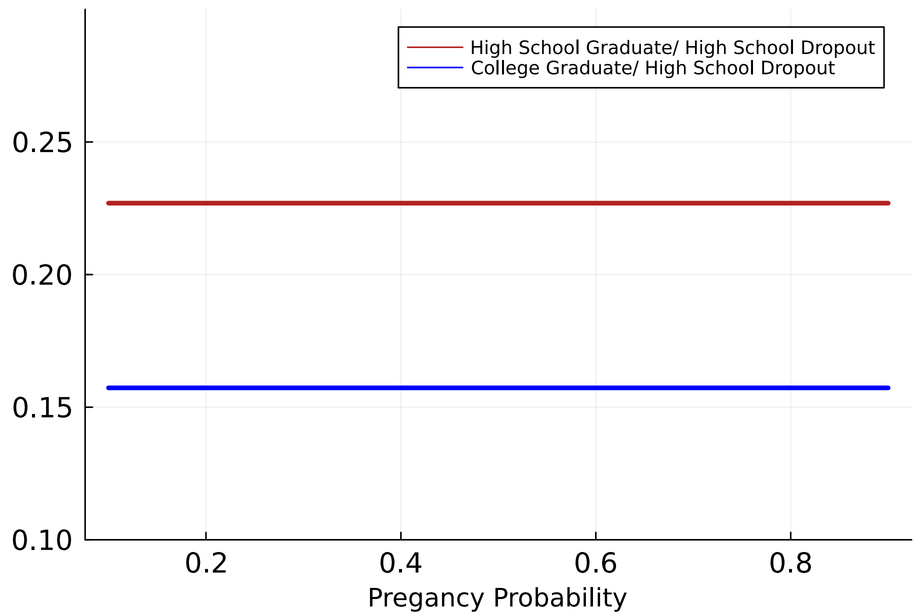


Figure 7. Contraception use ratio between education group to achieve same pregnancy probability

Figure 8 illustrates the importance of education and ability. We can see the probability of pregnancy at the same contraception level between 29-22 years old for different education and cognitive ability levels. First, as discussed before, the pregnancy probability of a high school dropout is considerably higher than high school graduates or college graduates for the same level of contraception. Second, at the average pregnancy probability in the data, women in the high cognitive ability quartile are four times more efficient in contraception than women at the bottom. Finally, given that most high-ability individuals are also college graduates, their probability of having an unintended pregnancy is almost zero.

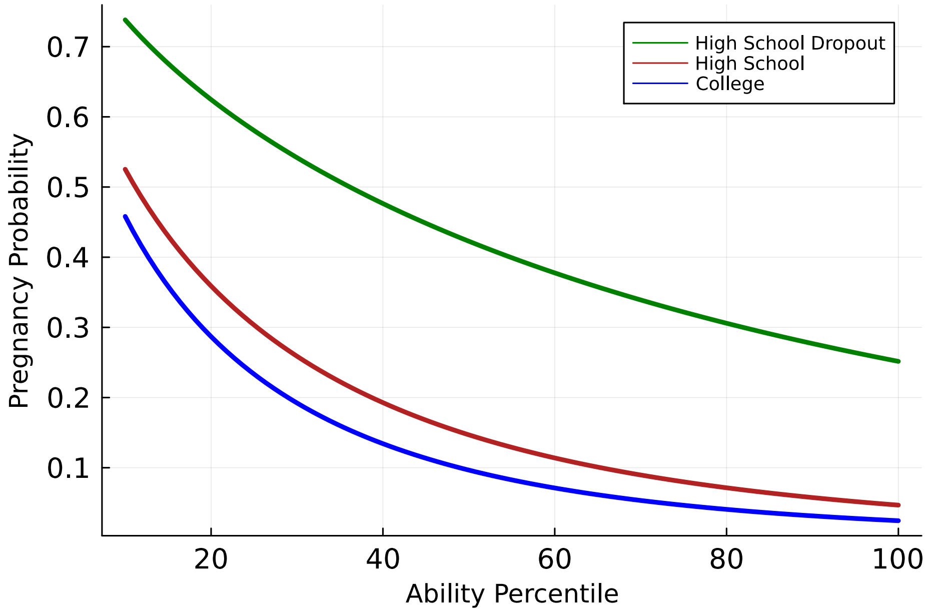


Figure 8. Pregnancy Probability at same effort level between 22-29 years old.

5.2 Mechanism Decomposition

I estimate two nested versions of the model to quantify the importance of ability and formal education on fertility. In the first, the contraception technology is homogeneous by education $\lambda_{1t}^{HSD} = \lambda_{1t}^{HS} = \lambda_{1t}^{Coll}$ and it does not depend on cognitive ability $\lambda^a = 0$. I call this the "baseline model". In the second version, I allow fertility to depend on ability $\lambda^a \geq 0$. First, each model version is estimated separately. Then, I analyze how each specification fits the data and if the mechanism is necessary to explain the data. To assess the fit, I use the sum squared error (SSE) normalized by the data moment:

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

where m_i is the data moments and $m_i(\hat{\theta})$ is the model moments for the parametrization θ. Like the previous section, I group the moments into three categories: Cognitive Ability and Pregnancies, Education, and Marital Moments. The top of table 14 shows the total SSE for each different version of the model, and the bottom displays the percentual improvement in the model fit when the mechanism is added $(1 - \frac{\text{SSE}_1}{\text{SSE}_0})$. The full set of moments for each model specification is shown in Table A1. As I am particularly interested in how cognitive ability affects pregnancies, in figure 9, I display the fraction of women that had a pregnancy for each age group, cognitive ability quartile, and model specification.

Table 14. Decomposing the Model Fit

	(1) Benchmark	(2) Benchmark + Educ. Het.	(3) Benchmark + Educ. Het. + Ab. Cont.
Total SSE	3.42	1.99	1.53
Pregnancies and Ability Moments SSE	1.07	0.87	0.88
Education Moments SSE	1.13	0.56	0.05
Marital Moments SSE	1.45	0.62	0.49
Fit Improvement $(1 - \frac{\text{SSE}_1}{\text{SSE}_0})$		+ Educ. Het.	+ Ab. Cont.
Total Fit		42%	23%
Pregnancies and Ability Moments		19%	0%
Education Moments		51%	91%
Marital Moments		57%	22%

The first column of table 14 shows the fit of the "baseline" model, the second column shows the fit when I allow heterogeneity in the contraception costs across education and age, and the third column is when fertility is allowed to depend on cognitive ability. The "baseline" model generates a positive relationship between ability and education, doing a very good job in the first period. In the second period, it cannot generate the positive relationship between ability and pregnancies that we see in the data, as the model underpredicts them for low-ability groups. In the third period, the model considerably overpredicts high-ability pregnancies. Further, the model overpredicts college graduation rates for mothers and non-mothers. Finally, the biggest model failure is that it considerably underpredicts pregnancies for college graduates and underpredicts them for high-school graduates.

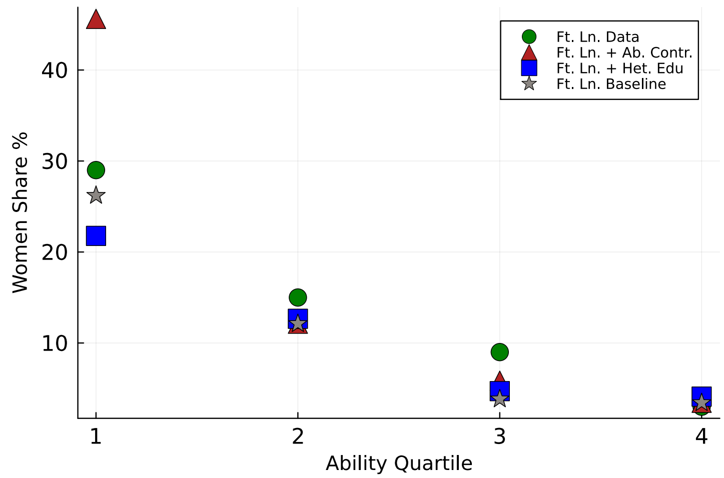
In column 2, we can see that allowing heterogeneity in contraception cost by education improves the total fit by 42%. The three dimensions improved with pregnancy: ability moments by 19%, education moments by 51%, and marital moments by 57%. In the case of ability and pregnancies, the gain comes from a better fit in the last period for low-ability women. In the case of education, adding heterogeneous contraception cost decreases college graduation rates, particularly for women with a college pregnancy. Finally, total pregnancies for 18-21 years old high school dropouts and 22-29 years old high school graduates fall, improving the fit of marital moments.

In column 3, we can see that allowing fertility technology to depend on women's ability improves the model fit by 23%. However, the moments related to ability and fertility do not improve their fit. Even when the model now creates a steeper relation between ability and pregnancies, it considerably overshoots the number of pregnancies for the low-ability group. Additionally, the introduction of ability greatly improves the fit of educational attainment conditional on pregnancies. Also, it enhances the fit of pregnancies, single mothers, and marriages in the third and four periods.

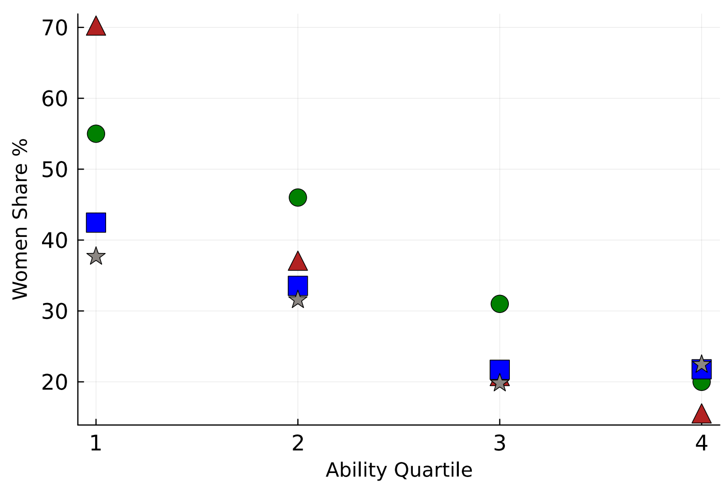
Even when the mechanism introduced in the model are insufficient to thoroughly explain the data, ability and heterogeneity by education in contraception technology are channels that are important to give an adequate description of fertility timing by age and cognitive ability. Additionally, both are relevant to link educational achievement with marital and fertility outcomes, providing an explanation to the strong relationship between ability and fertility

Figure 9. Fraction of Pregnancies by Age and Cognitive Ability Quartile

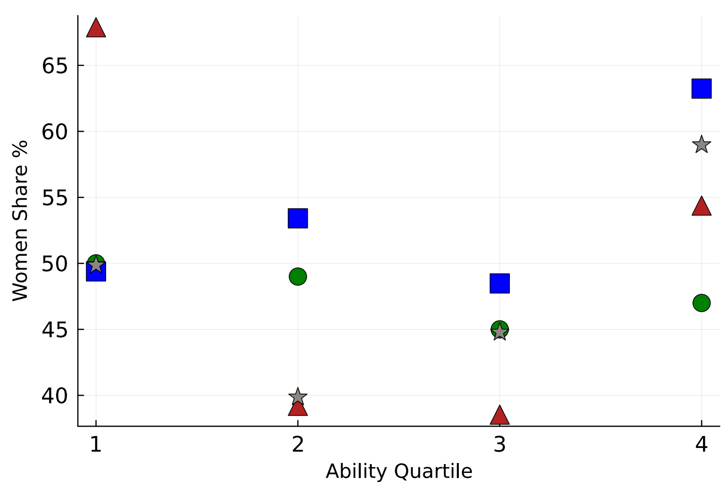
(a) First Period: Pregnancy between 14-17 years old



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



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



5.3 Model Margins

In this section, I analyze how the effect of early pregnancy on women's wages and their respective husbands affects decisions and outcomes in the model. Then, I examine how the cost of a pregnancy meanwhile study affects decisions and outcomes.

5.3.1 Wage Penalties

Table 15. Pregnancy and Wages

Moment	(1) - Moth. Pen	(2) - Husb. Wage	Moment	(1) - Moth. Pen	(2) - Husb. Wage
Preg. 14-17 yr. old	7.3%	0.0%	Preg. 18-21 yr. old | HSD, NPP	11.0%	0.2%
Preg. 18-21 yr. old	-0.3%	0.1%	Preg. 18-21 yr. old | HS, NPP	-0.6%	0.0%
Preg. 22-29 yr. old	-0.6%	0.2%	Preg. 18-21 yr. old | Att. Coll., NPP	1.8%	0.1%
Drop HS | No Preg	1.9%	0.0%	Sing. Mom 22-29 yr. old | HSD, NPP	-1.7%	-0.0%
Drop HS | Preg	71.3%	0.4%	Sing. Mom 22-29 yr. old | HS, NPP	-0.1%	-0.6%
Att. Coll. | No Preg	2.1%	0.3%	Sing. Mom 22-29 yr. old | Coll., NPP	0.0%	9.0%
Att. Coll. | Preg	-21.3%	1.3%	Married 22-29 yr. old | HSD, NPP	-3.7%	0.0%
Grad. Coll. | No Preg	-0.2%	0.1%	Married 22-29 yr. old | HS, NPP	-0.3%	0.4%
Grad. Coll. | Preg	9.0%	1.6%	Married 22-29 yr. old | Coll., NPP	-0.3%	-0.3%
Married 18-21 yr. old | HSD, NPP	-0.9%	0.0%	Preg. 22-29 yr. old | HSD, NPP	-3.2%	0.0%
Married 18-21 yr. old | HS, NPP	-0.9%	-0.2%	Preg. 22-29 yr. old | HS, NPP	-0.5%	0.0%
Sing. Mom 18-21 yr. old | HSD, NPP	2.6%	0.0%	Preg. 22-29 yr. old | Coll., NPP	0.0%	1.0%
Sing. Mom 18-21 yr. old | HS, NPP	1.0%	0.2%			

NPP = No Previous Pregnancy.

To analyze how the decreases in women's wages affect an early pregnancy, I set the wage penalty to zero so that teens and college-age pregnancies are not costly in terms of income. Table 15, column 1, shows the changes in the different model dimensions for both experiments.

The wage cost reduces teen pregnancy as contraception use increases. Without the wage penalty, they increase by 7.3%. Additionally, teen mothers high school dropout is more attractive as now work provides more resources to invest in the child, rising by 71.3%. College attendance increases by 2.1% for nonmothers as pregnancy during college is less costly, which is reflected in graduation for college mothers increasing by 9%. However, college attendance for teen mothers decreases by 21.3% as they drop high school and start working. Between 18-21 years old total pregnancies falls by 0.3%, and marriage decreases by 0.9% for high school graduates and dropouts. Additionally, single mothers increase for the first groups by 2.6% and 1.0% for the latter.

Total pregnancies increases for high school drop out and women attending college; however, it decreases for high school graduates. Finally, between 22-29 years, the number of single mothers, married women, and total pregnancies decreases for high school dropouts and high school graduates. For college women, as expected, total pregnancies remain constant. A pregnancy during these periods is not early, so there is no wage penalty in my model. The fall in pregnancies in the other two groups comes from the fact that women who before were not having a child before 21 now have early pregnancies as these are less costly.

In the second column of table 15, I eliminate the effect of out-of-wedlock on the wage of potential husbands. The husband penalty is relevant mainly for college graduate women. Without this penalty, the total number of pregnancies remains almost constant and only increases between 18-21 years old by 0.1% and 0.2% between 22-29 years old. As previous pregnancies do not affect future husbands' wages, college attendance for teens with pregnancies increased by 1.3%, and the graduation rate for women with pregnancy during college increased by 1.6% as college became a better tool for single mothers to attract a husband. As mentioned early, the only group that considerably increased the number of single mothers is college graduates, which increased by 9%, marriages decreased by 0.3% as now some women prefer being single to married in the case of having a bad match, and total college pregnancies increased by 1.0%.

5.3.2 Pregnancy Cost and Education Achievement

Finally, to understand how the cost associated with a pregnancy during different education stages affects decisions in the model, I set the parameters that quantify this cost to zero. Table 16 shows the results.

In the model, the utility cost of having a child considerably affects the contraception decision during high school and college, but also it is essential in the attendance decision as it increases the college cost in case of a pregnancy. Without these costs, pregnancies increase by 2.1% during high school and 16% during college. As graduating get easier in the case of a child, high school dropout fall by 12.3% for teen mothers and their college attendance increase by 1.5%. Additionally, college attendance increased by 6.9 for women without a teen pregnancy as now college is more attractive for women in the case of having a pregnancy during it, which is shown in the fact that graduation for college mothers increased by 83.3% for them.

Table 16. Pregnancy and Education Cost

	No Educ. Pen	Moment	No Educ. Pen
Preg. 14-17 yr. old	2.1%	Preg. 18-21 yr. old | HSD, NPP	-4.7%
Preg. 18-21 yr. old	2.2%	Preg. 18-21 yr. old | HS, NPP	-1.6%
Preg. 22-29 yr. old	0.1%	Preg. 18-21 yr. old | Att. Coll., NPP	16.0%
Drop HS | No Preg	-3.7%	Sing. Mom 22-29 yr. old | HSD, NPP	-0.9%
Drop HS | Preg	-12.3%	Sing. Mom 22-29 yr. old | HS, NPP	2.7%
Att. Coll. | No Preg	6.9%	Sing. Mom 22-29 yr. old | Coll., NPP	2.1%
Att. Coll. | Preg	1.5%	Married 22-29 yr. old | HSD, NPP	3.3%
Grad. Coll. | No Preg	0.0%	Married 22-29 yr. old | HS, NPP	0.4%
Grad. Coll. | Preg	83.8%	Married 22-29 yr. old | Coll., NPP	0.3%
Married 18-21 yr. old | HSD, NPP	-2.1%	Preg. 22-29 yr. old | HSD, NPP	5.7%
Married 18-21 yr. old | HSD, NPP	-0.6%	Preg. 22-29 yr. old | HS, NPP	-0.5%
Sing. Mom 18-21 yr. old | HSD, NPP	2.3%	Preg. 22-29 yr. old | Coll., NPP	0.6%
Sing. Mom 18-21 yr. old | HSD, NPP	0.6%		

NPP = No Previous Pregnancy.

6 Compulsory Education and Teens Pregnancies

There is a broad consensus that early pregnancies are a serious social problem as they negatively affect women's economic outcomes. A policy that has been effective in decrease teenagers pregnancies is mandatory schooling (Black et al., 2008; Kruger and Berthelon, 2009). However, an open question is how these policies affect women's fertility. Some channels suggested by the literature are an increase in lifetime income and earnings, improvements in information about fertility, accurate expectations about the future, and the "incarceration effect", in which teens spend more hours in school having less time for risky attitudes, which mechanically decreases pregnancies. In this section, I show that my model can accrue for almost all the effects on teen pregnancies through the impact of extra education time on cognitive ability.

The model presents a good tool for studying these policies as higher education attainment changes future income. Additionally, there is evidence that cognitive ability is still malleable in high school, with extra years of schooling increasing it (Falch and Sandgren Massih, 2011; Carlsson et al., 2015). Finally, the model can separate both channels and quantify their effects on reducing teen pregnancies. To study these reforms, I will use Black et al. (2008) results, which used time and state variation in the implementation of mandatory schooling and found that in the U.S., education achievement increased by 0.4 years. Furthermore, these reforms were associated with a decrease in pregnancies before 18 years old by 4.17% and before 21 by 4.52%. To quantify the effect of mandatory schooling, I use Carlsson et al. (2015) result that an extra year of education increase cognitive ability by 0.2 standard deviations. I show two model variations to separate the effect of ability in more efficient contraception and higher contraception use given higher future income. First, I increase cognitive ability by 6.8% in the model, which is the effect of 0.4 extra years of education. Second, I increase the ability only in the wage process, but I keep the ability constant in the contraception function.

Table 17. Compulsory Education

Moment	(1) Wage Effect + Contr. Eff.	(2) Wage Effect	Moment	(1) Wage Effect + Contr. Eff.	(2) Wage Effect
Preg. 14-17 yr. old	-3.9%	-0.1%	Preg. 18-21 yr. old | HSD, NPP	-1.6%	-0.4%
Preg. 18-21 yr. old	-4.0%	-0.2%	Preg. 18-21 yr. old | HS, NPP	-4.8%	-3.8%
Preg. 22-29 yr. old	5.9%	7.0%	Preg. 18-21 yr. old | Att. Coll., NPP	-2.0%	2.0%
Drop HS | No Preg	-0.5%	-1.7%	Sing. Mom 22-29 yr. old | HSD, NPP	0.2%	-0.8%
Drop HS | Preg	0.0%	-0.3%	Sing. Mom 22-29 yr. old | HS, NPP	-1.7%	1.1%
Att. Coll. | No Preg	4.7%	3.3%	Sing. Mom 22-29 yr. old | Coll., NPP	-5.4%	-4.3%
Att. Coll. | Preg	-1.4%	5.2%	Married 22-29 yr. old | HSD, NPP	1.3%	-0.4%
Grad. Coll. | No Preg	0.5%	0.2%	Married 22-29 yr. old | HS, NPP	2.8%	3.2%
Grad. Coll. | Preg	-0.5%	0.4%	Married 22-29 yr. old | Coll., NPP	0.4%	0.9%
Married 18-21 yr. old | HSD, NPP	-3.7%	0.8%	Preg. 22-29 yr. old | HSD, NPP	0.4%	1.1%
Married 18-21 yr. old | HS, NPP	1.3%	0.9%	Preg. 22-29 yr. old | HS, NPP	7.9%	9.2%
Sing. Mom 18-21 yr. old | HSD, NPP	2.3%	-0.8%	Preg. 22-29 yr. old | Coll., NPP	3.4%	4.8%
Sing. Mom 18-21 yr. old | HS, NPP	-3.3%	-2.7%			

NPP = No Previous Pregnancy.

In table 17, we can see the results. Column 1 shows the total effect of increasing compulsory education through cognitive ability. The model can explain 93% of the decrease in pregnancies before 18 years old and 84% of the decline before 21 years old. Column 2 shows the results when compulsory education only affects future wages. We can see that almost all the effect on pregnancies is caused by changes in contraception efficiency and not by higher wages. The fact that change in wages does not explain teen pregnancies is consistent with Stephens Jr and Yang (2014), which shows that change in compulsory education does not significantly increase wages and also with Black et al. (2008) result that the effect persists beyond teens attend high-school which suggest that mandatory education affect fertility beyond the "incarceration effect".

7 Conclusion

In this paper, I empirically and quantitatively explore cognitive ability's effects on fertility timing. The first contribution of the paper is to document empirically that differences in education and future income cannot explain differences in fertility timing and pregnancy intention across women with different levels of cognitive ability.

The paper's second contribution is to jointly study how cognitive ability, education, wages, and marriage affect early pregnancies in a dynamic life-cycle model. First, consistent with my empirical results, cognitive ability affects teen and young adult fertility risk beyond the difference in time opportunity cost and fertility risk by education. Then, through the lens of the model, I quantify the importance of cognitive ability and formal education in fertility. Finally, I show that changes in cognitive ability through mandatory education laws can explain the decreases in teen pregnancies generated by this type of policy.

My paper adds to the increasing literature showing cognitive ability's importance in noneconomic outcomes and highlights its importance in understanding fertility timing and intention. Additionally, it provides a framework to understand the effects of policies targeting cognitive ability on early pregnancies and educational outcomes. In ongoing work, I will extend the model to allow for children's human capital accumulation and assess the effect of early pregnancies on children's educational outcomes and intergenerational inequality when at least part of cognitive ability is persistent across generations.

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A Model Mechanism Contribution

Appendix Table A1. Pregnancy and Wages

Moments	Data	Benchmark + Educ. Het + Ab. Cont.	Benchmark + Educ. Het.	Benchmark
Q1 Ab Preg 14-17 yr. old	0.29	0.46	0.22	0.26
Q2 Ab Preg 14-17 yr. old	0.15	0.12	0.13	0.12
Q3 Ab Preg 14-17 yr. old	0.09	0.06	0.05	0.04
Q4 Ab Preg 14-17 yr. old	0.03	0.03	0.04	0.03
Drop HS, NPP | No Preg	0.06	0.06	0.06	0.07
Drop HS, NPP | Preg	0.28	0.27	0.12	0.20
Att. College | No Preg	0.41	0.33	0.39	0.46
Att. College | Preg	0.08	0.08	0.05	0.07
Q1 Ab Preg 18-21 yr. old	0.55	0.7	0.42	0.38
Q2 Ab Preg 18-21 yr. old	0.46	0.37	0.34	0.32
Q3 Ab Preg 18-21 yr. old	0.31	0.21	0.22	0.20
Q4 Ab Preg 18-21 yr. old	0.20	0.16	0.22	0.22
Graduate College | No Preg	0.63	0.56	0.77	0.80
Graduate College | Preg	0.30	0.31	0.38	0.58
Married 18-21 yr. old | HSD, NPP	0.51	0.52	0.51	0.56
Married 18-21 yr. old | HSD, NPP	0.53	0.57	0.56	0.56
Single Mom 18-21 yr. old | HS, NPP	0.43	0.47	0.45	0.40
Single Mom 18-21 yr. old | HS, NPP	0.39	0.41	0.44	0.41
Pregnancy 18-21 yr. old | HSD, NPP	0.62	0.66	0.65	0.74
Pregnancy 18-21 yr. old | HS, NPP	0.48	0.76	0.66	0.67
Pregnancy 18-21 yr. old | Att. Coll., NPP	0.16	0.19	0.14	0.10

NPP = No Previous Pregnancy.

Appendix Table A1. Pregnancy and Wages

Moments	Data	Benchmark + Educ. Het + Ab. Cont.	Benchmark + Educ. Het.	Benchmark
Q1 Ab Preg 22-29 yr. old	0.50	0.68	0.49	0.50
Q2 Ab Preg 22-29 yr. old	0.49	0.39	0.53	0.40
Q3 Ab Preg 22-29 yr. old	0.45	0.39	0.48	0.45
Q4 Ab Preg 22-29 yr. old	0.47	0.54	0.63	0.59
Single Mom 22-29 yr. old | HSD, NPP	0.24	0.21	0.18	0.12
Single Mom 22-29 yr. old | HS, NPP	0.15	0.13	0.10	0.16
Single Mom 22-29 yr. old | Coll, NPP	0.07	0.07	0.07	0.08
Married 22-29 yr. old | HSD, NPP	0.61	0.55	0.53	0.76
Married 22-29 yr. old | HS, NPP	0.67	0.59	0.53	0.68
Married 22-29 yr. old | Coll, NPP	0.68	0.58	0.60	0.56
Pregnancy 22-29 yr. old | HSD, NPP	0.48	0.53	0.58	0.43
Pregnancy 22-29 yr. old | HS, NPP	0.48	0.47	0.62	0.69
Pregnancy 22-29 yr. old | Coll, NPP	0.44	0.49	0.37	0.13

NPP = No Previous Pregnancy.

B Linear Model using AFQT

Appendix Table B1. Linear Regression

	(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
AFQT	-0.063***	-0.026***	-0.060***	-0.013*	0.026*	0.013*
	(0.006)	(0.004)	(0.010)	(0.007)	(0.014)	(0.008)
High School			0.037**	0.006		
			(0.017)	(0.013)		
Attend College			-0.245***	-0.090***		
			(0.020)	(0.014)		
Wage					-0.071***	-0.034***
					(0.012)	(0.007)
College					-0.084***	-0.030**
					(0.024)	(0.013)
Change in Probability						
$\Delta(d_{10} - d_1)$ Cog. Ab.	-131%	-109%	-49%	-62%	15%	44%
$\Delta(d_{10} - d_1)$ Wage					-36%	-98%
HS			11%	8%		
Att. Col.			-73%	-94%		
College					-18%	-38%
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3948	3948	3450	3450	2412	2412

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$