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Teenage Childbearing and the Welfare State

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Very Preliminary Version!

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Abstract

Teenage childbearing is a common incident in developed countries. However, the occurrence of teenage births is much more likely in the United States than in any other industrialized country. The majority of these births are delivered by female teenagers coming from low-income families. The hypothesis put forward here is that the *welfare state* (a set of redistributive institutions) plays a significant role for teenage childbearing behavior. We develop an economic theory of parental investments and risky sexual behavior of teenagers. The model is estimated to fit stylized facts about income inequality, intergenerational mobility, and sexual behavior of teenagers in the United States. The welfare state institutions are introduced via tax and public education expenditure functions derived from U.S. data. In a quantitative experiment, we impose Norwegian taxes and/or education spending in the economic environment. The Norwegian welfare state institutions go a long way in explaining the differences in teenage birth rates between the United States and Norway.

JEL Classifications: E24, H31, I28, J13, J24, J62.

Keywords: Teenage risky sexual behavior, teenage birth rates, progressive taxation, education, redistribution.

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[†]All errors are the sole responsibility of the authors.

1 Introduction

Teenage childbearing is a widespread phenomenon in the industrialized world. However, teenagers in the United States give birth far more often than their counterparts in any other developed country. American female adolescents are six times more likely to become mothers compared to their peers in the Scandinavian countries at the onset of the twenty-first century. What makes the U.S. rate of teenage childbearing so high? It turns out that American teen mothers come from families that inhabit the lowest centiles of the household income distribution. Thus, the degree of teenage childbearing is determined by the income and life choices of families at the bottom of the income ladder.

The hypothesis put forward in this paper is that teenage childbearing is influenced heavily by the amount of redistribution in a society. Think of a simple representation of the world in which families differ by their income which is spent on contemporaneous consumption and investments in their children. The government redistributes income in the cross-section through taxes and transfers and spends resources on educating children. In conjunction with the facts above, think of investments into children as an important determinant of teenage childbearing behavior. First, if the societal system of taxes and transfers is favorable towards families with lower income levels, then the investment levels in their offsprings would be altered leading to a different pattern of teenage childbearing. Indeed, tax progressivity and the rate of teenage births are highly and positively correlated across developed countries. Second, the amount of public education expenditures would also alter the levels of investment to children from poor families, which might lead to a lower rate of teenage births. Evidence for this channel is present too - countries with higher degree of public education expenditure tend to have lower rates of teenage childbearing.

The goal of this paper is to develop a theory of teenage childbearing which can be used to gauge how redistribution affects teenage childbearing. To achieve this goal, we consider an overlapping generation model of human capital investment into children and risky teenage sexual behavior. In our framework parents invest in the human capital of their teenage daughters. Teenagers choose whether to be sexually active or not. If the teenager is sexual active she might become a teenage mother with some probability. The odds of a teenage birth can be influenced by a costly birth control effort. Childbearing has negative effects on the human capital accumulation (and future income) of the teenager. Female teenagers weigh the utility gain from sexual intercourse against the human capital loss of having a baby. Based on this trade-off, they determine if they want to

be sexually active and if so, how much effort they would invest in preventing a teen birth. The assumed production function of human capital implies that teenage births have limited negative consequences for the future human capital stock of poor teenagers (in terms of parental income and investments), and more pronounced negative effect for rich teenagers. As a consequence, a large fraction of teenage births is carried by female teenagers at the lower end of the parental income distribution.¹ Finally, the economic environment features a government which collects taxes from, and delivers transfers to households. It also spends a fraction of the collected taxes for public education. We dub these two functions of the government as the *welfare state*.

The framework developed here matches stylized facts about inequality, intergenerational income mobility, teenage births and teenage sexual initiation rates in the United States at the start of the twenty-first century. The estimation strategy relies on a simulated method of moments procedure. The welfare state is introduced via average income tax and public education expenditure functions derived from U.S. data. The recovered structural parameters take reasonable values and are tightly estimated. In a quantitative experiment we then examine how teenage childbearing reacts to changes in the income tax progressivity and the distribution of public education expenditures. Our results show that imposing the Norwegian tax progressivity reduces U.S. teenage birth rates by around 7%. Imposing the Norwegian public education expenditure, on the other hand, reduces the U.S. teenage birth rate by approximately 30%.

The paper proceeds as follows. Section 1.1 reviews the existing literature. Section 2 describes the main empirical facts. In Section 4 we present the economic model of teenage childbearing. The estimation strategy is discussed in Section 5. Section 6 outlines the quantitative experiments and their results. In the final section we draw conclusions and present directions for future research.

1.1 Related Literature

We base our study on evidence that across developed countries teenage birth rates are positively correlated with inequality and child poverty and negatively correlated with intergenerational income mobility². This implies that countries with high income inequality and low intergenerational mobility of income and status have higher teenage birth rates. The negative correlation between

¹A large empirical literature documents that teenage childbearing has only limited negative consequences on the future wages of the mothers. Most of the literature agrees that this is due to a selection of teenage mothers based on socioeconomic characteristics. This selection occurs naturally in our framework. For details, see ?, ?, ?, and ? among others.

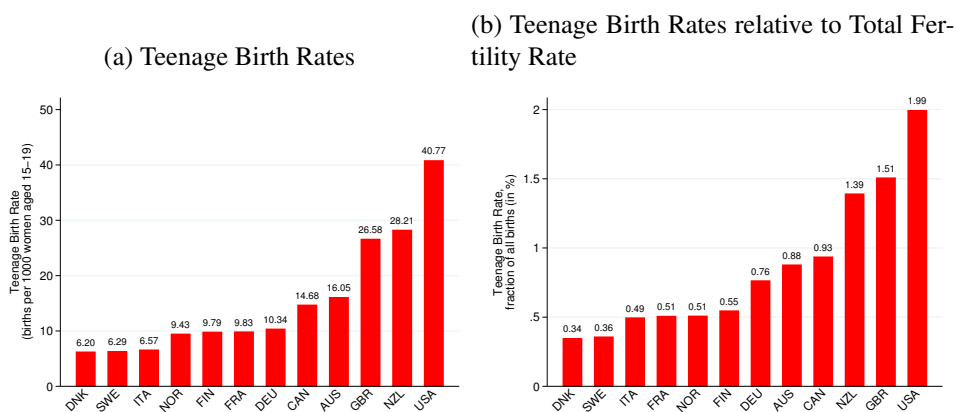
²See Section 2 for details.

inequality and intergenerational mobility across countries is documented by Corak (??) and was referred to by ? as “The Great Gatsby Curve”. Moving up the curve implies that as a society becomes more unequal, individual opportunities become more limited, and intergenerational mobility declines. Therefore, teenagers tend to have more births. Cross-country differences in inequality and intergenerational mobility can be attributed to some of the welfare state institutions such as redistribution through taxation and intergenerational redistribution through public education (???).

2 Stylized Facts

The patterns of teenage childbearing differ significantly across developed countries. The *teenage birth rate* represents the number of births per 1000 women between the ages of 15 and 19. It ranges from 6 births per 1000 adolescent females in Sweden, Italy and Denmark to 9 births in Norway, Germany and France, and to more than 37 births in the United States at the start of the twentieth-first century - see Figure 1a.³ Do differences in overall fertility play a role in generating these sharp disparities in teenage childbearing across countries? Controlling for the total fertility rate does not change the overall patterns of teen births - see Figure 1b.

Figure 1: Teenage Birth Rates across Countries (2000-2010)

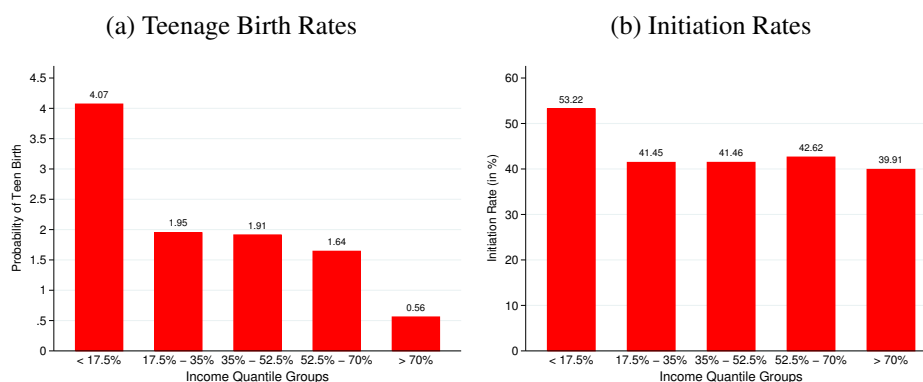


The teenage birth rate as a fraction of total fertility rate is xxx times higher in the United States than in Denmark. The huge differences in teenage childbearing between the United States and, especially, the Scandinavian countries are hard to explain because they occur in countries with similar levels of economic development and similar attitudes towards teenage sexual behavior.

³Data sources for this and all other figures are provided in the Appendix. The relevant time interval for the data is displayed in the the title of the figures.

A look at the teenage birth rates at different sections of the household income distribution in the United States reveals that the high number of teenage births comes for the lower end of the distribution - see Figure 2a. At the same time, the fraction of sexually active female teenagers is roughly constant across the distribution at around 40 percent with a very mild hike at the very bottom of the distribution (53 percent) - see Figure 2b. These observations point to the fact that teenage childbearing is high in the United States mainly because teenagers at the bottom of the distribution do not exert as much birth control effort as in the higher income categories.

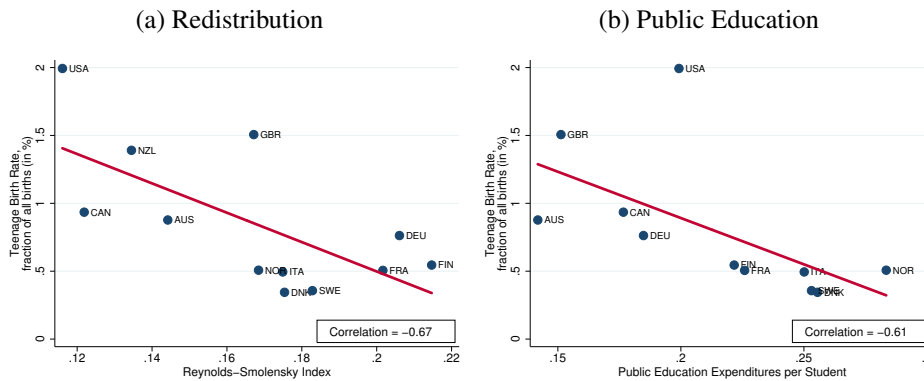
Figure 2: Teenage Birth Rates and Initiation Rates across Income (2006-2010)



If human capital investments of parents to children are an important determinant for teenage childbearing, especially at the bottom of the distribution, then societies which provide more redistribution towards relatively poor families through taxation and transfers might have lower teenage birth rates due to improved investments at the bottom of the distribution. A good proxy for the cross-sectional degree of redistribution of a society is the difference between the Gini coefficients of the pre-tax and after-tax income. Figure 3a plots this measure of redistribution against the teenage birth rate for a sample of OECD countries with available data on these two variables. The correlation between the cross-sectional redistribution measure and the teenage birth rate is -0.69. The basic intuition from above is confirmed - countries with high levels of redistribution tend to have lower teenage birth rates.

Another important mechanism of redistribution that provides human capital investment to children of poor parents is public education. Figure 3b provides evidence that countries which spend more on primary and secondary education per student (relative to the average household income) have lower teenage birth rates. The correlation between the public education expenditure per stu-

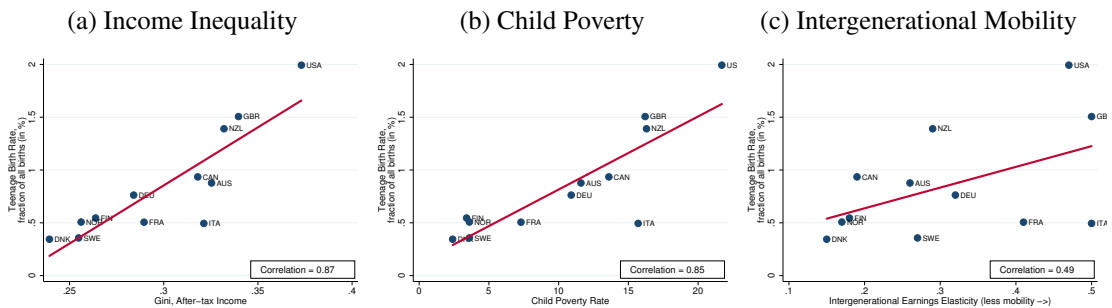
Figure 3: Teenage Birth Rates and the Welfare State (2000-2010)



dent and the teenage birth rate is -0.52 .

To the extent that high income inequality, in particular a pronounced lower tail of the income distribution, is an evidence of lack of economic opportunities for a large fraction of the population, one would expect that inequality and teenage birth rates are correlated. This conjecture turns to be true in a cross-country context - see Figure 4a. Moreover, we find a positive correlation between child poverty and teenage birth rates across the OECD countries - see Figure 4b. It is natural to think that limited and predetermined economic opportunities stem from the lack of adequate investments in the human capital of children. These poor investments in children are due to the limited resources available to poor parents (high poverty rates and income inequality) and, therefore, translate into lower intergenerational mobility in a society. Figure 4c shows that indeed intergenerational mobility is negatively correlated with teenage childbearing across countries.

Figure 4: Teenage Birth Rates, Child Poverty, Income Inequality and Intergenerational Mobility (2000-2010)

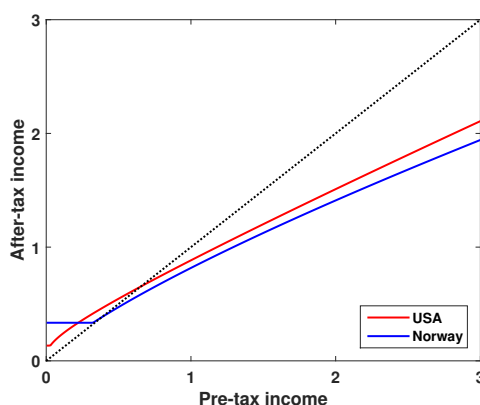


So far, we have argued that crucial factors which generate cross-country differences in teenage

birth rates, are attributes of the welfare state such as cross-sectional redistribution through taxation and intergenerational redistribution through public education. Later in the paper, the quantitative model of teenage childbearing fit to the U.S. data is used to explore the interactions between taxation, public education and teenage childbearing. To do that, the welfare state institutions of Norway are introduced to the U.S. economy. We select to study the disparities in teenage childbearing between the United States and Norway because these two countries have very different patterns of teenage childbearing - the United States has the highest teenage birth rate in the industrialized world, while Norway is a typical representative of the Scandinavian/Central European countries with low teenage childbearing rates. A secondary but very important reason for this selection is the availability of relevant data used in the quantitative analysis.

A brief preview of the welfare state institutions in these two countries is in order. Norway has a more progressive tax and transfer system than the United States (?). The level and distribution of public education expenditures across students ordered by their household income differs significantly between the two countries as well (?). Figure 5 plots after-tax *vis-à-vis* pre-tax income for the estimated tax schedule of the United States and Norway. We follow ? in the choice of the functional form for the tax functions and employ his estimates.

Figure 5: Taxation: U.S. and Norway

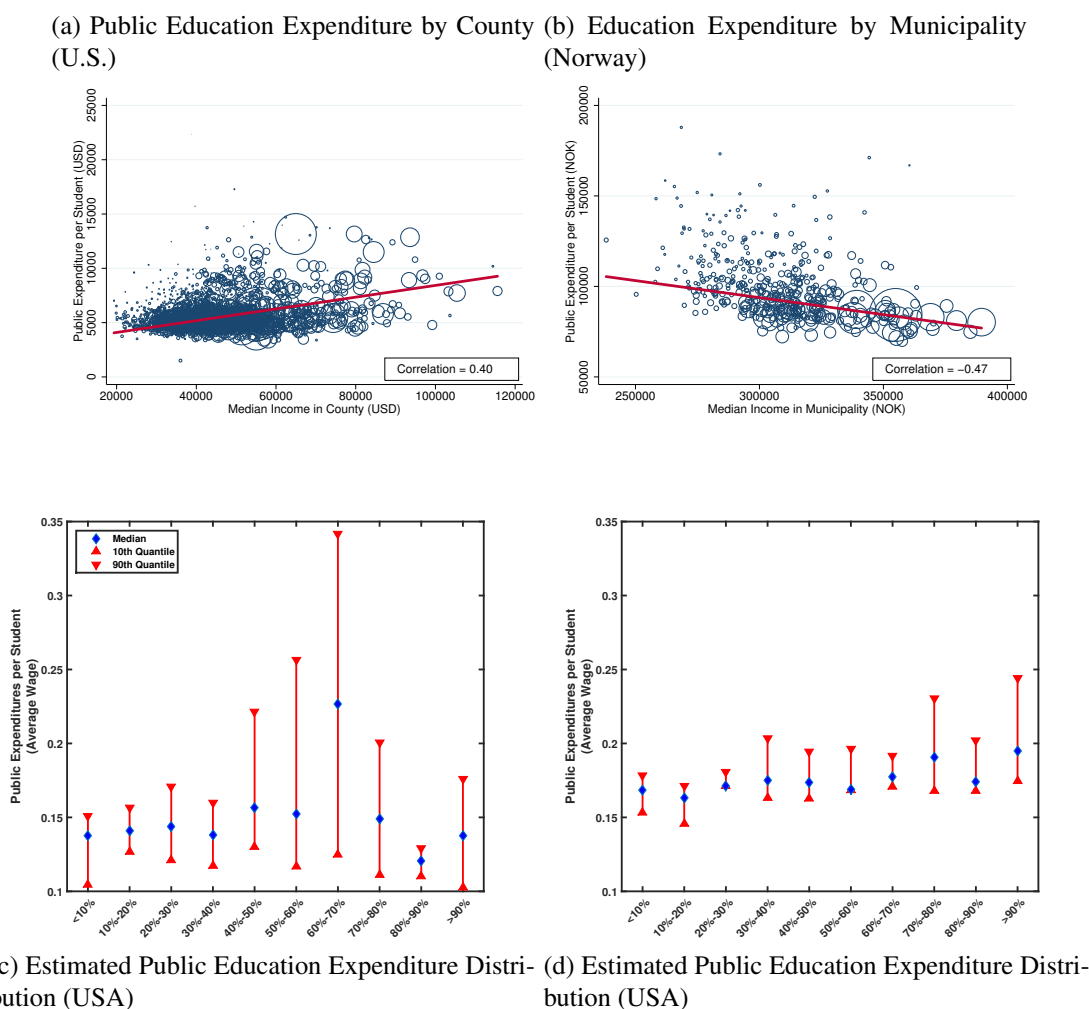


As Figure 5 shows the Norwegian tax schedule guarantees a higher minimum income for the poorest families, but calls for higher taxes (lower after-tax income) for higher income levels. Furthermore, after-tax income increases more slowly with pre-tax income in Norway than in the United States. This is so, because the average tax rate increases faster in Norway. All told, the Norwegian tax schedule is more progressive because it is beneficial for the poor and hurts house-

holds with higher income.

Figures 6a and 6b plot the distributions of public education expenditures across median income of counties in the United States and municipalities in Norway. The circles in the scatter plots are proportional to the number of students in each county or municipality, respectively, and the regression lines are weighted by the number of students. Public expenditure per student is positively correlated with the median household income in counties in the United States, whereas in Norway the opposite pattern occurs.⁴

Figure 6: Public Education Expenditures: U.S. (2006-2007) and Norway (2011)



Another insightful observation based on the information in Figure 6 is that the dispersion of education expenditures, across counties (municipalities) ordered by median income, differs sig-

⁴Our results are similar to those obtained by ?. He derives similar scatter plots but at a school district level.

nificantly between the United States and Norway. To capture the differences in dispersion and average public education expenditures across counties (municipalities), we estimate public education expenditure distributions by deciles of the countrywide income distribution. We assume that the county-level (municipality-level) income distribution is log-normal. For each county (municipality), the parameters of the log-normal income distribution are given by the mean and median income of that particular county (municipality). Using the county-level (municipality-level) income distributions and pupil populations we simulate a country-wide income distribution. We pair the draws in the simulation with the public education expenditures for the corresponding counties to create a sample of related incomes and public education expenditures. Then we separate the simulated country-wide income distribution into centiles and compute the empirical distribution functions of the related public education expenditures for each of the centiles. The results are presented in Figures 7c and 7d. We plot the median, as well as the 10th and 90th percentile of the public education expenditure distribution for all centiles of the income distribution.

The distribution of public education expenditures in the United States is much more dispersed than in Norway. The larger degree of dispersion in the U.S. is particularly pronounced for families between the 40th and the 80th deciles of the income distribution. These households tend to receive on average the highest public education expenditures in the United States. The Norwegian distribution is less progressive than what could be expected from Figure 6b. In particular, the estimates suggest that education spending on the poor relative to the rich is neither higher nor lower than in the United States, but for almost all centiles of the income distribution median public education expenditures are above their U.S. counterparts. To sum up, the patterns of public education spending between the two countries differ in an important dimension. The public education expenditures per student of the Norwegian government is larger than that in the U.S.

3 Economic Environment

Consider a two period economy populated by a unit continuum of females who live for two periods. In the first period females are daughters, and in the second period, they are mothers.⁵ Households consist of a mother and a daughter. A female gives birth to a child exactly once. Population is therefore constant. The child is born *either* when the mother is in her teens *or* at the start of adulthood. We assume that a teenage birth occurs just before the teenager becomes an adult.

⁵In our model males play no active role. Therefore we exclude them from the decision making process.

Consequently, the child is raised by the mother when she is an adult independently of the timing of the birth.

The basic setup here is that mothers invest in their daughter's human capital, while daughters decide on whether to engage in sex. If so, they face the risk of having a teenage birth. Teenage childbearing has a negative effect on human capital accumulation of the daughter and human capital determines future income. Sexually active daughters can exert effort to reduce the risk of having an unwanted birth. Birth control bears a utility cost but it diminishes the probability of a teenage birth. Once daughters become parents, in their turn, they decide how much to invest into their own daughter's human capital. This process perpetuates through time.

Daughters derive utility from having sex and they care about their income as parents. They weight the potential cost of having a teenage birth against the utility they receive from having sex when deciding whether they want to be initiated or not. Furthermore, if they become sexually active, they choose a level of birth control by comparing its utility cost versus its benefit in terms of higher expected future income.

Mothers derive utility from consumption and are altruistic towards their daughters in the sense that they value their daughters' future income. Mothers divide their income between household consumption and investments in the human capital of their daughters. In doing so, they take into account how their daughters will respond to the investment decision in terms of sexual initiation and birth control effort. The mother's investment b can be interpreted not only as the intensity with which parents invest resources in the human capital accumulation process of their children but also as an effort to generally familiarize the children to the existing social environment. The first interpretation implies that the parental investments are an input in the human capital production function of the daughter. The specification of the human capital technology follows closely ? early insights. A large literature spanning from ? to ? emphasizes the importance of parental investments for the future labor market success of children. The second function of the investment b , in the context of this paper is interpreted as general familiarization with the existing technology of birth control. ? summarize a large body of research in child development pointing out to strong influences of parent-child communication and closeness on the probability of female adolescents to have a teenage birth.

The economy features a government which collects an income tax and spends resources on the human capital development of teenagers. The fiscal and education policies of the government are given by estimates from Norway and the United States.

3.1 Daughters

Daughters live with their mothers and receive human capital investment b from them. The government spends g on each teenager's education. The public and private investments are inputs in the production of human capital of the teenagers.

Daughters receive a sex taste shock ξ . They make a decision of whether to have sex summarized by the indicator function s . If $s = 1$, the daughter is initiated, whereas $s = 0$ implies sexual abstinence. Active daughters can exercise birth control effort $e \in [0, \infty)$, which comes at a utility cost modeled by the differentiable, increasing, and convex cost function $c(e)$. The probability of teenage birth for an initiated teenager is given by the probability function $\Xi(e, b)$ which is differentiable in both arguments. The probability of a teenage birth is decreasing in both birth control effort e and private investments b . Daughters learn about sex from their parents. In particular, their attitudes towards contraception and their overall sex education is strongly influenced by their parents. We capture this influence by including private investment b directly into the probability function $\Xi(e, b)$. Empirical studies show that public sex education had only very limited influence on teenage childbearing (?). Therefore, we assume that g has no direct effect on the probability of having a teenage birth. The occurrence of a teenage birth is summarized by the indicator function

$$y = \begin{cases} 1, & \text{with probability } \Xi(e, b) \\ 0, & \text{with probability } 1 - \Xi(e, b) \end{cases}.$$

It takes the value 1 if a teenage birth occurs, and 0 otherwise.

3.1.1 Human Capital

Human capital stock h' is determined by⁶

$$\mathbf{h}(b, g, y', \epsilon') = \exp(\epsilon')(1 + (b^\pi + g^\pi)^{1/\pi})^{\theta_0(1-\theta_1 y')}. \quad (1)$$

The inputs are private and public investments b and g . The degree of substitutability between these inputs is given by the parameter π . The production function has non-increasing returns to scale, i.e. $\theta_0 \in (0, 1]$. A teenage birth can disrupt human capital accumulation. This is portrayed by the parameter θ_1 . Whenever a teenager experiences a birth, that is, $y = 1$, the produced stock of human capital decreases for given investment levels b and g . Moreover, the cost of teenage childbearing

⁶Variables reflecting the future of the teenager which are not known at the time of the decision making are indexed by prime. h' denotes the human capital stock of the future household of the teenager when she becomes a parent.

in terms of lost human capital is increasing in investments. This implies that teenagers with high investment levels would be more attentive to the consequences of teenage sex, which is in line with the cross-sectional evidence presented in Table 2.⁷ The production function (1) describes the creation of the household's stock of human capital and accounts for patterns of assortative mating and non-tangible investments in the human capital of the children. The parameter θ_1 captures not only the direct cost of teenage birth on the mother's skill formation but also the decline in her marriage perspectives in terms of spousal labor market skills (?). The ability shock ϵ' reflects non-tangible investments not captured by the production technology. Ability is thus transferred imperfectly from parents to children according to the autoregressive process

$$\epsilon' = \psi\epsilon + \nu, \quad (2)$$

where $\nu \sim N(0, \sigma_\nu^2)$ is the innovation term. The heritability parameter ψ is positive but strictly smaller than one. Denote the conditional distribution function of ϵ' stemming from the specification above as $E(\epsilon'|\epsilon)$.

3.1.2 Production and Income

Production takes place according to a linear constant returns technology used by each household. In particular, the future income of the teenager's household is given by

$$a' = \exp(\mu) h',$$

where μ denotes a common productivity parameter for all households and human capital h' is the production input. Consequently, log-income is a function of human capital

$$\log(a') = \mu + \log(h'). \quad (3)$$

The human capital production technology and the income process defined by equations (1) and (3) define the teenager's next period gross household income a' as a function of investments b and g , the realization of the ability shock ϵ' , and the presence of a teenage birth y . We denote this relationship as

$$a' = \mathbf{a}(b, g, \epsilon', y').$$

⁷We add the constant = 1 in equation (1) for two reasons. First, this technical assumption ensures that at any level of investment having a teen birth is costly in terms of producing human capital, and second, it allows us to interpret teenager's ability $\exp(\epsilon')$ as the realized teenager's human capital stock in case of no human capital investment ($b = g = 0$).

The government collects an income tax in this economy. The tax schedule is a function of income and is given by $\tau(a)$. Consequently, next period's disposable income, denoted by \tilde{a}' can be expressed as

$$\tilde{a}' = \tilde{\mathbf{a}}(b, g, \epsilon', y') = (1 - \tau(\mathbf{a}(b, g, \epsilon', y'))) \mathbf{a}(b, g, \epsilon', y').$$

3.1.3 Sexual Initiation and Birth Control

A daughter derives utility ξ from having sex. If she forgoes this utility and stays sexually abstinent, her instantaneous utility level is normalized to zero. Daughters value their expected disposable income as adults. The preferences of daughters are given by

$$(1 - \delta)(\xi - c(e))s + \delta \mathbf{E} \log(\tilde{a}'),$$

where δ is the utility weight on the expected future disposable income. The first term of the expression above describes the net utility derived out of sex. The cost of birth control effort, $c(e)$ is subtracted from the utility of sex ξ . The utility term of future disposable income is assumed to be logarithmic. Future disposable income is not determined at the time the teenager makes her decision about sexual initiation and birth control. In this sense, sexual activity is risky because it may decrease the level of after-tax income if a teen birth is realized. This gives an incentive to sexually active teenagers to exert birth control effort.

3.1.4 Daughter's Decision Making

Consider a daughter who is sexually initiated and makes a decision on the level of birth control. A daughter who has sex and receives investments b and g , has parents of ability ϵ , and a sex taste ξ , faces the following problem,

$$\begin{aligned} \tilde{V}^1(b, g, \epsilon, \xi) = & \max_{e \geq 0} (1 - \delta)(\xi - c(e)) \\ & + \delta \int_{\mathcal{E}} \left\{ \Xi(e, b) \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{1})) \right. \\ & \left. + (1 - \Xi(e, b)) \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})) \right\} dE(\epsilon' | \epsilon). \end{aligned} \quad (4)$$

The daughter has to choose an optimal level of birth control e . In doing so, she maximizes the weighted sum of her instantaneous utility from sex and the expected utility out of her disposable

household income in the future. The expected utility out of future income is formally expressed in the second and third lines of problem (4). The daughter chooses the optimal level of effort such that it balances the instantaneous utility cost and the merits of decreasing the probability that future after-tax income is reduced. We call this potential utility loss the option value of having no teenage birth and define

$$\Lambda(b, g, \epsilon) = \int_{\epsilon} \{\log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})) - \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{1}))\} dE(\epsilon'|\epsilon).$$

If the teenager has a level of birth control effort e , with probability $\Xi(e, b)$ she would have a teenage birth and consequently her future disposable income would be given by the function $\tilde{\mathbf{a}}'(b, g, \epsilon', \mathbf{1})$. With the complementary probability $1 - \Xi(e, b)$ the teenager will manage to avoid a teen birth and the future level of disposable income would be given by $\tilde{\mathbf{a}}'(b, g, \epsilon', \mathbf{0})$. To arrive at the final expression for the expected utility out of future income above, one needs to integrate over all possible realizations of the teenager's ability ϵ' using the conditional distribution function $E(\epsilon'|\epsilon)$. Denote the decision rule of the initiated teenager with respect to birth control as $\mathbf{e}(b, g, \epsilon)$.

Next, consider a daughter who decides on sexual initiation. We define the indirect utility function of an abstinent teenager as

$$\tilde{V}^0(b, g, \epsilon) = \delta \int_{\epsilon} \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})) dE(\epsilon'|\epsilon).$$

The instantaneous utility level in the case of sexual abstinence is normalized to zero. Therefore, the indirect utility function for the abstinent teenager is the expected utility out of future disposable income with respect to ability ϵ' .

The teenager will engage in sex whenever the value of being sexually initiated is higher than the value of being abstinent. The initiation problem is formalized as

$$V(b, g, \epsilon, \xi) = \max_{s \in \{0,1\}} \left\{ (1-s) \underbrace{\tilde{V}^0(b, g, \epsilon)}_{\text{Abstinence}} + s \underbrace{\tilde{V}^1(b, g, \epsilon, \xi)}_{\text{Sex}} \right\} \quad (5)$$

and the corresponding decision rule is given by

$$\mathbf{s}(b, g, \epsilon, \xi) = \begin{cases} 1 & \text{if } \tilde{V}^1(b, g, \epsilon, \xi) \geq \tilde{V}^0(b, g, \epsilon) \\ 0 & \text{if } \tilde{V}^1(b, g, \epsilon, \xi) < \tilde{V}^0(b, g, \epsilon) \end{cases}.$$

Teenagers are indifferent between sexual initiation and abstinence if the realization of the sex taste shock ξ^* is such that $\tilde{V}^1(b, g, \epsilon, \xi^*) = \tilde{V}^0(b, g, \epsilon)$. Teenagers with a taste for sex below ξ^* would be abstinent, while teenagers with a taste shock above it would be sexually active. The threshold value of the sex taste shock $\xi^* = \xi^*(b, g, \epsilon)$ can be represented as an implicit function of parent's ability ϵ , as well as private b and public g investment in human capital.

3.2 Mothers

Each mother is paired with a daughter in a household. Adults value current household consumption, c , and are paternalistic towards their child in the sense that they care about the future expected disposable income \tilde{a}' of the child (?). The preferences of mothers are given by

$$(1 - \alpha) \log(c) + \alpha \mathbf{E} \log(\tilde{a}'),$$

where α is the degree of paternalism of parents. Future income of daughters is not determined at the time of decision making of parents, thus the expectation operator in the expression above.

3.2.1 Mother's Decision Making

The mother observes public education expenditures g to her daughter. The ability of the mother ϵ is also known. She has a household income a and decides how to allocate it between household consumption, c , and the investment in human capital production of her daughter, b . The mother knows how human capital investment b influences her daughter's decisions about sexual initiation, $s(b, g, \epsilon, \xi)$, and birth control, $e(b, g, \epsilon)$. She takes into account her daughter's decision rules when making the investment decision. However, the mother does not know the daughter's preferences over sex, ξ . Also, at the time parental decisions are made, the level of ability, ϵ' , or the realization of the potential birth to the teenager, y' , is not yet known.

The mother's decision problem is given by

$$\begin{aligned}
W(a, g, \epsilon) = & \max_{b \in [0, (1-\tau(a))a]} (1 - \alpha) \log(c) \\
& + \alpha \int_{\mathcal{X}} \int_{\mathcal{E}} \left\{ (1 - \mathbf{s}(b, g, \epsilon, \xi)) \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})) \right. \\
& + \mathbf{s}(b, g, \epsilon, \xi) \Xi(\mathbf{e}(b, g, \epsilon), b) \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{1})) \\
& \left. + \mathbf{s}(b, g, \epsilon, \xi) (1 - \Xi(\mathbf{e}(b, g, \epsilon), b)) \log(\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})) \right\} dE(\epsilon'|\epsilon) dF(\xi)
\end{aligned} \tag{6}$$

subject to

$$(1 - \tau(a))a = c + b.$$

The mother has to choose an optimal level of household consumption, c , and the investment in the human capital of the teenager, b . In doing so, she needs to maximize a weighted sum of the utility out of consumption and the expected utility out of the disposable income of the teenager when she becomes an adult parent herself. The expected utility out of the income of the daughter in the future is expressed in the second, third, and fourth lines of problem (6). For a particular mix of investments, b and g , parental ability, ϵ , and sex taste, ξ , the teenager may decide to stay sexually abstinent, i.e. $\mathbf{s}(b, g, \epsilon, \xi) = 0$. In this case, her future income will be given by $\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})$. This is the case depicted in the second line of the problem. However, if the daughter has sex, $\mathbf{s}(b, g, \epsilon, \xi) = 1$, she faces a teenage birth with probability $\Xi(\mathbf{e}(b, g, \epsilon), b)$. In this case her disposable income is given by $\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{1})$. Of course, she might avoid giving birth while a teenager with probability $(1 - \Xi(\mathbf{e}(b, g, \epsilon), b))$. In this case, her disposable income in the future will be given by $\tilde{\mathbf{a}}(b, g, \epsilon', \mathbf{0})$. To form the final expression for the expected utility of the parent out of the future income of the teenager, one needs to integrate over all possible realizations of the ability, ϵ' , and the taste for sex, ξ . The decision rule of the mother on investing in the human capital of her daughter is $\mathbf{b}(a, g, \epsilon)$.

3.3 Equilibrium

The equilibrium in this economy is characterized by a stationary income distribution associated with optimal behavior of parents and teenagers. To characterize the stationary income distribution,

we first define the following function,

$$\mathbf{1}(a', a, g, \epsilon, \epsilon', y') = \begin{cases} 1 & \text{if } a' = \mathbf{a}(\mathbf{b}(a, g, \epsilon), g, \epsilon', y') \\ 0 & \text{otherwise} \end{cases}.$$

The function above takes the value of one if a teenager with ability level ϵ' , teenage birth status summarized by y' , and government expenditure g , ends up having an income level a' , given that her parental income and ability are a and ϵ . It takes the value of zero otherwise. Next, construct a transition probability function,

$$P(a'|a) = \int_{\mathcal{X}} \int_{\mathcal{E}} \int_{\mathcal{E}} \int_{\mathcal{G}} \mathbf{1}(a', a, g, \epsilon, \epsilon', y') dG(g|a) dE(\epsilon'|\epsilon) d\tilde{E}(\epsilon) dF(\xi),$$

which computes the probability of a teenager of attaining income level a' conditional on having a parental income level a . Based on that, define the stationary distribution function of income as

$$\mathcal{A}(a') = \int_{\mathcal{A}} P(a'|a) d\mathcal{A}(a). \quad (7)$$

Definition. A *stationary equilibrium* consists of a given distribution function for government expenditure conditional on income, $G(g|a)$, a set of indirect utility functions for teenagers, $\tilde{V}^1(b, g, \epsilon, \xi)$, $\tilde{V}^0(b, g, \epsilon)$, $V(b, g, \epsilon, \xi)$, and for parents, $W(a, g, \epsilon)$, decision rules for sexual initiation, $\mathbf{s}(b, g, \epsilon, \xi)$, birth control effort, $\mathbf{e}(b, g, \epsilon)$, and investments in children, $\mathbf{b}(a, g, \epsilon)$, and a stationary income distribution $\mathcal{A}(a)$, such that:

1. The function $\tilde{V}^1(b, g, \epsilon, \xi)$ solves the teenager's decision problem on the level of birth control effort (4), and $\mathbf{e}(b, g, \epsilon)$ is the corresponding decision rule.
2. The function $V(b, g, \epsilon, \xi)$ solves the teenager's decision problem on sexual initiation (5), taking as given the functions $\tilde{V}^1(b, g, \epsilon, \xi)$ and $\tilde{V}^0(b, g, \epsilon)$, and $\mathbf{s}(b, g, \epsilon, \xi)$ is the corresponding decision rule.
3. The function $W(a, g, \epsilon)$ solves the parent's decision problem (6), taking as given the teenager decision rule for sexual initiation, $\mathbf{s}(b, g, \epsilon, \xi)$, and for birth control effort, $\mathbf{e}(b, g, \epsilon)$, defined by problems (4 and 5), and $\mathbf{b}(a, g, \epsilon)$ is the corresponding decision rule.
4. The stationary distribution $\mathcal{A}(a)$ solves (7), taking as given the distribution function $G(g|a)$ and the decision rules $\mathbf{e}(b, g, \epsilon)$, $\mathbf{s}(b, g, \epsilon, \xi)$ and $\mathbf{b}(a, g, \epsilon)$.

4 Fitting the Model to the Data

The model developed here is fitted to U.S. data for the time period 2006-2010. The government policies in the model are exogenously given. Therefore, the parameters of the income tax schedule and the public education expenditure process can be set independently from the other targets on basis of a priori information. The remaining parameters will be fitted using a simulated method of moments estimation procedure. Important dimensions in which the model is matched to the data are: (i) the teenage birth rates and sex initiation rates across the parental household labor income distribution, (ii) household labor income distribution, (iii) average wage reductions associated with a teenage birth, and (iv) intergenerational patterns of income mobility.

4.1 A Priori Information

4.1.1 Tax schedule

Tax progressivity affects the incentives of parents to invest in the human capital of their daughters as well as the daughters' option value of having no teenage birth ($\Lambda(b, g, \epsilon)$). Therefore, the tax system affects the sexual decision-making process of the teenagers. We follow the literature (???) and assume a primitive average net income tax function. The tax function is defined as

$$\tau(a) = \lambda_0 + \lambda_1 a + \lambda_2 a^{\lambda_3},$$

where a denotes annual individual earnings divided by the average annual earnings in the country.

In other approaches the average tax rate is modeled using more simple functional forms with only two parameters such as $\tau(a) = 1 - \lambda_1 a^{-\lambda_2}$ (????) or $\tau(a) = \alpha + \beta \log(a)$ (??). To calibrate our model we employ the parameter estimates computed by ? because he provides average net income tax functions using data for households with children, for both the United States and Norway. Table 1 shows the results of his non-linear least squares regression.

4.1.2 Public Education Expenditures

Public education expenditures directly influence the human capital accumulation of teenagers and, consequently, their decisions on sexual initiation and optimal effort to avoid a teenage birth. Figure 6 in Section 2 shows that, both in the United States and in Norway, public education expenditures g tend to change with the median income of counties or municipalities, respectively. In particular,

Table 1: Tax Function Parameter Estimates

	United States	Norway
λ_0	0.434	1.106
λ_1	0.003	-0.002
λ_2	-0.321	-0.921
λ_3	-0.719	-0.190
R^2	0.993	0.998

Source: ?

public education expenditures in the United States tend to be more dispersed across counties and lower on average than in Norway. In order to model these differences we assume that public education expenditure is a random variable g , distributed according to a country-specific distribution, $G(g|a)$.

We use data on the mean and median income, as well as on public education expenditures of the individual counties in the United States (*2006-2010 American Community Survey 5-Year Estimates* and the *National Center for Education Statistics Common Core of Data*) to estimate the distribution $G(g|a)$ by semi-parametric methods. We assume that the county-level income distribution is log-normal. For each county, the parameters of the log-normal income distribution are given by the mean and median income of that particular county. Using the county-level income distributions and pupil populations we simulate a country-wide income distribution. We pair the draws in the simulation with the public education expenditures for the corresponding counties to create a sample of related incomes and public education expenditures. Then we separate the simulated country-wide income distribution into centiles and compute the empirical CDF of the related public education expenditures for each of the centiles.

In the simulated model parents draw from the empirical distribution functions before they make their decisions. In particular, they draw from the empirical CDF associated with their income. This assumption makes our simulated dataset a repeated cross-section with daughters being allocated to a new county when they become a mother.

4.2 Endogenous Parameters

4.2.1 Teenage Birth Rates and Initiation Rates

We use NSFG data to construct teenage birth rates and sexual initiation rates for different income groups. As described in Appendix A we adjust the teenage birth rates obtained from the NSFG

to make them consistent with aggregate data. Figure 2 in Section 2 shows that both teenage birth rates and sexual initiation rates decrease with parental income.

In our model teenagers decide if they want to get initiated by comparing the value of their sex taste shock ξ with the threshold $\xi^*(b, g, \epsilon)$. If the realization of the taste shock is below the threshold, the teenagers remain abstinent. We assume that the sex taste shock follows an exponential distribution $\xi \sim \exp(\zeta)$, with parameter ζ . The parameter ζ determines the mean of the sex taste shock distribution and therefore its value is recovered by the average initiation rate of the teenagers. The higher the mean of the distribution, the more teenagers find their realization of the taste shock being above the threshold.

The distributions of teenage childbearing and sexual initiation across parental income are pinned down by the utility weights α and δ , the human capital production parameter θ_0 , the probability function $\Xi(e, b)$, and the effort cost function $c(e)$. We assume the following functional form for the probability function

$$\Xi(e, b) = \gamma_0 \exp(-\gamma_1 e - \gamma_2 b e)$$

and for the effort cost function

$$c(e) = \exp(\omega_0 e^{\omega_1}) - \omega_2.$$

The utility weight α determines how much parents invest on average in their children, whereas the utility weight δ determines how much effort the teenagers exert on average to avoid having a baby. Furthermore, the higher the value of θ_0 , the higher is the human capital accumulated by a teenager and the expected value of their future after-tax income. This implies that a higher θ_0 corresponds to higher investment, higher effort, and a lower sex taste threshold value. Hence teenage birth rates and sexual initiation rates are on average lower when the parameter θ_0 is high. Finally, the form and parametrization of $\Xi(e, b)$ and $c(e)$ determine the shape of the teenage birth and sexual initiation distributions across parental income.

4.2.2 Costs of Teenage Childbearing

In our model, the parameter θ_1 governs the costs of having a teenage birth. However, the literature does not agree to which extent teenage childbearing is detrimental in terms of a teenage mother's future earnings. We follow ? who compute the income loss suffered by teenage mothers using Add Health data. They set the control group to teenagers that had a late miscarriage and also control for community fixed effects. ? estimate large reductions in wages and income associated with having

a teenage birth. We use their numbers and estimate the income loss of having a teenage birth to be approximately 17%.

4.2.3 Income Distribution

The remaining three parameters μ , σ_ν , and ψ can be identified using data on the income distribution and intergenerational mobility in the United States. We normalize mean income to one by adjusting the parameter μ accordingly. The parameter σ_ν pins down the variance of the income distribution and we use the Gini coefficient as a target. Finally, intergenerational income mobility allows us to recover the persistence of the ability process ψ . ? estimate that in the United States the intergenerational elasticity of combined (family) earnings for a female with respect to her parent's earnings is 0.408.

4.2.4 Elasticity between Private and Public Investment

One important parameter cannot be identified from the data, namely the elasticity of substitution between private and public human capital investment, π . Although public education expenditures can be interpreted as public human capital investment, we found no such clear interpretation for private human capital investment. In our model private human capital investment captures not only monetary investments but also quality time spent with children, which is hard to measure in the data. Therefore, we follow ? and ? and assume that private and public investments are perfect substitutes. Hence we set $\pi = 1$.⁸

4.2.5 Estimation Method

We estimate the fourteen endogenous parameters of the model using an overidentified simulated method of moments approach. We minimize the squared difference between the 16 simulated moments and their counterparts in the actual U.S. data.

We define $\Theta = \{\zeta, \alpha, \delta, \omega_0, \omega_1, \omega_2, \gamma_0, \gamma_1, \gamma_2, \theta_0, \theta_1, \mu, \psi, \sigma_\nu\}$ and compute the difference of the model moments $\hat{m}_i(\Theta)$ from the data moments m_i as $g_i(\Theta) = m_i - \hat{m}_i(\Theta)$. Let $g(\Theta) = (g_1(\Theta), \dots, g_{16}(\Theta))$ be the vector of differences between the simulated moments and the data moments and let

$$\hat{\Theta}_j = \min_{\Theta} g(\Theta)' \mathcal{W} g(\Theta) \\ \text{s.t. } \mathbb{E}\{a\} = 1$$

⁸See Appendix D.2 for a discussion of the implications when we change the elasticity parameter to $\pi = 0.5$.

Table 2: Estimated Parameters

Parameter	Description	Value	Std. Error	95% Confidence Interval
ζ	Sex taste shock	3.500	0.0099	[3.4805 3.5195]
α	Parents utility weight	0.800	0.0049	[0.7902 0.8095]
δ	Teenagers utility weight	0.805	0.0034	[0.7916 0.8176]
ω_0	Cost of effort	0.021	0.0540	[-0.0847 0.1271]
ω_1	Cost of effort	4.078	0.0001	[4.0775 4.0780]
ω_2	Cost of effort	0.802	0.0294	[0.7445 0.8597]
γ_0	Probability teenage birth	0.850	0.0036	[0.8430 0.8570]
γ_1	Probability teenage birth	3.200	0.0046	[3.1910 3.2090]
γ_2	Probability teenage birth	0.704	0.0105	[0.6838 0.7248]
ψ	Persistence of ability	0.180	0.0036	[0.1724 0.1866]
σ_ν	Variance of ability shock	0.705	0.0001	[0.7045 0.7051]
θ_0	Human capital curvature	0.902	0.0034	[0.8949 0.9081]
θ_1	Human capital cost of teenage birth	0.902	0.0097	[0.8824 0.9206]
μ	Income intercept	-0.619	0.0030	[-0.6316 -0.6197]

be the minimization problem where \mathcal{W} is a weighting matrix. The constraint captures the normalization of mean income to one. To compute the standard errors we employ the methodology proposed by ?.⁹ Table 2 summarizes the results and provides the standard errors of the estimates.

Table 3: Model Fit - Targets

	Data	Baseline Model
Teenage Birth Rate	1.84%	1.85%
Initiation Rate	43.25%	43.34%
Income Loss of Teenage Birth	17.26%	17.28%
Gini Coefficient	0.423	0.423
Intergenerational Persistence	0.408	0.409
Mean Income	1	1

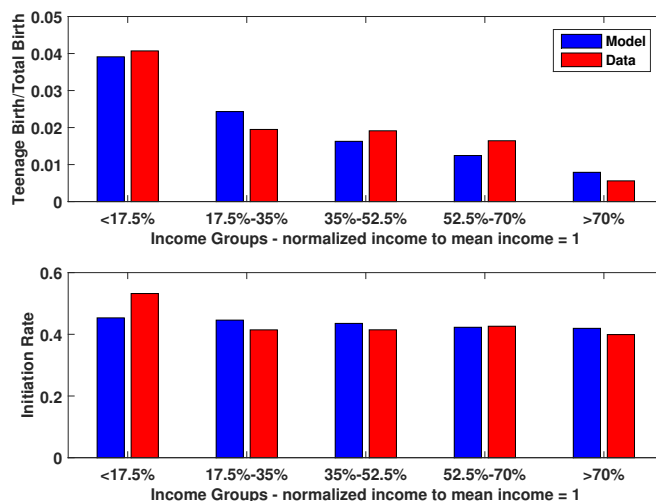
4.3 Model Fit

Our model matches well the teenage birth rate and sexual initiation rate, the household income distribution, the wage reduction associated with a teenage birth, and the intergenerational income mobility for the United States (see Table 3). The model is also able to replicate the distribution of

⁹See Appendix B for details on the computation of the standard errors.

teenage birth rates and sexual initiation rates across parental income groups. Figure 7 shows the model distributions and the empirical distributions from the NSFG (2006-2010).

Figure 7: Model Fit - Distributions



5 Quantitative Experiments

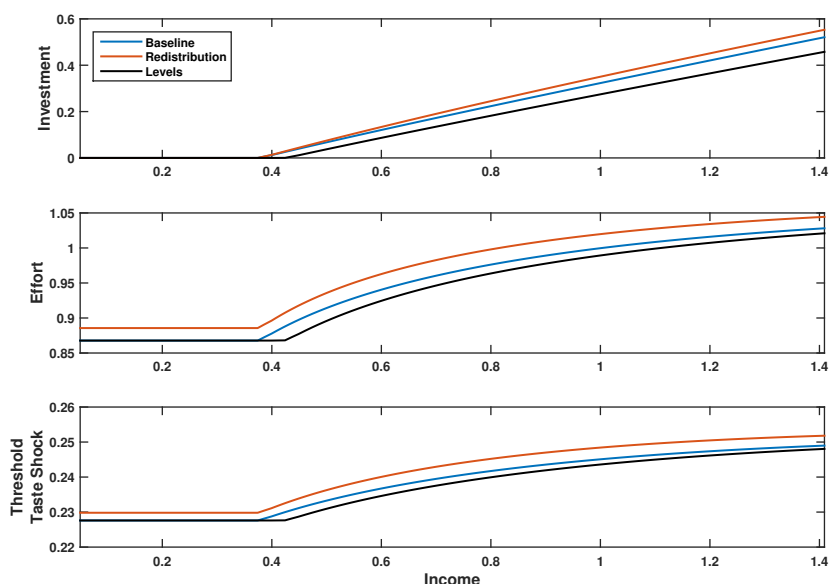
Section 2 documents large differences in teenage childbearing across countries and higher teenage birth rates in countries with low income redistribution. To quantify the extent to which these differences can be explained by different redistributive policies, we simulate counterfactuals of the U.S. economy with features of the Norwegian tax code and public education expenditure. Differences between the counterfactual economies and our baseline calibration can then be attributed to the specific features of these government policies. First, we investigate how changing the tax and the public education expenditure policies influences the optimal behaviour of mothers and daughters. Second, we discuss how the differences in government policies affect teenage birth rates and initiation rates at the aggregate level.

5.1 Tax Experiments

There are two basic differences between income taxation in the United States and Norway. First, the tax schedule is more progressive in Norway. This implies that average taxes grow at a faster rate in Norway and that the minimum income guaranteed by the government is higher in Norway,

as well. Second, the average tax burden is higher in Norway. Figure 8 plots the policy functions for parental investment, exerted effort to avoid a teen birth, and the sex taste threshold for families having average ability, facing average public education expenditures, and being in the first eight centiles of the parental income distribution. The blue line depicts the baseline model, where the U.S. tax function is employed; the red line depicts the redistribution experiment, where Norwegian progressivity is introduced into the U.S. tax schedule; and the black line depicts the level experiment, where we change the tax rates to the Norwegian level and keep progressivity as in the United States.¹⁰

Figure 8: Policy Functions - Tax Experiment



When progressivity is set to the Norwegian level, disposable income at the upper end of the income distribution decreases and at the lower end it increases. As can be seen in Figure 8 this policy change does not alter the behaviour of the poorest mothers; they are still constrained and use all available income for current consumption. The mothers who invest into their daughters' human capital in the baseline model will continue to invest even if tax progressivity changes to Norwegian levels. If their disposable income rises, these mothers increase their investment, and otherwise they decrease it. This implies that poorer mothers spend now more on their daughters' human capital and rich mothers spend less. Higher human capital investment increases expected

¹⁰See Appendix C for a description of how we compute counterfactual government policies from the data.

future earnings and, consequently, the daughters' incentives to avoid a teenage birth. Daughters exert more effort and become initiated less easily. Not only daughters of unconstrained parents adjust their behaviour, also daughters of mothers spending nothing on education increase effort and get initiated less easily. They do so because the option value of having no teenage birth increases significantly for the poor. Therefore, even if their mothers do not invest in their human capital it is profitable for them to decrease the probability of having a teenage birth.

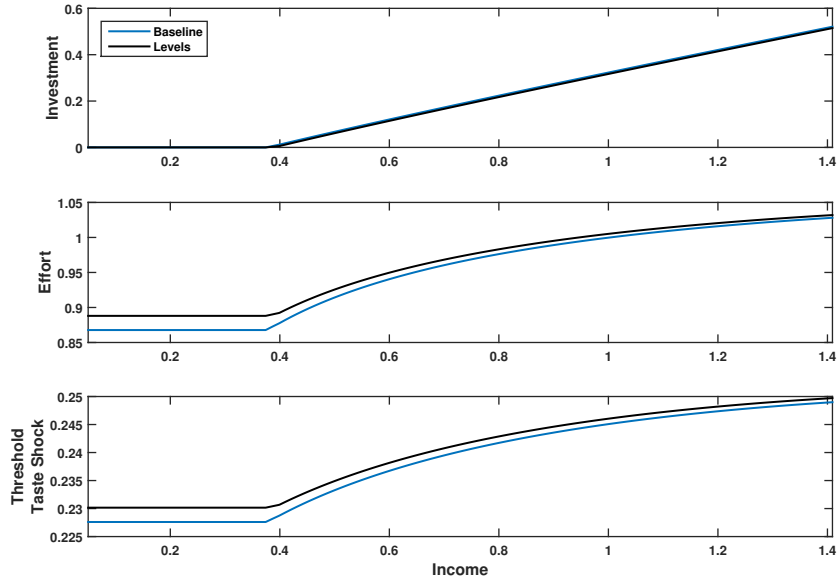
If, instead, the Norwegian tax level is imposed on the baseline model all households become poorer. Consequently, parents reduce their investment. In particular, parents who just start to invest in the baseline model become now constrained and stop investing with higher average taxes. The effect of this reduction in private human capital investment works through the same mechanism as before. Expected future income decreases and thereby incentives to avoid a teenage birth decrease as well. In particular, daughters of parents who become constrained when Norwegian tax levels are introduced decrease effort significantly and become initiated more easily.

5.2 Public Education Experiments

Public education expenditures are assumed to be an exogenous state variable that is known before mothers and daughters make their decisions. Therefore Figure 9 shows only the change in mothers' and daughters' decision rules for an increase in public education expenditures from the U.S. mean to the Norwegian mean. Because we assume private and public education expenditures to be perfect substitutes, an increase in public education expenditures should crowd out private education expenditures. The crowding out effect in our model is however weak. The reason for this is that an increase in government education spending works as an exogenous positive income shock on the daughter's future income. Mothers transfer then part of this income shock into the current period by reducing their own investment. Because in our estimation mothers put a lot of weight on their daughters' future income, the magnitude of the decrease in private investment is small. Consequently, overall investment in human capital grows.

An increase in public education expenditures from the U.S. mean to the Norwegian mean increases the option value of not having a teenage birth. Daughters exert therefore more effort and are less likely to be initiated with higher public education expenditures. Especially daughters of constrained mothers react strongly to an increase in public education expenditures because for them government spending is the only source of human capital investment.

Figure 9: Policy Functions - Public Education Experiment



5.3 Policy Experiments

We conduct three sets of experiments. In the first set we implement the Norwegian tax schedule in the baseline calibration, in the second set we replace the U.S. public education expenditures by their Norwegian counterpart and in the final set we combine the two welfare state instruments. Each set consists of three types of experiments. The first type introduces the redistributive characteristics of the Norwegian tax and education policies into the baseline calibration. For this, we keep average taxes and public education expenditures fixed at U.S. levels and introduce the Norwegian progressivity of the tax code and the Norwegian distribution of public education expenditures, respectively. The second type of experiments keeps redistribution constant and adjusts average taxes and education expenditures to their Norwegian levels. Finally, the last type incorporates the original Norwegian policies into the baseline model.

Table 4 summarizes the results of the counterfactual experiments for the teenage birth rates, initiation rates, pre-tax Gini coefficient, and intergenerational income persistence for the three sets of experiments. The upper panel shows the results of the experiments, the middle panel shows the percentage deviations from the baseline calibration and the lower panel shows how much of the difference in teenage birth rates between the United States and Norway can be explained by each experiment.

Changing the tax functions or public education expenditures affects the average income in the economy. Because disposable income pins down mothers' and daughters' decisions, a change in the average income leads to a change in teenage birth rates attributed only to this income effect. To make the results comparable to the baseline estimates, we adjust the parameter μ such that mean income remains always one.¹¹

A common result of all experiments is that initiation rates change only marginally when government policies change, whereas changes in teenage birth rates are more sizable relative to the baseline calibration. This suggests that teenagers adjust to different circumstances mainly by exerting more effort to avoid having a baby.

Our results on inequality and income mobility are in line with ? and ?. Both measures remain basically unchanged in the redistribution experiments but react stronger to changes in levels. In particular, increasing the average tax rate to Norwegian levels reduces intergenerational earnings persistence significantly.

The Norwegian tax system asks on average for higher taxes (higher mean), faces a steeper increase in average tax rates and guarantees a higher minimum income (more progressive) than its U.S. counterpart. If we impose Norwegian progressivity in the baseline calibration, the teenage birth rate decreases by 22.34%. A more progressive tax system increases the disposable income of the poor and therefore their expected future income. As discussed in Section 5.1, this gives daughters of poor parents more incentives to delay childbearing until the end of their education and avoid the negative effects of a teen birth on their human capital accumulation. Daughters of more wealthy parents who already received human capital investments from their mothers have only little incentives to change their behavior. The existing level of private human capital investments already ensures that they try to avoid teenage childbearing.

In contrast, increasing the average tax rates to Norwegian levels raises the teenage birth rate by 6.91%. An increase in average taxes makes all households poorer. This affects teenage childbearing in two ways. First, an increased number of mothers do not have enough disposable income to find it optimal to invest in their daughters. Because these mothers are financially constrained, their daughters are more likely to become a teenage mother. Second, unconstrained mothers spend now less money on their daughter's education and therefore the expected future income of teenagers decreases. This in turn reduces the benefits of delaying childbearing until adulthood. Consequently,

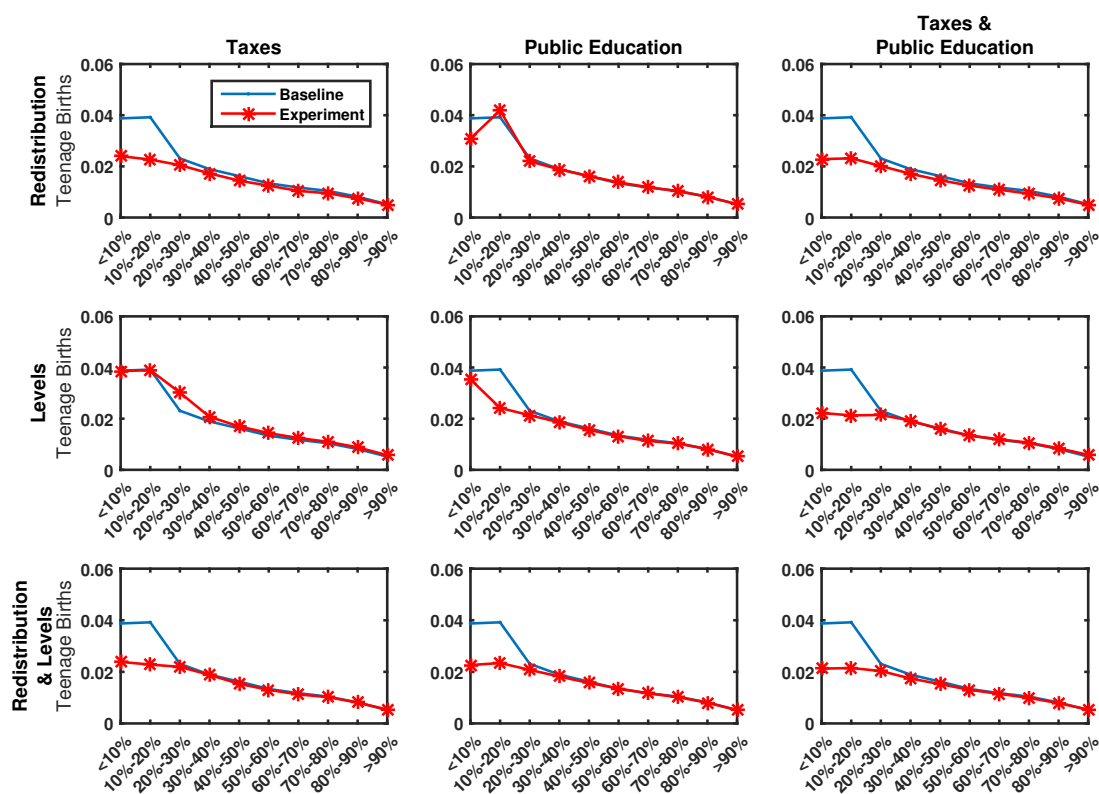
¹¹Results without adjustments to mean income can be found in Appendix D.

also daughters with more wealthy parents are more likely to have a teenage birth.

If we fully impose the Norwegian tax schedule on the baseline calibration, the redistribution effect dominates and the teenage birth rate decreases by 18.53%. The differences in taxation between the United States and Norway can explain 24.74% of the difference in teenage birth rates between the two countries.

Figure 10 plots the teenage birth rates across centiles of the parental income distribution in the three sets of experiments against the ones in the baseline model. The left column illustrates the three tax experiments. It shows that in the progressivity experiment, as well as in the full implementation of Norwegian taxes experiment, most of the reduction in teen births comes from the lowest two centiles of the parental income distribution. On the other hand, the increase observed in the second experiment is driven by an increase of teenage birth rate for the third decile of the parental income distribution.

Figure 10: Counterfactual Experiments - Distributional Changes



The introduction of Norwegian redistributive features of public education expenditures reduces

the teenage birth rate by 3.25%. The top panel of the middle column of Figure 10 shows that this reduction comes from the poorest decile of the parental income distribution, whereas the teenage birth rate for the second decile slightly increases. This pattern can be explained by the specific form of the public education expenditure distributions in the two countries. For the poorest deciles most households face higher public investment in human capital with the Norwegian distribution, whereas in the second decile they face slightly less public education expenditures. For families with higher income the increase in public education expenditures has only a minor impact on the teenage birth rate, because for them government spending on education is only a minor part of total human capital investment.

If we impose the Norwegian average of public education expenditures into the baseline model, all households face higher government investment in human capital, which reduces the teenage birth rate by 11.85%. As the middle panel of Figure 10 shows, the reduction in teenage births mainly comes from the second decile of the parental income distribution. This is because the estimated U.S. public education expenditure distribution favors the second decile of the income distribution over the first one.

The combination of redistributive features and Norwegian levels of education expenditures reduces the teenage birth rate by 19.30%. This effect is similar to the one achieved by introducing Norwegian tax policies into the baseline model. The reduction in teenage birth rates due to public education expenditures is able to explain 25.76% of the difference in teenage birth rates between the United States and Norway.

In the third set of experiments we study how combined changes in tax policies and public education expenditures can explain differences in teenage birth rates. If the Norwegian redistributive features of the tax code and public education expenditures are adopted into the baseline model, the teenage birth rate is reduced by 22.76%, a change in levels reduces the teenage birth rate by 18.76% and the full implementation of Norwegian government policies reduces the teenage birth rate by 22.50%. The reduction in teenage birth rates in this final set of experiments can then explain up to 30% of the country differences.

As shown by the last column of Figure 10, the reduction in teenage birth rates in all experiments comes primarily from the lower part of the income distribution. This is in line with the results in ? and ? who argue that a large share of teenage births comes from daughters who are stuck at the lower end of the income distribution. If their economic situation improves and they see chances for a decent future income, teenage birth rates among economically disadvantaged females might

go down significantly. How changes in the economic environment are induced seems to play only a minor role. What matters is that daughters perceive their future to be valuable enough to bear the utility cost of preventing a teenage birth.

We still leave approximately 70% of the differences in teenage birth rates between the United States and Norway unexplained. Possible explanations for the remaining differences in teenage birth rates are cultural differences with respect to the use of contraceptives and abortions, as well as differences in overall sexual education of teenagers.

6 Conclusion

We develop a partial equilibrium model of human capital accumulation and teenage childbearing that explains well the differences in teenage birth rates across countries. We find that differences in taxation and public education expenditures can explain up to 30% of the difference in teenage birth rates between the United States and Norway. Our results suggest that redistributing resources to daughters with constrained parents could be one way to incentivize them to avoid teenage childbearing and reduce teenage birth rates in the US.

References

A Data

A.1 NSFG

We use the 2006-2010 NSFG dataset to compute the distribution of sexual initiation rates and teenage birth rates across the parental income distributions. We use information on whether the teen respondents ever had sex (variable *rhadsex*) and whether they ever had a live birth (variable *hasbabes*). We summarize then these variable over the total income of the respondent's family (variable *totincr*). Total income is reported in intervals. In order to reduce the sensitivity of misreported family income, we regroup the respondents into income groups based on income quantiles. In particular, the lowest four quantiles contain 17.5% of respondents and the highest quantile contains the remaining 30%. We choose this particular classification because of the size of the income groups in the NSFG data and because this classification produces the smoothest teenage birth and initiation rate distributions.

The question to the variable *hasbabes* asks if the respondent ever had a live birth. The variable *hasbabes* consequently does not measure teenage births per year. In order to compute teenage birth rates across family incomes we need to make two assumptions:

Assumption 1: The distribution of teenage birth rates across age is constant over time.

Assumption 2: The distribution of teenage birth rates across family income is independent of the age profile and is constant over time.

Assumption 1 allows us to compute the implied teenage birth rates of the respondents of the NSFG. In the dataset we observe total teenage births by age. Births occurred at age 15 can only be associated to this age group. Therefore we can define the teenage birth rate for the 15 year old respondents as $TBR_{15} = \frac{\tilde{T}B_{15}}{N_{15}}$, where $\tilde{T}B_{15}$ is the number of observed births observed among the 15 year old respondents and N_{15} is the number of respondents aged 15. Births observed for respondents at age 16 can be attributed both to the birth obtained at age 15 and births obtained at age 16. Using **Assumption 1** we can write the number of births obtained at age 16 as $TB_{16} = TBR_{15} \times N_{16} - \tilde{T}B_{16}$. Consequently the teenage birth rate among respondents at age 16 is defined as $TBR_{16} = TBR_{15} - \frac{\tilde{T}B_{16}}{N_{16}}$. The same argument applies for all other age groups. The implied teenage birth rate of the NSFG is then obtained by

$$TBR^{NSFG} = \sum_{i=15}^{19} s_i TBR_i,$$

where $s_i = \frac{N_i}{N}$ is the share of respondents at age i . This computation yields a teenage birth rate of

$TBR^{NSFG} = 40.55$. This number is slightly higher than the average teenage birth rate we obtain from the World Bank ($TBR^{WB} = 37.73$).

We use the information from the NSFG to estimate our theoretical model. Because the data on teenage births is not fully consistent with our model structure we adjust it in two ways. First, we make it comparable to aggregate data on teenage births from the World Bank. We do this by adjusting the mean of the teenage birth distribution to the teenage birth rate provided by the World Bank (*Assumption 2*). This adjustment ensures that our estimation results are comparable to the Norwegian teenage birth rate. Second, in our model every woman has a child, whereas in reality in most countries women have on average more than one child. Hence we adjust the teenage birth rate for the total fertility rate (*Assumption 2*).

A.2 Inequality

For the cross-country analysis in Section 2 we measure inequality using the *Gini coefficient* based on equivalenced household disposable income, after taxes and transfers as reported by OECD. Income refers to cash income, regularly received over the year: earnings, self-employed income, capital income, public transfers, and household taxes. The value of the Gini coefficient ranges between 0, in the case of "perfect equality" (i.e. each share of the population gets the same share of income), and 1, in the case of "perfect inequality" (i.e. all income goes to the individual with the highest income). Data refers to the 2000s.

For the estimation exercise we estimate the Gini coefficient using data from *The Integrated Public Use Microdata Series (IPUMS-USA)*. We restrict the sample to households where the household head is 30-54 years old, has a teenage child, and the total household income is strictly positive, because those households are the relevant group in our model. Our estimate of the Gini coefficient for the year 2005 is 0.424.

A.3 Redistribution

We measure *redistribution* by the reduction of the Gini coefficient after taxes and transfers compared to the before taxation Gini coefficient. A higher number means that the difference between the two Gini coefficients is larger, inequality is reduced by more and consequently there is more redistribution. Data is taken from the OECD and refers to the time period 2000 to 2010.

A.4 Child Poverty

The *child poverty rate* represents the percentage of children living in households with incomes below 50% of national median income and refers to time points around the year 2000. We employ the data from ?.

A.5 Intergenerational Mobility

The *generational earnings elasticity* measures the percentage of parental earnings advantage passed on to the children. Higher values indicate less income mobile societies, whereas lower values indicate high generational earnings mobility. For the cross-country analysis in Section 2 we present father-son earnings elasticities computed and calculated by ?. They refer roughly to the 1990s and cover a wide range of countries. Since our model focuses on female teenagers we adopt the earning elasticity of combined (family) earnings for a female with respect to her parents' earnings from ?. They estimate the earning elasticity to be 0.408.

A.6 Taxes

? estimates the tax functions using data from the 2010 edition of the OECD publication *Taxing Wages*. The OECD dataset constructs average tax rates covering not only central and local government taxes but also social security contributions and government transfers to the households. For very low earnings the average tax rate might be negative. This implies that the households receive government transfers exceeding their income tax bill. We furthermore impose a lower bound on after tax income that is in line with empirical evidence on minimum income guaranteed by the government presented in ?.

A.7 Public Education Expenditure

We employ public expenditure data for the US from the National Center for Education Statistics Common Core of Data through the the Elementary/Secondary Information System (ELSi) application. We use the variable *total current expenditures on instruction per student* at county level and plot it against the median household income as reported by the 2006-2010 American Community Survey 5-Year Estimates. For Norway we use data from the Statistics Norway website through the StatBank application. We plot the *net operating expenditure on teaching at primary and lower-*

and upper-secondary level (Tables 04684 and 06939) at a municipality level against the median gross income for residents 17 years and older (Table 05854).

B Estimation and Standard Errors

B.1 Computation of optimal policies

We put boundaries on income, private investment, public investment, effort and ability and pick a grid in each dimension. We pick 400 equally spaced grid points on income in $\mathcal{A} = [a^{min}, a^{max}]$, 1000 equally spaced grid points on private investment in $\mathcal{B} = [0, (1 - \tau_{US}(a^{max}))a^{max}]$ and 11 equally spaced grid points on public investment in $\mathcal{G} = [g^{min}, g^{max}]$, where g^{min} is minimum public investment and g^{max} is maximum public expenditure as observed in the data. Furthermore we pick 700 equally spaced grid points on effort in $\mathcal{E} = [e^{min}, e^{max}]$. Following the method proposed by Tauchen and Hussey (?) we approximate the process for ability as a finite state Markov process with 13 grid points.

We solve the model by backward induction. This means we solve the model for daughters first. Their state space consists of $\mathcal{B} \times \mathcal{G} \times \mathcal{E}$ and we solve for their optimal policies at each point in the state space. Because parents take their daughter's behaviour into account and we want to allow them to choose optimal private investment levels off the grid we use cubic splines to approximate the daughter's policy functions over private investment. Using these splines we can solve for the parents policy function of every point in their state space $\mathcal{A} \times \mathcal{G} \times \mathcal{E}$.

B.2 Simulation

In order to simulate the model we compute linear interpolation arrays for all policy functions. We simulate our model for 10000 mother-daughter pairs and 170 periods. First we generate time series of the ability shock by drawing 10000×220 realization of $\nu \sim \mathcal{N}(0, \sigma_\nu)$ and iterating over equation 2. The initial value for equation 2 is set to 1. To ensure that initial values play no role for our results, we discard the first 10000×50 realizations of the ability process. We furthermore draw 10000×170 realizations of the sex taste shock $\xi \sim \exp(\zeta)$ and 10000×170 realizations of a uniform distributed shock that determines if teenage births are realized. We call the second shock teenage birth shock. Finally we draw an initial income distribution from a log-normal distribution with parameters $\mu = -\sigma_\epsilon^2/2$ and $\sigma = \sigma_\epsilon$ that is truncated to $[a^{min}, a^{max}]$. We then iterate over 170

generations.

An iteration starts with computing the deciles of the parental income distribution. Then parents draw public investment from the estimated public education expenditure distributions associated with their position in the income distribution. Now each mother in the generation knows the individual realization of the triple $\{a, g, \epsilon\}$. We use this information to extract optimal private investment from the interpolation matrix of private human capital investment. Then we use the obtained optimal investment together with public investment g and parent's ability ϵ to compute the daughters threshold values and optimal effort decisions. We compare the optimal threshold values with the corresponding realization of the sex taste shock to evaluate sexual initiation. For those daughters who are initiated we compare the probability of teenage birth associated with parents optimal education expenditures and optimal effort with the teenage birth shock. If the realization of the shock is higher than the probability of having a teenage birth, the birth is realized. With, the realization of teenage births, as well as private and public investments we can compute next periods income of the teenagers.

The next iteration starts with these incomes as the new parents' incomes. We iterate for 170 time periods. We discard the first 20 observations to make sure that the initial distribution does not influence our results.

B.3 Standard Errors

In order to compute standard errors for our estimates we need to estimate the jacobian of our minimization problem and the variance-covariance matrix of the estimated targets. The jacobian is estimated by perturbing the parameters one after another by 0.1% up and down. We then compute centered first differences as our estimate of the jacobian \mathcal{J} . The variance-covariance matrix \mathcal{V} is estimated by simulating the model 100 times with different draws for the random processes. Out of the resulting 100 samples of model moments we compute the variance-covariance matrix. The estimated parameters are distributed as follows

$$\hat{\theta} \sim \mathcal{N}(\theta, (\mathcal{J}'\mathcal{W}\mathcal{J})^{-1}\mathcal{J}'\mathcal{W}\mathcal{V}\mathcal{W}\mathcal{J}(\mathcal{J}'\mathcal{W}\mathcal{J})^{-1}),$$

where \mathcal{W} is the weighting matrix used in the estimation routine.

C Counterfactual Tax Schedule

In order to impose Norwegian tax progressivity and average taxes on the baseline model we need to compute counterfactual tax schedules. We follow ? and ? and use their approach to compute counterfactual tax schedules.

In the literature progressivity is often measured with progressivity wedges defined as

$$PW(a_1, a_2) = 1 - \frac{1 - \tau(a_2)}{1 - \tau(a_1)}.$$

For the progressivity experiment we want to compute a tax function $\tilde{\tau}_{US}(a)$ with US mean and Norwegian progressivity. Two tax schedules are equally progressive, if the progressivity wedge is the same for all income levels in the two tax schedules. Therefore we must have

$$1 - \frac{1 - \tilde{\tau}_{US}(a_2)}{1 - \tilde{\tau}_{US}(a_1)} = 1 - \frac{1 - \tau_{NO}(a_2)}{1 - \tau_{NO}(a_1)}, \quad \forall a_1, a_2.$$

This implies that the ratio of after tax-shares between the two countries is constant for all income levels

$$\frac{1 - \tilde{\tau}_{US}(a_2)}{1 - \tau_{NO}(a_2)} = \frac{1 - \tilde{\tau}_{US}(a_1)}{1 - \tau_{NO}(a_1)} = \Lambda.$$

The above equation can be rewritten to solve for the counterfactual tax schedule

$$\tilde{\tau}_{US}(a) = 1 - \Lambda + \Lambda\tau_{NO}(a).$$

In order to estimate Λ we compute the average tax rate with the US tax schedule and the Norwegian tax schedule for the income distribution implied by the baseline model. Since the average tax rate of the counterfactual tax schedule and the US tax schedule are the same, we can write

$$\bar{\tau}_{US} = \tilde{\tau}_{US} = 1 - \Lambda + \Lambda\bar{\tau}_{NO}.$$

Therefore

$$\Lambda = \frac{1 - \bar{\tau}_{US}}{1 - \bar{\tau}_{NO}}. \quad (8)$$

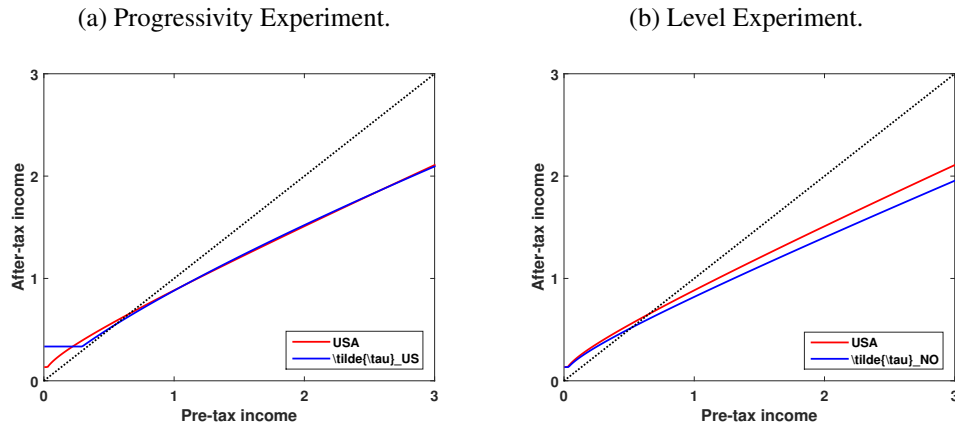
For the level experiment we also need to compute the counterfactual tax schedule

$$\tilde{\tau}_{NO}(a) = 1 - \tilde{\Lambda} + \tilde{\Lambda}\tau_{US}(a)$$

that features average Norwegian taxes and US progressivity. We use equation 8 to estimate $\tilde{\Lambda}$, which is just the inverse of Λ .

We estimate $\Lambda = 1.0783$ in our baseline model. The corresponding after tax incomes for the progressivity and the level experiment are shown in Figure 11.

Figure 11: Counterfactual Tax Functions.



D Robustness

In order to assess the robustness of our results we conduct to robustness tests. First, we show the results for the policy experiments when the mean is allowed to deviate from 1. Second we relax the assumption that private and public human capital investments are perfect substitutes and set $\pi = 0.5$. We re-estimate the model with $\pi = 0.5$ and show that the results of our policy experiments are qualitatively the same.

D.1 Unadjusted Mean

Table 5 depicts the results of the policy experiment, when we allow mean income to change. In general the results do not change much compare to what is presented in Table 4. But in policy experiments that reduce average income, teenage birth rates and initiation rates are higher. If everyone is poorer on average, parents also invest less on average. This decreases the incentives of teenagers to avoid a teenage birth. If the policy, instead, increases income the opposite pattern is observed.

D.2 Elasticity of Substitution π

In order to assess the robustness of our results to the assumption that private and public human capital investments are perfect substitutes we reestimate the model with $\pi = 0.5$. Table 6 shows the estimated parameters for the model with $\pi = 1$ and $\pi = 0.5$. It is evident DISCUSS WHEN RESULTS ARE READY

Table 7 provides the aggregate statistics of the benchmark estimation and the robustness check. Evidently we can generate a comparable fit when we estimate the model with $\pi = 0.5$.

Finally, Table 8 provides the results of the experiments for the model with $\pi = 0.5$. DISCUSS WHEN RESULTS ARE READY

Table 6: Robustness: Estimated Parameter

Parameter	Description	$\pi = 1.0$	$\pi = 0.5$
ζ	Sex taste shock	3.500	
α	Parents utility weight	0.800	
δ	Teenagers utility weight	0.805	
ω_0	Cost of effort	0.021	
ω_1	Cost of effort	4.078	
ω_2	Cost of effort	0.802	
γ_0	Probability teenage birth	0.850	
γ_1	Probability teenage birth	3.200	
γ_2	Probability teenage birth	0.704	
ψ	Persistence of ability	0.180	
σ_ν	Variance of ability shock	0.705	
θ_0	Human capital curvature	0.902	
θ_1	Human capital cost of teenage birth	0.902	
μ	Income intercept	-0.619	

Table 7: Robustness: Model Fit

	Data	Baseline Model	Robustness Model
Teenage Birth Rate	1.84%	1.85%	
Initiation Rate	43.25%	43.34%	
Income Loss of Teenage Birth	17.26%	17.28%	
Gini Coefficient	0.423	0.423	
Intergenerational Persistence	0.408	0.409	
Mean Income	1	1	

Table 8: Robustness: Counterfactual Experiments

	Experiments - Results					
	Taxes		Public Education		Taxes & Public Education	
	Redistribution	Mean Both	Redistribution	Mean Both	Redistribution	Mean Both
Teenage Birth Rate						
Sex Initiation Rate						
Gini Coefficient						
Intergenerational Persistence						
Mean Income						
Income Intercept μ						
	Deviations to Baseline Model					
	Taxes		Public Education		Taxes & Public Education	
	Redistribution	Mean Both	Redistribution	Mean Both	Redistribution	Mean Both
Teenage Birth Rate						
Sex Initiation Rate						
Gini Coefficient						
Intergenerational Persistence						
	Explaining Differences between USA and Norway					
	Taxes		Public Education		Taxes & Public Education	
	Redistribution	Mean Both	Redistribution	Mean Both	Redistribution	Mean Both
Teenage Birth Rate						