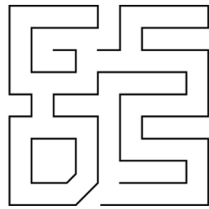
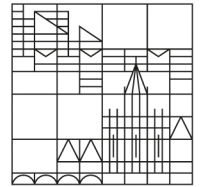


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Teenage Childbearing and the Welfare State

Andra Filote
Georgi Kocharkov
Jan Mellert

January 2017

Graduate School of Decision Sciences

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GSDS – Graduate School of Decision Sciences
University of Konstanz
Box 146
78457 Konstanz

Phone: +49 (0)7531 88 3633

Fax: +49 (0)7531 88 5193

E-mail: gds.office@uni-konstanz.de

-gds.uni-konstanz.de

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Teenage Childbearing and the Welfare State*

Andra Filote, Georgi Kocharkov and Jan Mellert[†]

University of Konstanz

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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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[†]Address: Box F145, Department of Economics, University of Konstanz, Universitätsstr. 10, 78457 Konstanz, Germany. Corresponding author's email: georgi@georgikocharkov.com.

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. For instance, 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 labor income distribution. Around 47 percent of the teenage births in the United States in the late 2000s occurred to teenagers with parental income below the 25th percentile of the parental income distribution. Thus, the degree of teenage childbearing is determined by the income levels and life choices of families at the bottom of the income ladder.¹

Preventing teenage childbearing is a high priority among policy makers in the United States throughout the last three decades (Hayes 1987, Solomon-Fears 2016). The general public is also concerned with the topic.² The economic consequences of teenage motherhood have been discussed widely in the academic literature. Compared with their peers, teenage mothers are more likely to drop out of high school, rely on assistance and be poor as adults. Their children are more likely to have poor educational and health outcomes and to become teenage mothers themselves.³ Teenage childbearing also leads to increased public spending due to increased health care, child welfare, incarceration, and lost tax revenue.⁴

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

¹Relevant data facts are detailed in Section 2.

²The *National Campaign to Prevent Teen and Unplanned Pregnancy* was founded in 1996 as a response to a nationwide concern with the high levels of teenage childbearing and its consequences. TV shows about teenage motherhood such as *16 and Pregnant* and *Teen Mom* attract millions of viewers. For a fascinating discussion of the behavioral effect of these popular shows on the teenagers at risk, see Kearney and Levine (2015).

³See Hoffman and Maynard (2008) for details. A large empirical literature assesses the detrimental causal effect of teenage childbearing on the future socioeconomic outcomes of teenage mothers and their children. The size of the *causal* effect of teenage childbearing is usually estimated to be negative but small. Thus, a non-trivial fraction of the observed correlation between teenage childbearing and inferior outcomes is due to a selection of teenage mothers based on socioeconomic characteristics. This selection occurs naturally in our framework. For details on the empirical literature, see Geronimus and Korenman (1992), Hotz et al. (2005), Fletcher and Wolfe (2009), and Ashcraft et al. (2013) among others.

⁴According to the National Campaign to Prevent Teen and Pregnancy (2013), teen childbearing in the United States cost taxpayers about 9.4 billion U.S. dollars annually. Most of these costs are associated with the negative consequences for the children of teen mothers. The study assesses only the increase in these costs that is associated with having a child before age 20 versus having a child later. Thus, these are net costs and not gross costs.

families differ by their income that is spent on contemporaneous consumption and investments in their teenage children. The government redistributes income in the cross-section by collecting taxes and giving transfers to the income poor. In addition, it spends resources on educating teenage children. Parental and governmental investments are factors that positively influence the future income of teenagers. On the other hand, teenage childbearing has a negative effect on future income especially if investments are high. We assume that the opportunity cost of bearing a child is much larger if the teenager has sizable investments in her future. As a consequence teenagers who receive higher investments from their parents and/or the government are more careful in avoiding unintended births.

How do the welfare state institutions influence teenage childbearing? First, if the societal system of taxes and transfers becomes more favorable towards families with lower income levels, the investments made by these families in their offsprings would be lifted up. This might lead to a lower levels of teenage childbearing due to the increased penalty of a teen birth for the affected teenagers growing up at the bottom of the income distribution. Indeed, income redistribution and the rate of teenage births are highly and positively correlated across developed countries (Figure 4a). Second, higher public education expenditures would also alter the childbearing behavior of teenagers. Teenage childbearing becomes costly when investments are higher. Therefore, an increase in public investments might lead to a lower rate of teenage births, too. Evidence for this channel is present - countries with higher degree of public education expenditures tend to have lower rates of teenage childbearing (Figure 4b).

The goal of this paper is to develop a theory of teenage risky activities which can be used to gauge how redistribution affects teenage childbearing. To achieve this goal, we build a model of parental investments into children and risky teenage sexual behavior. In our framework parents influence the future well-being of their teenage daughters by investing in them. These investments increase the expected future income of teenagers. Adolescents choose whether to be sexually active or not. If the teenager is active, she might become a teenage mother with some probability. The likelihood of a teenage birth can be influenced by a costly birth control effort. Early childbearing has negative effects on the future household income of the adolescent. Female teenagers weigh the utility gain from sex against the expected income loss related to having a baby. Based on this trade-off, they determine whether to become sexually active, and if so, how much effort to exert in preventing a teen birth. The assumed process for future income realizations implies that teenage births have limited negative consequences for the future income 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 out by female teenagers at the lower end of the parental income distribution. Finally, the economic environment features a government which collects taxes from, and delivers transfers to households. It also spends some of its resources on public education. We dub these two functions of the government as the *welfare state*.

The framework developed here matches stylized facts on inequality, intergenerational income mobility, teenage births and sexual initiation 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 tax-and-transfer and public education expenditure functions derived from U.S. data. The recovered structural parameters take reasonable values and are tightly estimated. In a series of quantitative experiments, we examine how teenage childbearing reacts to changes in taxation and the distribution of public education expenditures. Our results show that Norwegian taxes and transfers would reduce the U.S. rate of teenage childbearing by 14%. Imposing Norwegian public education expenditures, on the other hand, reduces teenage births in the U.S. by approximately 20%. How do these reductions affect the overall differences in teenage childbearing between the United States and Norway? In our model, differences in welfare state institutions can account for up to 28% of the overall gap in teenage childbearing between the U.S. and Norway.

The paper proceeds as follows. Section 1.1 reviews the existing literature. Section 2 describes the main empirical facts. In Section 3, we present the economic model of teenage childbearing. The estimation strategy is discussed in Section 4. Section 5 outlines the quantitative experiments and their results. In the final section we draw conclusions and present directions for future research.

1.1 Related Literature

[Kearney and Levine \(2012\)](#) argue that high teenage birth rates are a consequence of deeper, underlying social and economic problems. In a companion paper they document empirically that inequality at the lower end of the income distribution can account for a sizable fraction of the variation in teenage birth rates across the United States ([Kearney and Levine 2014](#)). Our work is similar in spirit. We base our study on the fact that across developed countries teenage birth rates are positively correlated with inequality and child poverty and negatively correlated with intergenerational income mobility.⁵ This implies that countries with high income inequality and low

⁵See Section 2 for details.

intergenerational mobility of income and social status tend to have higher teenage birth rates.⁶

Our work contributes to a recent literature in quantitative macroeconomics that utilizes structural economic models to quantify the importance of various driving forces behind the cross-country difference in terms of inequality and intergenerational mobility. In this literature differences in inequality and intergenerational mobility across countries are attributed to welfare state institutions such as redistribution through taxation and intergenerational redistribution through public education. [Guvenen et al. \(2014\)](#) utilize a detailed life-cycle model to study the role of labor income tax policies for cross-country differences in wage inequality and its evolution over time. Progressive taxation in their framework compresses the after-tax wage structure, thus, reducing incentives for human capital accumulation. [Holter \(2015\)](#), on the other hand, studies how taxes and education expenditures influence the intergenerational mobility of income. He concludes that differences in taxation can account for up to a half of the variation of mobility between the United States and other developed countries. In the same spirit, [Herrington \(2015\)](#) explores taxation and education expenditures as sources for differences in earnings inequality and intergenerational mobility between the United States and Norway. After carefully documenting cross-country facts about hours worked of married couples, [Bick and Fuchs-Schündeln \(2016\)](#) attribute a lot of the variation of married women's labor supply within Europe to differences in labor income taxes. Consumption taxes, on the other hand, account for the transatlantic difference in women's hours. We follow the lead of the above mentioned works but address a different question. We investigate the role of taxes and education expenditures for teenage childbearing differences across countries.

In our framework teenage sex is a risky activity. It can bring about an unintended birth to the female teenager which reduces her future household income. [Duncan and Hoffman \(1990\)](#), [Rosenzweig \(1999\)](#) and [Wolfe et al. \(2001\)](#) represent earlier attempts to relate childbearing choices of teenagers to choice-conditioned future opportunities. They all find that future expected income penalty of early childbearing have a significant impact on the probability of a teenage birth. Our modeling strategy is based on the same idea. However, we model explicitly the investments from parents and the government into the teenager's future. Furthermore, our framework allows for interactions between teenager's risky behavior, government education expenditures and parental

⁶The negative correlation between inequality and intergenerational mobility across countries is documented by Miles Corak ([Corak, 2006, 2013](#)) and was referred to by [Krueger \(2012\)](#) 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. Here we document that teenagers also tend to have more births when a country is moving up the curve.

investment decisions. Parents and teenagers are linked in our simulated model. Therefore, unlike previous studies we can generate and match the observed patterns of intergenerational mobility of teenage childbearing and income.

Finally, we place our contribution within a stream of economic research which combines the insights of Gary Becker ([Becker 1988](#)) on the role of the family in an economic context and techniques originating from quantitative economics to study family-related and macroeconomic outcomes.⁷ An economic model of parental socialization of children about sex is presented in [Fernández-Villaverde et al. \(2014\)](#). The framework is able to account for the increase of premarital sex and out-of-wedlock births over the course of the twentieth century. The advances in contraception technology are shown to be the main driver of this trend.⁸ The current work takes a different approach. We assess the forces behind the observed differences in teenage sexual behavior and birth outcomes across developed countries in recent years. The structural model presented here takes as given the prevailing contraceptive technology in the United States and evaluates how the introduction of North European welfare institutions would influence the U.S. teenage childbearing rate.

In a related paper, [Doepke and Zilibotti \(2015\)](#) provide a theory of preference transmission within the family. In their setup parents choose parenting styles which mold preferences of children and restrict the set of their economic actions. The results point out that parenting styles vary with respect to the return on human capital and the occupational specificity observed in the society. Our focus is not on endogenous preference transmission but rather on linking parental investments in children to their risky sexual behavior. Our framework features paternalistic parents who prefer their children to be sexually abstinent. Parental investments here also vary with economic conditions, namely, with the nature of the welfare state.

2 Stylized Facts

2.1 Teenage Childbearing

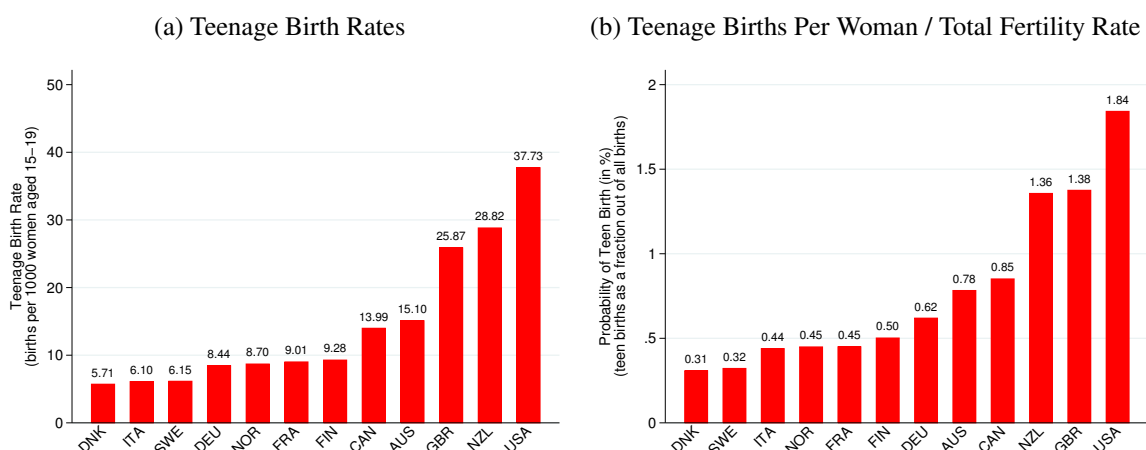
The patterns of teenage childbearing differ significantly across developed countries. The *teenage birth rate* represents the number of births per 1000 women between the ages of 15 and 19. It

⁷For a detailed description of this approach to economics and the existing literature, see [Doepke and Tertilt \(2016\)](#) and [Greenwood et al. \(2016\)](#).

⁸[Kennes and Knowles \(2015\)](#) build a model of marital matching and fertility and show that what matters for the rise of out-of-wedlock fertility is the interaction between better contraception and the decline of marital stability.

ranges from 6 births per 1000 adolescent females in Sweden, Italy and Denmark to around 9 births in Norway, Germany and France, and to 38 births in the United States in the second half of the 2000s - see Figure 1a.⁹ 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. We define the probability of a teen birth as the number of teenage births per woman as a fraction of her total fertility rate, or in other words, teenage births as a fraction of all births. This probability is almost six times higher in the United States than in Denmark.¹⁰ It is hard to rationalize the huge differences in teenage childbearing between the United States and, especially, the Scandinavian countries because both regions have similar levels of economic development and sexual activity/contraception practices among adolescents.¹¹

Figure 1: Teenage Birth Rates across Countries (2006-2010)



A look at the probability of teen birth at different sections of the income distribution of households with female teenagers in the United States reveals that the high number of teenage births comes from 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 41 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

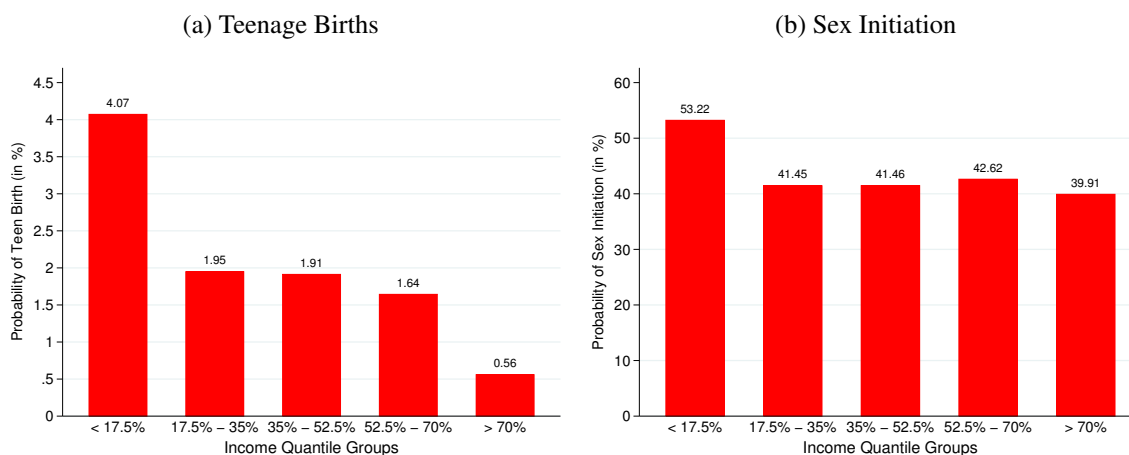
⁹Data sources for this and all other figures are provided in the Appendix. The relevant time interval for the data is displayed in the the title of the figures.

¹⁰From this point on, we use the terms *probability of teen birth* and *teen birth rate* interchangeably in the text. Both terms refer (in our usage) to the fraction of teenage births.

¹¹See Santelli et al. (2008) for more details.

teenagers at the bottom of the distribution do not exert as much birth control effort as in the higher income categories.

Figure 2: Teenage Births and Sex Initiation across Income Groups, U.S. (2006-2010)



Suppose we separate the parental households of female teenagers into two groups. The first group consists of households in which the parent, i.e. the mother, has had a teenage birth, while the second is of households with mothers who did not have a teenage birth. What is the probability that the female teenagers living in these households would have a teenage birth themselves? As shown by Figure 3a, the probability of teenage birth is much higher in households with parents who also had a teenage birth. Thus, teenage childbearing is correlated across generations. If teenage childbearing has a detrimental effect on future income of teenagers, then it must be that teen births persistence would contribute to the persistence of poverty across generations. Sex initiation rates are also slightly higher in families with parents who have had a teenage birth (Figure 3b). However, disparities of sex initiations, based on the teenage childbearing status of the parent in the household, are not so high as compared to teenage births.

If higher parental investments at the bottom of the income distribution suppress the number of teenage births by increasing the penalty of a birth to the future income of the affected teenagers, then societies which provide more income redistribution towards relatively poor families through taxation and transfers will tend to have lower teenage birth rates. A good proxy for the cross-sectional degree of redistribution of a society is the difference between the Gini coefficients of gross and net household income (Reynolds and Smolensky 1977). Figure 4a plots this measure of redistribution against the teenage birth probability for a sample of OECD countries with available

data on these two variables. The correlation between the cross-sectional redistribution measure and the probability of teenage birth rate is -0.65. The basic intuition from above is confirmed - countries with high levels of redistribution of household income tend to have lower number of teenage births as a fraction of all births.

Figure 3: Teenage Births and Sex Initiation across Income Groups Conditional on Parent Child-bearing Status, U. S. (2006-2010)

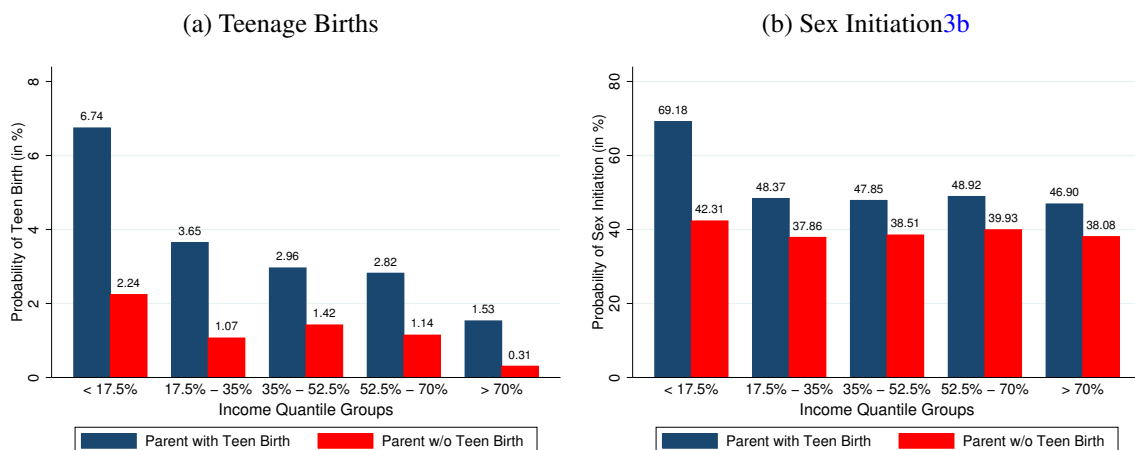
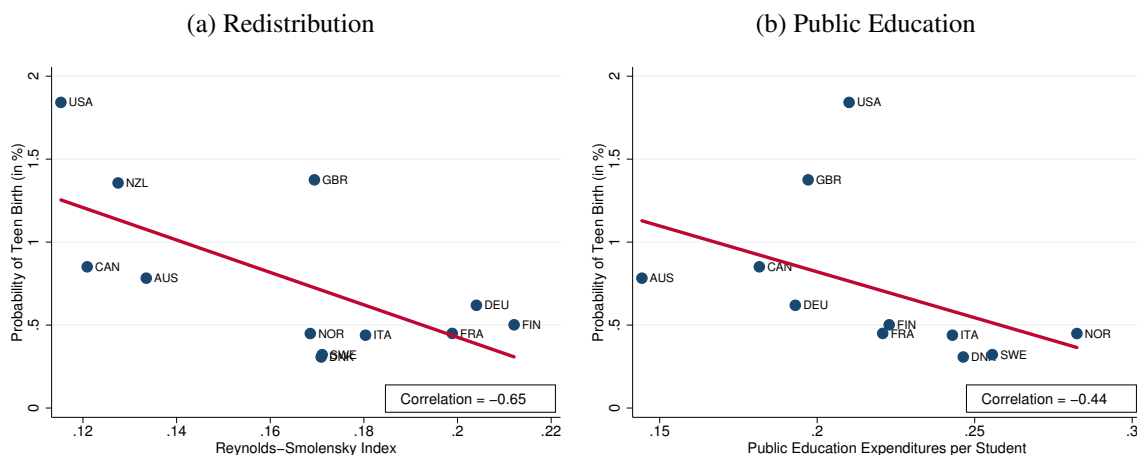


Figure 4: Teenage Births and the Welfare State (2006-2010)

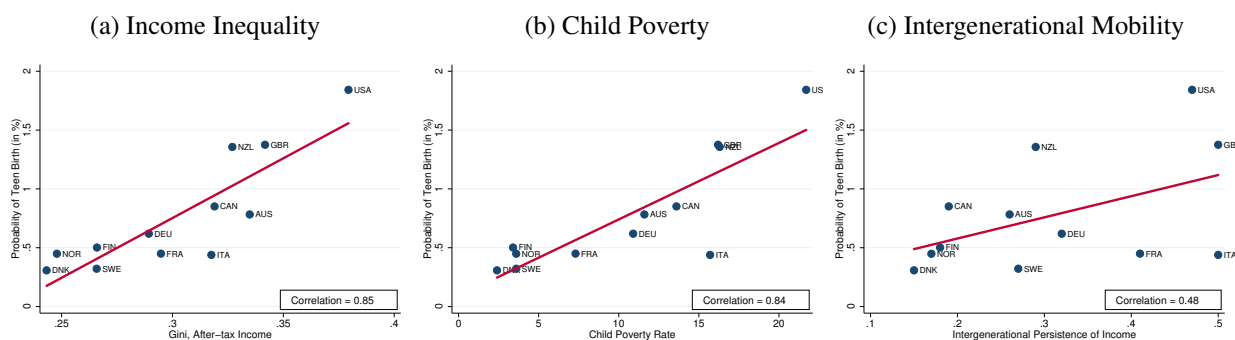


Another important mechanism of redistribution that provides investments for generating future income to children of poor parents is public education. Figure 4b provides evidence that countries which spend more on primary and secondary education per student (relative to the average

household income) have lower teenage birth rates. The correlation between the public education expenditure per student and the teenage birth rate is -0.44.

If high income inequality, in particular a pronounced lower tail of the income distribution, is an evidence of lack of economic opportunities for some fraction of the population, one would expect that inequality and teenage birth rates are correlated. This conjecture turns out to be true in a cross-country context - see Figure 5a. Moreover, we find a positive correlation between child poverty and teenage birth rates across the OECD countries - see Figure 5b.¹² It is natural to think that limited and predetermined economic opportunities stem from the lack of adequate investments in children. High poverty rates, and in general, high income inequality limit resources available to poor parents. This translates into lower levels of intergenerational income mobility in a society. Figure 5c confirms that intergenerational mobility is negatively correlated with teenage childbearing across countries.¹³

Figure 5: Teenage Births, Child Poverty, Income Inequality and Intergenerational Mobility (2006-2010)



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 is fit to the U.S. data and 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

¹²Child poverty is measure by the percentage of children living in households with incomes below 50% of national median income.

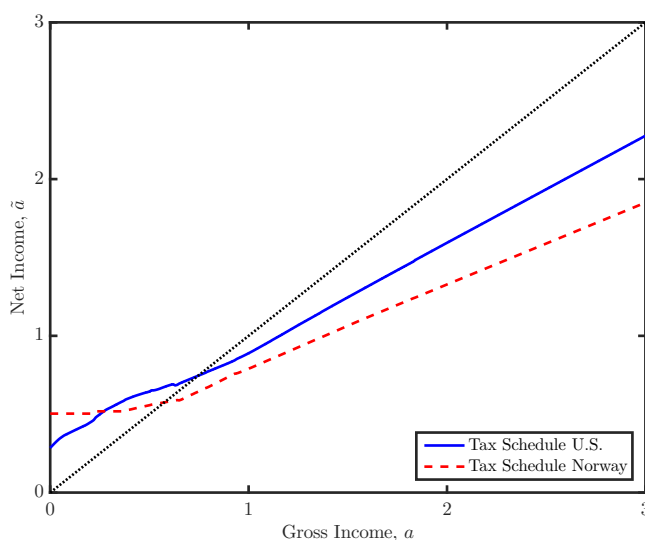
¹³Figure 5c documents a positive correlation of intergenerational persistence of income and the probability of a teenage birth. Therefore, teen births and intergenerational mobility are negatively correlated.

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.

2.2 The Welfare State

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 (see [Holter 2015](#)). The level and distribution of public education expenditures across students ordered by their household income differs significantly between the two countries as well (see [Herrington 2015](#)). Figure 6 presents the *tax and transfer* systems of the United States and Norway. This is the implied relationship between household net and gross labor income, where the measurement scale is relative to average household labor income in the respective country. The Norwegian tax and transfer schedule guarantees a higher minimum income for the poorest families, but calls for higher taxes when income rises. Consequently, as gross income rises, net income goes up less in Norway than in the United States. This is so, because average tax rates increase faster with income in Norway. Summing up, the Norwegian tax and transfer system is more progressive than the American one, because it is more beneficial to the poor and taxes richer households more.

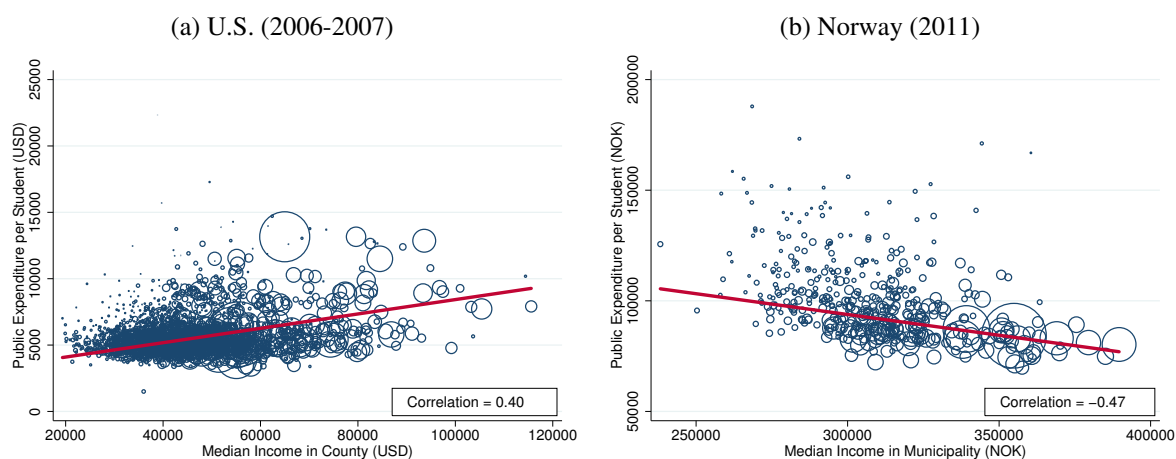
Figure 6: Taxes and Transfers, U. S. and Norway



Figures 7a and 7b plot the distributions of public education expenditures per student in pri-

mary/middle/high school on the median household labor 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.¹⁴

Figure 7: Public Education Expenditures by Counties/Municipalities



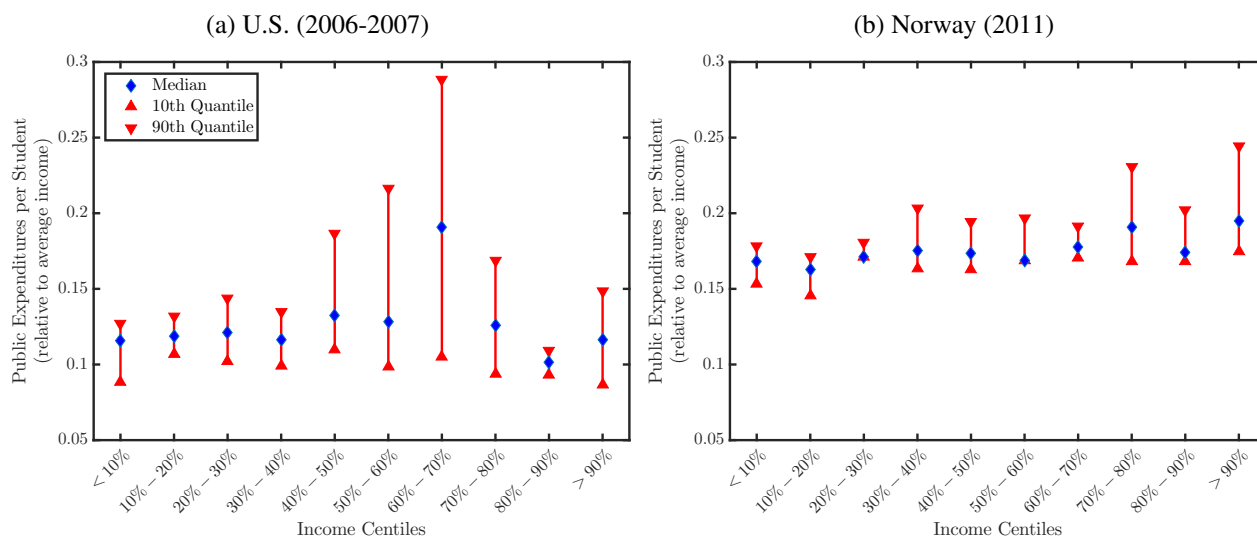
Another insightful observation based on the information in Figure 7 is that the dispersion of education expenditures, across counties/municipalities ordered by median income, differs significantly between the United States and Norway. To capture the differences in dispersion and average public education expenditures across counties/municipalities, we estimate public education expenditure distributions by deciles of the countrywide labor income distribution. We assume that the county/municipality-level income distribution is log-normal. For each county/municipality, the parameters of the log-normal income distribution are given by the observed mean and median of labor income. Using the county/municipality-level income distributions and the distribution of students across counties/municipalities, we simulate a country-wide income distribution. We pair the draws in the simulation with the public education expenditures for the corresponding counties/municipalities to create a sample of related incomes and public education expenditures. Then, we separate the simulated country-wide income distribution into deciles and compute the empirical distribution functions of the public education expenditures for each of these income groups. The

¹⁴Our results are similar to those obtained by [Herrington \(2015\)](#). He derives similar scatter plots but at a school district level.

results are presented in Figure 8. We plot the median, as well as the 10th and 90th percentile of the public education expenditure distribution for all income groups.

The distribution of public education expenditures in the United States is much more dispersed than the Norwegian one. Public education spending is particularly dispersed 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. Norwegian public spending is less progressive than what could be expected from Figure 7b. In particular, the estimates suggest that Norwegian education spending on the rich and the poor is similar in terms of median values. However, these median values in Norway are higher than in the United States for almost all income groups.

Figure 8: Estimated Public Education Distributions



3 Economic Environment

The framework presented here resembles in many aspects the models of [Becker and Tomes \(1979\)](#) and [Solon \(2004\)](#). The fortunes of children in these models are linked to the investments of their parents and the government as well as to luck. In addition to this classical setup, we add an explicit interaction between children and parents when it comes to risky activities such as teenage sex.

The model economy is populated by a large number of households. Each household consists of a

mother (parent) and a daughter (teenager).¹⁵ Teenagers derive utility of being sexually active and they care about their future household income as adults. Parents derive utility from consumption and from their teenager's future household income. The future income level of teenagers is determined partly by an innate ability and partly by an income process which takes as inputs private investment made by the parent and public investment provided by the government.¹⁶ Teenage sex is risky in this world. Teenagers might have a birth as a consequence of sex and teenage childbearing has a negative effect on the realization of future income.

Parents differ by their income, the government-provided investment to their children, and their innate ability which can be partially transferred to the offspring. Teenage daughters differ by their taste for sex and the investments they receive from their parents and the government. Each parent-teenager pair play a simple two-stage game. First, the parent makes a decision on how much to invest into her teenage daughter's future. Second, the daughter observes the investment of the parent, as well as the investment provided by the government, and decides whether to engage in the risky sexual activity. If the teenager is sexually active she faces the risk of having a birth. Teenage childbearing has a negative effect on future income of the teenager. Therefore, the sexually active teenager makes an additional decision on birth control effort which reduces the probability of a birth. Birth control is associated with a utility cost. Third, the potential birth occurs (or not) to the teenage daughter. The level of innate ability is realized, too. Thus, future household income of the teenager is fully resolved.

Parents divide their income between consumption and investments to their teenagers. In doing so, they take into account how teenagers will respond to the investment decision in terms of sexual initiation and birth control effort. Private investments can be interpreted as the intensity with which parents invest resources into the fortunes of their children. This interpretation implies that the parental investments are an input in the future income production function of the teenager. The specification of the income-generating technology follows closely [Becker and Tomes \(1986\)](#) early insights. A large literature spanning from [Bloom \(1976\)](#) to [Cunha et al. \(2010\)](#) emphasizes the importance of parental investments for the future labor/marriage market success of children.

The economy features a government which collects an income tax and spends resources on educating teenagers. The fiscal and education policies of the government are given by estimates

¹⁵In our model males play no active role. Therefore we exclude them from the decision making process.

¹⁶By innate ability, we have in mind a large set of unobserved characteristics which determine the level of household income. Such factors can be non-cognitive skills, labor market luck, ability to attract a suitable spouse, etc. As described later, these factors may be imperfectly transferred between parents and children.

from Norway and the United States.

3.1 Teenagers

Teenagers live with their parents and receive investments b from them. The government spends g on education per teenager. The public and private investments are inputs in the production of future income of the teenagers.

Teenagers 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 teenager is initiated, whereas $s = 0$ implies sexual abstinence. Active teenagers can exercise birth control effort $e \in [0, \infty)$, which comes at a utility cost modeled by a differentiable, increasing, and convex cost function $c(e)$. The probability of teenage birth for an initiated teenager is given by the probability function $\Xi(e)$, which is differentiable, decreasing and convex.

The occurrence of a teenage birth is summarized by the indicator function

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

It takes the value 1 if a teenage birth occurs, and 0 otherwise.¹⁷

3.1.1 Income

The future household income of the teenager when she becomes a parent is denoted by a' . It is a function of private and public investments b and g . In particular, future log-income is given by

$$a' = \exp(\epsilon')(1 + b + g)^{\theta_0(1-\theta_1 y')}. \quad (1)$$

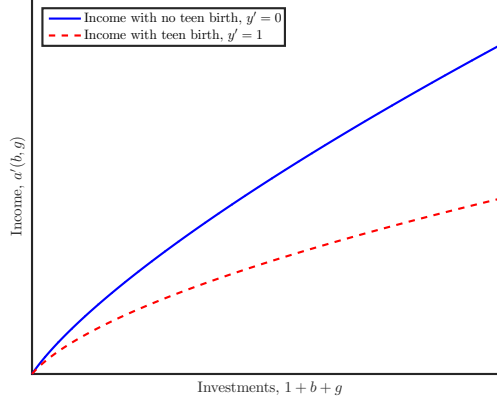
Investment inputs here are perfectly substitutable.¹⁸ The production function has non-increasing returns to scale, i.e. $\theta_0 \in (0, 1]$. A teenage birth can have some negative consequences for future income. This is portrayed by the parameter θ_1 . Whenever a teenager experiences a birth, that is, $y' = 1$, future income decreases for given investment levels b and g . Moreover, the cost of teenage childbearing in terms of lost income 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

¹⁷Variables reflecting the future of the teenager whose realizations are not known at the time of the decision making are indexed by a prime. The variable y' describes the occurrence of a teenage birth in the future.

¹⁸We relax this assumption in a series of robustness checks of the quantitative model. See the Online Appendix for further details.

line with the cross-sectional evidence presented in Figure 2. A graphical representation of this argument is outlined in Figure 9 below.¹⁹

Figure 9: Income and Investments - The Role of a Teen Birth



The production function (1) describes the creation of the household income 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 (Fernández et al. 2005). The ability shock ϵ' is distributed according to a distribution $A(\epsilon')$. It reflects non-tangible investments not captured by the production technology.²⁰ The logarithm of future income of the teenager is linear in the innate ability ϵ' . This property is used when defining the decision-making problems later. In particular, future income is given by

$$\log(a') = \log(\mathbf{a}(b, g, y')) + \epsilon', \quad (2)$$

where $\mathbf{a}(b, g, y')$ denotes future income net of innate ability.

3.1.2 Sexual Initiation and Birth Control

Teenagers derive utility ξ from having sex. The preference shock ξ comes from a distribution F . If a teenager forgoes this utility and stays sexually abstinent, her instantaneous utility level is

¹⁹We add the constant of 1 in equation (1) for two reasons. First, this technical assumption ensures that at any level of investment having a teen birth is somewhat costly in terms of future income, and second, it allows us to interpret teenager's ability $\exp(\epsilon')$ as the realized teenager's future log household income in case of no investment ($b = g = 0$).

²⁰In the quantitative version of the model described in Section 4 we impose a conditional distribution $A(\epsilon'|\epsilon)$, that is, the ability of a teenager correlates with the ability of the parent. This allows us to match the correct level of intergenerational mobility of income in the data.

normalized to zero. Teenagers value their expected income as adults. Their preferences are given by

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

where δ is the utility weight on the expected future 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 income is assumed to be logarithmic. Future 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 income if a teen birth is realized. This gives an incentive to sexually active teenagers to exert birth control effort.

3.1.3 Teenager's Decision Making

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

$$\begin{aligned} \tilde{V}^1(b, g, \xi) = & \max_{e \geq 0} (1 - \delta)(\xi - c(e)) \\ & + \delta \Xi(e) \log(\mathbf{a}(b, g, \mathbf{1})) \\ & + \delta(1 - \Xi(e)) \log(\mathbf{a}(b, g, \mathbf{0})). \end{aligned} \quad (3)$$

The teenager 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 household income in the future. The expected utility out of future income is formally expressed in the second and third lines of problem (3). The expectation is formed with respect to the odds of having a teenage birth in the future conditional on the amount of exerted birth control effort. The expectation with respect to the realization of the ability ϵ' is missing because it just adds an additional constant term, $E(\epsilon')$, to the expected utility function. The teenager chooses an optimal level of effort such that it balances the instantaneous utility cost and the benefits of decreasing the probability with which future income is reduced. We call this potential utility loss the *option value of avoiding*

teenage childbearing and define it as

$$\Lambda(b, g) = \log(\mathbf{a}(b, g, \mathbf{0})) - \log(\mathbf{a}(b, g, \mathbf{1})).$$

One can show that the option value is increasing in both private and public investments and is a concave function.²¹ If the teenager has a level of birth control effort e , with probability $\Xi(e)$ she would have a teenage birth and consequently her future income would be determined by the function $\mathbf{a}'(b, g, \mathbf{1})$. With the complementary probability $1 - \Xi(e)$ the teenager will manage to avoid a teen birth and the future level of income would be determined by $\mathbf{a}'(b, g, \mathbf{0})$. Denote the decision rule of the initiated teenager with respect to birth control as $\mathbf{e}(b, g)$.

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

$$\tilde{V}^0(b, g) = \delta \log(\mathbf{a}(b, g, \mathbf{0})).$$

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 income with respect to ability ϵ' . The expectation over the ability of the teenager adds a constant $E(\epsilon')$ to the expected utility and, therefore, is omitted.

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

$$V(b, g, \xi) = \max_{s \in \{0,1\}} \left\{ (1-s) \underbrace{\tilde{V}^0(b, g)}_{\text{Abstinence}} + s \underbrace{\tilde{V}^1(b, g, \xi)}_{\text{Sex}} \right\} \quad (4)$$

and the corresponding decision rule is given by

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

Teenagers are indifferent between sexual initiation and abstinence if the realization of the sex taste shock ξ^* is such that $\tilde{V}^1(b, g, \xi^*) = \tilde{V}^0(b, g)$. 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 $\xi^* = \xi^*(b, g)$ can be represented as a function of private and public investment in the teenager's future.

²¹For details see Lemma 1 in the Appendix.

3.2 Parents

Parents value household consumption, c , and are paternalistic in the sense that they care about the future expected income a' of the child (Doepke and Zilibotti 2015). Parental preferences are given by

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

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

3.2.1 Parent's Decision Making

The parent observes public education expenditures g to her teenager. She has a household income a which is taxed at an average tax rate given by the increasing function $\tau(a)$. The parent decides how to allocate net income between household consumption, c , and the investment in the future income of her child, b . The parent knows how investment b influences her teenage daughter's decisions about sexual initiation, $s(b, g, \xi)$, and birth control, $e(b, g)$, and she takes into account these decision rules when making the investment. However, the parent does not know the preferences of the teenager over sex, ξ . Also, at the time parental decisions are made, the level of ability, e' , or the realization of the potential birth to the teenager, y' , is not yet known. Again, the expectation over the ability of the teenager does not play a role in the decision-making process here because it adds a constant term to the expected utility out of future income.

The decision problem of the parent is given by

$$\begin{aligned} W(a, g) = & \max_{b \in [0, (1-\tau(a))a]} (1 - \alpha) \log(c) \\ & + \alpha \int_{\xi} \left\{ (1 - s(b, g, \xi)) \log(\mathbf{a}(b, g, \mathbf{0})) \right. \\ & + s(b, g, \xi) \Xi(e(b, g)) \log(\mathbf{a}(b, g, \mathbf{1})) \\ & \left. + s(b, g, \xi) (1 - \Xi(e(b, g))) \log(\mathbf{a}(b, g, \mathbf{0})) \right\} dF(\xi) \end{aligned} \tag{5}$$

subject to

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

The parent has to choose an optimal level of household consumption, c , and the investment to 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 income of the teenager when she becomes an adult parent herself. The expected utility out of the income of the teenager in the future is expressed in the second, third, and fourth lines of problem (5). For a particular mix of investments, b and g , and sex taste, ξ , the teenager may decide to stay sexually abstinent, i.e. $s(b, g, \xi) = 0$. In this case, her future income (net of innate ability) will be given by $a(b, g, 0)$. This is the case depicted in the second line of the problem. However, if the teenager has sex, $s(b, g, \xi) = 1$, she faces a teenage birth with probability $\Xi(e(b, g))$. In this case her future income is determined by $a(b, g, 1)$. Of course, she might avoid giving birth while a teenager with probability $1 - \Xi(e(b, g))$. In this case, her income in the future is defined by $a(b, g, 0)$. 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 taste for sex, ξ . The decision rule of the parent with respect to investments is $b(a, g)$.

3.3 Equilibrium Characterization

Each parent-teenager pair play a game in which the parent moves first and decides how much to invest in her teenage child. The teenager observes the investment, learns her sex taste and makes a decision on sexual initiation. In addition, she decides how much birth control effort to exert if she is sexually active. The natural way to solve this problem is using *backward induction*. Start at the final decision node, i.e. when parental investment and sex taste are realized and the teenager has to make her decisions. The optimal behavior of the teenager is summarized by the decision rules $s(b, g, \xi)$ and $e(b, g)$. Now move to the decision problem of the parent. She takes into consideration the optimal behavior of her teenage daughter and makes an investment decision $b(a, g)$. The solution concept applied to the outcomes of each household in the economic environment is *sub-game perfect Nash equilibrium*. The concept requires that the decision rules of the teenager, $s(b, g, \xi)$ and $e(b, g)$, are optimal *given* that the parent has already determined the investment level b . This implies that the teenager cannot internalize the decision making process of the parent when it comes to private investments.

If multiple equilibria are never encountered in any step of the backward induction solution

process, the derived decision rules of parents and teenagers constitute a unique sub-game perfect Nash equilibrium. The two decision sub-problems of the teenager (3) and (4) yield a unique solution in terms of decision rules $e(b, g)$ and $s(b, g, \xi)$. The assumptions on the probability function of having a teenage birth, $\Xi(e)$, and on the cost function, $c(e)$, ensure that the sufficient second-order condition in problem (3) is satisfied. If the solution of the parental problem (5) yields a unique solution, then the sub-game perfect Nash equilibrium is also unique.²²

The decision problem of a sexually initiated teenager depicted in (3) gives rise to the following optimality condition (in the case of an interior solution) for the choice of birth control effort, e ,

$$-(1 - \delta)c'(e) = \delta\Xi'(e)\Lambda(b, g). \quad (6)$$

Condition (6) above states that the marginal utility cost of birth control effort should be equal to the marginal benefit of effort in terms of future expected income. Using the *Implicit Function Theorem* we can show that the decision rule function $e(b, g)$ exists and the level of optimal effort rises with both investments (see Lemma 2 in the Appendix).

The decision problem of the parent can be rewritten in a more convenient way. First, define the perceived probability of a teenage birth to the parent of the teenager as a function of her investments b and the government investments g as $\Xi^*(b, g)$. Recall that the parent does not know the realized sex taste of her teenager. Thus, the probability of a teen birth can be expressed as

$$\Xi^*(b, g) = \int_{\xi} s(b, g, \xi) dF(\xi) \Xi(e(b, g)) = (1 - F(\xi^*(b, g))) \Xi(e(b, g)).$$

The probability of a teenage birth perceived by the parent decreases in investments b and g (see Lemma 6 in the Appendix). We can reformulate the decision problem (5) of the parent using this probability,

$$\begin{aligned} W(a, g) = & \max_{b \in [0, (1-\tau(a))a]} (1 - \alpha) \log(c) \\ & + \alpha(1 - \Xi^*(b, g)) \log(\mathbf{a}(b, g, \mathbf{0})) \\ & + \alpha\Xi^*(b, g) \log(\mathbf{a}(b, g, \mathbf{1})) \end{aligned} \quad (7)$$

subject to

²²We impose a sufficient second-order condition, so that (5) yields a unique solution. Further details are presented in the Appendix.

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

The decision problem (7) of a parent who invests resources for her daughter's future has the following optimality condition in case of an interior solution for the invested amount b ,

$$\frac{1 - \alpha}{(1 - \tau(a))a - b} = \alpha [1 - \Xi^*(b, g)] \frac{\frac{\partial \mathbf{a}}{\partial b}(b, g, 0)}{\mathbf{a}(b, g, 0)} + \alpha \Xi^*(b, g) \frac{\frac{\partial \mathbf{a}}{\partial b}(b, g, 1)}{\mathbf{a}(b, g, 1)} - \alpha \frac{\partial \Xi^*}{\partial b}(b, g) \Lambda(b, g), \quad (8)$$

where $\tilde{a} = (1 - \tau(a))a$ is net income of the parent. Condition (8) states that at the optimal level of investment b , the marginal utility of a unit of forgone consumption equals the marginal benefit of investing an extra unit into the future of the teenager. The expression for this marginal utility benefit on the left-hand side of condition (8) consists of three parts. The first and the second summands represent the marginal utility gained due to the increase in the future income of the teenager holding the probability of a teenage birth constant. The third term stands for the marginal utility benefit related to the declining probability of teenage birth holding constant the option value of avoiding teenage childbearing. The decision rule $\mathbf{b}(\tilde{a}, g)$ associated with condition (8) exists and the level of parental investment rises with net income of the household but decreases with government investments (see Lemma 7 in the Appendix).

Proposition 1. *The probability of a teenage birth as a function of parental net household income $\tilde{a} = (1 - \tau(a))a$ and the government investment g , while taking into account the optimal behavior of the parent and the teenager is defined as*

$$\Xi^{**}(\tilde{a}, g) = \Xi^*(\mathbf{b}(\tilde{a}, g), g).$$

*It can be shown that this probability is decreasing in net income and is decreasing in government investments, that is, $\frac{\partial \Xi^{**}}{\partial \tilde{a}}(\tilde{a}, g) < 0$ and $\frac{\partial \Xi^{**}}{\partial g}(\tilde{a}, g) < 0$.*

Proof. See Appendix. □

This result points out that the unconditional probability of a teenage birth occurrence goes down when net parental income rises. Similarly, when public investments rise, teenager births decline. Thus, the economic model captures the basic intuition outlined in the introductory paragraphs. Larger amount of redistribution, that is, a rise in net income in the lower fractions of the income distribution would bring about a declining trend of teenage childbearing among the affected teenagers. The same is true for an increase in public education expenditures. Which of

these effects is stronger? Are these channels at work only at the bottom of distribution? That is, suppose income is redistributed from the top of the distribution to the bottom. Can a declining trend in teenage childbearing at the bottom of the distribution be offset by a rise in teenage births at the middle or at the top of the distribution due to such redistributive policies? These questions are quantitative in nature. We can only address them by bringing the economic model to the data.

4 Fitting the Model to the Data

The model developed here is fitted to 2006-2010 U.S. data on teenage childbearing behavior. The government policies in the model are exogenously given. Therefore, the tax and transfer schedule and the public education expenditure process can be set independently on the basis of a priori information. The parameters of the model are 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 income distribution, (ii) the household income distribution, (iii) the average wage reduction associated with a teenage birth, and (iv) the intergenerational patterns of income mobility.

The model economy is simulated from an initial sample of 10,000 households. Their descendants are followed for the next 170 generations. We discard the first 20 generations to ensure that that the statistical properties of the resulting simulated dataset are not driven by initial conditions. In each generation, households receive a level of government educational investments drawn from the conditional distribution $G(g|a)$. The distribution is estimated from regional data on public education expenditures in the United States. First, parents make their investment decisions conditional on the levels of household income and public education expenditures. Then, teenagers make decisions on sexual initiation and optimal birth control effort. These decisions are used to simulate teenage births. Based on the pattern of teenage births and investments, household income of the next generation's parents is determined.

4.1 Features of the Quantitative Model

The theoretical model described in the previous section has to be augmented in several dimensions before using it for quantitative work. These adjustments are made without distorting the main mechanisms at work in the model.

First, as shown in Figure 3a, a teenager is much more likely to have a birth if the parent of

the teenager had a teenage birth herself, irrespective of the position in the parental household income distribution. In order to allow the model to replicate this feature of the data we introduce an additional cost in the income process. The income process is now defined as

$$a' = \exp(\mu) \exp(\epsilon') (1 + \lambda(b + g))^{\theta_0(1-\theta_1 y')(1-\theta_2 M)}. \quad (9)$$

If the teenager was born to a teenage mother ($M = 1$), private and public investments are less efficient in generating future income. This inefficiency is captured by the parameter θ_2 . The intercept μ is added to income process (9). The purpose of this adjustment is to normalize mean income in this economy to one in estimation.²³ The slope-parameter λ controls for the overall efficiency of investments. It allows us to adjust the marginal returns on parental investments in estimation. In line with the existing literature (Holter 2015 and Herrington 2015), we assume that the investment inputs b and g are perfect substitutes. In a series of robustness checks, we relax this assumption and obtain similar quantitative results.²⁴

Second, we allow for a fixed component in the cost of birth control effort, $c(e)$. This fixed cost helps us to match the high teenage birth rates at the lower end of the income distribution.²⁵

Third, general functional forms are imposed on the cost of the birth control effort, $c(e)$, and the probability function of a teenage birth conditional on the exerted effort, $\Xi(e)$. These functional forms are given by

$$c(e) = \exp(\omega_0 e) - \omega_1$$

and

$$\Xi(e) = \exp(-\gamma e).$$

Forth, the distribution of the sex preference shock, ξ , is assumed to follow an exponential distribution with an inverse-scale parameter ζ . Finally, the ability levels, ϵ , are transferred between parents and children according to an autoregressive process,

$$\epsilon' = \psi \epsilon + \nu,$$

with a disturbance term $\nu \sim N(0, \sigma_\nu^2)$.

²³The tax schedule used as an input to the quantitative model is estimated for income levels with a mean of one.

²⁴In particular, the income process is given by $a' = \exp(\mu) \exp(\epsilon') (1 + \lambda(b^\pi + g^\pi)^{1/\pi})^{\theta_0(1-\theta_1 y')(1-\theta_2 M)}$. The degree of substitution between inputs is measured by the parameter π . Robustness checks in the Online Appendix reduce π from one to 0.75 and to 0.5. The main results in our quantitative exercises remain intact.

²⁵We add a relevant targeted data moment in the estimation in order to recover the level of this fixed cost. The model is to generate the fraction of sexually active teenagers who do not use contraception observed in the data.

4.2 A Priori Information

4.2.1 Tax and transfer schedule

We use data on income taxes, social security contributions and transfers for the United States and Norway from the OECD Taxing Wages modules. The U.S. data is used when setting the exogenous tax and transfer schedule in the estimation procedure below. The Norwegian tax and transfer schedule is utilized in the quantitative experiments performed later.

The data provides detailed information on net household income levels for gross household labor income between zero and twice the mean income level. The OECD Taxing Wages module provides separate tax and transfer schedules for single and married households, with and without children. Since our model is populated by families with children, we take the weighted average of the tax and transfer schedules of single and married households with children and linearly interpolate the data for the purposes of the quantitative model. If simulated gross income is larger than the maximum level obtained from the data, we linearly extrapolate the schedule to obtain net income.²⁶

4.2.2 Public Education Expenditures

Public education expenditures per student vary with the median income of counties or municipalities in the United States and in Norway, respectively (Figure 7). U.S. education expenditures are more dispersed across counties and on average lower than Norwegian education spending. In order to capture the dispersion of education expenditure across space, we assume that public education expenditures g in the model come from a distribution conditional on household income, $G(g|a)$.

We estimate the distribution $G(g|a)$ by semi-parametric methods using data on public education expenditures on a county-level in the United States (*2006-2010 American Community Survey 5-Year Estimates* and the *National Center for Education Statistics Common Core of Data*). We assume that the county-level income distribution is log-normal. The parameters of the log-normal income distribution in each county can be derived from the observed mean and median income levels. Using the county-level income distributions and student population sizes, we simulate a U.S. empirical income distribution. We pair the draws from the income simulation with the public education expenditures per student for the corresponding counties from which the income draw is made. This procedure produces a large sample of income levels and public education expen-

²⁶The non-parametric tax and transfer schedules used in the analysis are depicted in Figure 6 in Section 2.

ditures. Then, we divide the simulated U.S. income distribution into decile groups and compute the empirical distribution of the public education expenditures for each of these groups.²⁷ In the simulation of the quantitative model households receive education expenditure levels g from the decile-specific empirical distribution associated with their income.

4.3 Estimation

The estimation procedure involves **13** parameters. There are three preference parameters, $\{\alpha, \delta, \zeta\}$, seven parameters for the income process, $\{\lambda, \theta_0, \theta_1, \theta_2, \mu, \sigma_\nu\}$, two parameters for the birth control effort function, $\{\omega_0, \omega_1\}$, and one parameter for the probability of having a teen birth, $\{\zeta\}$.

These parameters are estimated to match as close as possible the following list of **25** data targets:

1. Teenage birth rates and sex initiation rates for five parental household income groups and conditional on whether the parent of the teenager has a teenage birth herself. In essence, these are the 20 data moments presented in Figures 3a and 3b.
2. Average income cost of a teenage birth. This target is computed as the average income loss associated with a birth to the teenager.
3. Share of sexually active teenagers who do not use any contraceptive technique.
4. Income inequality. We use the Gini coefficient of household income of families with teenage children.
5. Intergenerational mobility of household income. We use the intergenerational income elasticity of females with respect to their parents.
6. The average of household income is normalized to one in the benchmark economy.

Before proceeding with the estimation procedure and the resulting model fit, let us take a detour and discuss in depth the utilized data targets and how they help in the process of estimation of concrete parameters of the model.

²⁷The Norwegian distribution of education expenditures is estimated using identical procedure on data from Statistics Norway. Basic statistics of the resulting distributions are plotted in Figure 8.

4.3.1 Teenage Birth Rates and Sexual Initiation Rates

We utilize the National Survey of Family Growth (NSFG) for the period 2006-2010 to construct teenage birth rates and sexual initiation rates for different income groups. As described in the Online Appendix, 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 a teenager decides whether to be sexually active or not by comparing the value of the sex taste shock ξ with the threshold $\xi^*(b, g)$. If the realization of the taste shock is below the threshold, the teenager remains abstinent. As mentioned above, the sex taste shock follows an exponential distribution, $\xi \sim \text{Exp}(\zeta)$. The parameter ζ determines the mean of the sex taste shock distribution, and therefore, it is identified by the average initiation rate of the teenagers. When the mean of the exponential distribution is higher, more teenagers find that the realization of their taste shock is above the threshold and become sexually active.

The overall shape of the distributions of teenage births and sexual initiation across parental income in the model is influenced by the utility weights α and δ , the income process parameters θ_0 , θ_2 and λ , the birth control effort cost function $c(e)$, and the probability function $\Xi(e)$.

The utility weight α determines the average level of parental investments, whereas the utility weight δ controls how much teenagers care about the risk to loose income related to having a teenage birth. Furthermore, a higher value of the parameter θ_0 leads to a higher future income level of a teenager conditional on the level of investments. This implies that a higher θ_0 incentivizes parents to invest more in their children and incentivizes children to exert more birth control effort whenever they are sexually active. Higher investments would also lead to higher sex taste threshold value. Hence, teenage birth rates and sexual initiation rates are on average lower when the parameter θ_0 is higher. The parameter λ plays a similar role but it is more important for decisions at lower levels of family income. The parameter θ_2 is responsible for the differences in teenage birth and initiation rates between teenagers born to a teenage parent and otherwise. Finally, the parameterization of $c(e)$ and $\Xi(e)$ determine the shape of the teenage birth and sexual initiation distributions across parental income. Here, the data target related to the fraction of sexually active teenagers who do not exert any birth control identifies the fixed cost component of $c(e)$.

4.3.2 Costs of Teenage Childbearing

The parameter θ_1 determines the cost of having a teenage birth in terms of future household income in the model. We follow [Fletcher and Wolfe \(2009\)](#) who compute the income loss associated with teenage motherhood using The National Longitudinal Study of Adolescent to Adult Health (Add Health). They use teenagers that had a late miscarriage as a control group to identify the effect of having a teenage birth on future earnings. The procedure controls for community fixed effects too. [Fletcher and Wolfe \(2009\)](#) estimate significant reductions in income due to teenage childbearing. We use their estimates and set the income loss due to a teenage birth to be approximately 17%.

4.3.3 Income Distribution

The remaining three parameters μ , ψ , and σ_ν are identified by data targets related to income inequality and intergenerational mobility in the United States. We normalize average income to one by adjusting the parameter μ . The parameter σ_ν is identified by the dispersion of the income distribution and we use the Gini coefficient of gross household income of families with teenagers of 0.423 as a target. Finally, intergenerational income mobility allows us to recover the persistence of the ability process ψ . [Raaum et al. \(2007\)](#) find that the intergenerational elasticity of family income of a female with respect to her parents' income is 0.408 in the United States.

4.3.4 Simulated Method of Moments

We define the parameter vector to be estimated as $\Theta = \{\alpha, \delta, \zeta, \theta_0, \theta_1, \theta_2, \lambda, \psi, \sigma_\nu, \mu, \omega_0, \omega_1, \gamma\}$ and compute the difference between the simulated model moments $\hat{m}_i(\Theta)$ and 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 a vector that contains all these differences. The estimation of the parameter vector amounts to choosing parameter values that minimize the squared deviation between the data and the model,

$$\hat{\Theta} = \min_{\Theta} g(\Theta)' \mathcal{W} g(\Theta),$$

where \mathcal{W} is a diagonal weighting matrix. The difference between data and model moments is weighted by the inverse of the observed data moment. The individual bins of the teenage birth and initiation rate distributions are also weighted by their relative population size to account for their importance in the total distribution. Finally we impose higher weights on central targets to facilitate the estimation process.²⁸ Standard errors of the parameter estimates are computed using

²⁸We put higher weights on average income and the distributions of teenage birth and initiation rates.

the methodology proposed by [Lee and Ingram \(1991\)](#). Table 1 reports the parameter estimates and the corresponding standard errors. The parameters are tightly estimated as evident by the 95% confidence intervals.

Table 1: Estimated Parameters

Parameter	Description	Value	Std. Error	95% Confidence Interval
α	Parents utility weight	0.4183	0.0029	[0.4127 0.4239]
δ	Teenagers utility weight	0.2629	0.0019	[0.2592 0.2666]
ζ	Sex taste shock	19.8000	0.1119	[19.5807 20.0193]
θ_0	Income process	0.7424	0.0029	[0.7366 0.7481]
θ_1	Income process	0.2024	0.0021	[0.1983 0.2065]
θ_2	Income process	0.5077	0.0035	[0.5009 0.5146]
λ	Income process	23.7334	0.1755	[23.3895 24.0774]
ψ	Persistence of ability	0.1059	0.0015	[0.1029 0.1089]
σ_ν	Std of ability shock	0.6332	0.0034	[0.6266 0.6398]
μ	Income intercept	-1.6709	0.0102	[-1.6909 -1.6509]
ω_0	Cost of effort	0.0791	0.0007	[0.0778 0.0805]
ω_1	Cost of effort	0.9707	0.0002	[0.9711 0.9703]
γ	Probability teenage birth	31.5602	0.2803	[31.0108 32.1097]

The utility weight which parents put on their child's future outcomes, $\alpha = 0.42$, is larger than the teenager's utility weight, $\delta = 0.26$. Thus, parents indeed act in a paternalistic fashion when investing in their children. Why is the point estimate for λ so large? Recall that the model features a log-utility of consumption and its weight, $1 - \alpha$, is sizable. In order for parents, especially from the lower end of the household income distribution, to invest positive amounts into their children, the marginal benefit of an extra unit of investment should be large enough to be equal to the forgone marginal utility of consumption; see condition (8). This requires a fairly high value of λ .

The standard deviation of the disturbance term ν is estimated to be 0.63. Therefore, the standard deviation of the stationary log-normal distribution of innate ability ϵ is 0.45.²⁹ The Gini coefficient associated with the stationary log-normal distribution of ϵ is 0.25.³⁰ Recall that the Gini coefficient of household income in the data (and in the model) is 0.42. At the same time, the persistence of innate ability $\psi = 0.10$ is used to match a level of intergenerational persistence of income of 0.41. Thus, the model amplifies the innate ability in generating cross-sectional variance and intergenerational persistence of income.

²⁹The variance of the stationary distribution of ϵ is $\sigma_\nu^2/(1 - \psi)$.

³⁰The Gini coefficient associated with a log-normal distribution with variance σ^2 can be expressed as $2\Phi(\sigma/\sqrt{2}) - 1$, where Φ is the standard normal cumulative distribution function. For more details, see [Aitchison and Brown \(1963\)](#).

The estimated parameter $\omega_1 = 0.97$ implies that the fixed cost of exerting birth control effort is 0.03. This fixed cost represents around 75% of the incurred birth control cost to a sexually active teenager from an average income household with a parent who did not have a birth as a teenager. If the parent was a teenage mother herself, then the fixed cost accounts for 80% of the exerted birth control cost. The estimated parameter $\gamma = 31.56$ points out that going from a zero birth control effort to the effort exerted by a teenager in an average income family reduces the odds of a teenage birth from 100% to less than 5%.

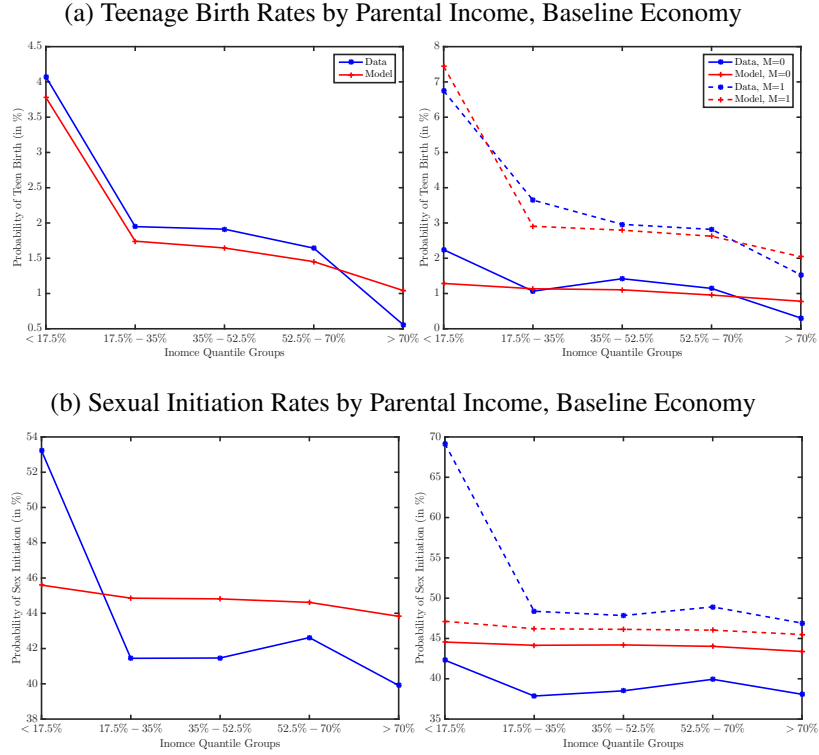
4.4 Model Fit

The model matches remarkably well the overall teenage birth and sexual initiation rates, as well as the rest of the targets for the United States (see Table 2). As Figure 10a illustrates, the model has no trouble capturing the teenage childbearing levels by parental income groups (left panel). Moreover, this behavior is matched for teenagers with a parent who has had a teenage birth as well ($M = 1$), and for teenagers with a parent who has not experienced a teenage birth ($M = 0$); see the right panel. Teenage childbearing in the model is exacerbated at the lower end of the income distribution and within the group of teenagers with a parent who has also been a teenage mother in line with the observed patterns in the data. The model captures well the sexual initiation rates (Figure 10b) but it misses the high rate of sexual initiation of teenagers at the bottom of the income distribution and with a parent who has also been a teenage mother.

Table 2: Model Fit - Aggregate Statistics

	Data	Baseline Model
Teenage Birth Rate	1.84%	1.82%
Sex Initiation Rate	43.25%	44.63%
Income Loss of Teenage Birth	17.26%	16.98%
Share with No Birth Control	1.14%	0.75%
Gini Income	0.423	0.453
Intergen Mobility	0.408	0.418

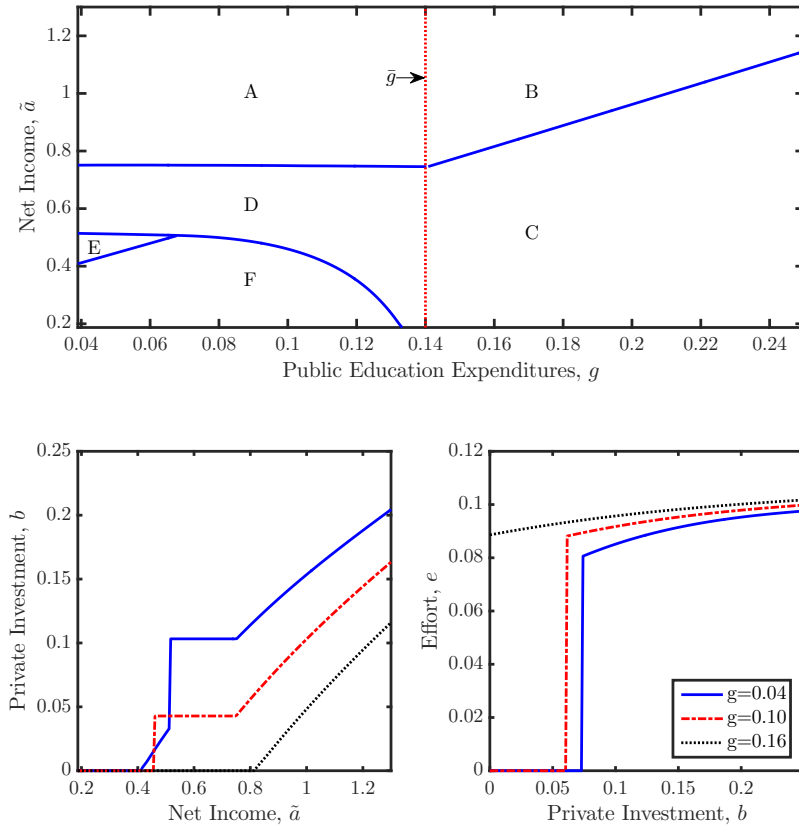
Figure 10: Model Fit - Distributions



4.4.1 Who is Who in the Baseline Economy

The baseline economy is populated by households which exhibit different behavior in terms of parental investment decisions, $b(\tilde{a}, g)$, teenage sex initiation decisions, $s(b, g, \xi)$, and birth control effort decisions, $e(b, g)$. Let us concentrate on families whose teenage daughters are sexually initiated, that is, $s(b, g, \xi) = 1$. We group households in the simulated economy based on their decisions which depend on the realizations of net household income \tilde{a} and government education expenditures on the teenager, g . Defining different household types allows us to trace how changes in taxation and education policies affect household decisions. The type separation of the state space of parents, (\tilde{a}, g) , is depicted in the upper panel of Figure 11. The lower left panel shows several decision rules for private investments $b(\tilde{a}, \cdot)$ at different levels of government investments g . The optimal birth control effort of initiated teenagers $e(b, \cdot)$ at different levels of g is presented in the lower right panel of Figure 11.

Figure 11: Equilibrium Household Types



To start with, households can be differentiated with respect to the amount of public education expenditures g . The vertical dotted line in the upper panel of Figure 11 represents the minimum level of government expenditures, $\bar{g} \approx 0.14$, for which initiated teenagers exert positive birth control effort independent of the amount of private investments received. All families with a public investments at this level or above (types **B** and **C**) have a teenage daughter who always exerts birth control effort if she decides to be sexually active. This can be also seen in the lower left panel, where optimal birth control effort is always positive for $g = 0.16$. Some parents whose teenage children receive public education expenditures above \bar{g} may consume all of their household income (type **C**). This happens whenever net household income \tilde{a} is low enough and the marginal utility of consuming all of it is higher than the the marginal benefit of investing into the child. When net income is high enough, marginal utility of consumption decreases and parents start investing positive amounts into their children (type **B**). The lower right panel shows these two patterns of

private investments when public education expenditures are $g = 0.16$.

When public investments are below \bar{g} , sexually initiated teenage daughters would exert positive amount of birth control effort only if the parent complements the public investment with an adequate level of private investments. When household net income is sufficiently high, the parent invests in her child and the investment level is high enough to ensure that the daughter exerts strictly positive birth control effort when sexually active (type **A**). Whenever the government investment is below the threshold level \bar{g} and net household income is not high enough for the family to be of type **A**, then parents are constrained in their investment decisions. However, not all of them would forgo the opportunity to invest into the future of their teenage child. Since public investments are not high enough to ensure that the initiated teenager exerts positive effort, the parent can use her investment to incentivize the teenager by investing just the amount that makes her start exercising birth control. If the parent invests this minimum amount (the flat part of the dash-dotted line at $b \approx 0.05$ in the left panel), then the optimal birth control effort jumps from zero to a strictly positive amount (the discrete jump in the dotted schedule in the right panel). Such constrained households who strategically use minimum amounts of investment to make their teenagers use birth control are categorized as type **D**.

If government expenditures g are sufficiently close to zero and the net household income is low as well, then the teenager does not exert effort (types **E** and **F**). Parents of these types do not have the capacity to invest the minimum amount which would make their teenagers exert effort. Therefore, a teenage birth is very likely. The low level of government investment g and the likely teenage birth reduces dramatically the expected income of the teenager. Thus, parents find it optimally to invest some small amounts. Households with such net income-public education expenditure combinations are categorized as type **E**. The investment behavior of such parents is captured by the increasing part of the solid line in the left panel for net incomes between 0.4 and 0.55. Finally, type **F** parents do not invest anything and their teenager do not exert any birth control effort.

5 Quantitative Analysis

To quantify the role of redistributive policies in accounting for cross-country differences in teenage childbearing, we simulate counterfactuals of the U.S. economy with features of the Norwegian tax code and/or public education expenditures. Differences between the counterfactuals and our

baseline economy can be attributed to the specific features of these government policies.

We conduct three sets of counterfactual experiments. In a first set of experiments, we incorporate the Norwegian tax schedule in the baseline economy. In the second set we replace the U.S. public education expenditures by their Norwegian counterpart. Finally, we introduce both of these Norwegian welfare state instruments into the U.S. economy. The upper panel of Table 3 summarizes the results of the counterfactual experiments in terms of realized aggregate outcomes such as the teenage birth and sex initiation rates, the Gini coefficient of gross income and the level of intergenerational mobility of income. The middle panel depicts the percentage deviations of these outcomes from the baseline economy. The lower panel shows how much of the difference in teenage birth rates between the United States and Norway can be accounted for by the Norwegian welfare state institutions introduced in the experiments.

When substituting the U.S. taxes or public education spending by their Norwegian counterparts, we distinguish between two features, namely, the *redistributive* role and the average *levels* of taxes or public education expenditures. Thus, in the first two sets of experiments (*Norwegian Taxes* and *Norwegian Public Education*), we proceed in three steps. First, we introduce the redistributive characteristics of the Norwegian tax or education policies into the baseline economy. For this, we keep average taxes or public education expenditures fixed at the observed U.S. levels and insert the Norwegian tax progressivity or the Norwegian distribution of public education expenditures adjusted to match the average U.S. education spending. Second, we retain redistribution at observed U.S. levels and adjust average taxes or education expenditures to Norwegian levels. Third, we fully substitute the U.S. taxes or education expenditures with their Norwegian counterparts. The final column in Table 3 presents the resulting outcomes when we introduce all features of the Norwegian welfare state, that is, both taxes and public education.

Shifts in the levels of income inequality and income mobility as a consequence of the changing welfare state are in line with the existing macroeconomic literature on the topic (Lee and Seshadri 2014, Holter 2015 and Herrington 2015). The Gini coefficient of income and the intergenerational income elasticity do not change much when we introduce the *Norwegian Public Education* policies. However, they react strongly to changes in taxes and transfers (*Norwegian Taxes*). In particular, imposing the overall *Norwegian Taxes* improves significantly the level of intergenerational income mobility - the income elasticity goes from 0.418 down to 0.353. With Norwegian taxes and transfers, families at the lower end of the income distribution receive more transfers, allowing them to start to invest in the future income of their teenage children. This also increases educa-

Table 3: Quantitative Results

	Baseline			Experiments						
	<i>U.S. Welfare State</i>	<i>Norwegian Taxes</i>		<i>Norwegian Public Education</i>		<i>Norwegian Welfare State</i>				
	Redistribution	Levels	Both	Redistribution	Levels	Both	Redistribution	Levels	Both	
Teenage Birth Rate	1.82%	1.51%	2.04%	1.57%	1.47%	1.46%	1.52%	1.47%	1.52%	
Sex Initiation Rate	44.63%	44.60%	44.76%	44.71%	44.52%	44.53%	44.60%	44.52%	44.64%	
Income Loss of Teenage Birth	0.170	0.187	0.159	0.182	0.192	0.192	0.185	0.192	0.186	
Gini Income	0.453	0.442	0.440	0.430	0.452	0.454	0.455	0.452	0.432	
Intergen Mobility	0.418	0.371	0.399	0.353	0.414	0.412	0.416	0.414	0.353	
Deviations from Baseline Economy										
	<i>Norwegian Taxes</i>			<i>Norwegian Public Education</i>			<i>Norwegian Welfare State</i>			
	Redistribution	Levels	Both	Redistribution	Levels	Both	Redistribution	Levels	Both	
Teenage Birth Rate, $\Delta\%$	-17.16%	11.98%	-13.99%	-17.16%	-19.16%	-19.83%	-16.31%	-19.16%	-16.75%	
Sex Initiation Rate, $\Delta\%$	-0.07%	0.28%	0.17%	-0.07%	-0.24%	-0.22%	-0.07%	-0.24%	0.02%	
Income Loss of Teenage Birth, $\Delta\%$	-	10.01%	-6.17%	6.90%	8.90%	13.02%	8.90%	12.79%	9.76%	
Gini Coefficient, $\Delta\%$	-	-2.47%	-2.78%	-4.93%	0.42%	0.27%	0.42%	-0.14%	-4.54%	
Intergen Mobility, $\Delta\%$	-	-11.22%	-4.55%	-15.66%	-0.54%	-1.52%	-0.54%	-0.95%	-15.46%	
Accounting for Differences in Teenage Childbearing between the U.S. and Norway										
	<i>Norwegian Taxes</i>			<i>Norwegian Public Education</i>			<i>Norwegian Welfare State</i>			
	Redistribution	Mean	Both	Redistribution	Mean	Both	Redistribution	Mean	Both	
Teenage Birth Rate, $\Delta\%$	-24.15%	14.16%	-19.99%	-23.04%	-26.79%	-27.67%	-23.04%	-26.79%	-23.62%	

tion investments into teenagers from poor families relative to education investments into teenagers from high income families. Therefore, intergenerational persistence goes down significantly. The weak effect of Norwegian public education on inequality and income mobility can be attributed to parents not altering their investments too much as a response to the changing public investments in their children. An increase in government education spending works in our model as an exogenous positive income shock to the teenage daughter's future income. This might drive parents to reduce their own investment levels, however, they put a high utility weight on their daughters' future income. Therefore, the magnitude of this income decrease in private investment is rather small. Therefore, the overall parental investment level increases and all households become richer, which does not affect inequality and mobility.

A common result of all experiments is that sex initiation rates change only marginally when government policies are altered. However, changes in teenage birth rates are more pronounced relative to the case of the baseline economy. This suggests that teenagers are more likely to adjust their behavior as response to changing policies through exerting more birth control effort rather than abstaining from sex.³¹

The levels of teenage childbearing across the quantitative experiments is negatively correlated with the observed average income loss due to teenage childbearing. Whenever the number of teenage births goes down, the associated income loss becomes higher. When teenage childbearing is reduced due to the new welfare state policies, the general investment levels in teenagers increase all across the distribution of parents but especially at the bottom. These higher investments imply that the income loss of teenage childbearing would be higher.³²

The Norwegian tax and transfer system imposes higher positive average tax rates, features a more pronounced increase of marginal tax rates with income and guarantees a higher minimum income than its U.S. counterpart. When we impose the Norwegian levels of redistribution (keeping average taxes at the mean at U.S. levels) on the baseline economy, the teenage birth rate decreases by 17.16%. A more progressive tax and transfer system increases the disposable income of poor parents, and therefore, their investments and the expected future income of their child. This gives teenage daughters of poor parents more incentives to delay childbearing since the loss of income in

³¹These results are consistent with the existing medical literature on the effect of social policies on the likelihood of sexual initiation and teenage childbearing. Most studies report that teenagers adjust their birth control effort and not the odds of engaging in sexual intercourse. See, for instance, [Rosenbaum \(2009\)](#) and [Kohler et al. \(2008\)](#) among others.

³²The income penalty of teenage childbearing increases in investments as depicted in Figure 9.

the future due to teenage childbearing rises with investments. Teenagers of more wealthy parents have little incentives to change their behavior. The existing level of private investments already ensures that they try to avoid teenage childbearing through birth control whenever they are sexually active. On average, the introduction of the redistributive features of the Norwegian tax and transfer system increases the realized loss of having a teenage birth by 10%.

In contrast, increasing the average tax rates to Norwegian levels but keeping the U.S. level of redistribution raises the teenage birth rate by 11.98%. An increase in average taxes makes all households poorer. This affects teenage childbearing in two ways. First, an increased number of parents are constrained in their investment decisions. Without investments, their teenage daughters are more likely to have a teenage birth. Second, unconstrained wealthier parents reduce their investments too. Therefore, the expected future income of their teenagers falls. This in turn reduces the benefits of delaying childbearing until adulthood and reduces the average income loss due to having a teenage birth by 6.17%.

If we fully introduce the *Norwegian Taxes* in the baseline economy, the redistribution effect dominates and the teenage birth rate decreases by 13.99%. The differences in taxation between the United States and Norway can account for 19.99% of the difference in teenage birth rates between the two countries. The average income loss due to teenage childbearing reaches 6.90%.

The introduction of Norwegian redistributive features of public education expenditures reduces the teenage birth rate by 16.31%. This quantitative experiment affects mostly households at the lower end of the income distribution. This is due to the fact that the dispersion of education spending for households at the bottom of the income distribution is higher in the U.S. than in Norway. This implies that by introducing the redistributive features of *Norwegian Public Education* we reduce the number of poor families that receive very low public education investments. Therefore, the teenage birth rate for teenagers growing up in these families drops.

If we impose the average levels of Norwegian public education expenditures into the baseline economy, all households face higher government investments, which reduces the teenage birth rate by 19.16%. An increase in public education expenditures from the U.S. mean levels to those of Norway increases the option value of not having a teenage birth. This effect is again more pronounced among the very poor. Teenage daughters of constrained parents start exerting birth control effort now, since their only source of investments, the government, increases spending.

The combination of the redistributive features and levels of *Norwegian Public Education* reduces the teenage birth rate by 19.83%. This effect is slightly higher to the one achieved by

introducing *Norwegian Taxes* in the baseline economy, because it does not reduce the incentives to avoid a teenage birth for teenagers coming from high income families. The reduction in teenage birth rates due to public education expenditures is able to account for 27.67% 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 and transfer and public education policies can account for the differences in teenage births between the United States and Norway. The full implementation of the *Norwegian Welfare State* reduces the teenage birth rate in the baseline economy by 16.75%. The reduction in teenage birth rates in this final set of experiments can then account for 23.62% of the observed country differences in teenage childbearing. The total reduction is smaller than the reduction due to the implementation of the *Norwegian Public Education* policy, because higher average tax rates reduce disposable income at the upper end of the income distribution. This translates to lower investments and slightly higher teenage birth rates in high income families.

Figure 12: Quantitative Experiments - Distributional Changes

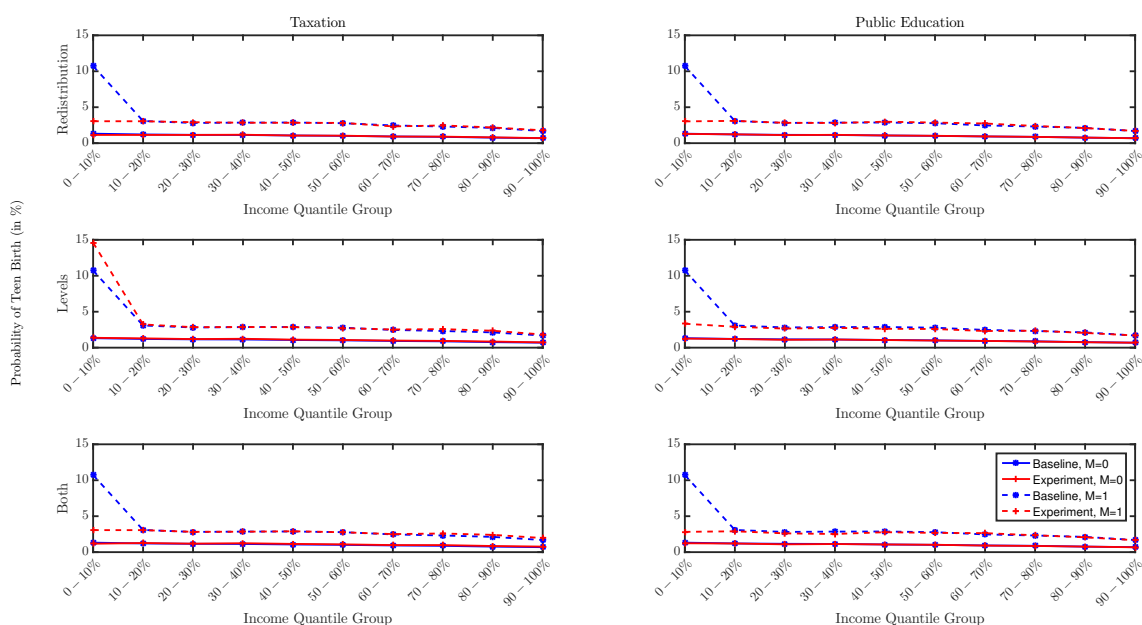


Figure 12 plots the teenage birth rates across deciles of the parental income distribution in the quantitative experiments against the ones in the baseline economy. The left-hand side column of figures illustrates the three tax and transfer experiments and the right-hand side figures present

the three education spending experiments. The reduction of teenage births comes almost entirely from families at the lower end of the income distribution (more specifically in the poorest decile), where the parent had a teenage birth herself ($M = 1$). This is in line with the results in [Kearney and Levine \(2012\)](#) and [Kearney and Levine \(2014\)](#) who argue that a large share of teenage births comes from teenage daughters who are stuck at the lower end of the income distribution, and that if their economic situation improves and they see chances for a decent future income, teenage birth rates among these economically disadvantaged females might go down significantly. How changes in the economic environment are induced seems to play only a secondary role. What matters is that due to more redistributive public policies, teenagers perceive their future to be valuable enough to bear the utility cost of preventing a teenage birth.

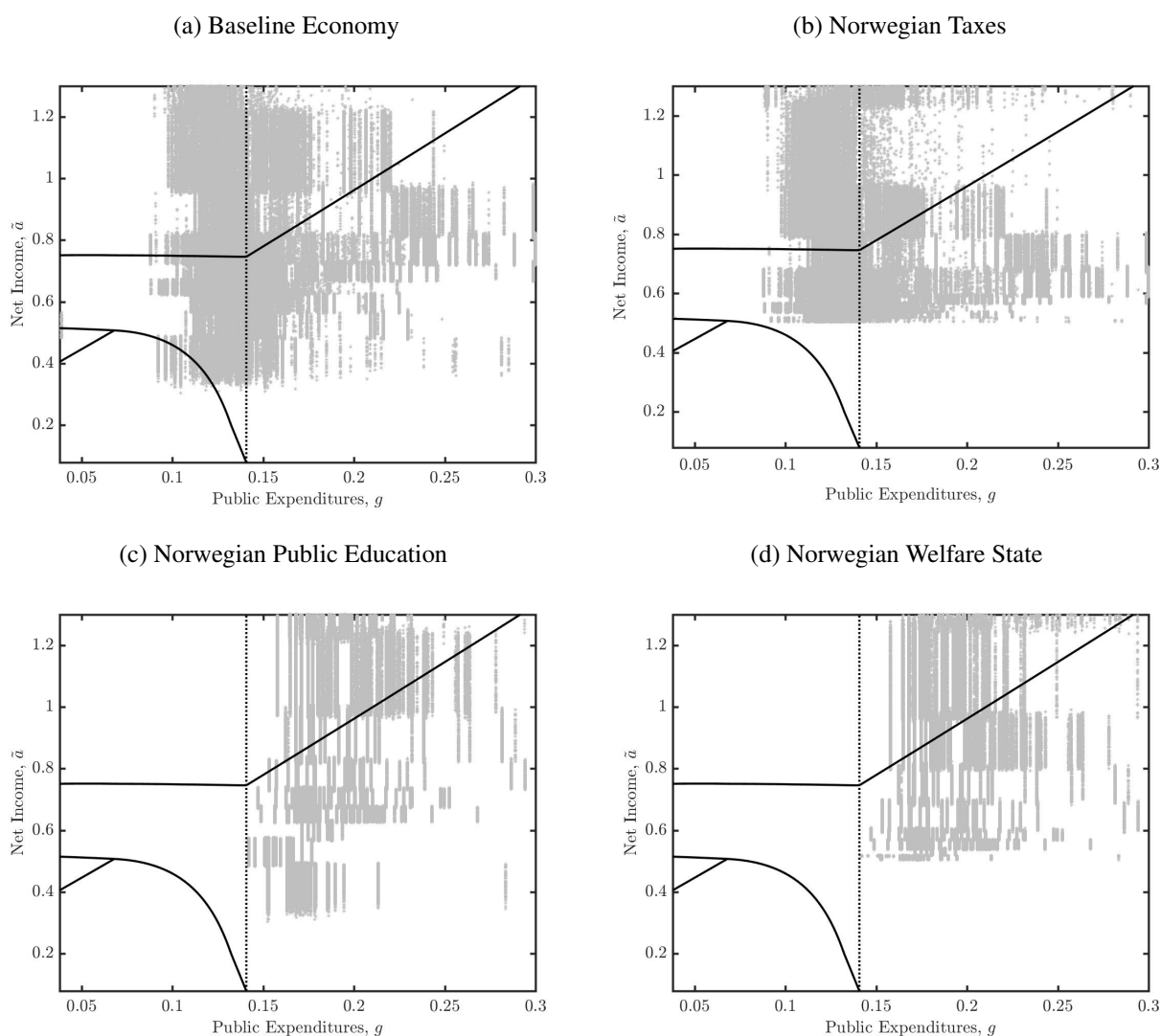
The decline of teenage childbearing in the poorest decile is particularly strong, because the number of households of family types **D**, **E** and **F** decreases dramatically when *Norwegian Public Education* policies and/or *Norwegian Taxes* are introduced. Figures 13a to 13d depict the distribution of households of different family types in the baseline economy and in the counterfactual experiments.³³

In the baseline economy 78.0% of the households are of type **A** or **B**, where parents are unconstrained and invest in their children. The parents in 7.9% of the households use private investments only to incentivize their teenage daughters to exert effort in order to avoid teenage childbearing (type **D**). 13.5% of all parents are type **C** households. They do not invest in their children, but public investments are enough to ensure that their teenagers exert effort. Finally, there are 0.6% of type **E** and **F** households. Teenagers living in these households have high risk of teenage birth, because they do not exert effort when they are initiated.

When *Norwegian Taxes* are introduced, the distribution of households moves *north* in the plane of public expenditures and net income and households formerly belonging to type **E** or type **F** now move to type **D** (see Figures 13a and 13b). As a consequence, teenagers in these households start to exert effort when initiated and the rate of teenage childbearing falls. Similarly, the introduction of the *Norwegian Public Education* policies shifts the distribution *east* and all households are located above the threshold \bar{g} (Figure 13c). Therefore, all teenagers exert birth control effort, even in the absence of private investments. Combining both policies does not produce a further reduction of teenage childbearing because each of the two policies, *Norwegian Taxes* and *Norwegian Public*

³³The location of different household types in the plane of public expenditures and net income is defined in Section 4.4.1 and Figure 11.

Figure 13: Distributions of Household Types



Education, already ensures that all teenagers exert some birth control effort.

6 Conclusions

Teenage childbearing patterns vary across developed countries. The teen birth rate in the United States is several times higher than in all other countries. “Children” having children is a sensitive social matter in American context because it carries consequences for both the teenagers and the future of their babies. Here we construct and estimate a game-theoretic model of teenage risky sexual activity. The simulated version of the model matches well stylized facts about teenage

childbearing in the United States. Through a series of counterfactual experiments based on the model, we find that differences in taxation and public education expenditures can account for up to 28% of the difference in teenage birth rates between the United States and Norway. Our results suggest that redistributive policies can successfully reduce the teenage birth rate and improve social mobility.

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Appendices

A Data

Figure 1 - The teenage birth rate is defined as the number of births per 1000 women aged 15-19 and the data is from the Worldbank's World Development Indicators (series SP.ADO.TFRT). The probability of teen birth is defined as the share of teenage births out of total births. It is computed by adjusting the teenage birth rate by the total fertility rate (series SP.DYN.TFRT.IN).

Figure 2 - The income groups in Figure 2 are defined using total income of the respondent's family (variable *totincr*) from the 2006-2010 NSFG. The probability of teen birth is defined as in Figure 1. It is computed from the variable *hasbabes* and indicates if a respondent ever had a live birth. The probability of sex initiation is the share of teenagers that become sexually active before they turn 20. It is computed based on the variable *rhadsex*. Details for the definition of the income groups and the computation of the probability of teen birth and the probability of sex initiation can be found in the Online Appendix.

Figure 3 - The probability of teen birth and the probability of sex initiation are defined and computed as in Figure 2. The division of data by parent childbearing status is based on variable *agemomb1* from the NSFG 2006-2010.

Figure 4 - Redistribution is measured by the the Reynolds-Smolensky index, that is, net income Gini coefficient minus the gross income Gini coefficient. Public education expenditures per student are normalized to the annual average wage. We employ data from OECD.Stat.

Figure 5 - We measure inequality using the net income Gini coefficient from OECD.Stat. 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 UNICEF (2007). The *generational earnings elasticity* measures the percentage of parental earnings advantage passed on to the children. We present father-son earnings elasticities computed by Corak (2013). They refer roughly to the 1990s.

Figure 6 - Net-income schedules are obtained from OECD wage benefits data. The online appendix provides further information on computational details.

Figure 7 - 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).

Figure 8 - We estimate the distribution of public education expenditures by centile of the income distribution using the data from Figure 7.

B Proofs

First, we outline some basic properties of the model in the Lemmas below. Second, we present a concise proof of Proposition 1 in the text. We also state an assumption which ensures that the second-order sufficient condition in problem (5) is satisfied.

Lemma 1. *The option value of avoiding teenage childbearing has the following properties:*

(i) *It is a non-negative increasing function of investments, $\frac{\partial \Lambda}{\partial b}(b, g) = \frac{\partial \Lambda}{\partial g}(b, g) > 0$.*

(ii) *It is a concave function, which in this case implies that $\frac{\partial^2 \Lambda}{\partial b^2}(b, g) = \frac{\partial^2 \Lambda}{\partial g^2}(b, g) = \frac{\partial^2 \Lambda}{\partial b \partial g}(b, g) < 0$.*

Proof. The option value can be expressed as $\Lambda(b, g) = \theta_0 \theta_1 \log(1 + \lambda(b + g))$ using equation (1). Straightforward differentiation leads to the results in (i) and (ii). \square

Lemma 2. *Assuming an interior solution, the decision rule function $e(b, g)$ exists, is continuously differentiable and increasing in investments, that is, $\frac{\partial e}{\partial b}(b, g) > 0$ and $\frac{\partial e}{\partial g}(b, g) > 0$.*

Proof. The statements follow directly from the Implicit Function Theorem. In particular, it is easy to show that

$$\frac{\partial e}{\partial b}(b, g) = \frac{\partial e}{\partial g}(b, g) = -\frac{\delta \Xi'(e(b, g)) \frac{\partial \Lambda(b, g)}{\partial b}}{\delta \Xi''(e(b, g)) \Lambda(b, g) + (1 - \delta) c''(e(b, g))} > 0.$$

The signs of the partial derivatives above are derived using the assumed properties of $c(e)$ and $\Xi(e)$, and the fact that $\Lambda(b, g)$ is a non-negative and increasing function (Lemma 1). \square

Lemma 3. *The probability of having a teenage birth for an initiated teenager, $\Xi(e)$, evaluated at the optimal effort of birth control $\mathbf{e}(b, g)$ is a decreasing function of investments, $\frac{\partial \Xi}{\partial b}(\mathbf{e}(b, g)) < 0$ and $\frac{\partial \Xi}{\partial g}(\mathbf{e}(b, g)) < 0$.*

Proof. The first derivatives of Ξ with respect to investments are

$$\frac{\partial \Xi}{\partial b}(\mathbf{e}(b, g)) = \Xi'(\mathbf{e}(b, g)) \frac{\partial \mathbf{e}}{\partial b}(b, g) < 0$$

and

$$\frac{\partial \Xi}{\partial g}(\mathbf{e}(b, g)) = \Xi'(\mathbf{e}(b, g)) \frac{\partial \mathbf{e}}{\partial g}(b, g) < 0.$$

The signs of the derivatives above come from the fact that $\Xi'(e) < 0$ and Lemma 2. \square

Lemma 4. *The threshold value for sexual initiation $\xi^*(b, g)$ is increasing in investments b and g .*

Proof. The threshold value as a function of b and g is given by

$$\xi^*(b, g) = c(\mathbf{e}(b, g)) + \frac{\delta}{1 - \delta} \Xi(\mathbf{e}(b, g)) \Lambda(b, g).$$

We can use the first-order condition (6) for the teenager's problem to express

$$\frac{\delta}{1 - \delta} \Lambda(b, g) = -\frac{c'(e)}{\Xi'(e)}.$$

Therefore,

$$\xi^*(b, g) = c(\mathbf{e}(b, g)) - c'(\mathbf{e}(b, g)) \frac{\Xi(\mathbf{e}(b, g))}{\Xi'(\mathbf{e}(b, g))}.$$

Differentiating and rearranging terms we get

$$\frac{\partial \xi^*}{\partial b}(b, g) = \Upsilon(b, g) \frac{\partial \mathbf{e}}{\partial b}(b, g) > 0,$$

$$\frac{\partial \xi^*}{\partial g}(b, g) = \Upsilon(b, g) \frac{\partial \mathbf{e}}{\partial g}(b, g) > 0,$$

where

$$\Upsilon(b, g) = \frac{\Xi(\mathbf{e}(b, g))}{\Xi'(\mathbf{e}(b, g))^2} (c'(\mathbf{e}(b, g))\Xi''(\mathbf{e}(b, g)) - c''(\mathbf{e}(b, g))\Xi'(\mathbf{e}(b, g))) > 0$$

Taking into account the results in Lemma 2, the sign of the partial derivatives above is determined by the sign of the expression $\Upsilon(b, g)$. It can be shown to be positive using the assumed properties of $c(e)$ and $\Xi(e)$. \square

Lemma 5. *The probability of sexual initiation as a function of investments when the preference shock ξ is unknown is given by $\int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi)$. It can be shown that this probability is decreasing in investments b and g , that is, $\frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi)}{\partial b} < 0$ and $\frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi)}{\partial g} < 0$.*

Proof. We can express the probability of initiation as

$$\int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi) = \int_{\xi^*(b, g)} dF(\xi) = 1 - F(\xi^*(b, g)).$$

Thus,

$$\frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi)}{\partial b} = -F'(\xi^*(b, g)) \frac{\partial \xi^*}{\partial b}(b, g) < 0,$$

and

$$\frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi)}{\partial g} = -F'(\xi^*(b, g)) \frac{\partial \xi^*}{\partial g}(b, g) < 0.$$

The signs of the partial derivatives above are derived by using Lemma 4. □

Lemma 6. *The probability of a teenage birth as a function of investments, when the preference shock ξ is unknown, is given by*

$$\Xi^*(b, g) = \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi) \Xi(\mathbf{e}(b, g)).$$

It can be shown that this probability is decreasing in investments b and g , that is, $\frac{\partial \Xi^(b, g)}{\partial b} < 0$ and $\frac{\partial \Xi^*(b, g)}{\partial g} < 0$.*

Proof. We can express the partial derivatives of interest as

$$\begin{aligned} \frac{\partial \Xi^*(b, g)}{\partial b} &= \frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi^*) dF(\xi)}{\partial b} \Xi(\mathbf{e}(b, g)) + \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi) \Xi'(\mathbf{e}(b, g)) \frac{\partial \mathbf{e}}{\partial b}(b, g) \\ &= \Phi(b, g) \frac{\partial \mathbf{e}}{\partial b}(b, g) < 0, \end{aligned}$$

and

$$\begin{aligned} \frac{\partial \Xi^*(b, g)}{\partial g} &= \frac{\partial \int_{\xi} \mathbf{s}(b, g, \xi^*) dF(\xi)}{\partial g} \Xi(\mathbf{e}(b, g)) + \int_{\xi} \mathbf{s}(b, g, \xi) dF(\xi) \Xi'(\mathbf{e}(b, g)) \frac{\partial \mathbf{e}}{\partial g}(b, g) \\ &= \Phi(b, g) \frac{\partial \mathbf{e}}{\partial g}(b, g) < 0, \end{aligned}$$

where

$$\Phi(b, g) = -F'(\xi^*(b, g)) \Upsilon(b, g) \Xi(\mathbf{e}(b, g)) + (1 - F(\xi^*(b, g))) \Xi'(\mathbf{e}(b, g)) < 0$$

The signs of $\Phi(b, g)$ and the partial derivatives above are derived using Lemmas 2, 4 and 5. □

Assumption 1. The expected utility from the future income of the teenager to the parent is given by

$$\mathcal{EU}(b, g) = (1 - \Xi^*(b, g)) \log(\mathbf{a}(b, g, \mathbf{0})) + \Xi^*(b, g) \log(\mathbf{a}(b, g, \mathbf{1})).$$

Assume that

$$\alpha \frac{\partial^2 \mathcal{EU}(b, g)}{\partial b^2} < \frac{1 - \alpha}{(\tilde{a} - b)^2}.$$

This ensures that the second-order condition of problem (5) is satisfied. The condition is satisfied when the probability function $\Xi^*(b, g)$ is sufficiently convex.

Lemma 7. Assuming an interior solution, the decision rule function $\mathbf{b}(\tilde{a}, g)$ exists and is continuous, differentiable, increasing and concave in income, that is, $\frac{\partial \mathbf{b}}{\partial \tilde{a}}(\tilde{a}, g) > 0$ and $\frac{\partial^2 \mathbf{b}}{\partial \tilde{a}^2}(\tilde{a}, g) < 0$. A unit increase in public investments g crowds out less than a unit of private investment, that is, $|\frac{\partial \mathbf{b}}{\partial g}(\tilde{a}, g)| < 1$.

Proof. The Implicit Function Theorem can be applied to the optimality condition (8) for parental investments,

$$\frac{\partial \mathbf{b}}{\partial \tilde{a}}(\tilde{a}, g) = \frac{\frac{1-\alpha}{(\tilde{a}-b)^2}}{\frac{1-\alpha}{(\tilde{a}-b)^2} - \alpha \frac{\partial^2 \mathcal{EU}(b, g)}{\partial b^2}} > 0.$$

Furthermore,

$$\frac{\partial \mathbf{b}}{\partial g}(\tilde{a}, g) = \frac{\alpha \frac{\partial^2 \mathcal{EU}(b, g)}{\partial b \partial g}}{\frac{1-\alpha}{(\tilde{a}-b)^2} - \alpha \frac{\partial^2 \mathcal{EU}(b, g)}{\partial b^2}} < 0$$

and

$$|\frac{\partial \mathbf{b}}{\partial g}(\tilde{a}, g)| < 1.$$

The signs of the expressions are derived using the assumed properties of $\mathcal{EU}(b, g)$ and the fact that $\frac{\partial^2 \mathcal{EU}(b, g)}{\partial b \partial g} = \frac{\partial^2 \mathcal{EU}(b, g)}{\partial b^2}$. \square

Proof of Propostion 1. The partial derivatives of interest can be expressed as

$$\frac{\partial \Xi^{**}}{\partial \tilde{a}}(\tilde{a}, g) = \frac{\partial \Xi^*}{\partial b}(\mathbf{b}(\tilde{a}, g), g) \frac{\partial \mathbf{b}}{\partial \tilde{a}}(\tilde{a}, g) < 0.$$

Next,

$$\begin{aligned} \frac{\partial \Xi^{**}}{\partial g}(\tilde{a}, g) &= \frac{\partial \Xi^*}{\partial b}(\mathbf{b}(\tilde{a}, g), g) \frac{\partial \mathbf{b}}{\partial g}(\tilde{a}, g) + \frac{\partial \Xi^*}{\partial g}(\mathbf{b}(\tilde{a}, g), g) \\ &= \Phi(b, g) \frac{\partial \mathbf{e}}{\partial b}(b, g) \frac{\partial \mathbf{b}}{\partial g}(\tilde{a}, g) + \Phi(b, g) \frac{\partial \mathbf{e}}{\partial g}(b, g) < 0. \end{aligned}$$

The signs of the partial derivatives are derived using Lemmas 6 and 7.

Online Appendices

C Data

C.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 *rhadssex*) and whether they ever had a live birth (variable *hasbabes*). We summarize 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 dataset and because this classification produces the smoothest teenage birth and initiation rate distributions.

The variable *hasbabes* reports whether 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 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 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 reported by 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*).

C.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 the 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 2006-2010.

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 these households are the relevant group in our model. Our estimate of the Gini coefficient for the year 2005 is 0.424.

C.3 Redistribution

We measure *redistribution* by the reduction of the net income Gini coefficient compared to the gross income 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 2006 to 2010.

C.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 [UNICEF \(2007\)](#).

C.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 by [Corak \(2013\)](#). They refer roughly to the 1990s and cover a wide range of countries. Because our model focuses on female teenagers, we adopt in our estimation the earning elasticity of combined (family) earnings for a female with respect to her parents' earnings from [Raaum et al. \(2007\)](#). They estimate the earning elasticity to be 0.408.

C.6 Taxes

We build our tax functions using data from the 2010 edition of the OECD publication *Taxing Wages* ([OECD, 2011](#); [Immervoll, 2010](#)). The OECD dataset provides data on net income taking into account central and local government taxes, social security contributions and government transfers to households. For low earnings the average tax rate might be negative. This implies that households receive government transfers exceeding their income tax bill. The OECD.Stat webpage provides³⁴ a dataset where net income is presented as a function of gross income, measured in units of the annual average wage. The dataset contains net incomes for gross income levels ranging from 0% to 200% of the average wage, in 1% increments. We compute average net income for the period 2006-2010 for single earner married couples and single mothers with 2 children. We take the weighted average across the two net income schedules and store the generated data as a linear spline interpolant. The weights reflect the relative share of single and married households in the

³⁴See http://stats.oecd.org/index.aspx?DataSetCode=TABLE_I6# for the dataset.

data.

C.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).

D Robustness

D.1 Elasticity of substitution between b and g

When we estimate the model we assume that private and public investments in education are perfect substitutes. In order to assess the robustness of our mechanism we relax this assumption and reduce the value of the parameter π from one to 0.75 and 0.5. We re-estimate the value of the parameters related to the income process (θ_0 , θ_1 , θ_2 , λ , ψ , σ_ν and μ) and keep the remaining ones at their baseline values. The initial guess for the optimization routine is the baseline solution. Table B.1 shows the estimates and summary statistics for the simulated economies. The point estimates of the model parameters do not change much when the elasticity of substitution between private and public substitution is reduced. A lower value of π increases the curvature of the productions function. As a consequences the new estimates of the parameters that determine the curvature of the production function (θ_0 , θ_1 , θ_2 and λ) change to adjust for it. This means that θ_0 and λ decrease, while θ_1 and θ_2 increase. Furthermore, the lower values of π imply higher values for the persistence parameter ψ and the volatility parameter σ_ν , and the lower values for the constant μ .

When we only re-estimate the parameters that determine the the teenager's income process, the model fit becomes slightly worse. In particular, the teenage birth rate and intergenerational mobility fall and the income loss due to having a teenage birth rises.

When we change the elasticity of substitution between private and public investments the re-

sults of the counterfactual experiments do not change qualitatively. With lower values of π , the impact of a change in the welfare state institutions tends to have a stronger impact on the teenage birth rate, the sex initiation rate and the wage loss. We observe this effect, despite lower teenage birth and sex initiation rates and a larger wage loss in the baseline model.

Table B.1: Robustness - Parameters and Summary Statistics

Parameter	Description	$\pi = 1.00$	$\pi = 0.75$	$\pi = 0.50$
θ_0	Income process	0.7424	0.7233	0.7168
θ_1	Income process	0.2024	0.2185	0.2186
θ_2	Income process	0.5077	0.5591	0.5862
λ	Income process	23.7334	22.2933	15.9454
ψ	Persistence of ability	0.1059	0.1094	0.1374
σ_ν	Std of ability shock	0.6332	0.62777	0.6921
μ	Income intercept	-1.6709	-1.7263	-1.8283
	Teenage Birth Rate	1.82%	1.74%	1.71%
	Sex Initiation Rate	44.63%	44.46%	44.42%
	Income Loss of Teenage Birth	16.98%	17.59%	18.00%
	Share with No Birth Control	0.75%	0.76%	0.75%
	Mean Income	1.01	1.00	1.01
	Gini Income	0.453	0.446	0.471
	Intergen Mobility	0.418	0.360	0.325

Table B.2: Robustness - Quantitative Results

Elasticity Parameter	Deviations from Baseline Economy							
	Norwegian Taxes		Norwegian Public Education		Norwegian Welfare State			
	Redistribution	Levels	Both	Redistribution	Levels	Both		
Teenage Birth Rate, $\Delta\%$	$\pi = 1.00$	-17.16%	11.98%	-13.99%	-16.31%	-19.16%	-19.83%	-16.75%
	$\pi = 0.75$	-16.85%	21.97%	-15.04%	-17.51%	-16.48%	-20.07%	-17.13%
	$\pi = 0.50$	-18.20%	55.07%	-15.08%	-13.63%	-14.62%	-20.63%	-18.04%
Sex Initiation Rate, $\Delta\%$	$\pi = 1.00$	-0.07%	0.28%	0.17%	-0.07%	-0.24%	-0.22%	0.02%
	$\pi = 0.75$	-0.10%	0.32%	0.11%	-0.12%	-0.24%	-0.27%	-0.08%
	$\pi = 0.50$	-0.24%	0.65%	-0.06%	-0.15%	-0.30%	-0.36%	-0.23%
Wage Loss, $\Delta\%$	$\pi = 1.00$	10.01%	-6.17%	6.90%	8.90%	12.79%	13.02%	9.76%
	$\pi = 0.75$	11.06%	-10.05%	9.00%	11.63%	11.56%	13.91%	10.33%
	$\pi = 0.50$	13.26%	-22.10%	10.54%	9.44%	10.67%	16.14%	13.52%