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ARTICLE

Teenage childbearing and the welfare state

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Abstract

Teenage childbearing is a common incident in developed countries. However, teenage births are much more likely in the USA than in any other industrialized country. Most of these births are delivered by female teenagers from low-income families. The hypothesis put forward here is that the *welfare state* (a set of redistributive institutions) has a significant influence on teenage childbearing behavior. We develop an economic theory of parental investments and the risky sexual behavior of teenagers. The model is estimated to fit stylized facts about income inequality, intergenerational mobility, and the sexual behavior of teenagers in the USA. The welfare state institutions are introduced via tax and public education expenditure functions derived from US data. In a quantitative experiment, we impose Norwegian taxes and 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 USA and Norway.

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

JEL Classification: E24; H31; I28; J13; J24; J62

1. Introduction

Teenage childbearing is a widespread phenomenon in the industrialized world. However, teenagers in the USA give birth far more often than their counterparts in other developed countries. 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.[1] What makes the US 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% of teenage births in the USA 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.[2]

Preventing teenage childbearing has been a high priority among policymakers in the USA throughout the last three decades (National Research Council 1987; Solomon-Fears 2016). The general public is also concerned with the topic.[3] 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 become teenage mothers.[4] Teenage childbearing also leads to increased public spending due to increased health care, child welfare, incarceration, and lost tax revenue.[5]

While factors such as religiosity and cultural attitudes can contribute to the cross-country difference in the teenage birth rate, recent empirical work suggests that geographic variation in economic inequality also plays an important role (Kearney and Levine (2012)).[6] In this paper, we hypothesize that teenage childbearing is influenced heavily by the amount of redistribution in society. Think of a simple representation of the world in which 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 negatively affects future income, especially if investments are high. Teenagers who receive more investments from their parents or the government are potentially more cautious in avoiding unintended births due to the higher opportunity cost of bearing a child.

How do the welfare state institutions influence teenage childbearing? First, if the societal system of taxes and transfers becomes more favorable toward families with lower income levels, the investments made by these families in their offsprings would be lifted up. This might lead to 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 negatively correlated across developed countries (Fig. 4a). Second, higher public education expenditures would also alter the childbearing behavior of teenagers. Teenage childbearing becomes costly when investments are higher.[7] 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 (Fig. 4b).[8]

This paper aims to develop a theory of teenage risky activities and to quantitatively assess the extent to which redistribution can affect teenage childbearing. To achieve this goal, we build a model of parental investments in children and risky teenage sexual behavior. In our framework, parents influence the future well-being of their teenage daughters by investing in their education. The investment increases the expected future income of teenagers. Teenager daughters choose whether to be sexually active or not. If sexually active, she might become a teenage mother with some probability. A costly birth control effort can influence the likelihood of teenage birth. Early childbearing has adverse effects on the future household income of the adolescent. Teenager daughters 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 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 a 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 that collects taxes from and delivers transfers to households. It also spends some of its resources on public education. We dub these two government functions as the *welfare state*.

In order to take the model to the data, we enrich the economic environment with additional features including birth control and childcare expenses. The estimation strategy relies on a *simulated method of moments* procedure. The estimated model replicates stylized facts on inequality, intergenerational income mobility, teenage births, and sexual initiation in the USA at the start of the twenty-first century. The welfare state is introduced via tax-and-transfer and public education expenditure functions derived from US 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 adopting the Norwegian taxation and public education expenditure policies in the USA leads to a 17.42% reduction in the teenage birth rate, accounting for 25.75% of the USA–Norway gap in the teenage birth rate.[9] The effect is mostly driven by the Norwegian public education expenditure policy, which is more generous on average. While the Norwegian taxation policy is more progressive, the average tax rate is also higher, which reduces the ability for poor households to invest in their children in order to incentivize abstinence or birth control.

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 result from deeper, underlying social and economic problems. A companion paper empirically documents 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 USA (Kearney and Levine (2014)). Our work is similar in spirit. We base our study on the fact that teenage birth rates are positively correlated with inequality and child poverty and negatively correlated with intergenerational income mobility across developed countries.[10] This implies that countries with high-income inequality and low intergenerational mobility of income and social status tend to have higher teenage birth rates.[11]

Our work contributes to 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 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 half of the variation in mobility between the USA and other developed countries. Similarly, Herrington (2015) explores taxation and education expenditures as sources for differences in earnings inequality and intergenerational mobility between the USA and Norway. After carefully documenting cross-country facts about hours worked by married couples, Bick and Fuchs-Schündeln (2017) 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 an unintended birth to the female teenager, reducing her future household income. Duncan and Hoffman (1990), Rosenzweig (1999), and Wolfe et al. (2001) represent earlier attempts to relate the childbearing choices of teenagers to choice-conditioned future opportunities. They all find that future expected income penalties for early childbearing significantly impact the probability of 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 interactions between teenagers' risky behavior, government education expenditures, and parental 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.[12] Keane and Wolpin (2010) build and estimate a structural model to understand the variations in economic behavior between white and minority women. An economic model of parental socialization of children about sex is presented in Fernández-Villaverde et al. (2014). The framework can account for increased premarital sex and out-of-wedlock births over the twentieth century. The advances in contraception technology are shown to be the primary driver of this trend.[13] 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 USA and evaluates how the introduction of North European welfare institutions would influence the US teenage childbearing rate.

Doepke and Zilibotti (2017) provide a theory of preference transmission within the family. In their setup, parents choose parenting styles that mold children's preferences and restrict 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 society. Our focus is not on endogenous preference transmission but instead 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, the nature of the welfare state.

In a closely related paper, Seshadri and Zhou (2022) document a negative relationship between the rate of unintended births and education, highlighting its detrimental impact on intergenerational mobility. They find that reducing the cost of family planning among the poor increases upward mobility, thereby reducing income inequality. While we also study the consequence of fertility on intergenerational mobility, we focus on how welfare state institutions affect teenage childbearing and the implications for inequality.[14]

2. Stylized facts

This section documents the following stylized facts regarding teenage childbearing and the welfare state. These facts motivate the quantitative model we consider in the next section and quantitative analyses.

1. There is a large variation in the teenage birth rate among developed countries, with the USA having one of the highest rates. The variation is robust even after controlling for the total fertility rate.
2. Teenagers from low-income households have disproportionately high birth rates despite having similar sex initiation rate as other teenagers.
3. Teenagers that are children of teenage mothers are more likely to be sexually active and give birth.
4. Countries with high levels of redistribution tend to have fewer teenage births as a fraction of all births.
5. The teenage birth rate positively correlates with inequality and child poverty.
6. Relative to the USA, the Norwegian tax and transfer system is more progressive.
7. Relative to the USA, public education expenditure is more redistributive and higher per student in Norway.

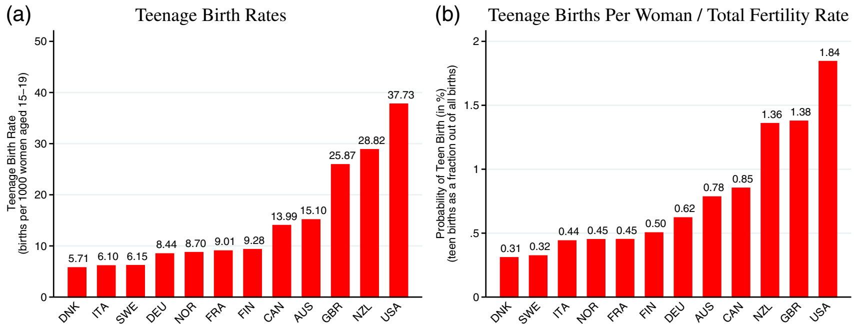

Figure 1. Teenage birth rates across countries (2006–2010).
Note: *(a)* The teenage birth rate is defined as the number of births per 1000 women aged 15–19 years, and the data are from the Worldbank's World Development Indicators (series SP.ADO.TFRT). *(b)* The probability of teen birth is defined as 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).

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 years. It 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 USA in the second half of the 2000s—see Fig. 1a.[15] 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 Fig. 1a. 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 USA than in Denmark.[16] It is hard to rationalize the huge differences in teenage childbearing between the USA and, especially, the Scandinavian countries because both regions have similar levels of economic development and sexual activity/contraception practices among adolescents.[17]

A look at the probability of teen birth at different sections of the income distribution of households with female teenagers in the USA reveals that the high number of teenage births comes from the lower end of the distribution—see Fig. 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 Fig. 2b. These observations point to the fact that teenage childbearing is high in the USA mainly because teenagers at the bottom of the distribution do not exert as much birth control effort as in the higher income categories.

Suppose we separate the parental households of female teenagers into two groups. The first group consists of households in which the parent, that is 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 Fig. 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 (Fig. 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.

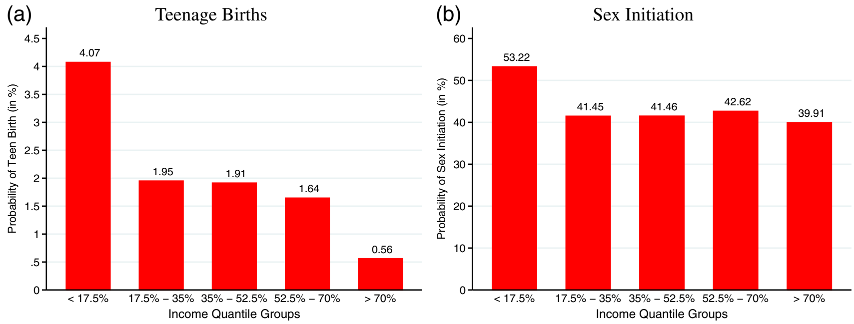

Figure 2. Teenage births and sex initiation across income groups, USA (2006–2010).
Note: *(a)* The income groups are defined using total income of the respondent's family (variable *totincr*) from the 2006–2010 NSFG. The probability of teen birth is defined as in Fig. 1. It is computed from the variable *hasbabes* and indicates if a respondent ever had a live birth. *(b)* 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 Appendix C.

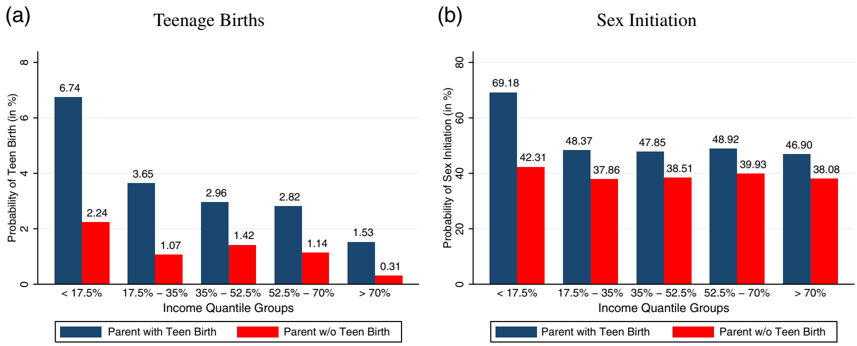

Figure 3. Teenage births and sex initiation across income groups conditional on parent childbearing status, USA (2006–2010).
Note: The probability of teen birth and the probability of sex initiation are defined and computed as in Fig. 2. The division of data by parent childbearing status is based on variable *agemomb1* from the NSFG 2006–2010.

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 toward 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)). Fig. 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.

Another important mechanism of redistribution that provides investments for generating future income to children of poor parents is public education. Fig. 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.[18]

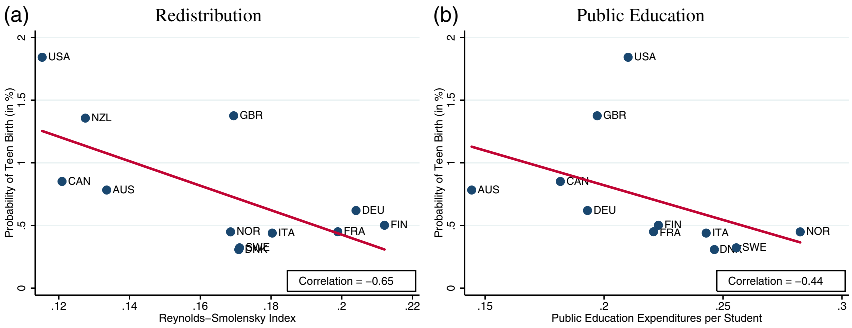

Figure 4. Teenage births and the welfare state (2006–2010).
Note: *(a)* Redistribution is measured by the Reynolds–Smolensky index, that is, net income Gini coefficient minus the gross income Gini coefficient. *(b)* Public education expenditures per student are normalized to the annual average wage. We employ data from OECD.Stat.

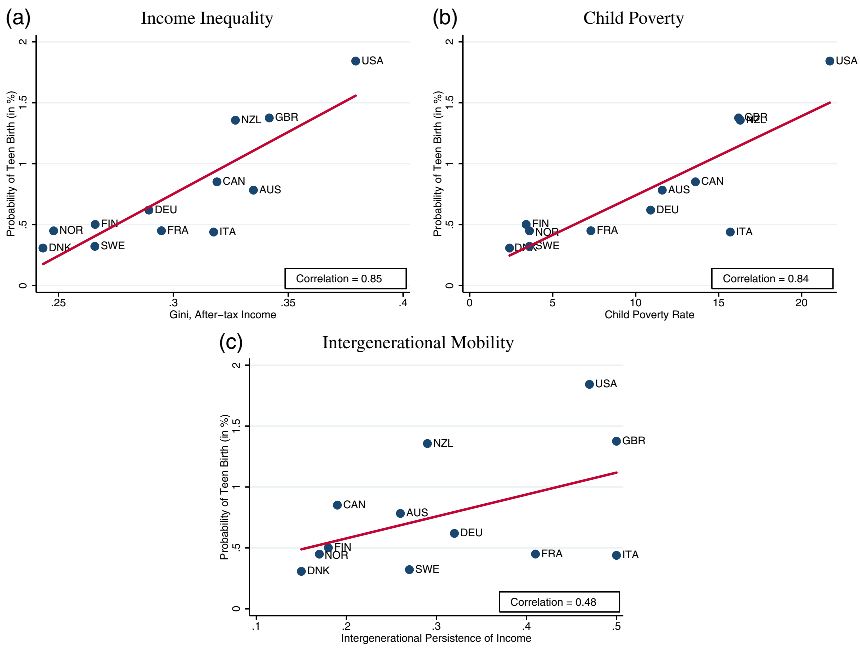

Figure 5. Teenage births, child poverty, income inequality, and intergenerational mobility (2006–2010).
Note: *(a)* We measure inequality using the net income Gini coefficient from OECD.Stat. *(b)* The *child poverty rate* represents the percentage of children living in households with incomes below 50% of national median income and refers to time points around the year 2000. We employ the data from UNICEF (2007). *(c)* 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.

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 Fig. 5a. Moreover, we find a positive correlation between child poverty and teenage birth rates across the OECD countries—see Fig. 5b.[19] 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. Fig. 5c confirms that intergenerational mobility is negatively correlated with teenage childbearing across countries.[20]

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 US data and is used to explore the interactions between taxation, public education, and teenage childbearing. We examine this interaction by introducing the Norwegian welfare state institutions into the US economy. We select to study the disparities in teenage childbearing between the USA and Norway because these two countries have very different patterns of teenage childbearing. The USA 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 USA (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)). Fig. 6 presents the *tax and transfer* systems of the USA 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 USA. 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.

Fig. 7a and b plot the distributions of public education expenditures per student in primary/middle/high school on the median household labor income of counties in the USA 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 USA, whereas in Norway the opposite pattern occurs.[21]

Another insightful observation based on the information in Fig. 7 is that the dispersion of education expenditures, across counties/municipalities ordered by median income, differs significantly between the USA 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 country-wide 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.

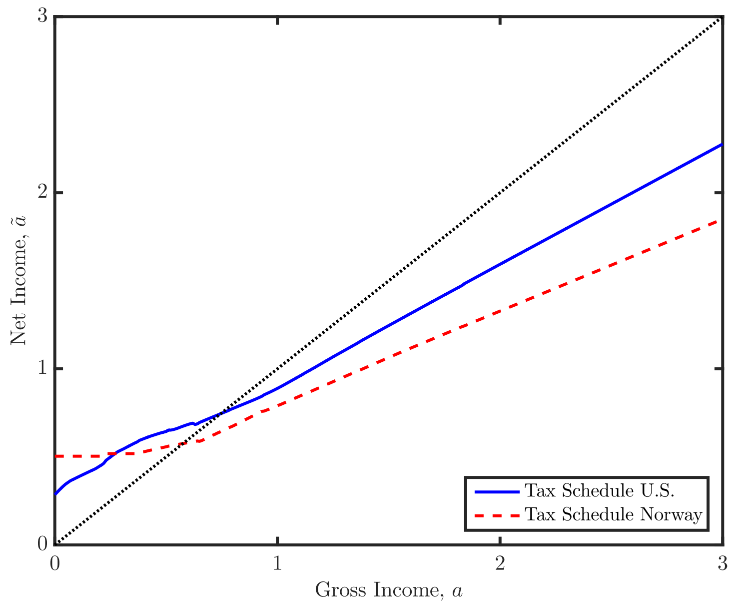

Figure 6. Taxes and transfers, USA and Norway.
Note: Net income schedules are obtained from OECD wage benefits data. One unit corresponds to the average annual wage. Appendix C.6 provides further information on computational details.

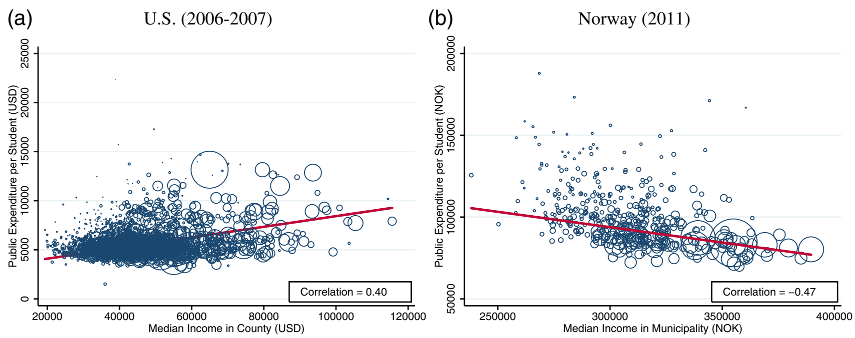

Figure 7. Public education expenditures by counties/municipalities.
Note: *(a)* We employ public expenditure data for the USA from the National Center for Education Statistics Common Core of Data through the Elementary/Secondary Information System (ELSi) application. We use the variable *total current 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. *(b)* 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).

The results are presented in Fig. 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 USA is much more dispersed than the Norwegian one and dispersion is increasing with income. Norwegian public spending is less progressive than what could be expected from Fig. 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 USA for almost all income groups.

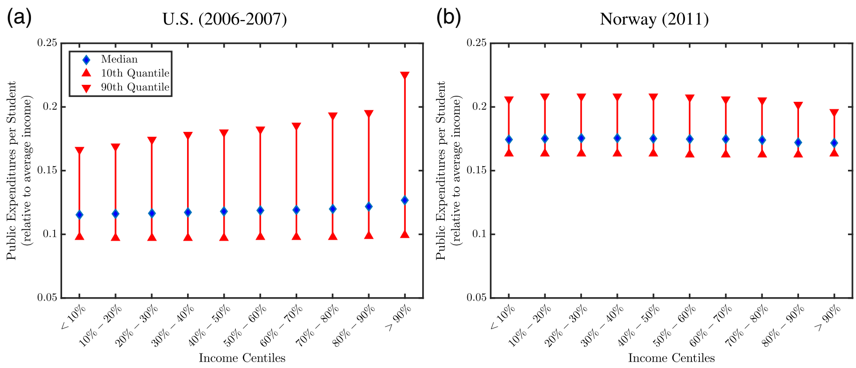

Figure 8. Estimated public education distributions.
Note: We estimate the distribution of public education expenditures by centile of the income distribution using the data from Fig. 7.

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).[22] Teenagers derive utility of being sexually active, and they care about their future household income as adults. Parents derive utility from consumption and from the teenager's future household income. The future income level of teenagers is determined by an income process which takes as inputs private investment made by the parent and public investment provided by the government. 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 and the government-provided investment to their children. Teenage daughters differ by their taste for sex and the investments they receive from their parents and the government. Each parent–teenager pair plays 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 sexual activities. 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.[23] Birth control is associated with a utility cost. Finally, the potential birth occurs (or not) to the teenage daughter and future household income 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 from Norway and the USA.

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 and increasing 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.[24]

3.1.1. Income

The future household income of the teenager when she becomes a parent is denoted by $a' = \mathbf{a}(b, g, y')$, a function of private and public investments b and g and the teenage birth indicator y'. In particular, future log-income is given by:

$$\log(\mathbf{a}(b, g, y')) = (1 - \theta_0 y')\,(b + g)^{\lambda}. \tag{1}$$

Investment inputs here are perfectly substitutable and the parameter $\lambda \in (0, 1)$ implies decreasing returns to total investment.[25] A teenage birth can have some negative consequences for future income. This is portrayed by the parameter θ_0. 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 line with the cross-sectional evidence presented in Fig. 2. A graphical representation of this argument is outlined in Fig. 9 below.

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_0 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)).

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

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

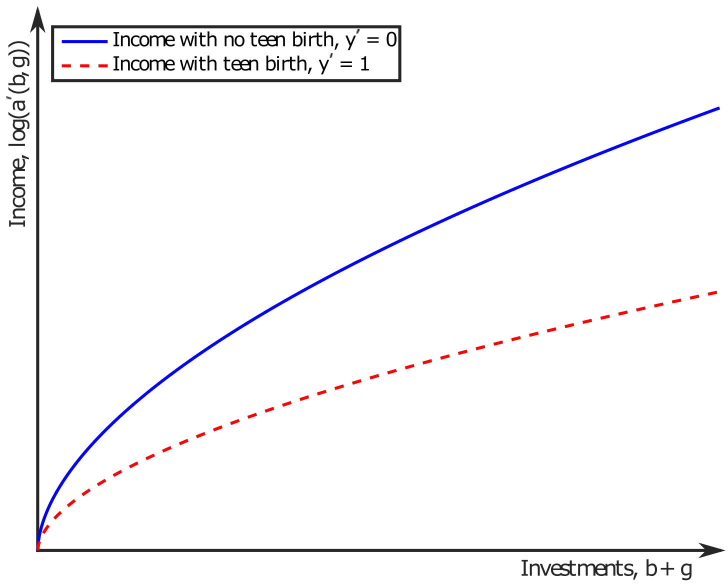

Figure 9. Income and investments—the role of a teen birth.

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:

$$\widetilde{V}^1(b,g,\xi) = \max_{e\geq 0} (1-\delta)\,(\xi - c(e))$$

$$+\,\delta\,\Xi(e)\log(\mathbf{a}(b,g,\mathbf{1}))$$

$$+\,\delta(1-\Xi(e))\log(\mathbf{a}(b,g,\mathbf{0})). \tag{2}$$

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 (2). 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 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.[26] 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

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

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 utility of future income without a teen birth.

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:

$$V(b, g, \xi) = \max_{s \in \{0,1\}} \{(1 - s) \underbrace{\tilde{V}^0(b, g)}_{\text{Abstinence}} + s\underbrace{\tilde{V}^1(b, g, \xi)}_{\text{Sex}}\} \tag{3}$$

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 $\xi^\star$ is such that $\tilde{V}^1(b, g, \xi^\star) = \tilde{V}^0(b, g)$. Teenagers with a taste for sex below $\xi^\star$ would be abstinent, while teenagers with a taste shock above it would be sexually active. The threshold value of the sex taste shock $\xi^\star = \xi^\star(b, g)$ can be represented as a function of private and public investment in the teenager's future.

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 (2017)). 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, $\mathbf{s}(b, g, \xi)$, and birth control, $\mathbf{e}(b, g)$, 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 realization of the potential birth to the teenager, y', is not yet known.

The decision problem of the parent is given by:

$$W(a,g) = \max_{b \in [0,(1-\tau(a))a]} (1-\alpha)\log(c)$$

$$+\alpha \int_{\xi} \Big\{ (1-\mathbf{s}(b,g,\xi))\log(\mathbf{a}(b,g,\mathbf{0}))$$

$$+\mathbf{s}(b,g,\xi)\Xi(\mathbf{e}(b,g))\log(\mathbf{a}(b,g,\mathbf{1}))$$

$$+\mathbf{s}(b,g,\xi)(1-\Xi(\mathbf{e}(b,g)))\log(\mathbf{a}(b,g,\mathbf{0}))\Big\} dF(\xi) \tag{4}$$

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 (4). For a particular mix of investments, b and g, and sex taste, ξ, the teenager may decide to stay sexually abstinent, that is $\mathbf{s}(b,g,\xi)=0$. In this case, her future income will be given by $\mathbf{a}(b,g,\mathbf{0})$. This is the case depicted in the second line of the problem. However, if the teenager has sex, $\mathbf{s}(b,g,\xi)=1$, she faces a teenage birth with probability $\Xi(\mathbf{e}(b,g))$. In this case her future income is determined by $\mathbf{a}(b,g,\mathbf{1})$. Of course, she might avoid giving birth while a teenager with probability $1-\Xi(\mathbf{e}(b,g))$. In this case, her income in the future is defined by $\mathbf{a}(b,g,\mathbf{0})$. To form the final expression for the expected utility of the parent out of the future income of the teenager, one needs to integrate over all possible realizations of the taste for sex, ξ. The decision rule of the parent with respect to investments is $\mathbf{b}(a,g)$.

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, that is 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 $\mathbf{s}(b,g,\xi)$ and $\mathbf{e}(b,g)$. 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 $\mathbf{b}(a,g)$. 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, $\mathbf{s}(b,g,\xi)$ and $\mathbf{e}(b,g)$, 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 the equilibrium is unique, the derived decision rules of parents and teenagers constitute a unique sub-game perfect Nash equilibrium. The two decision sub-problems of the teenager (2) and (3) yield a unique solution in terms of decision rules $\mathbf{e}(b,g)$ and $\mathbf{s}(b,g,\xi)$. 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 (2) is satisfied. If the solution of the parental problem (4) yields a unique solution, then the sub-game perfect Nash equilibrium is also unique.[27]

The decision problem of a sexually initiated teenager depicted in (2) gives rise to the following optimality condition (in the case of an interior solution) for the choice of birth control effort, e,

$$-(1-\delta)\,c'(e)=\delta\,\Xi'(e)\Lambda(b,g). \tag{5}$$

Condition (5) 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 $\mathbf{e}(b,g)$ exists and the level of optimal effort rises with both investments (see Lemma 2 in Appendix B).

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 $\Xi^\star\left(b,g\right)$. 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:

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

The probability of a teenage birth perceived by the parent decreases in investments b and g (see Lemma 6 in Appendix B). We can reformulate the decision problem (4) of the parent using this probability:

$$\begin{aligned}W(a,g)=\max_{b\in[0,(1-\tau(a))a]}&\,(1-\alpha)\log\left(c\right)\\ &+\alpha(1-\Xi^\star\left(b,g\right))\log\left(\mathbf{a}(b,g,\mathbf{0})\right)\\ &+\alpha\,\Xi^\star\left(b,g\right)\log\left(\mathbf{a}(b,g,\mathbf{1})\right)\end{aligned} \tag{6}$$

subject to

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

The decision problem (6) 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,

$$\frac{1-\alpha}{\tilde{a}}=\alpha\left[1-\Xi^\star\left(b,g\right)\right]\frac{\frac{\partial\mathbf{a}}{\partial b}(b,g,0)}{\mathbf{a}\left(b,g,0\right)}+\alpha\,\Xi^\star\left(b,g\right)\frac{\frac{\partial\mathbf{a}}{\partial b}(b,g,1)}{\mathbf{a}\left(b,g,1\right)}-\alpha\frac{\partial\,\Xi^\star}{\partial b}(b,g)\Lambda(b,g), \tag{7}$$

where $\tilde{a}=(1-\tau(a))a$ is net income of the parent. Condition (7) 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 (7) 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 (7) exists and the level of parental investment rises with net income of the household but decreases with government investments (see Lemma 7 in Appendix B).

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:*

$$\Xi^{\star\star}\left(\widetilde{a},g\right)=\Xi^\star\left(\mathbf{b}(\widetilde{a},g),g\right).$$

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

Proof. *See Appendix B.* □

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 US 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 1,000,000 households. We draw household incomes from county-specific income distributions and pair them with public education expenditures drawn from the conditional distribution $G\left(g|a\right)$.[28] The distribution is estimated from regional data on public education expenditures in the USA. 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 teenagers 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.

Birth Control and Childcare Expenses. In the model introduced in Section 3, greater tax progressivity has the unambiguous effect of reducing the teenage birth rate because low-income parents can afford to invest more in their children's education. In reality, however, families also have to contemplate the potential cost of raising a grandchild born to a teenage daughter. Parents are incentivized to invest in their children's education not only out of altruism but also to reduce the likelihood of having grandchildren born to their teenage daughters. Greater tax progressivity can ease the financial burden of raising a grandchild for low-income families, potentially weakening the incentive to prevent the arrival of a grandchild. Considering the cost of raising a grandchild, the effect of tax progressivity on the teenage birth rate becomes an open quantitative question.

To better capture the interplay between the welfare state and the teenage fertility decision, we introduce a childcare cost in the case of teenage child birth in our quantitative model. We also allow for a monetary cost of birth control that incurs to the parents of teenage girls. We assume the cost of raising a grandchild born to a teenage daughter is κ share of the parent's income. In addition to the private education investment b, parents choose to spend d on birth control, which reflects the costs of contraception and abortion. The birth control expenditure translates into a maximum birth control effort $\bar{e}(d)$ that the daughter can exert, which is an increasing function in d. That is, a sexually active daughter can only exercise safe sex or get an abortion if the parent is willing to pay for these birth control measures.

Specifically, a sexually active teenager's problem (equation (2)) becomes

$$V^1(b, d, g, \xi) = \max_e \left\{(1-\delta)(\xi - c(e)) + \delta\,\Xi(e)\log\left(\mathbf{a}(b, g, 1)\right) + \delta(1-\Xi(e))\log\left(\mathbf{a}(b, g, 0)\right)\right\},$$

subject to

$$e \geq 0, \quad e \leq \bar{e}(d).$$

The parent's problem (equation (6)) becomes

$$\begin{aligned} W(a, g) = \max_{b,d} \Big\{ &\Xi^*(b, d, g)\left[(1-\alpha)\log\left(c^1\right) + \alpha\log\left(\mathbf{a}(b, g, 1)\right)\right] \\ &+(1-\Xi^*(b, d, g))\left[(1-\alpha)\log\left(c^0\right) + \alpha\log\left(\mathbf{a}(b, g, 0)\right)\right]\Big\}, \end{aligned}$$

subject to

$$\begin{aligned} c^1 &= (1-\kappa)(1-\tau(a))a - b - d, \\ c^0 &= (1-\tau(a))a - b - d, \\ b &\geq 0, d \geq 0, \end{aligned}$$

where $\Xi^*(b, d, g)$ is the probability of a teen birth, which now also depend on the birth control expenditure d because the optimal birth control effort depends on d. c^0 and c^1 are the consumption of the parent in the case without and with teen birth, respectively.

Intergenerational Transmission of Teenage Childbearing. As shown in Fig. 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

$$\log\left(a'\right) = (1-\theta_0 y')(1-\theta_1 M)(b+g)^{\lambda}. \tag{8}$$

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_1.[29] The parameter λ controls the efficiency of investments and 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.[30]

Disutility of exerting birth control effort. We allow for a fixed component in the utility cost of exerting 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.[31] We assume that the disutility of the birth control effort, $c(e)$, is given by:

$$c(e) = \mathbb{I}_{\{e>0\}}\left(\omega_0 + \omega_1 e\right).$$

Other functional form assumptions. The probability function of a teenage birth conditional on the exerted effort, $\Xi(e)$ in assumed to be

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

The distribution of the sex preference shock, ξ, is assumed to follow a normal distribution conditional on the status of the mother as a teenage parent. The distribution of ξ for those who did not born to a teenage parent has mean μ_0 and variance σ_0^2. For those born to a teenage parent, the mean and variance are μ_1 and variance σ_1^2.

4.2. A priori information

4.2.1. Tax and transfer schedule

We calibrate the tax function $\tau(\cdot)$ to the observed relationship between net and gross incomes in the data. Specifically, we use data on income taxes, social security contributions and transfers for the USA and Norway from the OECD Taxing Wages modules. The US 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 the simulated gross income is larger than the maximum level obtained from the data, we linearly extrapolate the schedule to obtain net income.[32]

4.2.2. Public education expenditures

Public education expenditures per student vary with the median income of counties or municipalities in the USA and in Norway, respectively (Fig. 7). US 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 USA (*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 US 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 expenditures. Then, we divide the simulated US income distribution into decile groups and compute the empirical distribution of the public education expenditures for each of these groups.[33] In the simulation of the quantitative model households receive education expenditure levels g from the decile-specific empirical distribution associated with their income.

4.2.3. Birth control and childcare expenses

Guner et al. (2012) estimate that the cost of raising a child between age 0 and 5 years is about 10% of the average household income in 2005 based on data from the Survey of Income and Program Participation. We use this to calibrate the cost of raising a child to be $\kappa = 0.1$.

To calibrate the function $\bar{e}(d)$, the maximum birth control effort given expenditure d (as a fraction of the mean annual gross income), we note the maximum birth control effort translates into the maximum birth control success probability given by $\bar{\Xi}(\bar{e}) \equiv 1 - \Xi(\bar{e}) = \exp(-\bar{e})$. We can then write the relationship between birth control expense d and maximum birth control success probability Ξ as follows:

$$\bar{e}(d) = -\ln(\bar{\Xi}).$$

We use the observed relationship between birth control expenses and success rates to calibrate the function $\bar{e}(d)$. At zero birth control expense, the birth control success rate is 0%. According to Frost et al. (2019), the annual cost of contraception in the USA is \$316. The annual safe sex success rate is 72% according to Fernández-Villaverde et al. (2014). Planned Parenthood estimates that the average cost of an abortion (before the overturn of Roe v. Wade) is around \$1500. The abortion completion rate is 99.7% according to Weitz et al. (2013). Using these data points, we calibrate the function $\bar{e}(d)$ to be a linear function with a zero intercept and a slope equal to 157.18.[34]

4.3. Estimation

The estimation procedure involves **9** parameters. There are six preference parameters, $\{\alpha, \delta, \mu_0, \sigma_0, \mu_1, \sigma_1\}$, three parameters for the income process, $\{\lambda, \theta_0, \theta_1\}$ and two parameters for the birth control effort function, $\{\omega_0, \omega_1\}$.

These parameters are estimated to match as close as possible the following list of **24** 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 Fig. 3a and b.
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 mobilty of household income. We use the intergenerational income elasticity of females with respect to their parents.

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 the model parameters. The parameter θ_0 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). For the estimation, they use as a control group the teenagers that had a late miscarriage. 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%.

The fixed cost of effort ω_0 influences the share of teenagers who do not exert birth control effort in the model. Therefore, we recover the value of this parameter by targeting the fraction of sexually active teenagers who do not use any contraceptive technique. This data target is derived from the National Survey of Family Growth (NSFG) 2006–2010.

The remaining parameters are identified by the distributions of teenage birth rates and sexual initiation rates across income groups. We utilize again data from the NSFG for the period 2006–2010 to construct these distributions. In Appendix C.1 we describe how we adjust the teenage birth rates derived from the NSFG to make them consistent with aggregate data. Fig. 3 in Section 2 shows that teenage birth rates and sexual initiation rates decrease with parental income and are higher for teenagers with mothers who had teenage births themselves.

In our model, a teenager decides whether to be sexually active or not by comparing the value of the sex taste shock ξ to the threshold $\xi^\star(b,g)$. If the realization of the taste shock is below the threshold, the teenager remains abstinent. Thus, the parameters μ_M and σ_M for $M=0,1$ of the distributions of ξ are set to match the overall distribution of sex initiation by the status of the parent as a teenage mother (M). The parameter θ_1 controls the degree of investment inefficiency associated with a parent who had a teenage birth herself. Therefore, we can identify this parameter by matching the observed differences in teenage birth and initiation rates based on the teenage childbearing status of the parent.

We use the intergenerational income mobility to recover the utility weight α. The utility weight determines how much parents value the future income of their daughters and determines the level of private investment. 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 USA. The parameter λ determines the curvature of the income production function and influences the dispersion of future income. We use the Gini coefficient of gross household income of families with teenagers of 0.423 as a target.

The utility weight δ controls how much teenagers care about the income loss related to having a teenage birth. Therefore, an increase in δ leads to lower sexual initiation rates and teenage childbearing. An increase in the slope parameter of the effort cost function ω_1 makes it more costly to exert effort. Consequently, initiated teenagers exert less effort increasing the probability of having a teenage birth rate. However, higher utility costs of effort reduce the incentives to be sexually active and reduces sex initiation rates.

The discussion above points out that the parameters μ_0, σ_0, μ_1, σ_1, δ, and ω_1 are jointly determined by the level and shape of the teenage birth and sex initiation distributions. In Appendix D, we further discuss how these six parameters influence the targeted distributions.

4.3.1. Simulated method of moments

We define the parameter vector to be estimated as $\Theta=\{\alpha,\delta,\mu,\sigma,\theta_0,\theta_1,\lambda,\omega_0,\omega_1\}$ 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 $g(\Theta)=(g_1(\Theta),\ldots,g_{24}(\Theta))$ 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. Standard errors of the parameter estimates are computed using 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.

Parents put a high value on their child's future outcomes, $\alpha=0.916$. The parent's utility weight on future outcomes of the child is also larger than the teenager's utility weight, $\delta=0.183$. Thus, parents act in a paternalistic fashion when investing in their children. The fixed cost of exerting birth control effort is 0.022, which constitutes around 82% of the total birth control disutility cost

Table 1. Estimated parameters

Parameter	Description	Value	Std. error	95% confidence interval
α	Parents utility weight	0.9155	0.0640	[0.8448,0.9862]
δ	Teenagers utility weight	0.1829	0.0076	[0.1679,0.1979]
μ_0	Sex taste shock, M0	0.0170	0.0054	[0.0064,0.0276]
σ_0	Sex taste shock, M0	0.0466	0.014	[0.0186,0.0746]
μ_1	Sex taste shock, M1	0.0285	0.0049	[0.0189,0.0381]
σ_1	Sex taste shock, M1	0.0172	0.0082	[0.0011,0.0333]
θ_0	Income process	0.1786	0.0630	[0.0551,0.3021]
θ_1	Income process	0.4397	0.1082	[0.2276,0.6518]
λ	Income process	0.4840	0.0314	[0.4225,0.5455]
ω_0	Cost of effort	0.0220	0.0025	[0.0171,0.0269]
ω_1	Cost of effort	0.0012	0.0002	[0.0008,0.0016]

Table 2. Model fit—aggregate statistics

	Data	Baseline model
Teenage birth rate	1.84%	1.90%
Sex initiation rate	43.25%	43.17%
Income loss of teenage birth	17.26%	18.69%
Share with no birth control	1.14%	0.94%
Gini income	0.423	0.402
Intergen mobility	0.408	0.442

incurred to a sexually active teenager from an average-income household with a parent who did not have a birth as a teenager.

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 USA (see Table 2). As Fig. 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 (Fig. 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.

4.4.1. Decisions in the baseline economy

Figs 11a and b show how the optimal decisions of parents depend on their net income $\tilde{a}$ and public education expenditure g. Richer parents are able to spend more on their children in education investment and birth control. Birth control expense is smaller than private education investment because a small birth control expense can already achieve a high maximum birth control effort. Public education expenditure crowds out private education investment as the two are substitutes,

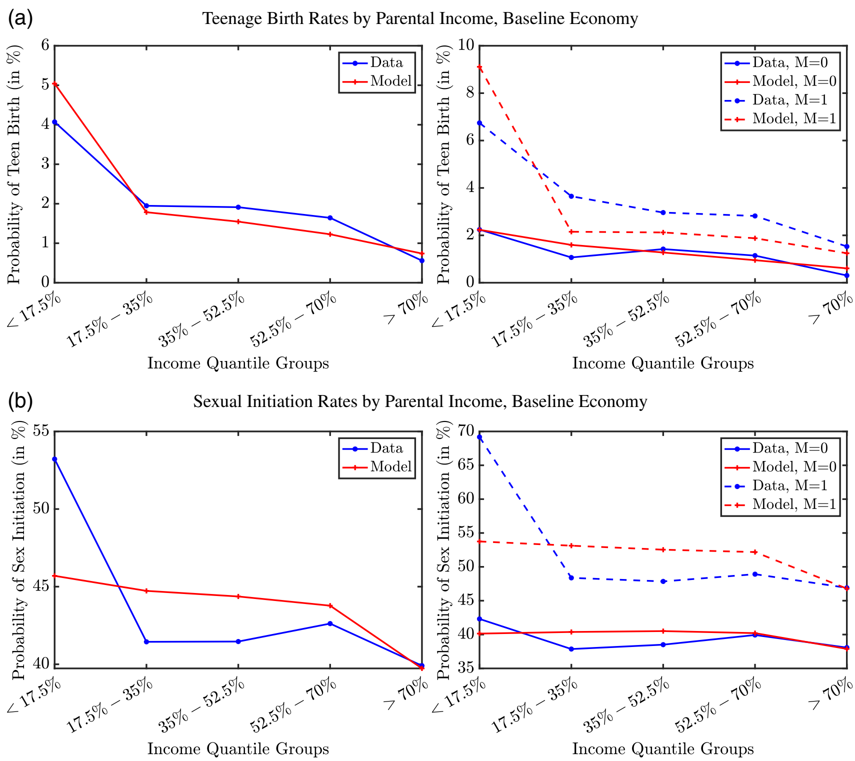

Figure 10. Model fit—distributions.

but the effect is small quantitatively. A higher public education expenditure leads to higher future incomes of the daughter in equilibrium, and thus a higher opporunity cost of a teenage birth. Therefore, parents spend more on birth control when g is higher.

Fig. 11c shows the optimal birth control effort decision of a teenager who faces a non-binding maximum effort constraint. The teenager's optimal effort decision increases in both private and public education spending (b and g). Higher education spendings increase the opportunity of a teenage birth, leading the teenager to exert more effort in birth control. The fixed cost ω_0 of birth control effort causes the optimal effort to have a discrete upward jump. When the sum of public and private education spending is too low, a sexually active teenage chooses to exert zero birth control effort because the marginal cost of effort at zero is high due to the fixed cost. Once the teenage decides to exert effort, she faces a lower marginal cost.

5. Quantitative analysis

To quantify the role of welfare state institutions in accounting for cross-country differences in teenage childbearing, we simulate counterfactual economies by substituting the US tax code and/or public education expenditures in the baseline US economy with that from Norway.[35]

Aggregate Effects. We conduct three sets of counterfactual experiments. In the first set of experiments, we incorporate the Norwegian tax schedule in the baseline economy. In the second set, we replace the US public education expenditures by their Norwegian counterpart. Finally, we introduce both of these Norwegian welfare state instruments into the US economy. The upper panel of Table 3 summarizes the results of the counterfactual experiments in terms of realized

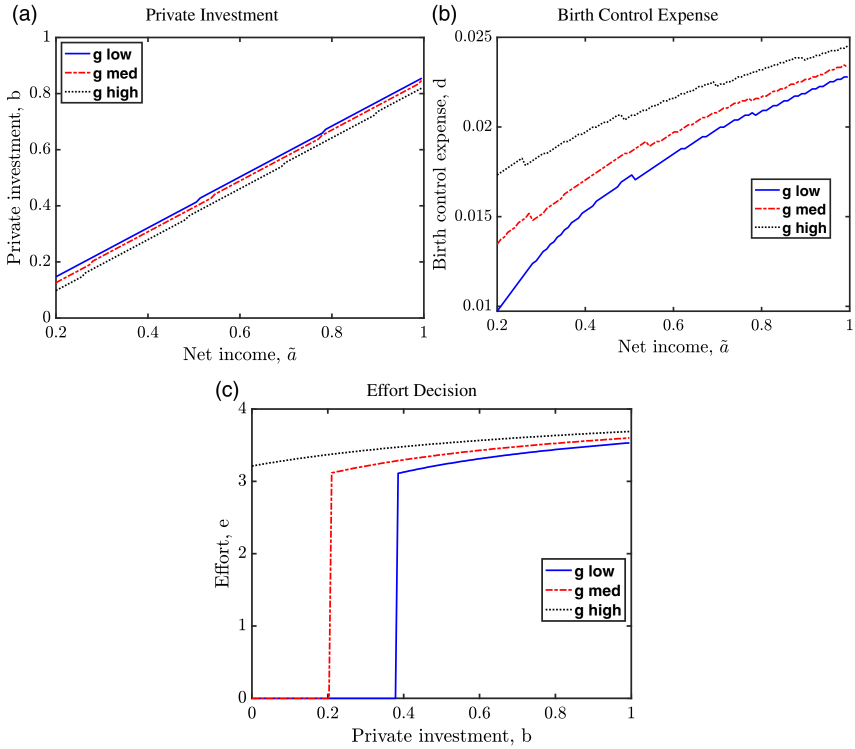

Figure 11. Household policy function.
Note: The policy functions are plotted for families with parents who were not a teenage mother. *Panel (c):* Effort decision is for the case when the maximum birth control constraint is not binding.

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 USA and Norway can be accounted for by the Norwegian welfare state institutions introduced in the experiments.

When substituting the US 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 US levels and insert the Norwegian tax progressivity or the Norwegian distribution of public education expenditures adjusted to match the average US education spending. Second, we retain redistribution at observed US levels and adjust average taxes or education expenditures to Norwegian levels. Third, we fully substitute the US 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 (2016), 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

Table 3. Quantitative results

	Baseline	Experiments						
	USA	Norwegian taxes			Norwegian public education			Norwegian
	Welfare state	Redistribution	Levels	Both	Redistribution	Levels	Both	*Welfare state*
Teenage birth rate	1.90%	1.37%	2.80%	1.95%	1.90%	1.57%	1.54%	1.57%
Sex initiation rate	43.17%	43.34%	43.58%	43.60%	43.17%	43.07%	43.08%	43.56%
Income loss of teenage birth	18.69%	21.67%	16.24%	19.05%	18.78%	20.57%	20.78%	21.04%
Gini income	0.402	0.386	0.390	0.374	0.401	0.397	0.396	0.368
Intergen mobility	0.442	0.400	0.425	0.383	0.439	0.424	0.424	0.366
		Deviations from baseline economy						
		Norwegian taxes			Norwegian public education			Norwegian
		Redistribution	Levels	Both	Redistribution	Levels	Both	*Welfare state*
Teenage birth rate, Δ%	–	−27.80%	47.01%	2.35%	−0.28%	−17.22%	−18.92%	−17.42%
Sex initiation rate,Δ%	–	0.40%	0.95%	1.00%	0.01%	−0.22%	−0.21%	0.90%
Income loss of teenage birth, Δ%	-	15.94%	−13.11%	1.91%	0.46%	10.05%	11.18%	12.57%
Gini coefficient, Δ%	–	−4.13%	−3.03%	−7.12%	−0.32%	−1.28%	−1.4%	−8.50%
Intergen mobility, Δ%	–	−9.60%	−3.92%	−13.40%	−0.61%	−4.06%	−3.96%	−17.14%
		Accounting for differences in teenage childbearing between the USA and Norway						
		Norwegian taxes			Norwegian public education			Norwegian
		Redistribution	Mean	Both	Redistribution	Mean	Both	*Welfare state*
USA–Norway teenage birth rate, Δ%	–	−41.07%	69.45%	3.46%	−0.41%	−25.45%	−27.96%	−25.75%

particular, imposing the overall *Norwegian Taxes* reduces significantly the level of intergenerational income mobility—the income elasticity goes from 0.442 down to 0.383. 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 education 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, as they put a high utility weight on their daughters' future income, the magnitude of this decrease in private investment is rather small.

A common result of all experiments is that sex initiation rates change only marginally when government policies are altered. In contrast, 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 in response to changing policies through exerting more birth control effort rather than abstaining from sex.[36]

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.[37]

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 US counterpart. When we impose the Norwegian levels of redistribution (keeping average taxes at the mean at US levels) on the baseline economy, the teenage birth rate decreases by 27.8%. 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 future income due to teenage childbearing rises with investments. Teenagers of more wealthy parents have little incentive 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 15.94%.

In contrast, increasing the average tax rates to Norwegian levels but keeping the US level of redistribution raises the teenage birth rate by 47.01%. 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 13.11%.

If we fully introduce the *Norwegian Taxes* in the baseline economy, the level effect dominates, and the teenage birth rate increases modestly by 2.35%. The average income loss due to teenage childbearing changes by merely 1.91%.

The introduction of Norwegian redistributive features of public education expenditures reduces the teenage birth rate by 0.28%. 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

USA 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 17.22%. An increase in public education expenditures from the USA 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 18.92%.

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 USA and Norway. The full implementation of the *Norwegian Welfare State* reduces the teenage birth rate in the baseline economy by 17.42%.

Overall, the introduction of the Norwegian welfare state policies can reduce the cross-country difference in the teenage birth rate by 25.75%, and this reduction is mostly driven by the introduction of the Norwegian public education policies. Although the Norwegian tax system leads to a more pronounced reduction in inequality, its high tax levels discourage private education investment, resulting in a higher teenage birth rate.

In addition to the welfare state policies we consider, the USA and Norway also differ in policies directly related to fertility such as public expenditure on birth control and childcare. In Appendix E.2, we show that, while more generous public birth control expenditures may reduce the teenage birth rate, more generous childcare subsidies may increase it.

Distributional Effects. We now turn to the distributional effects of the counterfactual experiments. Figs. 12a and 13a depict the effect of the counterfactual experiments on the teenage birth rate across the parental income distribution. Separately, both the Norwegian tax progressivity and its tax levels lead to a strong effect on the teenage birth rate of the lowest income group. However, the effects are opposite, with the former reducing the teenage birth rate and the latter increasing it. The two effects largely cancel out when both are introduced.

In contrast, implementing the Norwegian public education expenditure policy leads to a strong reduction in the teenage birth rate among the lowest income group, and this is driven by the effect of the Norwegian public education levels. The Norwegian public education progressivity has a negligible effect on the teenage birth rate for any income group. The effect from the lowest income group leads to an aggregate reduction in the teenage birth rate when the Norwegian public education policy is introduced.

To better understand the mechanisms behind the distributional effects, we plot the average private investment and birth control expense across the parental income distribution in Figs. 12b and c for the Norwegian tax experiments, and in Figs. 13b and c for the Norwegian public education experiments.

Implementing the Norwegian tax progressivity leads to a strong increase in both private education investment and the birth control expense for the lowest income group because the more progressive taxation increases the disposable income of the poor, allowing them to invest more in their children, both in education and birth control. The increase in parental education investment increases the opportunity cost of having a teenage birth, and the increase in birth control expense allows teenagers to exercise more birth control efforts. Overall, the teenage birth rate decreases for the lowest income group.

Instead, the higher Norwegian tax level lowers the disposable income of all households, reducing their private education investment and birth control expenses and increasing the teenage birth

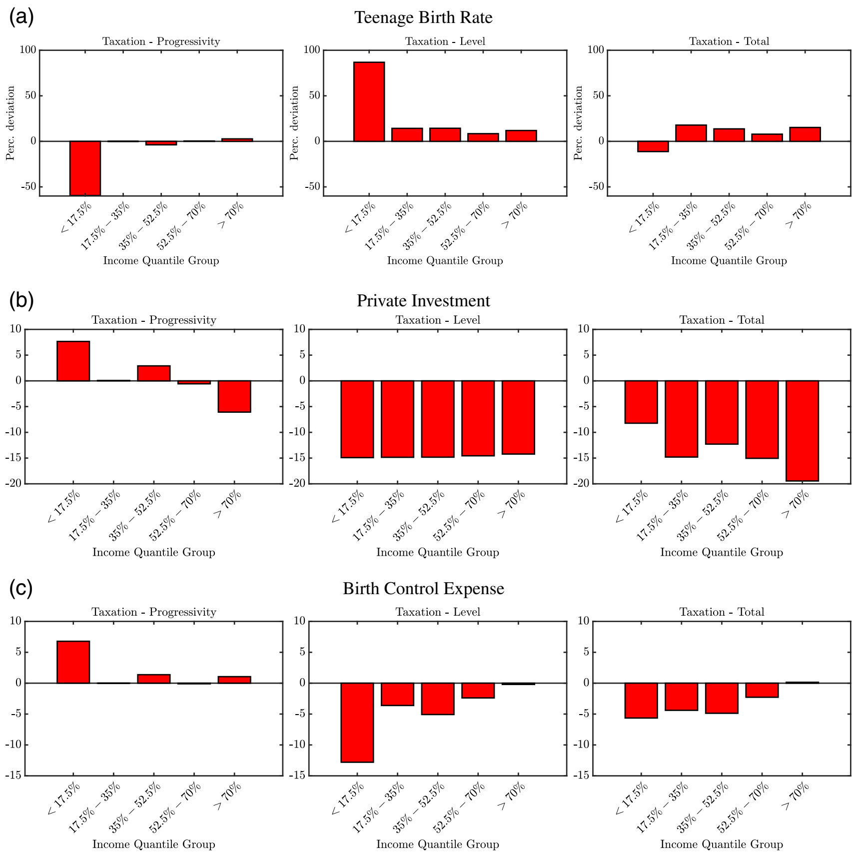

Figure 12. Distributional changes—taxation experiments.
Note: The graphs show the effects of counterfactual taxation experiments by parental income groups, measured in percentage deviation from the baseline experiment. "Progressivity": changing only the progressivity to the Norwegian level while keeping average taxes fixed at the US level. "Level": changing only the average taxes to the Norwegian level while keeping progressivity at the US level. "Total": changing both progressivity and level of the policy.

rate. The reductions are the most pronounced for the lowest income group, particularly for the birth control expense. As a result, the Norwegian tax level leads to an increase in the teenage birth rate, particularly for the lowest income group.

Public education expenditure policies have opposite effects on the private education investment and birth control expense. We focus on the experiment of introducing the Norwegian public education levels, as the progressivity experiment yields little quantitative effects. Increasing the average public education expenditure to the Norwegian level leads to reductions in the private education investment for all households, but most prominently for the lowest income group. This is because public education expenditure is a substitute for private education investment, and higher public education expenditure allows budget constraint low-income families to save on education investment.

The reduction in private education investment is accompanied by an increase in the birth control expense for all households; this increase is again the most pronounced for the lowest income group as poor parents can shift some of their budget from education investment to birth control expense. Overall, the effect of increased birth control expenses dominates the effect of reduced private education investment, and the teenage birth rate decreases for the lowest income group.

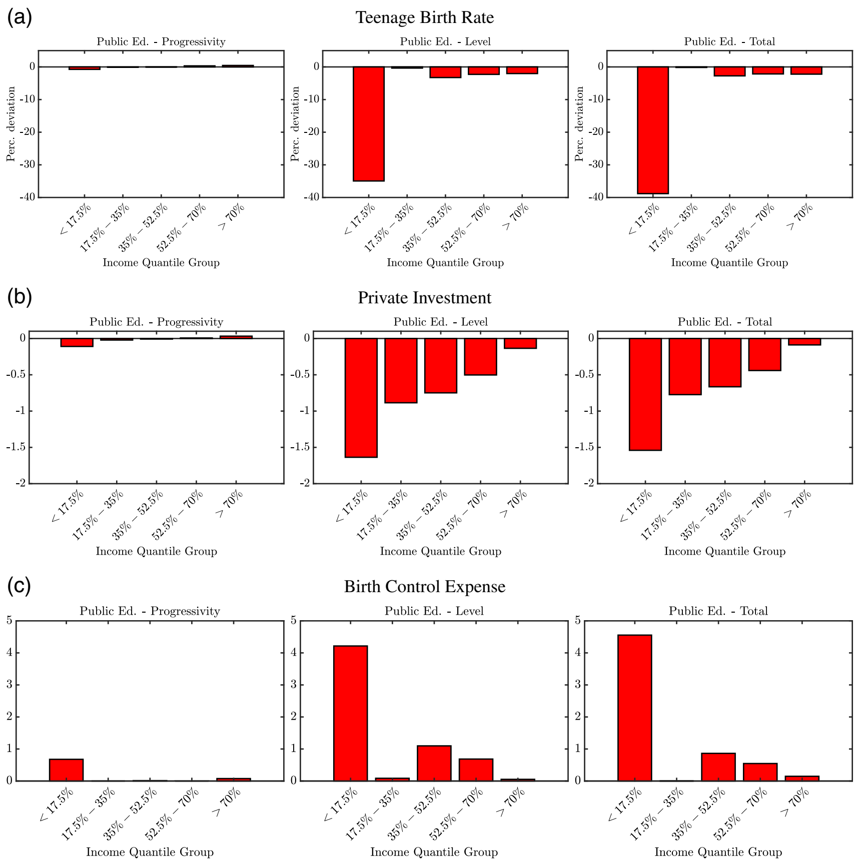

Figure 13. Distributional changes—public education expenditure experiments.
Note: The graphs show the effects of counterfactual public education expenditure experiments by parental income groups, measured in percentage deviation from the baseline experiment. "Progressivity": changing only the progressivity to the Norwegian level while keeping the average public education expenditure fixed at the US level. "Level": changing only the average public education expenditure to the Norwegian level while keeping progressivity at the US level. "Total": changing both progressivity and level of the policy.

6. Conclusions

Teenage childbearing patterns vary across developed countries. The teen birth rate in the USA is several times higher than in all other countries. "Children" having children is a sensitive social matter in the 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 USA.

Through a series of counterfactual experiments based on the model, we find that adopting the Norwegian taxation and public education expenditure policies in the USA can reduce the USA–Norway gap in the teenage birth rate by a quarter. The effect is mostly driven by the Norwegian public education expenditure policy, which is more generous on average. Our results suggest that public policies play an important role in understanding cross-country differences in teenage birth rates and point towards a potentially important mechanism that also could help explain other socially undesirable behaviors such as drug abuse and related criminal offenses.

Furthermore, we document that across all income groups, teenage birth rates and sex initiation rates are higher when the mother of the teenager had a teenage birth herself. Understanding the mechanism behind this observation is an interesting venue for future research.

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Notes

1 There has been a secular decline in teenage childbirths in the last three decades in OECD countries (Fig. 15). While the gap between the USA and Scandinavian countries has narrowed, it remains sizable. According to data from the World Bank, in 2020, the teen birth rate was 2.8 per 1000 women ages 15–19 in Norway, while the rate was 15.8 in the USA, 5.6 times that of Norway.

2 Relevant data facts are detailed in Section 2.

3 The *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 teenagers at risk, see Kearney and Levine (2015).

4 See 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.

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

6 Religiosity and cultural attitudes can, for example, affect teenagers' liberal attitudes toward abortion, which directly affect birth control decisions.

7 Sex education is part of public education and different countries may choose to fund different sex education programs with varying effectiveness in promoting safe sex. Such difference may also contribute to the cross-country gap in the teenage birth rate. However, only a very small fraction of public education expenditure is used for sex education in every country. The USA spends $261 million on sex education programs (Santelli et al. (2017)), while public K-12 expenditures total is $795 billion (Hanson (2023)). Throughout this paper, we consider only the impact of public education on human capital.

8 There is also evidence of this channel for the geographic variation in teenage childbearing across US states (Fig. 14).

9 The remaining gap may be due to factors such as effectiveness of public sex education, religiosity and cultural attitudes, and costs of birth control. In Appendix E.2, we find that the cross-country difference in the cost of birth control plays a quantitatively minor role in closing the gap in the teenage birth rate.

10 See Section 2 for details.

11 The 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 moves up the curve.

12 For a detailed description of this approach to economics and the existing literature, see Doepke and Tertilt (2016) and Greenwood et al. (2017).

13 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.

14 Bishnu et al. (2023) also study the effects of the public education policiy on fertility, but they focus on the policy interactions with pension support.

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

16 From 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.
17 See Santelli et al. (2008) for more details.
18 A similar negative correlation between public spending on education and teenage birth rates is present across US states, as shown in Fig. A.1 in Appendix A.
19 Child poverty is measured by the percentage of children living in households with incomes below 50% of national median income.
20 Fig. 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.
21 Our results are similar to those obtained by Herrington (2015). He derives similar scatter plots but at a school district level.
22 In our model males play no active role. Therefore, we exclude them from the decision-making process.
23 Birth control effort is a continuous variable that reflects efforts to both prevent pregnancies and abortion efforts. A lower birth control effort corresponds to only contraception, and a high effort corresponds to abortion.
24 Variables 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.
25 We relax this assumption in a series of robustness checks of the quantitative model. See Appendix E.1 for further details.
26 For details see Lemma 1 in the Appendix.
27 We impose a sufficient second-order condition, so that (4) yields a unique solution. Further details are presented in Appendix B.
28 We allocate households according to the relative size of the student population across counties and draw their income from a county-specific income distribution. We assume that the income distribution in each county is log-normal and recover its parameters from mean and median household income.
29 This inefficiency relates to the finding of Kahn and Anderson (1992) who argue that the intergenerational persistence of teenage childbearing operates at least partly through the socieconomic and family context in which children grow up.
30 In particular, the income process in these exercises is given by $\log(a') = (1-\theta_0 y')(1-\theta_1 M)(b^\pi + g^\pi)^{\lambda/\pi}$. The degree of substitution between inputs is measured by the parameter π. In the benchmark model, b and g are perfect substitutes, that is, $\pi = 1$. In robustness checks in Appendix E.1, we vary π between 0.75 to 0.5. The main results in our quantitative exercises remain intact.
31 We 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 as observed in the data.
32 The non-parametric tax and transfer schedules used in the analysis are depicted in Fig. 6 in Section 2.
33 The Norwegian distribution of education expenditures is estimated using identical procedure on data from Statistics Norway. Basic statistics of the resulting distributions are plotted in Fig. 8.
34 Note that the birth control expense as a function of birth control success rate is an increasing and convex function because $1 - \Xi(\bar{e})$ is increasing and concave in $\bar{e}$.
35 We do not consider policy differences between the two countries directly related to fertility, such as differences in childcare benefits or birth control subsidies. In Appendix E.2, we consider counterfactual economies with fertility policies.
36 These 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.
37 The income penalty of teenage childbearing increases in investments as depicted in Fig. 9.
38 See http://stats.oecd.org/index.aspx?DataSetCode=TABLE_I6# for the dataset.
39 Since the sex initiation threshold $\xi(b, g)$ is independent of the distribution of the sex taste shock, changes in the parameters μ and σ leave the decision rules of teenagers unchanged.

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Appendix

A. Additional stylized facts

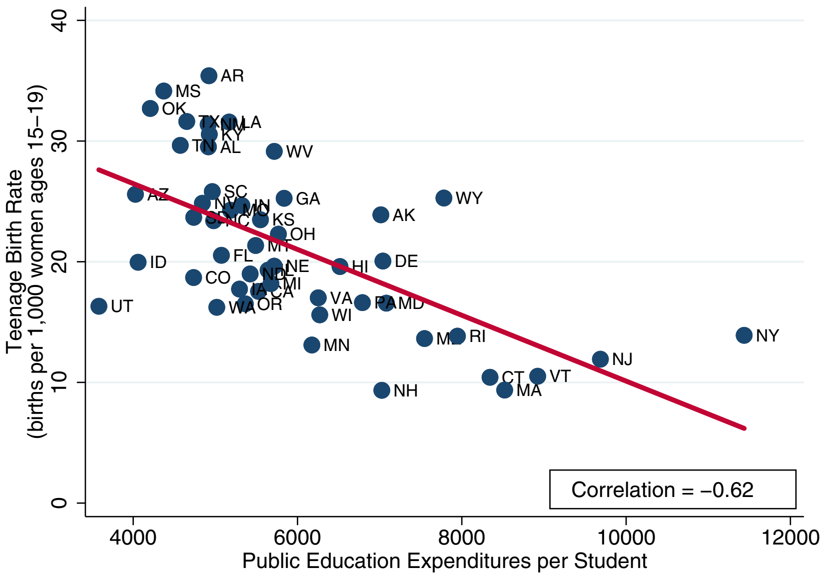

Figure A.1. Teenage births and public education across US states.

Note: Public expenditure data come from the National Center for Education Statistics Common Core of Data through the Elementary/Secondary Information System (ELSi) application. Teenage birth rate is defined as the number of births per 1000 women aged 15–19 years, and the data are from the World bank WDI.

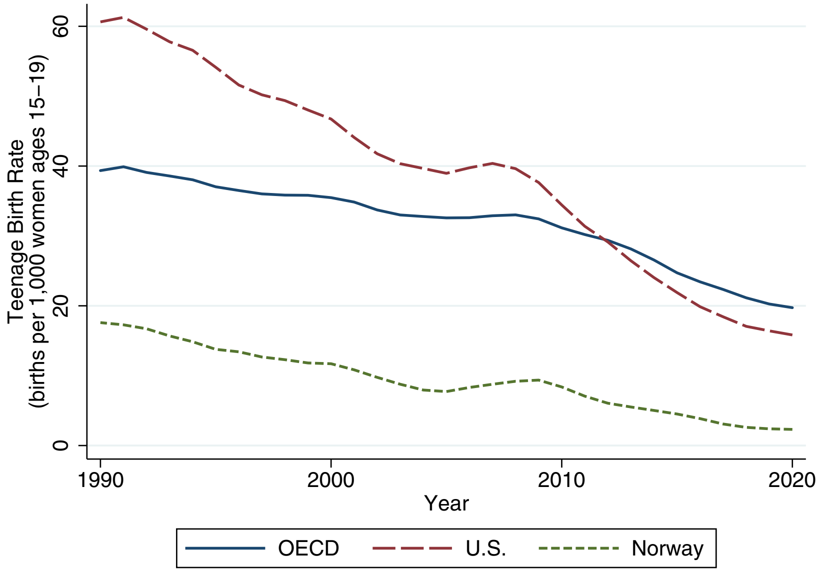

Figure A.2. Teenage birth rate over time.
Note: Teenage birth rate is defined as the number of births per 1000 women aged 15–19 years, and the data are from the World bank WDI.

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 (4) 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* $\Lambda(b,g) = \theta_0 (b+g)^{\lambda}$ *using equation (1). Straightforward differentiation leads to the results in (i) and (ii).* □

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

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

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

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).* □

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. □

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

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

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

We can use the first-order condition (5) for the teenager's problem to express

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

Therefore,

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

Differentiating and rearranging terms, we get

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

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

where

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

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 $\Xi(e)$. □

Lemma 5. *The probability of sexual initiation as a function of investments when the preference shock ξ is unknown is given by $\int_\xi \mathbf{s}\left(b,g,\xi\right) dF\left(\xi\right)$. 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:*

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

Thus,

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

and

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

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:*

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

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

Proof. *We can express the partial derivatives of interest as:*

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

and

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

where

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

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:*

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

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 (4) is satisfied. The condition is satisfied when the probability function $\Xi^{\star}(b,g)$ 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 (7) 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 $\frac{\partial^2 \mathcal{EU}(b,g)}{\partial b \partial g} = \frac{\partial^2 \mathcal{EU}(b,g)}{\partial b^2}$. □

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

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

Next,

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

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

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 *rhadsex*) 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 2. *The distribution of teenage birth rates across age is constant over time.*

Assumption 3. *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 occured at the age of 15 years can only be associated to this age group. Therefore we can define the teenage birth rate for the 15-year-old respondents as $TBR_{15} = \frac{\tilde{TB}_{15}}{N_{15}}$, where $\tilde{TB}_{15}$ is the number of births observed among the 15-year-old respondents and N_{15} is the number of respondents aged 15 years. Births observed for respondents at age 16 can be attributed both to birth obtained at age 15 years and births obtained at age 16 years. Using Assumption 1 we can write the number of births obtained at age 16 years as $TB_{16} = TBR_{15} \times N_{16} - \tilde{TB}_{16}$. Consequently the teenage birth rate among respondents at age 16 years is defined as $TBR_{16} = TBR_{15} - \frac{\tilde{TB}_{16}}{N_{16}}$. 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 redistribtuion. Data is taken from the OECD and refers to the time period 2006–2010.

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* (Immervoll (2010), OECD (2011)). 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 provides[38] 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 two 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 data.

C.7. Public Education Expenditure

We employ public expenditure data for the USA from the National Center for Education Statistics Common Core of Data through 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. Identification

Although all of the parameters μ_0, σ_0, μ_1, σ_1, δ, and ω_1 influence the aggregate teenage birth rate, they have different effects on the distributions of the teenage birth and sex initiation rates across income groups.

Since we match the difference in both the sex initiation rate distribution by the parental status as a teenage mother, we are able to identify the difference between $\{\mu_0, \sigma_0\}$ and $\{\mu_1, \sigma_1\}$ as the two sets of parameters differ in parental status. The rest of the discussion abstracts from the status

Table B.1. Robustness—parameters and summary statistics

Parameter	Description	$\pi = 1.00$	$\pi = 0.75$	$\pi = 0.50$
θ_0	Income process	0.4153	0.3799	0.3090
θ_1	Income process	0.3390	0.3927	0.4598
λ	Income process	0.5646	0.5642	0.5553
	Teenage birth rate	1.89%	1.88%	1.85%
	Sex initiation rate	43.32%	43.19%	42.89%
	Income loss of teenage birth	17.18%	16.99%	17.49%
	Share with no birth control	0.81%	0.84%	0.88%
	Gini income	0.421	0.423	0.418
	Intergen mobility	0.405	0.401	0.432

of the parent as a teenage mother and focuses on the separate identification of μ and σ, and of δ and ω_1.

The parameters μ and σ characterize the distribution of the sex taste shock, and both increase the aggregate sex initiation rate. However, a higher value of μ shifts the cumulative distribution function of the sex initiation shock to the right. Together with the unchanged initiation threshold, this implies that initiation rates go up across all income levels by a similar amount.[39] In contrast, a higher σ translates into a flatter cumulative distribution function of the sex initiation shock, implying that the probability of initiation rises more for teenagers with a high initiation threshold. Thus, σ skews the sex initiation rate distribution by increasing the rate more strongly for those in high-income families.

Turning our attention to δ and ω_1, a lower δ or a higher ω_1 both lead to a higher aggregate teenage birth rate, but they differ in their effects on the sex initiation rate. A lower value of δ implies that the teenager cares less about her future and, therefore, is going to be more likely to be sexually initiated and will exert less effort when sexually active. Thus, a lower δ simultaneously increases the sex initiation rate and the teenage birth rate across all income levels.

An increase in ω_1 makes it more costly to exert effort and, consequently, sexually active teenagers exert less effort. At the same time, the increased cost of effort decreases the incentives to be sexually active and more teenagers stay abstinent. The incentives to be sexually abstinent are stronger for higher investment levels and therefore the decline in sex initiation rates are more pronounced at the upper end of the income distribution. The joint effect of lower effort and lower sex initiation leads to higher teenage birth rates at the lower end of the income distribution and higher rates at its upper end.

E. Robustness Checks and Additional Policy Experiments

E.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, and λ) 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 production function. As a consequence, the new estimates of the parameters that determine the curvature of

Table B.2. Robustness—quantitative results under alternative elasticity values

	Elasticity parameter	Deviations from baseline economy						
		Norwegian taxes			Norwegian public education			Norwegian
		Redistribution	Levels	Both	Redistribution	Levels	Both	*Welfare state*
Teenage birth rate, Δ%	$\pi = 1.00$	−27.80%	47.01%	2.35%	−0.28%	−17.22%	−18.92%	−17.42%
	$\pi = 0.75$	−27.66%	47.46%	8.82%	−2.01%	−20.18%	−23.66%	−20.07%
	$\pi = 0.50$	−28.52%	46.67%	10.97%	−4.03%	−22.89%	−27.26%	−24.25%
Sex initiation rate,Δ%	$\pi = 1.00$	0.40%	0.95%	1.00%	0.01%	−0.22%	−0.21%	0.90%
	$\pi = 0.75$	0.09%	0.30%	0.18%	0.00%	−0.21%	−0.20%	0.10%
	$\pi = 0.50$	0.01%	0.11%	−0.04%	−0.03%	−0.22%	−0.22%	−0.18%
Wage loss,Δ%	$\pi = 1.00$	15.94%	−13.11%	1.91%	0.46%	10.05%	11.18%	12.57%
	$\pi = 0.75$	15.21%	−12.05%	−0.12%	1.04%	11.78%	14.24%	14.41%
	$\pi = 0.50$	14.41%	−11.33%	−1.05%	2.06%	13.96%	17.25%	17.32%

Note: The table shows the effects of counterfactual policy experiments measured as a percentage deviation from the baseline model.

Table B.3. Robustness—quantitative results in fertility policy experiments

	USA Welfare state	Norwegian Welfare state	Free Birth control	Reduced Childcare cost
Teenage birth rate	1.90%	1.57%	1.51%	1.82%
Sex initiation rate	43.17%	43.56%	43.45%	42.90%
Income loss of teenage birth	18.69%	21.04%	21.13%	21.55%
Gini income	0.402	0.368	0.368	0.369
Intergen mobility	0.442	0.366	0.366	0.368

Note: "*U.S. Welfare State*" is the baseline model, which corresponds to the first column in Table 3. "*Norwegian Welfare State*" is the counterfactual model with Norwegian taxes and public education, which corresponds to the last column in Table 3. "*Free Birth Control*" is the counterfactual model with Norwegian taxes and public education and free birth control. "*Reduced Childcare Cost*" is the counterfactual model with Norwegian taxes and public education and reduced childcare cost ($\kappa = 0.05$).

the production function (θ_0, θ_1, and λ) change to adjust for it. This means that θ_0 and λ decrease, while θ_1 increases. The re-estimated model still fits the data very well.

When we change the elasticity of substitution between private and public investments, the results of the counterfactual experiments do not change qualitatively. With lower values of π, the impact of a change in the welfare state institutions has a more negative effect on the teenage birth rate and the sex initiation rate.

E.2. Fertility Policy Experiments

We consider two additional counterfactual policy environments where in addition to Norwegian tax and public education policies, we also impose policies targeting fertility. In the first experiment, we consider birth control subsidies such that the private monetary cost of birth control is zero. In the second experiment, we consider childcare benefits that reduce the private childcare cost by 50%. In this case, the parameter $\kappa = 0.05$. Table B.3 compares aggregate statistics from these two counterfactual economies to those from the baseline economy (with US tax and public education policies) and the counterfactual economy with Norwegian tax and public education policies.

Subsidizing birth control leads to a further, albeit small, reduction in the teenage birth rate because daughters of poor parents no longer face the constraint imposed by the maximum birth control effort. Unsurprisingly, reducing private childcare costs incentivizes fertility and leads to an increase in the teenage birth rate, from 1.57% in the economy with Norwegian tax and public education policies to 1.82% in the economy with Norwegian tax and public education policies and reduced childcare costs.

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