Implications of Public Education Financing Systems for Earnings Inequality and Intergenerational Mobility*

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Abstract

Among OECD countries there are large and well-documented differences in earnings inequality and intergenerational earnings mobility. Systems for financing and allocating public education also feature striking differences among these countries. This paper documents novel facts about how public education expenditures are financed and allocated among individuals in two particular countries, the U.S. and Norway. I focus on these countries because they represent the extreme cases of both earnings distributions and public education systems, plus uniquely rich data is available for each. Using the empirical analysis to discipline a dynamic stochastic general equilibrium model, I investigate how important public education financing systems are for cross-country differences in earnings distribution. Despite significant differences in public education financing systems, this accounts for only about 15% of differences in earnings inequality and 10% of differences in intergenerational persistence between the two countries. I argue that the distribution of public education spending and the option of private education spending are both important model features to include for cross-country analysis. Counterfactual experiments also indicate that the distribution of public education spending is quantitatively more important for intergenerational earnings persistence, whereas tax policies have greater impact on earnings inequality.

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1 Introduction

There are large and well-known differences across OECD countries in both earnings inequality and the persistence of earnings across family generations (also commonly referred to as intergenerational earnings mobility). These countries also feature notable differences in how public education expenditures are financed and allocated across individuals. In the United States, for example, public primary and secondary schools receive a significant share of funding from local tax revenue. As a result, public education spending per student is positively correlated with local incomes and varies widely across school districts. By contrast, many European countries finance public primary and secondary schools with federal tax revenue and provide a more uniform distribution of expenditures per student across schools. The goal of this paper is to establish empirical evidence on the distributions of public education expenditures that result from different public education financing systems, and determine whether or not this accounts for the large differences in earnings inequality and intergenerational earnings persistence across countries.

I begin by documenting several novel facts about the distribution of public education expenditures in the U.S. and Norway. I focus on these countries for two main reasons. First, detailed and disaggregated data are available for both, allowing for examination of public education expenditures at the school district level. Additionally, the U.S. and Norway are an interesting case study because they are polar opposites in several important aspects relating to both earnings distributions and education systems. For countries in the Organisation for Economic Co-operation and Development (OECD), the U.S. generally ranks among those with the highest earnings inequality and intergenerational earnings persistence, while Norway ranks among those with the lowest earnings inequality and

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1See, e.g., evidence presented in Aaberge et al. (2002), Bratsberg et al. (2007), Andrews and Leigh (2009) and Corak (Forthcoming).
intergenerational earnings persistence. The education systems in the two countries also exhibit several stark contrasts. First, the relative contributions from local, state, and federal funding sources varies widely across U.S. school districts, but Norwegian public schools are almost exclusively funded by the federal government. Second, there is a positive correlation between income and public expenditures per student across school districts in the U.S., whereas in Norway this correlation is strongly negative. Third, the variance of public spending per student across school districts in the U.S. is double that of Norway. Finally, private sources account for nearly one-third of total education spending in the U.S., but only about 5% in Norway.\footnote{The first three facts regarding education are documented in section 2. The fourth fact is from OECD Education at a Glance 2010, Table B3.1.}

Motivated by these observations in the data, I depart from the traditional concept of “public education” in which all individuals receive the same amount of public expenditures. Instead I estimate functions for public education spending so that children of parents with different earnings receive different amounts of public spending on their education. I then incorporate these estimated public education spending functions into a calibrated dynamic stochastic general equilibrium model in order to assess quantitatively the impact of public education expenditures on earnings inequality and intergenerational persistence. In the model, overlapping generations of parent-child pairs are heterogeneous with respect to the parent’s acquired human capital (which determines labor earnings), the child’s endowed learning ability, and the child’s tastes for schooling. Public spending on compulsory (primary/secondary) education for each child is determined as a function of parent earnings. Parents may supplement public education expenditures with their own private spending, but they may not borrow against the child’s future earnings to do so. Upon completing compulsory education, children may obtain non-compulsory (tertiary) education which is subsidized by the government. After completing all education children enter the labor force,
become adults, and have children of their own. I examine the stationary recursive competitive equilibrium in this economy and conduct counterfactual experiments with respect to the public education and taxation systems.

There are several channels through which the model may generate cross-country differences in earnings inequality and intergenerational persistence. First, public education spending may ease credit constraints for low income parents who would otherwise invest less in high ability children. All else equal, this increases average human capital and income levels in the economy and decreases intergenerational earnings persistence. Second, increased public education spending crowds out private spending on education by lowering the marginal return on investment of each additional private dollar, which lowers the variance of the earnings distribution. Third, a more equal distribution of resources across schools reduces variance in the resulting human capital distribution of the population, thus reducing earnings variance. Finally, the level and progressivity of taxes on labor earnings affect net returns to human capital, and thus the incentives to make additional private investments.\(^3\)

Ultimately, the magnitude of these effects must be determined quantitatively. After estimating public education spending functions from data and calibrating remaining parameters of the model to match salient features of the U.S., I compute a counterfactual economy in which the U.S. public education and taxation systems are replaced by the Norwegian counterparts. Despite significant differences in public education financing systems between the two countries, this can account for only about 15\% of the cross-country differences in earnings inequality and less than 10\% of differences in intergenerational earnings persistence. Furthermore, I find that the progressivity of education spending is responsible

\(^3\)See, e.g., Trostel (1993), which finds a negative effect of proportional income taxation on human capital, Erosa and Koreshkova (2007), which find a negative effect of progressive taxation on human capital, and Guvenen et al. (2011) which examine both average tax levels and progressivity in a cross-country study.
for most of predicted model differences in intergenerational earnings persistence, whereas
tax system differences are responsible for most of the differences in earnings inequality.
This result suggests that while earnings inequality and earnings persistence are highly cor-
related across countries, they are not necessarily driven by the same factors, and they may
respond independently to tax and education spending policies.

This paper builds on early theoretical work by Becker and Tomes (1979), Becker and
Tomes (1986), and Loury (1981), which examined the role of credit constraints and the
transmission of ability from parents to children in generating income persistence over time
within families. Solon (2004) advances this theoretical literature by expanding the Becker
and Tomes (1979) model in a way that allows one to explicitly account for cross-country
differences in intergenerational persistence. Solon’s analytical result that intergenerational
earnings elasticity should be decreasing with respect to the progressivity of public invest-
ment in education is of particular interest for this paper. I contribute to the insights from
this literature by quantifying the extent to which progressive public education expenditures
may increase earnings mobility.

Other papers including Restuccia and Urrutia (2004), Holter (2011), and Taska (2011)
have also examined quantitatively the impact of taxation and public education spending on
income inequality and intergenerational persistence. There is also a tradition of studying
these issues in a cross-country setting. For example, Björklund and Jäntti (1997) study
the case of Sweden and the U.S., Checchi et al. (1999) examine the case of Italy and the
U.S., and Corak (2006) analyzes nearly a dozen OECD countries. The value added in
this paper is that I explicitly model the heterogeneity in public education spending both
within and across countries. This allows me to conduct policy experiments that incorporate
differences in the distribution of public education expenditures rather than only differences
in aggregate measures of public spending, such as average public expenditure per student.
This paper is also related to another influential strand of literature including Glomm and Ravikumar (1992), Durlauf (1996), Bénabou (1996), and Fernandez and Rogerson (1998). These papers model households that are organized (either exogenously or endogenously) into separate local communities. They study the differences in income inequality, growth, and intergenerational income persistence when locally provided public education is replaced with a system in which education spending is equalized across communities through state redistribution. As I show in this paper, public education spending is neither purely local nor equalized across communities in either the U.S. or Norway. By estimating public education spending as a function of parent income, I am able to account more precisely for the actual differences between the education financing systems in place in these two countries.

The remainder of this paper proceeds as follows. Section 2 presents motivating evidence on public education financing in the U.S. and Norway. Section 3 outlines the model. In section 4 I estimate functions for taxes and public education spending, then calibrate remaining parameters of the model to features of the U.S. and Norwegian economies. Section 5 provides computational results and policy analysis, and section 6 concludes.

2 Empirical Evidence

This section examines data on revenue sources and the distribution of public primary and secondary education expenditures in the U.S. and Norway.\footnote{U.S. data is obtained from the National Center for Education Statistics Common Core of Data and School District Demographics System. Norway data is obtained from the StatBank data service on the Statistics Norway website at: http://statbank.ssb.no/statistikkbanken/}
2.1 Revenue

In the United States, public primary and secondary school districts receive funding from local, state, and federal sources. Yet the share of revenue accruing from each of these sources varies widely across districts. By contrast, local governments in Norway, which are responsible for funding local public schools, are largely financed through federal government grants and federally regulated income tax sharing, as described in Fiva and Rønning (2008). Accordingly, federal sources account for the vast majority of total revenue in almost all Norwegian school districts.

Figure 1: Histogram of School Districts by Local Revenue Share

Panel (a) shows the distribution of public school districts in the U.S. by the share of their total revenue that is generated locally, and panel (b) shows the same for Norway.\(^5\) Notably, school districts in the U.S. range from one extreme of having almost no local funding to the

\(^5\)Data for Norway begins in 2000 as well, but there are many missing values in 2000 and 2001. Year 2002 was chosen for Norway because it was the first year with complete data for nearly all districts. The patterns described here are broadly consistent across all years since 2000.
other extreme of being completely reliant on local revenue sources. The system of strong federal control in Norway, however, results in a much more concentrated distribution. Most Norwegian school districts raise less than 20% of revenues locally.

Of course, a public school system funded strictly at the local level would exhibit strong positive correlations between local household incomes and local education expenditures, as demonstrated in Glomm and Ravikumar (1992) and Fernandez and Rogerson (1998). To offset the disparities that would arise in school systems funded strictly by local sources, state and federal governments redistribute money across districts. Figure 1 suggests that the Norwegian system likely results in greater redistribution than the U.S. system, and Table 1 confirms this fact. Panel (a) of Table 1 provides a summary of correlations for U.S. school district level revenue and income data in 2000. The variables included are median household income in the district, revenue from local sources, revenue from non-local sources, total revenue, and the share of total revenue from local sources.

Differences between the U.S. and Norwegian systems are apparent from the table. As expected, the correlation between median income and local revenue for the U.S. is indeed strongly positive (0.58). Also, the correlation between median income and state/federal revenue is strongly negative (-0.36). The redistribution of state/federal funds partially offsets the revenue disparities caused by local funding, but the correlation between median income and total revenue is still positive at 0.31. In contrast, the correlations between local revenue and median income in Norway are quite different. Panel (b) of table 1 provides the same information for Norway in 2002 as Panel (a) did for the U.S. in 2000. From the first column it is apparent that unlike the U.S., median income is almost completely uncorrelated with either local or federal revenue across districts.

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613,990 school districts in the U.S. are included. Year 2000 was chosen because median income at the school district level is matched to 2000 U.S. Census data. Producing the same table with more recent revenue data yields very similar correlations.
Table 1: Revenue and Income Correlations

(a) United States in 2000

<table>
<thead>
<tr>
<th></th>
<th>Median income</th>
<th>Local revenue</th>
<th>Fed/state revenue</th>
<th>Total revenue</th>
<th>Local share of revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median income</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Local revenue</td>
<td>0.58</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fed/state revenue</td>
<td>-0.36</td>
<td>-0.48</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total revenue</td>
<td>0.31</td>
<td>0.67</td>
<td>0.33</td>
<td>1.00</td>
<td>-</td>
</tr>
<tr>
<td>Local share of revenue</td>
<td>0.57</td>
<td>0.88</td>
<td>-0.76</td>
<td>0.29</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(b) Norway in 2002

<table>
<thead>
<tr>
<th></th>
<th>Median income</th>
<th>Local revenue</th>
<th>Federal revenue</th>
<th>Total revenue</th>
<th>Local share of revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median income</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Local revenue</td>
<td>0.02</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Federal revenue</td>
<td>0.03</td>
<td>0.41</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total revenue</td>
<td>0.03</td>
<td>0.67</td>
<td>0.95</td>
<td>1.00</td>
<td>-</td>
</tr>
<tr>
<td>Local share of revenue</td>
<td>0.03</td>
<td>0.77</td>
<td>-0.12</td>
<td>0.15</td>
<td>1.00</td>
</tr>
</tbody>
</table>
2.2 Spending

Having provided evidence for the sources of public primary and secondary education revenue in the U.S. and Norway, I now examine how public education spending is distributed among individuals within the two countries. Panel (a) of figure 2 is a scatter plot of the “total current expenditures on instruction per student” for school districts in the U.S. against the median income in those districts.\(^7\) Likewise, Panel (b) of figure 2 plots the “net operating expenditures on instruction per student” for school districts in Norway against the median income in those districts.\(^8\) While these data are from different sources and thus have different names, they are comparable in that both series include only public education expenditures directly related to student instruction. Both income and expenditure data in figure 2 are divided by average annual wage earnings of full-time equivalent workers in the respective country in order to make the units comparable.\(^9\) Circles in the scatter plots vary in size proportional to the number of students in each school district, and regression lines overlaying the scatter plots are weighted by the number of students each district.

Perhaps the most obvious difference between the distribution of public education expenditures in the U.S. and Norway is that there is a positive correlation of 0.27 between median income and expenditures on instruction per student in the U.S., whereas in Norway this correlation is strongly negative at -0.51. Thus, school districts in the U.S. with higher median income tend to have higher public education expenditures per student. In Norway, however, districts with higher median income tend to have lower public education expenditures per student.

Another noticeable difference in the panels of figure 2 is that the variance of public

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\(^7\)The income measure for the U.S. is median earnings for the total population 16 and over, from Table P85 of the 2000 Census School District Tabulation (STP2) Data.

\(^8\)The income measure for districts in Norway is median gross income for residents 17 and over, from Table 05671 in Statistics Norway’s StatBank.

\(^9\)Annual wage earnings for the U.S. and Norway taken from the OECD Taxing Wages database.
Figure 2: Distributions of Public Education Expenditures

(a) United States in 2000
(b) Norway in 2002

Expenditures across districts is much greater in the U.S. than Norway. One simple summary statistic which captures this difference is the coefficient of variation in public expenditures per student. For the U.S. this is 0.273, but for Norway it is only 0.136. This means that there is twice as much dispersion in public education expenditures per student across school districts in the U.S as in Norway.

Figure 3 goes one step further, however, and shows the coefficient of variation for public education expenditures per student within income deciles. As above, both income and public education expenditures are taken relative to average annual earnings. For all income deciles, the dispersion of public education spending in the U.S. exceeds that of Norway. Yet the difference between the countries is fairly small among the lowest income deciles and grows significantly larger among the higher income deciles.

Combining the above evidence paints a picture of two countries in which systems for both funding and distributing public education to individuals are very different. This implies that modeling public education as a system in which every individual receives an
identical allocation may lead to erroneous results, especially when making cross-country comparisons. This paper provides a first step toward modeling a more realistic public education financing system. In the following model and quantitative exercises, I allow for heterogeneous individuals to receive different amounts of public education expenditures. This richer environment allows for more accurate accounting of the role that public education spending plays in generating cross-country differences in earnings inequality and intergenerational earnings persistence.
3 Model Economy

3.1 Timing, Demographics, and Preferences

Time in the model economy is discrete with an infinite horizon, and the economy is populated by two-period lived individuals. A model period corresponds to 30 years, where model ages 1 and 2 correspond to actual ages 5-34 and 35-64, respectively. Since the focus here is on public education and lifetime labor earnings, I do not model the period of early childhood prior to formal schooling, nor the retirement period of life.\textsuperscript{10}

During the first period of life each individual is referred to as a “child,” and during the second period of life the individual is a “parent.” Each parent has a child at the beginning of the second period of life. A family at a given point in time consists of one parent and one child, and an infinite sequence of overlapping generations of parent-child pairs is referred to as a family dynasty. The parent in each family is assumed to make all decisions for the family in that period.

At the beginning of each period, the state vector for each family is given by $x = (h_p, \alpha, \zeta)$, where $h_p$ is the human capital of the parent acquired through education in the previous period, $\alpha$ is the learning ability of the child, and $\zeta$ is the child’s taste for schooling. The child’s learning ability and tastes for school are both random endowments. Learning ability may be correlated across generations, but tastes for schooling are independently and identically distributed across individuals and time. The aggregate state of the economy is the distribution over individual state vectors, defined by $\mu(x)$.

Preferences are similar to those in Barro and Becker (1989). Parents value the family’s consumption in the current period, and they are altruistic in that they also value the child’s

\textsuperscript{10}In 2009 early childhood education was established as an individual, legal right in Norway. By 2010 nearly 90\% of Norwegian children aged 1-5 attended kindergartens. However, since I focus on data around the year 2000, these recent changes are irrelevant for this paper. Nonetheless, the policy change in Norway should provide a rich natural experiment for future research.
utility from schooling and the consumption of all future generations in their family dynasty. As in Restuccia and Vandenbroucke (2012), ζ is allowed to be either positive or negative so that schooling may provide either a utility benefit or a cost to the child. The recursive formulation of the parent’s decision problem in section 3.5 will make the formulation for preferences more precise.

All individuals are endowed with one unit of time each period. Individuals do not value leisure. Parents devote their full time endowment inelastically to the labor market. Children divide their time endowment into the following three fractions. First, they devote an exogenous fraction $\phi_1 \in (0, 1)$ of their time endowment to compulsory education. This assumption is consistent with the fact that all OECD countries require children to complete some minimum amount of education, generally corresponding to the primary and secondary levels. Next, children spend a fraction $\phi_2 \in [0, 1 - \phi_1]$ in non-compulsory education, where $\phi_2$ is chosen by each parent for the child. The non-compulsory stage may be thought to include all forms of tertiary education, including two and four-year colleges and universities, trade schools, professional schools, and graduate programs. Finally, the remaining fraction $1 - \phi_1 - \phi_2$ is supplied as labor to the market after all education is complete. Figure 4 provides a graphical example of the division of the child’s time endowment.
3.2 Human Capital and Ability

As previously mentioned, each child is endowed with learning ability \( \alpha \). I use the term *ability* to describe an individual’s efficiency in producing human capital, while *human capital* determines an individual’s labor efficiency in the production of final output. In practice, an individual’s learning ability is likely affected by genetic endowment, early childhood environment, parental education, peer influence, and many other factors. For simplicity, however, I assume that learning ability is transmitted stochastically from parent to child via a transition function \( Q(\alpha, \alpha') \). This modeling assumption has been widely employed in similar contexts, including Becker and Tomes (1979) and (1986), as well as Restuccia and Urrutia (2004).

All individuals are assumed to begin life with initial human capital \( h_1 \), which is normalized to one. New human capital is created by a human capital production function which takes the individual’s learning ability, current human capital stock, time, and education spending as inputs. Production in each of the two education stages is of the form in Ben-Porath (1967). The acquired human capital stock after compulsory education is denoted \( h_2 \), and human capital after non-compulsory education denoted \( h_3 \). Human capital evolves as follows:

\[
\begin{align*}
    h_2 &= h_1 + \alpha [(h_1 \phi_1)^{\nu} s_1^{1-\nu}]^{\gamma_1} \\
    h_3 &= h_2 + \alpha [(h_2 \phi_2)^{\nu} s_2^{1-\nu}]^{\gamma_2}
\end{align*}
\]

where \( \alpha \) is ability, \( \phi_j \) is the fraction of time devoted to schooling in stage \( j = \{1, 2\} \), \( s_j \) is education spending in stage \( j = \{1, 2\} \), and \( \nu \in (0, 1) \), \( \gamma_1 \in (0, 1) \), and \( \gamma_2 \in (0, 1) \) are exogenous parameters. I assume that public and private expenditures on education, denoted \( g_j \) and \( e_j \) respectively, are perfect substitutes, so that total spending in each stage
is \( s_j = g_j + e_j \) for \( j = \{1, 2\} \).

To simplify notation in the recursive formulation to follow, denote the human capital production function obtained after substituting equation (1) into (2) by \( f(s_1, s_2, \phi_2; x) \). In addition, to distinguish between the human capital supplied to the labor market by parent and child within a family, denote the acquired human capital of the child after completing all education by \( h_c \). Thus,

\[
h_c \equiv h_3 = f(s_1, s_2, \phi_2; x)
\]

Some additional properties of the human capital production function should be noted. First, human capital does not depreciate, so a child who obtains no additional education beyond the compulsory stage will enter the labor market with human capital they acquired through compulsory education, i.e., \( h_c = h_3 = h_2 \). Also, the human capital acquired in compulsory education affects the returns to investment in non-compulsory education. In other words, individuals with more human capital after high school would gain more from additional human capital production in college.

While all human capital investment occurs in the first period of life, i.e., prior to age 35, I follow Erosa et al. (2010) in assuming that each individual receives a shock to their human capital stock at the beginning of the second period of life, which I interpret as “market luck”. In particular, a child with human capital \( h_c \) today will have have human capital \( h_p' \) when they become a parent tomorrow according to:

\[
h_p' = \eta h_c
\]

where \( \ln(\eta) \sim N(0, \sigma^2) \). The inclusion of market luck shocks is made for consistency with the following facts: (i) earnings variance within cohorts grows over the life cycle, as documented by Huggett et al. (2006); and (ii) more than one-third of the variance in
lifetime earnings is attributable to post-education factors (after age 23), as documented by Huggett et al. (2011).

3.3 Final Output Technology

A representative firm produces the single final output good according to a linear production function $Y = L$, where $Y$ is aggregate output and $L$ is aggregate effective labor supply. Since labor efficiency units are equal to human capital, aggregate effective labor supply is:

$$L = \int [h_p(x) + (1 - \phi_1 - \phi_2(x))h_c(x)]d\mu(x).$$  \hspace{1cm} (5)

Additionally, the wage per efficiency unit of labor with this technology is normalized to one, so the labor earnings of parent and child, denoted $y_p$ and $y_c$, are equivalent to the amount parent and child human capital supplied to the labor market, $h_p$ and $(1 - \phi_1 - \phi_2(x))h_c(x)$.

The final output good is used for family consumption $c$, government consumption $G_c$ (discussed below), and as the expenditure input to the human capital production function via $e_1$, $e_2$, $g_1$, and $g_2$. Denoting aggregate quantities by capital letters, market clearing in final output each period requires:

$$Y = C + E_1 + E_2 + G_1 + G_2 + G_c.$$  \hspace{1cm} (6)

3.4 Government

A government imposes taxes on labor earnings according to the average tax rate function $\tau(y)$, where $y$ is labor earnings and $\tau'(y) > 0$. Taxes are levied at the individual rather than family level, so that a parent and child within a family may face different average and marginal tax rates. The total tax obligation of a family is denoted by $T(y_p, y_c) \equiv \tau(y_p)y_p + \tau(y_c)y_c$, so a family’s period net earnings are: $y_p + y_c - T(y_p, y_c)$. Tax revenues
fund public spending on compulsory education, subsidies for non-compulsory education, and government consumption, which provides no utility to individuals. The government budget balances each period.

In the computational work to follow, the key distinctions between the U.S. and Norway will be the tax functions and the public education spending functions. These are estimated for each country in the next section. For now, however, I define more general public education spending functions as follows. First, compulsory education spending may be a function of the entire family state vector $x = (h_p, \alpha, \zeta)$, and parents know $g_1(x)$ when making decisions for the family. Recall that total spending on compulsory education is $s_1 = g_1 + e_1$, so parents may choose to supplement the public spending on their child with private spending. Second, government subsidies for non-compulsory education are modeled as a fraction of the total cost of non-compulsory education, where that fraction may depend on the family state vector $x$. Specifically, if a family described by state vector $x$ chooses a college or university education with total cost $s_2$, then the government subsidy will be $g_2 = \theta(x)s_2$ and the share paid out of pocket by the family will be $e_2 = (1 - \theta(x))s_2$, where $\theta(x) \in [0, 1]$ for all $x$.

3.5 Decision Problems

A parent who enters a period with state vector $x = (h_p, \alpha, \zeta)$ chooses consumption, private education spending on the child’s compulsory education, total (and thus also private) spending on non-compulsory education, and the fraction of child’s time spent in non-compulsory education. The parent’s objective is to maximize utility from current consumption and the current child’s taste for school, as well as the expected discounted utility of future generations in the family dynasty. The full decision problem is specified
recursively as follows:

\[
V(h_p, \alpha, \zeta) = \max_{c, e_1, s_2, \phi_2} \left\{ u(c) + \zeta \phi_2 + \beta \mathbb{E}_{\alpha', \eta', \zeta'} \left[ V(h_p', \alpha', \zeta') | \alpha \right] \right\}
\]

subject to

\[
c + e_1 + (1 - \theta(x))s_2 = y_p + y_c - T(y_p, y_c)
\]

\[
y_p = h_p; \quad y_c = (1 - \phi_1 - \phi_2) h_c
\]

\[
h_c = f(s_1, s_2, \phi_2; x)
\]

\[
s_1(x) = g_1(x) + e_1
\]

\[
h_p' = \eta h_c
\]

\[
\phi_2 \in [0, 1 - \phi_1]
\]

where \(V(h_p, \alpha, \zeta)\) is the value function of a family with state \(x = (h_p, \alpha, \zeta)\). Substituting the budget constraint into the objective function, the problem above can be written as a decision problem for three choice variables: \(e_1, e_2,\) and \(\phi_2\). A solution to this problem consists of optimal decision rules \(e_1^*(x), e_2^*(x),\) and \(\phi_2^*(x)\). I will focus on the stationary recursive competitive equilibrium in this economy, defined below.

**3.6 Equilibrium**

A stationary recursive competitive equilibrium in this economy consists of optimal decision rules \(e_1^*(x), e_2^*(x),\) and \(\phi_2^*(x)\), labor demand \(L^*\), and stationary distribution \(\mu(x)\) such that in every period:

1. Parents choose \(e_1^*(x),\) and \(e_2^*(x),\) and \(\phi_2^*(x)\) to solve their decision problem;
2. The representative firm chooses $L^*$ to maximize profits;

3. The government budget balances each period;

4. The stationary distribution $\mu(x)$ is consistent with the decision rules and exogenous stochastic processes for $\alpha$, $\eta$, and $\zeta$;

5. Output and labor markets clear.

4 Model Parameterization

This section discusses parameterization of the model for the purpose of running computational experiments. I first estimate the labor income tax functions $\tau(y)$ and public education spending functions $g_1(x)$ and $g_2(x)$ for both the U.S. and Norway. Then I select the remaining parameters for preferences and human capital production, in addition to the stochastic processes for ability, market luck, and tastes for schooling.

4.1 Estimation of Tax Functions

Tax systems in OECD countries vary along many dimensions, including average and marginal labor income tax rates, social security taxes, and the credits and benefits available for families with children. Variations in average and marginal tax rates may affect incentives for parents to invest in their children’s human capital. In addition, implicit transfers embedded in the tax code - such as credits for families with children - should be taken into account when making cross-country comparisons of pre- and post-tax earnings inequality. For these reasons, I utilize OECD data which are comparable across countries and include central and local government taxes, family tax benefits, and social security tax contributions.
Table 2: Tax Function Parameter Estimates

<table>
<thead>
<tr>
<th></th>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\beta_3$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>0.434</td>
<td>0.003</td>
<td>-0.321</td>
<td>-0.719</td>
<td>0.993</td>
</tr>
<tr>
<td>Norway</td>
<td>1.106</td>
<td>-0.002</td>
<td>-0.921</td>
<td>-0.190</td>
<td>0.998</td>
</tr>
</tbody>
</table>

Following Guvenen et al. (2011), I estimate by nonlinear least squares for both the U.S. and Norway, a net average tax function of the following form:

$$
\tau(\hat{y}) = \beta_0 + \beta_1 \hat{y} + \beta_2 \hat{y}^\beta_3
$$

where $\hat{y}$ denotes earnings relative to the average earnings in that country.\footnote{The OECD reports average annual wage earnings for single individuals in each country and normalizes all tax calculations relative to these numbers. Hence, I do the same. For the year 2000, these amounts were 33,129 (in U.S. dollars) for the U.S. and 298,385 (in Norwegian Kroner) for Norway.} The regression results are reported in table 2 and the estimated tax functions are plotted in figure 5. It is worth noting that net average tax rates (both in the raw OECD data and resulting from the estimated tax functions) are actually negative for some individuals with very low earnings. This is due to the fact that the family benefits transfers they receive from the government are larger than the taxes they pay.

4.2 Government Investment in Education

4.2.1 Compulsory Stage

In defining the model, I allowed for government spending to be a function of the family state vector $(h_p, \alpha, \zeta)$. However, child ability and tastes for schooling are generally unobserved by the government, and therefore public education spending is usually not conditioned on
these characteristics. In order to utilize the data discussed in section 2, I now assume that government spending on compulsory education is only a function of parent human capital, not child ability or tastes for school. Since parent income is proportional to parent human capital in the model, conditioning the child’s public education expenditure on parent human capital in the model maps directly into the data discussed earlier. I estimate the following linear function:

\[ \hat{g}_1(\hat{y}_p) = a_1 + b_1 \hat{y}_p. \]  

(9)

where, as before, \( \hat{g}_1 \) and \( \hat{y}_p \) indicate that those variables are normalized with respect to average wage earnings in the respective economy. This ensures that \( \hat{g}_1(\hat{y}_p) \) in the model

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12Notable exceptions where public education spending might depend on a child’s ability or tastes for schooling include public charter or magnet schools, special education and gifted education programs, etc. However, these are a small fraction of overall public schooling; therefore this paper abstracts from these special schools and programs.
Table 3: Parameters for $\hat{g}_1(\hat{y}_p)$

<table>
<thead>
<tr>
<th></th>
<th>$a_1$</th>
<th>$b_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>0.096</td>
<td>0.051</td>
</tr>
<tr>
<td>Norway</td>
<td>0.210</td>
<td>-0.121</td>
</tr>
</tbody>
</table>

does not depend on the units (e.g., U.S. dollars or Norwegian kroner) in which income and education spending are measured in the data.

Equation (9) is estimated by ordinary least squares regression (weighted by the number of students in each school district) for both the U.S. and Norway using the data from year 2000.\(^{13}\) Table 3 provides the estimated parameters for each country. Consistent with the observations made regarding figure 2 earlier, two points should be noted. First, the intercept term $a_1$ is more than twice as large for Norway as for the U.S., indicating that individuals at the bottom of the earnings distribution in Norway receive much greater public education funding (as a share of that country’s average wage earnings) than would individuals at the bottom of the U.S. earnings distribution. Additionally, the fact that $b_1$ is positive for the U.S. and negative for Norway indicates that public expenditures will be increasing with respect to parent earnings (i.e., with respect to parent human capital) in the U.S. but decreasing in Norway.\(^ {14}\)

\(^{13}\)As noted before, year 2000 data for Norway is missing many observations; nevertheless, the estimated parameters for Norway in 2000 and 2002 are remarkably similar. Therefore, I use the estimated parameters for 2000 in computation in order to be consistent with the U.S. year 2000 estimation.

\(^{14}\)Due to the linear form of $\hat{g}_1(\hat{y}_p)$, it is possible that households at the extreme ends of the earnings distribution may receive unreasonably high or low (or possibly even negative, in the case of Norway) amounts of public education funding. To avoid this problem in computation, I bound $\hat{g}_1(\hat{y}_p)$ below and above by the 1st and 99th percentiles of public education expenditures in the data. As a share of average earnings, these limits are approximately 0.08 and 0.31 for the U.S., and 0.11 and 0.25 for Norway. As noted in section 2, these limits confirm that the variance of public education spending is much larger in the U.S. than Norway.
4.2.2 Non-compulsory Stage

Now consider $g_2(x)$, which determines government investment in non-compulsory education. In the U.S., public colleges and universities are subsidized by tax dollars, so the sticker price of tuition is lower than would prevail without such subsidies. In addition, students are eligible for federal and state grants and loans based on their financial need. Students who apply for public financial aid submit detailed financial information including their parents’ income and assets. Based on that information an amount called Expected Family Contribution (EFC) is computed. EFC is the amount that the government expects a student’s family to provide out-of-pocket for the student’s tertiary education expenses.\(^\text{15}\)

I will assume that a family’s EFC equals the fraction of total college or university expenses not paid by the government subsidy, i.e., in the model language, $\text{EFC} = (1 - \theta(x))$.

Since I do not model asset holdings, the actual EFC formula can not be included directly in the model. However, as pointed out by Belley et al. (2011), assets only play a minor role in the calculation of EFC, so abstracting from asset holdings should not seriously affect the estimation. Fortunately, the U.S. National Center for Education Statistics (NCES) publishes data on the average EFC for families of various income levels, which I use to estimate the following relationship between average EFC and parent earnings:

$$\text{EFC}(\hat{y}_p) = a_2 + b_2(\hat{y}_p) \quad (10)$$

where $\hat{y}_p$ is defined relative to average wage earnings as before. Average EFC is computed relative to the average 4-year public university cost, so the left hand side of the equation (10) should be interpreted as the average share of total public university costs that parents

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\(^{15}\)The EFC concept has also been utilized recently by Brown et al. (Forthcoming). Whereas they use it to determine which families are potentially borrowing constrained in financing college education for their children, I take EFC as a proxy for the average private share of total higher education expenses.
with relative earnings $\hat{y}_p$ would be expected to pay for their child’s college education. For the U.S. in 2000, I estimate $a_2 = -0.093$ and $b_2 = 0.226$. In order to bound the government subsidy below by zero and above by the total cost of a 4-year public university degree, I utilize the following in computation:

$$g_2(\hat{y}_p, s_2) = \begin{cases} 
0, & \text{if } \text{EFC}(\hat{y}_p) \geq 1 \\
(1 - \text{EFC}(\hat{y}_p))s_2, & \text{if } \text{EFC}(\hat{y}_p) \in (0, 1) \\
s_2, & \text{if } \text{EFC}(\hat{y}_p) \leq 0 
\end{cases}$$

where $g_2(\hat{y}_p, s_2)$ is limited to a maximum government subsidy amount of $\overline{g}_2$. Thus, given their relative earnings $\hat{y}_p$ and knowledge of the government subsidization system described above, parents choose the total amount of education spending for their child, $s_2$, understanding that they will pay a share of the total cost equal to their expected family contribution. I choose $\overline{g}_2$ to match the average public university tuition in the United States. According to the NCES, that amount was $7,586 for the 2000-2001 school year, or about 23% of average annual wage earnings. A four year degree, therefore, costs about 92% of average annual earnings.

In contrast to the U.S., higher education in Norway is available to all individuals free of charge, with the exception of some small fees. The OECD reports that 96.2% of tertiary education expenditures in Norway for the year 2000 came from public sources with only 3.8% from private sources. Therefore, I assume that the share of total higher education costs paid by the government in the case of Norway is constant at 0.962 for all individuals.

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16 $R^2 = 0.987$ for this regression.
17 The maximum subsidy level prevents individuals with low earnings in the model from getting infinitely large government subsidies.
18 Since a model period is 30 years, “annual earnings” in the model are $\frac{1}{30}$ of total earnings. Putting $\overline{g}_2$ on the same annual basis, therefore, implies $\overline{g}_2 = 0.92(\frac{1}{30})y_m \approx 0.03y_m$.
independent of parental income.\footnote{See Table B3.2 from OECD Education at a Glance 2003.} As in the case of the U.S., I constrain the government subsidy function for Norway to the interval $[0, g^2]$, where $g^2$ is the same as in the U.S. case described above.

### 4.3 Selection of Remaining Parameters

Having estimated functions for taxes and public education spending, I now discuss calibration of the utility function, the human capital production function, and the stochastic processes for initial ability, tastes for schooling, and market luck shocks. The utility function is assumed to exhibit constant relative risk aversion and is given by

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

with discount factor $\beta$. I also assume that ability is transmitted across generations according to a first-order autoregressive process:

$$\ln \alpha_{it} = \rho_\alpha \ln \alpha_{i,t-1} + \varepsilon_{it},$$

(11)

where $\varepsilon_{it} \sim N(0, \sigma^2_\alpha)$, $\alpha_{it}$ and $\alpha_{i,t-1}$ denote the ability of the individual in family $i$ born in periods $t$ and $t - 1$, and $\rho_\alpha$ determines the persistence of ability across generations. And as stated previously, the shocks to schooling tastes $\zeta$ and market luck $\eta$ are distributed according to $\zeta \sim N(0, \sigma^2_\zeta)$ and $\ln(\eta) \sim N(0, \sigma^2_\eta)$.\footnote{For computation, the stochastic processes for ability, schooling tastes, and market luck are all discretized according to the method in Tauchen (1986).} Hence, the remaining parameters to be chosen are $\sigma$, $\beta$, $\rho_\alpha$, $\sigma_\alpha$, $\nu$, $\gamma_1$, $\gamma_2$, $\phi_1$, $\sigma_\eta$, and $\sigma_\zeta$. Table 4 summarizes the benchmark parameter values and the remainder of the section discusses their selection.

First, $\sigma$ and $\phi_1$ are chosen prior to solving the model. I set $\sigma = 1$, which implies $u(c) = \log(c)$. The fraction of time spent in compulsory schooling is $\phi_1 = 0.345$. This corresponds to 10.4 actual years of compulsory education, which is the average number of
Table 4: Summary of Benchmark Model Parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of relative risk aversion</td>
<td>$\sigma$</td>
<td>1</td>
<td>$u(c) = \log(c)$</td>
</tr>
<tr>
<td>Fraction of time in compulsory schooling</td>
<td>$\phi_1$</td>
<td>0.35</td>
<td>Calculated from U.S. Digest of Education Statistics</td>
</tr>
</tbody>
</table>

Jointly Calibrated Parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generational time discounting (altruism)</td>
<td>$\beta$</td>
<td>0.13</td>
<td>Private share of total education spending = 0.327</td>
</tr>
<tr>
<td>Persistence in AR(1) process for $\alpha$</td>
<td>$\rho_\alpha$</td>
<td>0.71</td>
<td>Intergenerational earnings elasticity = 0.47</td>
</tr>
<tr>
<td>Std dev of noise in AR(1) process for $\alpha$</td>
<td>$\sigma_\alpha$</td>
<td>0.36</td>
<td>Pre-tax Gini coefficient = 0.44</td>
</tr>
<tr>
<td>Elasticity of HC output w.r.t. inputs</td>
<td>$\nu$</td>
<td>0.60</td>
<td>Average years of schooling = 13.1</td>
</tr>
<tr>
<td>Exponent on compulsory HC production</td>
<td>$\gamma_1$</td>
<td>0.51</td>
<td>High school completion rate = 0.841</td>
</tr>
<tr>
<td>Exponent on non-compulsory HC production</td>
<td>$\gamma_2$</td>
<td>0.76</td>
<td>College completion rate = 0.256</td>
</tr>
<tr>
<td>Variance of market luck shocks</td>
<td>$\sigma_\eta$</td>
<td>0.53</td>
<td>Share of earnings variance post-schooling = 0.385</td>
</tr>
<tr>
<td>Variance of taste for schooling shocks</td>
<td>$\sigma_\zeta$</td>
<td>0.25</td>
<td>Mincer returns to schooling = 0.10</td>
</tr>
</tbody>
</table>

Table notes: The intergenerational earnings elasticity is taken from Corak (2006). The Gini coefficient is an OECD estimate before taxes and transfers, for the working age population (18-65) around the year 2000, and is taken from http://stats.oecd.org/. Average years of schooling is the author’s calculation from 2000 U.S. Census data. High school and college completion rates are from National Center for Education Statistics Digest of Education Statistics. The share of earnings variance due to post-schooling factors is based on the finding of Huggett et al. (2011) that the fraction of variance in lifetime earnings due to conditions before age 23 is 0.615. Finally, the target of 10% Mincer returns per year of schooling is approximately the average return as estimated by many studies of the U.S. since 1950, as surveyed, for example, in Heckman et al. (2006).
years of compulsory schooling across U.S. states in 2000.\footnote{22}{Calculated from data in Table 165 in the 2008 Digest of Education Statistics.} The remaining eight parameters \(\beta\), \(\rho_\alpha\), \(\sigma_\alpha\), \(\nu\), \(\gamma_1\), \(\gamma_2\), \(\sigma_\eta\), and \(\sigma_\zeta\) are jointly calibrated to minimize a quadratic loss function so that the model replicates relevant statistics from U.S. data.

The targeted statistics are chosen so that the model captures salient features of both the earnings and education distributions. While there are no direct one-to-one mappings between the parameters and moments above, the choice of data targets above is justified as follows. First, \(\beta\) controls time discounting across generations, or “altruism” toward future generations, by affecting how much parents value the consumption of future generations relative to the family’s current period utility. Parents affect the income and consumption of future generations by investing in their child’s education in the current period, so \(\beta\) impacts how much private education spending there is in equilibrium. Parameter \(\rho_\alpha\) determines how persistent the transmission of ability is across generations, which in turn affects how persistent human capital, and thus earnings, is across generations within families. Parameter \(\sigma_\alpha\) determines the variance of the ability distribution in the population, which affects earnings dispersion. Parameter \(\nu\) affects the relative importance of time versus expenditures as inputs to human capital production, and so affects how long individuals tend to spend in school on average. Parameters \(\gamma_1\) and \(\gamma_2\) determine the returns to compulsory and non-compulsory education, respectively, and so affect the share of individuals in the population who will choose to complete each level of education. Parameter \(\sigma_\eta\) determines the variance of market luck shocks, which translate the human capital produced through schooling, \(h_c\), into the acquired human capital stock that parents supply to the labor market, \(h'_p\). Thus, \(\sigma_\eta\) effectively controls how much of the variance in lifetime earnings is due to post-schooling shocks versus the differences among individuals that are already present at the time of labor market entry. Finally, \(\sigma_\zeta\) affects average returns to an additional year
of schooling by ensuring that time spent in school is not perfectly correlated with learning ability, in which case Mincer returns would actually reflect the skill premium and therefore be unrealistically high. Idiosyncratic tastes for schooling result in some high ability children spending less time in school, and some low ability children spending more time in school. Hence, increasing the variance of taste shocks lowers the average return to an additional year of schooling to more empirically reasonable level.

5 Computational Results

5.1 Benchmark Model Fit

Before using the model to conduct counterfactual experiments and examine policy implications, it must be verified that the model matches relevant features of the U.S. economy. Table 5 shows that the model does indeed match features of the earnings and education distributions that were targeted in the calibration routine described above. The two main aspects of interest regarding the earnings distribution are the intergenerational earnings elasticity and income inequality. The model predicts an elasticity of parent-child earnings of 0.475 and pre-tax Gini coefficient of 0.440, both of which are very close to their targeted values. The model prediction of 0.34 for private share of total education spending on both compulsory and non-compulsory levels is also quite close to the data value of 0.327. The average share of children’s time endowment spent in school is somewhat higher in the model than the data. The model value of 0.493 corresponds to 14.8 years of schooling, whereas the data value of 0.437 corresponds to only 13.1 years of schooling. However, the next two rows indicate that despite overestimating the average years of schooling, the model nonetheless matches the completion rates for high school and college fairly well. In the model, 86.1% of individuals complete high school, compared to 84.1% in the data. Likewise, the college
Table 5: Benchmark Model Fit

<table>
<thead>
<tr>
<th>Target</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intergenerational earnings elasticity</td>
<td>0.470</td>
<td>0.475</td>
</tr>
<tr>
<td>Gini coefficient (pre-tax)</td>
<td>0.440</td>
<td>0.440</td>
</tr>
<tr>
<td>Private share of total education spending</td>
<td>0.327</td>
<td>0.340</td>
</tr>
<tr>
<td>Average share of time in school</td>
<td>0.437</td>
<td>0.493</td>
</tr>
<tr>
<td>High school completion rate</td>
<td>0.841</td>
<td>0.861</td>
</tr>
<tr>
<td>College completion rate</td>
<td>0.256</td>
<td>0.258</td>
</tr>
<tr>
<td>Share of earnings variance post-schooling</td>
<td>0.385</td>
<td>0.394</td>
</tr>
<tr>
<td>Mincer returns to additional year of schooling</td>
<td>0.100</td>
<td>0.097</td>
</tr>
</tbody>
</table>

completion rate of 25.8% is only slightly above the data value of 25.6%. The share of earnings variance due to factors after schooling completion in the data is 0.385, and in the model this value is 0.394. Finally, the Mincer returns to an additional year of schooling is both matched almost exactly.

Overall, the model matches nicely the data moments targeted in calibration. But in fact the model also makes predictions for other important, non-targeted statistics. For instance, much of the private education spending in the U.S. occurs at the college and university level since primary and secondary education is publicly funded. According to the OECD, 91.4% of primary and secondary education funding in the U.S. is public, while only 8.6% is private. By contrast, at the tertiary level 31.1% is public, while 68.9% is private. The model targeted only the aggregate level of private spending, but in fact comes close to matching the division by education level. In the model, private spending comprises 12.7% of total compulsory stage expenditures and 53.2% of total non-compulsory stage expenditures. I conclude that the private education spending decisions of model households are generally
an accurate representation of actual decisions made by U.S. households. It is important that the model is correct along this dimension because in the cross-country analysis it will become apparent that the option to supplement the public provision with private spending is a crucial one.

5.2 Quantitative Effects of Taxes and Public Education Expenditures

The goal of the main computational exercise is to determine how much of the differences in earnings inequality and intergenerational persistence can be accounted for by the differences in public education systems between the U.S. and Norway. Toward this end, I first compute the stationary recursive equilibrium of the model with the parameterization described above for the U.S. economy. I then compute the stationary equilibrium in three counterfactual economies. The first counterfactual assumes that the U.S. adopts only the Norwegian education financing system, i.e., I replace the functions $g_1(\cdot)$ and $g_2(\cdot)$ for the U.S. with those for Norway. Any differences in equilibrium earnings inequality and intergenerational persistence generated by this experiment will be attributable to the different public education expenditures. The second counterfactual assumes that the U.S. keeps its own education financing system while adopting the Norwegian tax function, i.e., I replace $\tau(\cdot)$ for the U.S. with that for Norway. This experiment reveals the marginal effects of the tax system on earnings inequality and intergenerational earnings persistence. The final counterfactual assumes the U.S. adopts both the Norwegian education and tax functions.

Table 6 shows results for the exercises just described. The first row shows again that the benchmark calibration replicates the intergenerational earnings elasticity and earnings inequality (as measured by the pre-tax Gini coefficient) seen in the U.S. data for 2000. The second row indicates that when the U.S. public education functions are replaced by those for Norway, the model generates a decrease in the intergenerational earnings elasticity.
Table 6: Accounting for Taxes and Public Education Systems

<table>
<thead>
<tr>
<th>Education System</th>
<th>Tax System</th>
<th>Intergenerational earnings elasticity</th>
<th>Pre-tax Gini coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td>U.S.</td>
<td>U.S.</td>
<td>0.470</td>
<td>0.475</td>
</tr>
<tr>
<td>Norway</td>
<td>U.S.</td>
<td>-</td>
<td>0.441</td>
</tr>
<tr>
<td>U.S.</td>
<td>Norway</td>
<td>-</td>
<td>0.471</td>
</tr>
<tr>
<td>Norway</td>
<td>Norway</td>
<td>0.170</td>
<td>0.444</td>
</tr>
</tbody>
</table>

Table notes: Data estimates of earnings elasticities are from Corak (2006) and pre-tax Gini coefficients are from the OECD.

from 0.475 to 0.441. Additionally, earnings inequality as measured by the pre-tax Gini coefficient declines from 0.440 to 0.434. By contrast, the marginal effects of the tax system are seen in the third row, where intergenerational earnings mobility falls from 0.475 to 0.471, and the Gini coefficient declines from 0.440 to 0.430. Finally, the fourth row shows the combined effects of including both Norwegian taxes and public education expenditures. The intergenerational earnings elasticity declines to 0.444, and the Gini coefficient declines to 0.431.

The change in intergenerational earnings elasticity between the benchmark U.S. economy and counterfactual economy with both Norwegian taxes and public education financing represents about 10.6% of the observed difference between the U.S. and Norway in the data, while the decline in the Gini coefficient is about 14.3% of the data difference.\(^{23}\) Importantly, most of the decrease in the intergenerational earnings elasticity is due to changing the education system, whereas most of the decrease in the Gini coefficient is due to changing the

\(^{23}\) The share of intergenerational earnings elasticity accounted for by the model is calculated as \(\frac{\Delta_{\text{model}}}{\Delta_{\text{data}}} = \frac{0.475 - 0.441}{0.475 - 0.170} = 0.106\). Similarly, the share of earnings inequality accounted for by the model is calculated as \(\frac{\Delta_{\text{model}}}{\Delta_{\text{data}}} = \frac{0.440 - 0.431}{0.440 - 0.140} = 0.143\)
tax system. From these experiments I conclude that the progressivity of public education spending has a larger impact on intergenerational earnings mobility, while progressivity of the tax system has a larger impact on earnings inequality. It is also worth noting that, as in Guvenen et al. (2011), general equilibrium effects of the tax and transfer system are borne out even in pre-tax earnings. This result stems from the fact that progressivity in the tax function provides a disincentive to invest in human capital. This is especially true for the highest ability individuals who would experience the largest earnings gains from investing in education, and therefore also face the largest tax penalties.

Given the seemingly large differences in public education financing systems discussed earlier, why does the model predict relatively small changes in earnings inequality and intergenerational persistence? There are a couple of important contributing factors. First, the differences in public education spending between the U.S. and Norway are not as large as some of the summary statistics might initially suggest. For example, even though household earnings and public education expenditures are positively correlated in the U.S but negatively correlated in Norway, most individuals (except those in the lower and upper tails of the earnings distribution) receive public education expenditures that are similar in the two economies. Second, the private education spending feature of the model gives parents a option to offset differences in public education spending. This channel is important in matching features of the U.S. education system, but it also predicts too much private education spending in the counterfactual Norwegian version of the model. By limiting private spending to levels matching the Norwegian data (5%, as compared to nearly 33% in the U.S.) this model is able, in fact, to account for nearly half of the cross-country difference in intergenerational earnings persistence and 150% of the difference in earnings inequality. This result suggests that cross-country differences in private education spending are perhaps even more important than public education spending for understanding the
cross-country differences in earnings distributions. Future work should consider even more carefully the factors leading to such large cross-country differences in private education spending.

6 Conclusion

This paper has provided evidence for cross-country differences in the funding and distribution of public education. In doing so, I have argued that aggregate measures of public education spending, such as average expenditures per student, do not capture all of the relevant differences in the allocation of public education spending either within or across countries. As a first step toward more accurately modeling the many differences in public education financing systems, I have estimated public education spending functions from school district-level financial data and incorporated these into a dynamic general equilibrium model. I then computed how much of cross-country differences in earnings inequality and intergenerational persistence can be accounted for by differences in public education funding systems. Results in the case of the U.S. and Norway suggest that less than 15% of differences in earnings inequality and about 10% of differences in intergenerational earnings persistence are due to public education and taxation differences. Furthermore, I find that the progressivity of education spending is responsible for most of the model changes in intergenerational earnings persistence, whereas tax systems are responsible for most of the model changes in earnings inequality.

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——— (Forthcoming) “Inequality from generation to generation: the United States in comparison,” in Robert Rycroft ed. *The Economics of Inequality, Poverty, and Discrimination in the 21st Century*: ABC-CLIO.


A Details on Estimation of Tax Functions

Tax functions for the U.S. and Norway are estimated using data from the 2010 edition of the OECD publication *Taxing Wages*. This edition contained a special feature section on tax reforms and changes in tax burdens from 2000-2009. Included with this special section are year 2000 net personal average tax rates for the following types of households: single
individuals with either zero or two children; one earner married couples with either zero or two children; and two earner married couples with either zero or two children.

Net personal average tax rates include employee social security contributions plus central and local government income taxes, less cash benefits to families. The tax rates are computed for earnings levels varying from 50% of the average wage (AW) to 250% of the AW, in 1% increments, where the average wage is defined as the average gross wage earnings of a private sector adult male full-time (manual or non-manual) worker in that year and country.

For the two earner married couples, net personal average tax rates are computed assuming: (i) the husband’s earnings are variable, and the wife earns 67% of the average wage, or (ii) the husband’s earnings are variable, and the wife earns 100% of the average wage. Thus, in the first case tax rates are computed for households whose total earnings range from 50% + 67% = 117% of AW up to 250% + 67% = 317% of AW. Similarly, in the second case tax rates are computed for households whose total earnings range from 50% + 100% = 150% of AW up to 250% + 100% = 350% of AW.

Because childless families are not modeled, I only utilize tax data for households with children in the estimation. As in the text, denote the net average tax rate by $\tau(\hat{y})$, where $\hat{y} = \frac{y}{AW}$. Thus, for example, $\tau(2.5)$ is the net average tax rate paid by a parent whose labor earnings are 250% of the average wage. The estimation procedure is as follows:

1. For the four types of households with children, average the available OECD estimated tax rates at each 1% increment from 50% to 350% of AW.

2. Compute the marginal tax rate from 325% to 350% of AW as:

$$\frac{3.5 \cdot \tau(3.5) - 3.25 \cdot \tau(3.25)}{3.5 - 3.25}$$
3. Tax each additional 1% income increment up to the top income tax bracket (see next step) based on the marginal tax rate computed in step 2.

4. The OECD provides the top marginal personal income tax rate rates in each country, along with the level (as a % of AW) at which that rate becomes effective. For the U.S. in 2000, this rate was 48% at 8.9 times AW, and for Norway in 2000 it was 55.3% at 2.6 times AW. Assuming a two earner household where the wife makes 100% of AW, then this rate would become effective on the husband’s variable earnings when household earnings are 9.9 times AW for the U.S. and 3.6 times AW for Norway. I thus assume that each additional 1% income increment beyond these thresholds is taxed at their respective top marginal rates.

5. Having constructed this series from 0.5 times AW to 10 times AW, estimate the following functional form:

\[ \tau(\hat{y}) = \beta_0 + \beta_1 \hat{y} + \beta_2 \hat{y}^2 + \beta_3 \hat{y}^3 \]  

(12)

6. The estimated parameters imply a tax liability that approaches negative infinity as income approaches zero. Therefore, I assume that \( \tau(\hat{y}) \geq 0.10AW, \forall \hat{y} \). This lower bound was chosen because the lowest net personal average tax rate in the OECD data is \(-11.8\%\) for single parents with two children in the U.S. at 0.5 times AW, meaning these parents are net recipients of transfer payments from the government equal to 5.9% of AW. Setting the bound at 10% of AW allows for the possibility that individuals between 0% and 50% of AW may receive somewhat larger transfers, but the government will not write anyone a blank check. I have set the bound as high as 100% of AW, and results are not sensitive to this choice.
B Robustness to Alternative Calibration Targets

The benchmark calibration of this model for the U.S. matched an intergenerational earnings elasticity of 0.47, taken from Corak (2006). However, there is some discrepancy regarding the true value of this statistic in the U.S. population. In fact, Corak (2006) summarizes estimates of the intergenerational earnings elasticity for the U.S. ranging from 0.09 to 0.61. However, since Solon (1992) demonstrated the downward bias in many of these estimates, a growing consensus has placed the likely true value in the range of 0.4 to 0.6. I now examine the robustness of the benchmark results above to changing the target value of this parameter.

Table 7 presents results of the benchmark counterfactual exercise along with two alternative calibrations for the targeted intergenerational earnings elasticity. In each case, I change both the public education funding system and the taxation system from the U.S. to Norway and record the model changes in earnings persistence and inequality. The first row of table 7 repeats the main result that the benchmark model accounts for about 9% of the data difference in earnings persistence and about 33% of the data difference in the pre-tax Gini coefficient. Rows two and three show that this result is fairly robust to targeting a lower or higher value for the U.S. intergenerational earnings elasticity. In the lower elasticity case, the model still accounts for 7.8% of the data difference in earnings persistence and 30% of the data difference in the pre-tax Gini coefficient. In the higher elasticity case, these numbers increase to 8.1% and 38.3%.
<table>
<thead>
<tr>
<th>Calibration</th>
<th>Intergenerational earnings elasticity</th>
<th>Pre-tax Gini Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.</td>
<td>Norway</td>
</tr>
<tr>
<td>Benchmark</td>
<td>0.470</td>
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<tr>
<td>Target elasticity = 0.40</td>
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<td>0.378</td>
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<tr>
<td>Target elasticity = 0.60</td>
<td>0.596</td>
<td>0.561</td>
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