

Public Education Financing Systems, Earnings Inequality, and Intergenerational Mobility

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Abstract

Among developed countries there are large and well-documented differences in earnings inequality and intergenerational earnings mobility. Public education financing systems are investigated as a possible source for these cross-country differences. This paper first documents facts about public education in two particular countries, the U.S. and Norway. These countries provide an interesting case study because they have very different earnings distributions and public education systems. An overlapping generations model is calibrated to match U.S. data, and tax and public education spending functions are estimated for each country. The main finding is that taxes and public education spending account for about 15% of differences in earnings inequality and 10% of differences in intergenerational earnings persistence between the U.S. and Norway. Notably, these differences are largely due to changes in the distribution of public education spending rather than average level differences.

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1 Introduction

Among developed countries there are large and well-known differences in both earnings inequality and the persistence of earnings across family generations (commonly referred to as intergenerational earnings mobility).¹ There are also 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 goals of this paper are: (i) to document empirical evidence on the distributions of public education expenditures that result from different public education financing systems; and (ii) to ask whether or not differences in taxation and public education spending can account for the large differences in earnings inequality and intergenerational earnings persistence across countries.

The empirical and quantitative exercises in this paper focus on the U.S. and Norway for two reasons. First, disaggregated education financing data are available for both countries, allowing for examination of public primary and secondary education spending at the school district level. Second, the U.S. and Norway provide an interesting case study because they are polar opposites in several important aspects relating to earnings distributions. 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

¹See, e.g., evidence presented in Aaberge et al. (2002), Bratsberg et al. (2007), Andrews and Leigh (2009) and Corak (Forthcoming).

and intergenerational earnings persistence.

I begin by documenting several facts about the public education systems in the U.S. and Norway. 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. Fourth, private sources account for nearly one-third of total education spending in the U.S., but only about 5% of total education spending in Norway.² Finally, tertiary education is essentially free in Norway, while publicly subsidized grants and loans in the U.S. are generally dependent on a student's other financial resources.

Motivated by these empirical observations, I depart from the traditional concept of “public education” in which all individuals receive the same amount of public resources. 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 overlapping generations model in order to assess quantitatively the impact of public education expenditures on earnings inequality and intergenerational earnings persistence. In the model, families consisting 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 and secondary level) education for each child is determined by a function of parent earnings. Parents may supplement public education expenditures with their own private spending,

²The first three facts regarding education are documented in Section 3. The fourth fact is from OECD *Education at a Glance 2010*, Table B3.1.

but they may not borrow against the child’s future earnings to do so. Upon completing compulsory education, children may obtain non-compulsory (tertiary level) 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 can 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, a more equal distribution of resources across schools reduces variance in the resulting human capital distribution of the population, thus reducing earnings variance. Third, the level and progressivity of taxes on labor earnings affect net returns to human capital, and thus the incentives to make additional private investments beyond the publicly provided allotment.³

Ultimately, the magnitude of these effects must be determined quantitatively. In the main quantitative exercise, I estimate public education spending functions from data and calibrate remaining parameters of the model to match features of the U.S. education and earnings distributions. I then compute a counterfactual economy in which the U.S. public education and taxation systems are replaced by the Norwegian counterparts. I find that these features account for about 15% of the cross-country differences in earnings inequality and 10% of differences in intergenerational earnings persistence. Importantly, these differences are largely due to changes in the *distribution* of public education spending rather

³See, 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.

than average level differences. Furthermore, I find that the public education spending is responsible 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 correlated across countries, they are not necessarily driven by the same factors, and they may respond independently to tax and education spending policies.

The remainder of this paper proceeds as follows. Section 2 discusses the related literature. Section 3 presents motivating evidence on public education systems in the U.S. and Norway. Section 4 outlines the model. Section 5 covers estimation of the tax and public education spending functions, as well as calibration of remaining model parameters. Section 6 discusses the benchmark model fit and results from the main quantitative exercise. Section 7 presents additional experiments and sensitivity analysis, and Section 8 concludes.

2 Related Literature

This paper builds on an extensive literature dating back at least to early theoretical work by Becker and Tomes (1979), Loury (1981), and Becker and Tomes (1986), 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) contributed to this literature by expanding the model to explicitly account for cross-country differences in intergenerational persistence. On the empirical side, many papers have measured cross-country differences in both intergenerational earnings persistence and earnings inequality. A recent summary of these can be found in Corak (2006).

Other papers including Restuccia and Urrutia (2004), Seshadri and Yuki (2004), and Taska (2011) have also examined quantitatively the impact of taxation and public education spending on income inequality and intergenerational persistence. Several papers have also

studied these issues in a cross-country setting. For example, Björklund and Jäntti (1997) study the case of the U.S. and Sweden, Checchi et al. (1999) examine the case of the U.S. and Italy, and Holter (2012) analyzes the U.S. versus 10 other OECD countries. The main value added of this paper relative to existing quantitative analyses 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 Section 3, 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.

Of course, it is well-known that public education spending is not uniform, and some papers have studied how various education financing systems can affect the distribution of public education spending. One important contribution is by Fernandez and Rogerson (2003) who examine five different education financing systems in a general equilibrium political economy model, and compare the effects on welfare and the distribution of education resources. Also, Murray et al. (1998) study changes in the distribution of public school re-

sources following legal challenges from the 1970s through 1990s. They find that inequality in education spending declined significantly during these decades in states where public finance reform was ordered by the courts. To my knowledge, though, this is the first paper to compare distributions of education spending across countries and examine implications for earnings distributions in a general equilibrium framework.

Perhaps the most closely related papers are Bénabou (2002) and Seshadri and Yuki (2004). Bénabou (2002) develops a dynastic heterogeneous-agent economy and calibrates to match U.S. tax and education finance policies. He then conducts separate exercises to assess the impact of progressivity in taxes and education spending for economic growth, aggregate welfare, inequality, and intergenerational mobility. In this paper, however, I integrate both the fiscal and education finance policies for a joint quantitative analysis, yet I am still able to quantify marginal effects of each, as well. Seshadri and Yuki (2004) also have a dynamic general equilibrium setting with heterogeneity in which they quantify the relative effects of monetary versus educational transfers. This paper extends their work along several important dimensions by modeling multiple stages of education in which both schooling time and expenditures matter for human capital production, and disciplining the magnitude of educational transfers using rich disaggregated data.

3 Empirical Evidence

This section first examines data on revenue sources and the distribution of public education expenditures in the U.S. and Norway. I then briefly discuss the higher education subsidies available in each country. The data discussed here are incorporated later in the quantitative analysis in Sections 5 and 6. Further details on the data construction and sources are found in Appendix A.

3.1 Public School District Revenues

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

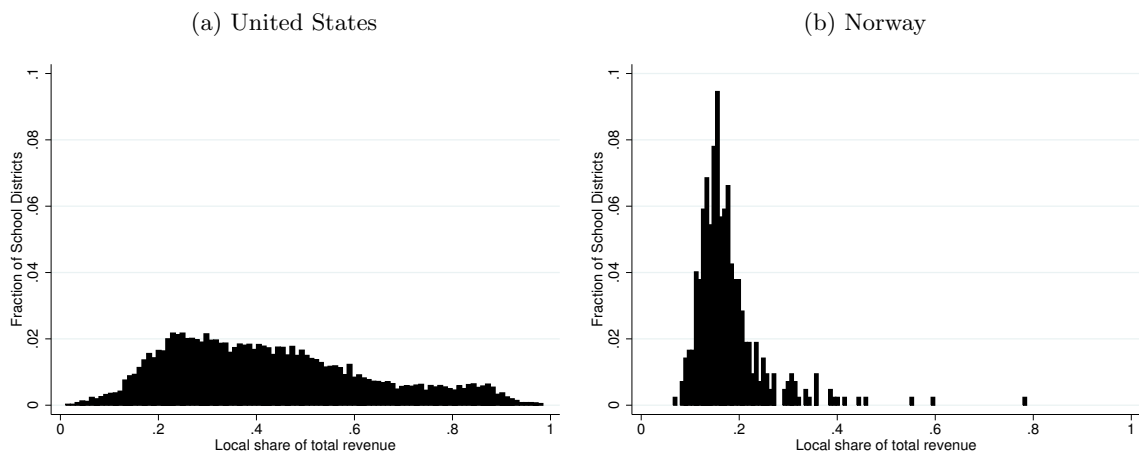


Figure 1 illustrates the distinction in financing systems between the two countries. Panel (a) shows the distribution of public school districts in the U.S. by the share of their total revenue that is generated locally, and Panel (b) shows the same for Norway. Notably, school districts in the U.S. range from one extreme of having almost no local funding to the other extreme of being completely reliant on local revenue sources. The system of strong federal control in Norway, however, results in the much more concentrated distribution

Table 1: Correlations Across School Districts Between Median Income and Public Education Revenues

Variable	United States	Norway
Local revenue	0.58	0.02
Non-local revenue	-0.36	0.03
Total revenue	0.31	0.03
Local share of total revenue	0.57	0.03

Notes: All correlations are significant at the 1% level.

seen in Panel (b). Nearly nine out of ten Norwegian school districts raise less than 25% of public education revenues from local sources.

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. For both the United States and Norway, Table 1 reports correlations between school district median income and school district revenue variables, including the public education revenue from local sources, revenue from non-local sources, total revenue, and the share of total revenue from local sources.

Several remarkable differences between the U.S. and Norwegian public education financing systems are apparent from the table. As expected, the correlation between median income and local revenue for the U.S. is indeed strongly positive at 0.58. In other words, school districts with higher median income tend to raise greater amounts of local revenue. In addition, those school districts with higher median income tend also to raise a greater share of revenue locally, as indicated by the correlation of 0.57 between median

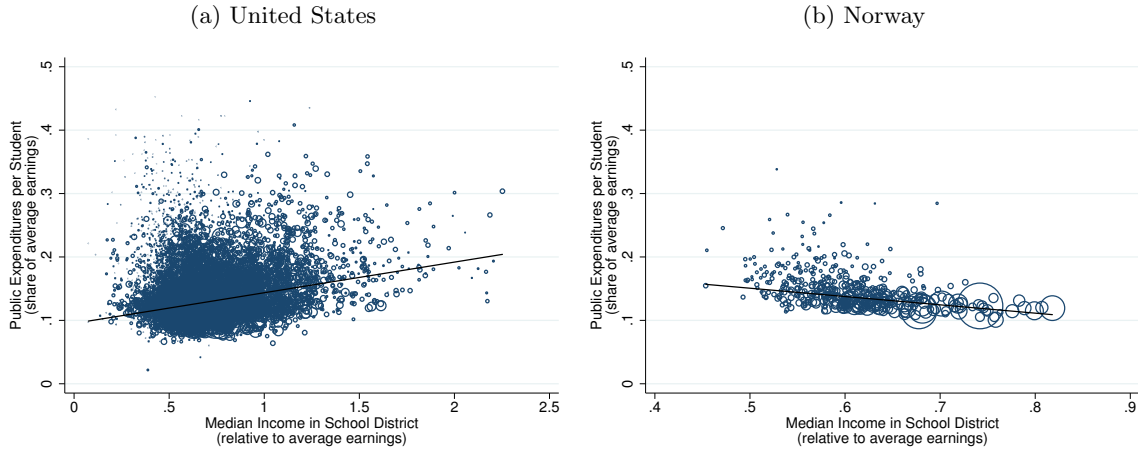
income and the local share of total revenue. Also, the correlation between median income and non-local revenue is strongly negative at -0.36 indicating that that state and federal governments do redistribute funds in an attempt to offset revenue disparities due to local funding. Nevertheless, the correlation between median income and total revenue is still positive at 0.31. In contrast, the correlations between public education revenue variables and median income in Norway are quite different. Unlike the U.S., median income in Norway is essentially uncorrelated across school districts with local, federal, or total revenue, as seen in the far right column of Table 1.

3.2 Public School District 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. 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. 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.⁴ Circles in the scatter plots vary in size proportional to the number of students in each school district, and regression

⁴Annual wage earnings for the U.S. and Norway are from the OECD Taxing Wages database. Alternatively, one could convert the data from local currencies using PPPs to make the units comparable. However, it turns out that different PPP indexes (such as those by Gheary-Khamis and Èltetö-Köves-Szulc-Sergeev) provide very different answers for the U.S. and Norway, so I use this normalization in order to avoid PPP conversions altogether.

Figure 2: Distributions of Public Education Expenditures



lines overlaying the scatter plots are weighted by the number of students each district.⁵

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 notable difference in the panels of Figure 2 is that the variance of public expenditures across districts is much greater in the U.S. than Norway. One simple summary

⁵The astute reader may be curious as to why the horizontal axis of the Norwegian scatter plot does not have data both above and below one, as in the U.S. version. The measure of income in each school district is median personal wage earnings for all persons over 17. These data are normalized relative to the mean annual wage earnings of full-time equivalent workers. Due to skewness in the income distribution, the median will tend to be smaller than the mean. Also, because some individuals work only part-time, or not at all, the numerator will generally be smaller than the denominator. In the U.S., there are some particularly high income districts where the numerator exceeds the denominator, but this is not the case for Norway.

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 (relative to the mean expenditures per student) across school districts in the U.S as in Norway.⁶

Despite the distributional differences between the U.S. and Norway, it turns out that the differences for the “average” student are actually quite small. Using the same data as in Figure 2, the mean annual public expenditure on instruction per student is 13.3% of average earnings in the U.S., and 13.0% of average earnings in Norway. In essence, this is why modeling the distribution of public expenditures is potentially important. If one only examines differences in average public spending per student, then the U.S. and Norway appear quite similar, but there are significant differences once the full distribution of public spending is taken into account.

3.3 Public Subsidies for Higher Education

Public funding for higher education in the U.S. is a complicated web of subsidies, grants, and loans. Some of these public expenditures directly lower the prices paid by students, while others provide a low-cost source of borrowing for students who might otherwise be credit constrained. By contrast, the Norwegian higher education system is essentially free for all admitted students, with the exception of some small fees.

A couple of aggregate statistics illustrate well the fiscal implications of these different systems. According to OECD data, public spending on tertiary education in the year 2000 amounted to 1.1% of GDP in the U.S. and 1.7% of GDP in Norway.⁷ In other words, public spending on tertiary education relative to GDP was about 50% higher in Norway than the

⁶It is interesting to note that such large dispersion still existed in the U.S. as of 2000 despite reduced inequality across school districts in many states from the 1970s through 1990s, as described in Murray et al. (1998).

⁷See OECD *Education at a Glance 2003*, Table B4.1.

United States. The lower levels of public spending in the U.S. are compensated by higher levels of private spending. Public sources in the U.S. accounted for 31.1% of total tertiary education spending in 2000, and the remaining 68.9% was privately funded. By contrast, 96.3% of total tertiary education spending in Norway in the year 2000 was public.⁸

Overall the above data paints a picture of two countries in which systems for both funding and distributing public education expenditures are very different. Based on this evidence, modeling public education as a system in which every individual receives an identical allocation may result in misleading or 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 model and quantitative exercises to follow, I allow for heterogeneous individuals to receive different amounts of public education expenditures during compulsory education. I also model higher education subsidies that are dependent on parent income. This environment allows for more accurate accounting of the role that public education financing plays in generating cross-country differences in earnings inequality and intergenerational earnings persistence.

4 Model Economy

4.1 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. The focus here is on public education and lifetime labor earnings, so I do not model the period of early childhood prior to formal schooling, nor the retirement period of life.

During the first period of life each individual is referred to as a “child,” and during the

⁸See OECD *Education at a Glance 2012*, Table B3.2b.

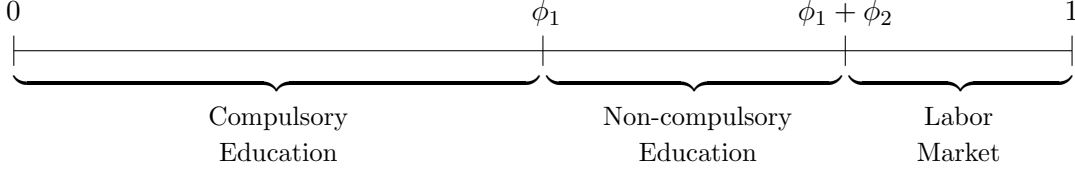
second period of life the individual is a “parent.” Each parent has a child at the beginning of the second period of life. A family at a given point in time consists of one parent and one child, and an infinite sequence of overlapping generations of parent-child pairs is referred to as a family dynasty.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

At the beginning of each period, each family is characterized by a state vector $\mathbf{x} = (h_p, \alpha, \zeta)$, where h_p is the human capital of the parent acquired through education in the previous period, α is the learning ability of the child, and ζ 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 $\mu(\mathbf{x})$.

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 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.

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 ϕ_2 is chosen by each parent for the child. The non-compulsory stage nests all forms of post-

Figure 3: Division of a child's time endowment



secondary 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 market labor after all education is complete. Figure 3 provides a graphical example of the division of the child's time endowment.

4.2 Human Capital and Ability

As previously mentioned, each child is endowed with learning ability α . 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:

$$h_2 = h_1 + \alpha[(h_1\phi_1)^\nu s_1^{1-\nu}]^{\gamma_1} \quad (1)$$

$$h_3 = h_2 + \alpha[(h_2\phi_2)^\nu s_2^{1-\nu}]^{\gamma_2} \quad (2)$$

where α is ability, ϕ_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 $f(s_1, s_2, \phi_2; \mathbf{x})$. In addition, to distinguish between the human capital of parent and child within a family, denote the acquired human capital of the child after completing all education by h_c . Thus,

$$h_c \equiv h_3 = f(s_1, s_2, \phi_2; \mathbf{x}) \quad (3)$$

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. Also, the human capital acquired in compulsory education is an input to the non-compulsory stage human capital production function. In other words, individuals with more human capital after high school would gain more from additional time spent 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. This type of shock is commonly referred to as “market luck,” but it may also simply represent unobserved heterogeneity resulting in different earnings among individuals with similar levels of observable human capital. More specifically, a child with human capital h_c today will have human capital h'_p when they become a parent tomorrow according to:

$$h'_p = \eta h_c \quad (4)$$

where $\ln(\eta) \sim N(0, \sigma_\eta^2)$. 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).

4.3 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 in a given period is:

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

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 $(1 - \phi_1 - \phi_2(\mathbf{x}))h_c(\mathbf{x})$.

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:

$$Y = C + E_1 + E_2 + G_1 + G_2 + G_c. \quad (6)$$

4.4 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 $T(y_p, y_c) = \tau(y_p) \cdot y_p + \tau(y_c) \cdot y_c$, 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, general public education spending functions are defined as follows. First, compulsory education spending is potentially a function of the entire family state vector $\mathbf{x} = (h_p, \alpha, \zeta)$, and parents observe $g_1(\mathbf{x})$ 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 $\mathbf{x}$. Specifically, if a family described by state vector $\mathbf{x}$ chooses

a college or university education with total cost s_2 , then the government subsidy will be $g_2 = \theta(\mathbf{x})s_2$ and the share paid out-of-pocket by the family will be $e_2 = (1 - \theta(\mathbf{x}))s_2$, where $\theta(\mathbf{x}) \in [0, 1]$ for all $\mathbf{x}$.

4.5 Decision Problems

A parent who enters a period with state vector $\mathbf{x} = (h_p, \alpha, \zeta)$ chooses consumption, private education spending on the child's compulsory education, total spending on non-compulsory education (which, given the subsidy $g_2(\mathbf{x})$, also yields a choice for private spending), and the fraction of the child's time spent in non-compulsory education. The parent's objective is to maximize utility from current consumption and the 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:

$$V(h_p, \alpha, \zeta) = \max_{c, e_1, s_2, \phi_2} \{u(c) + \zeta\phi_2 + \beta\mathbb{E}_{\alpha', \eta', \zeta'} [V(h'_p, \alpha', \zeta')|\alpha]\} \quad (7)$$

subject to

$$c + e_1 + (1 - \theta(\mathbf{x}))s_2 = y_p + y_c - T(y_p, y_c)$$

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

$$h_c = f(s_1, s_2, \phi_2; \mathbf{x})$$

$$s_1(\mathbf{x}) = g_1(\mathbf{x}) + e_1$$

$$h'_p = \eta h_c$$

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

where $V(h_p, \alpha, \zeta)$ is the value function of a family with state $\mathbf{x} = (h_p, \alpha, \zeta)$. Substituting the budget constraint into the objective function, the problem above can be written as

a decision problem for three choice variables: private education spending on compulsory education e_1 , total spending on non-compulsory education s_2 (which, given $\theta(\mathbf{x})$, implies a choice for private spending e_2), and time spent in non-compulsory education ϕ_2 . A solution to this problem consists of optimal decision rules $e_1^*(\mathbf{x})$, $s_2^*(\mathbf{x})$, and $\phi_2^*(\mathbf{x})$. I will examine the stationary recursive competitive equilibrium in this economy, defined below.

4.6 Equilibrium

A stationary recursive competitive equilibrium in this economy consists of optimal decision rules $e_1^*(\mathbf{x})$, $s_2^*(\mathbf{x})$, and $\phi_2^*(\mathbf{x})$, labor demand L^* , and stationary distribution $\mu(\mathbf{x})$ such that in every period:

1. Parents choose $e_1^*(\mathbf{x})$, $s_2^*(\mathbf{x})$, and $\phi_2^*(\mathbf{x})$ 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 $\mu(\mathbf{x})$ is consistent with the decision rules and exogenous stochastic processes for α , η , and ζ ;
5. Output and labor markets clear.

5 Model Parameterization

The main quantitative exercise consists of parameterizing the model to match important features of the U.S. data, and then computing a counterfactual economy in which the U.S. education financing system (including the progressive tax functions, compulsory public education expenditures, and subsidies for non-compulsory education) are replaced by the Norwegian counterparts, holding all else fixed. Comparing earnings inequality and intergenerational earnings persistence between the benchmark and counterfactual economies then

identifies the share of cross-country differences accounted for *only* by the public education financing systems. Toward this end, this section discusses the benchmark parameterization of the model. I first estimate the labor income tax functions $\tau(y)$ and public education spending functions $g_1(\mathbf{x})$ and $g_2(\mathbf{x})$ for both the U.S. and Norway. Then I calibrate the remaining parameters for preferences and human capital production, as well as the stochastic processes for ability, market luck, and tastes for schooling.

5.1 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 affect incentives to invest in human capital by altering the after-tax return on investment. 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.

For both the U.S. and Norway, I estimate a tax function of the following form:

$$\tau(\hat{y}) = \beta_0 + \beta_1 \hat{y} + \beta_2 \hat{y}^{\beta_3} \quad (8)$$

where $\hat{y}$ denotes annualized individual earnings relative to the average annual earnings in that country, and $\tau(\hat{y})$ denotes the *net average tax rate* paid by an individual with relative earnings $\hat{y}$.⁹ This form has recently been employed for similar use in cross-country

⁹The OECD reports average annual wage earnings 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.

Table 2: Tax Function Parameter Estimates

Parameter	United States	Norway
β_0	0.434 (0.007)	1.106 (0.060)
β_1	0.003 (0.0004)	-0.002 (0.0005)
β_2	-0.321 (0.008)	-0.921 (0.060)
β_3	-0.719 (0.018)	-0.190 (0.013)
R^2	0.993	0.998

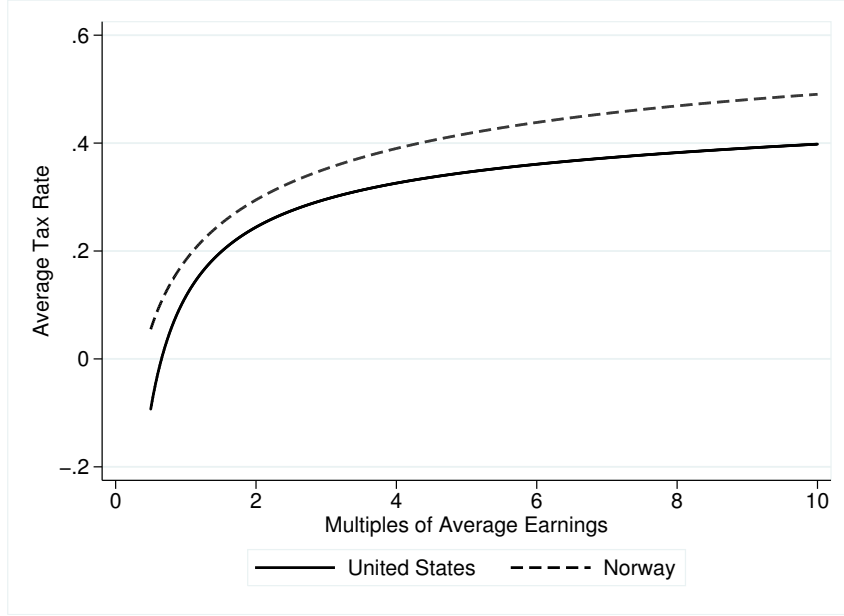
quantitative analysis by Guvenen et al. (2011), and builds on earlier use of the isoelastic form by Bénabou (2000). The nonlinear least squares regression results are reported in Table 2 and the estimated tax functions are plotted in Figure 4. It is worth noting that net average tax rates (both in the raw OECD data and resulting from the estimated tax functions) are actually negative for some individuals with very low earnings. This is due to features of the tax code (such as the earned income tax credit in the U.S.) which result in some individuals receiving transfers from the government that are larger than the taxes they pay.

5.2 Public Education Expenditures

5.2.1 Compulsory Stage

In defining the model, I allowed for government spending to be a function of the family state vector (h_p, α, ζ) . However, public education expenditures are generally not conditioned on

Figure 4: Estimated Average Tax Functions



child-specific characteristics such as ability and tastes for schooling.¹⁰ For this reason, and in order to utilize the data discussed in Section 3, I assume that government spending on compulsory education depends only on parent human capital, not child ability or tastes for school. Since parent income is proportional to parent human capital in the model, I can use the data shown in Figure 2 to estimate children's public education expenditure as a function of their parent's human capital via the following form:

$$\hat{g}_1(\hat{y}_p) = a_1 + b_1 \hat{y}_p. \quad (9)$$

¹⁰Notable 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.

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 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 the year 2000.¹¹ 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 shows 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.¹²

5.2.2 Non-compulsory Stage

Now consider public investment in non-compulsory education. As discussed in Section 3 public colleges and universities in the U.S. are subsidized by tax dollars, so the list price of tuition is lower than would prevail without such subsidies. In addition, students are eligible

¹¹As noted in Appendix A, the Norwegian data for 2000 are 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.

¹²Due 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 3, these limits confirm that the variance of public education spending is much larger in the U.S. than Norway.

Table 3: Parameters for $\hat{g}_1(\hat{y}_p)$

Parameter	United States	Norway
a_1	0.096 (0.00002)	0.210 (0.0003)
b_1	0.051 (0.00003)	-0.121 (0.0004)
R^2	0.08	0.22

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 post-secondary education expenses.¹³ I use the EFC concept to discipline the public subsidy for higher education, $\theta(\mathbf{x})$, by assuming that EFC is the fraction of higher education expenses remaining after the government subsidy.

Because this model does not include assets, the actual EFC formula can not be included directly. 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:

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

¹³The EFC concept has also been utilized recently by Brown et al. (2012). 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.

Table 4: Parameters for $\text{EFC}(\hat{y}_p)$

Parameter	United States
a_2	-0.093 (0.010)
b_2	0.226 (0.007)
R^2	0.986

where, as before, $\hat{y}_p$ is parent income relative to average wage earnings. Average EFC is normalized by the average 4-year public university cost, so the left hand side of equation (10) should be interpreted as the average *share* of total public university costs that a parent with relative earnings $\hat{y}_p$ would be expected to pay for her child's college education. The estimated coefficients for equation (10) are shown in Table 4. The key point to take from those estimates is that the coefficient on parent income is positive, so parents with higher income must pay a larger share of their child's college education expenses.

With this linear formulation, I need to bound the government subsidy above and below, so I utilize the following in computation:

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

where $\overline{g_2}$ is the maximum government subsidy, which prevents individuals with low earnings in the model from getting infinitely large government subsidies. To summarize this formulation in words, parents with relative earnings $\hat{y}_p$ choose total education spending s_2 for their child, receive public subsidy $g_2(\hat{y}_p, s_2)$, and pay the remaining share of the

total cost $\text{EFC}(\hat{y}_p)s_2$. The maximum public subsidy $\bar{g}_2$ is set equal to 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.¹⁴

In contrast to this complicated formulation for the U.S., the Norwegian public subsidy for non-compulsory is much simpler to specify because higher education in Norway is essentially free.¹⁵ As mentioned earlier, 96.3% of tertiary education expenditures in Norway for the year 2000 came from public sources and only 3.7% 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 0.963 for all individuals independent of parental income. As in the case of the U.S., I constrain the government subsidy function for Norway to the interval $[0, \bar{g}_2]$, where $\bar{g}_2$ is the same as in the U.S. case described above, so that parents can not extract arbitrarily large public subsidies.

5.3 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 β . I also assume that ability is transmitted across generations according to a first-order autoregressive process:

$$\ln \alpha_{it} = \rho_\alpha \ln \alpha_{i,t-1} + \varepsilon_{it}, \quad (11)$$

¹⁴Since a model period is 30 years, “annual earnings” in the model are 1/30 of period earnings. Annualizing $\bar{g}_2$, therefore, implies $\bar{g}_2 = 0.92(\frac{1}{30})\bar{y} \approx 0.03\bar{y}$, where $\bar{y}$ is average earnings.

¹⁵A complete description of the organization and funding of the education system in Norway is available at: http://eacea.ec.europa.eu/education/eurydice/eurybase_en.php.

where $\varepsilon_{it} \sim N(0, \sigma_\alpha^2)$, α_{it} and $\alpha_{i,t-1}$ denote the ability of the individual in family i born in periods t and $t - 1$, and ρ_α determines the persistence of ability across generations. And as stated previously, the shocks to schooling tastes ζ and market luck η are distributed according to $\zeta \sim N(0, \sigma_\zeta^2)$ and $\ln(\eta) \sim N(0, \sigma_\eta^2)$. Hence, the remaining parameters to be chosen are σ , β , ρ_α , σ_α , ν , γ_1 , γ_2 , ϕ_1 , σ_η , and σ_ζ . Table 5 summarizes the benchmark parameter values and the remainder of the section discusses their selection.

First, σ and ϕ_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 years of compulsory schooling across U.S. states in 2000.¹⁶ The remaining eight parameters β , ρ_α , σ_α , ν , γ_1 , γ_2 , σ_η , and σ_ζ 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. Data targets related to the earnings distribution are the intergenerational earnings elasticity, the pre-tax Gini coefficient, and the share of lifetime earnings variance due to post-schooling factors.¹⁷ Education related statistics are the private share of total education spending, average years of schooling, high school and college completion rates, and the Mincer returns for an additional year of schooling.

While there are no direct one-to-one mappings between the parameters and moments above, the target statistics are justified as follows. First, β controls time discounting (altruism) across generations, i.e., how much the current generation values the utility of future generations relative to own utility. Parents affect the income and consumption of

¹⁶Calculated from data in Table 165 in the 2008 Digest of Education Statistics.

¹⁷I focus on *pre-tax* earnings inequality rather than *post-tax* because I want to uncover differences due only to public education financing systems, not due to other social programs which re-distribute income among the population. Such programs are likely responsible for large cross-country differences in post-tax income inequality and consumption inequality, but they are not the focus of this paper.

Table 5: Summary of Benchmark Model Parameters

Description	Independently Chosen Parameters		
	Parameter	Value	Target
Coefficient of relative risk aversion	σ	1	$u(c) = \log(c)$
Fraction of time in compulsory schooling	ϕ_1	0.35	Calculated from U.S. Digest of Education Statistics
Jointly Calibrated Parameters			
Description	Parameter	Value	Target
Generational time discounting (altruism)	β	0.94 ³⁰	Private share of total education spending = 0.327
Persistence in AR(1) process for α	ρ_α	0.71	Intergenerational earnings elasticity = 0.47
Std dev of noise in AR(1) process for α	σ_α	0.36	Pre-tax Gini coefficient = 0.44
Elasticity of HC output w.r.t. inputs	ν	0.60	Average years of schooling = 13.1
Exponent on compulsory HC production	γ_1	0.51	High school completion rate = 0.841
Exponent on non-compulsory HC production	γ_2	0.76	College completion rate = 0.256
Std dev of market luck shocks	σ_η	0.53	Share of earnings variance post-schooling = 0.385
Std dev of taste for schooling shocks	σ_ζ	0.25	Mincer returns to schooling = 0.10

Notes: Data for the private share of total U.S. education spending is from Table 3B.1 in OECD *Education at a Glance 2012*. 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).

future generations by investing in education in the current period, so β primarily impacts the amount of private education spending in equilibrium. Parameter ρ_α determines how persistent the transmission of ability is across generations, which in turn affects how persistent human capital, and thus earnings, is across generations. Parameter σ_α determines the variance of the ability distribution in the population, which affects earnings dispersion. Parameter ν affects the relative importance of time versus expenditures as inputs to human capital production, and so is intended to target the average time spent in school. Parameters γ_1 and γ_2 determine the returns to compulsory and non-compulsory education, and so affect the share of individuals in the population completing high school and college education. Parameter σ_η determines the variance of market luck shocks, which transforms human capital from childhood to parenthood according to $h'_p = \eta h_c$. Thus, σ_η effectively controls how much of the variance in lifetime earnings is due to post-schooling shocks relative to the differences already present at the time of labor market entry. Finally, σ_ζ controls the variance of schooling taste shocks in the population, but indirectly it also affects the average return to an additional year of schooling by ensuring that time spent in school is not perfectly correlated with learning ability. Idiosyncratic tastes for schooling result in some higher ability children spending less time in school, while some lower ability children spending more time in school. Hence, increasing the variance of taste shocks lowers the average return to an additional year of schooling.

6 Results

6.1 Benchmark Model Fit

Before using the model to conduct counterfactual experiments and examine policy implications, it must be verified that the model replicates relevant features of the U.S. economy.

Table 6 shows that the model matches well the features of the earnings and education distributions that were targeted in calibration. The two main statistics of interest regarding the earnings distribution are the intergenerational earnings elasticity and earnings 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. In the model 34% of total education spending is private, which is also quite close to the data value of 32.7%. One statistic that the model does not match quite as well is the average share of children’s time endowment spent in school, which 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 completion rate of 25.8% is only slightly above the data value of 25.6%.¹⁸ 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 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. According to the OECD, only 8.6% of primary and secondary education spending in the U.S. is private. This is quite comparable to the model, where in equilibrium 12.7% of compulsory stage expenditures are privately funded. OECD data also indicates

¹⁸The reason that the model matches the high school and college completion rates while overestimating the mean years of school is that data for years of schooling is lumpy, i.e., there are spikes in the distribution around high school and college graduation points. The model has no feature to generate such a lumpy distribution.

Table 6: Benchmark Model Fit

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

that 68.9% of all tertiary level expenditures in the U.S. are private, and in the model 53.2% of non-compulsory stage expenditures are private. Thus, while the model targeted only the aggregate level of private spending, it nonetheless replicates an important pattern in the U.S. data in that most private spending is for higher education. 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.

6.2 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 benchmark U.S. economy calibrated

Table 7: Earnings Distribution Statistics for Various Education and Tax Systems

Education System	Tax System	Intergenerational earnings elasticity		Pre-tax Gini coefficient	
		Data	Model	Data	Model
U.S.	U.S.	0.470	0.475	0.440	0.440
Norway	U.S.	-	0.441	-	0.434
U.S.	Norway	-	0.471	-	0.430
Norway	Norway	0.170	0.444	0.377	0.431

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

above. I then compute the stationary equilibrium in three counterfactual economies. The first counterfactual assumes that the U.S. adopts only the Norwegian public education spending, 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 public education 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 public education and tax functions.

Table 7 shows results for the exercises just described. The first row shows again that the benchmark calibration replicates the U.S. intergenerational earnings elasticity and earnings inequality (as measured by the pre-tax Gini coefficient). According to results in the second row, the model generates a decrease in the intergenerational earnings elasticity from 0.475 to 0.441 when the U.S. public education functions are replaced by those for Norway. Addi-

tionally, earnings inequality as measured by the pre-tax Gini coefficient declines from 0.440 to 0.434. The marginal effects of the tax system are shown 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 switching to 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 spending represents 10.6% of the observed difference between the U.S. and Norway in the data, while the decline in the Gini coefficient is 14.3% of the data difference.¹⁹ Importantly, most of the decrease in the intergenerational earnings elasticity is due to changing the public education spending functions, whereas most of the decrease in the Gini coefficient is due to changing the tax system. From these experiments I conclude that the redistribution 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 emphasizing 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.

Recall from Section 3 that average public spending per student is nearly identical in the U.S. and Norwegian data. Because of this, it is actually the *distribution* of public education spending across individuals that drives these results. To confirm this, I take

¹⁹The share of intergenerational earnings elasticity accounted for by the model is calculated as $\frac{\Delta_{\text{model}}}{\Delta_{\text{data}}} = \frac{0.475-0.444}{0.47-0.17} = 0.106$. Similarly, the share of earnings inequality accounted for by the model is calculated as $\frac{\Delta_{\text{model}}}{\Delta_{\text{data}}} = \frac{0.440-0.431}{0.44-0.377} = 0.143$

the benchmark U.S. model and change only the compulsory public education spending function g_1 to the Norwegian version, leaving the U.S. tax system and subsidies for non-compulsory education the same. With this change, the average amount of public education spending (which is endogenous because it depends on average model income) decreases by only 0.2%.²⁰ Thus, the average level of public spending is essentially unchanged, but the distribution of spending across individuals shifts substantially. Low income children now receive much more public spending, while high income children receive much less. In this experiment the intergenerational earnings elasticity falls from 0.475 to 0.448. Compare this to the last row of Table 7 where Norwegian tax and non-compulsory education subsidies were also changed, and the intergenerational earnings elasticity fell to 0.444. Similarly, in this experiment the pre-tax Gini coefficient decreases to 0.436, compared to 0.431 when the tax and non-compulsory education subsidies also change to the Norwegian versions. To summarize, nearly 90% of the model difference in intergenerational earnings persistence, and nearly half of the model difference in pre-tax Gini coefficients occurs due to changing the distribution of compulsory level public education spending.

This confirms an important result from existing research including Restuccia and Urrutia (2004) and Holter (2012). These papers examine differences in average public spending per student and find that additional public spending on early education has a larger impact on intergenerational earnings persistence than additional public subsidies for higher education. While the change in average public spending per student in my experiment is essentially zero, I still find that the distribution of public spending on earlier (compulsory) education is quantitatively much more important than changes in public subsidies for non-compulsory education. As in their models, this result is due to the dynamic complementarity between stages of education. That is, human capital production in non-compulsory

²⁰Again, this model prediction is consistent with the data from Section 3 showing that average public spending per student in compulsory education is nearly identical for the U.S. and Norway.

education depends on the human capital produced during compulsory education, so redistribution of public expenditures has greater impact on earnings mobility when it is targeted toward earlier stages of education.

Finally, I want to emphasize the importance of the private education spending for these results. Recall that the benchmark model matches the private share of education spending in the U.S. education system; however, the model also predicts too much private education spending in the counterfactual exercise with Norwegian public education and tax systems. According to the OECD, fully 99% of spending on primary and secondary education in Norway is publicly provided. One reason for this is that private schools in Norway are subject to government approval, and those approved have 85% of their expenses covered by the government.²¹ Hence, a simple and reasonable way to make the model more accurately reflect the Norwegian education system is to limit private education spending. By exogenously restricting private spending on compulsory education to zero and limiting private spending on non-compulsory education to levels matching the Norwegian data (5%, as compared to nearly 33% in the U.S.), the intergenerational earnings elasticity decreases to 0.34, and the pre-tax Gini coefficient decreases to 0.35. In other words, this model would account for nearly half of the cross-country difference in intergenerational earnings persistence and 150% of the difference in earnings inequality. This 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.

²¹According to the European Commission's *National System Overview of Education Systems in Europe*, 2011 Edition.

7 Discussion

Having presented the benchmark model results, this section discusses other potentially important differences between the U.S. and Norwegian economies that may help explain the residual differences in earnings inequality and intergenerational earnings persistence which are unaccounted for by public education spending and taxation policies.

7.1 The Role of Time and Goods in Human Capital Production

Human capital production functions take many forms in the economics literature. Some authors, such as Guvenen et al. (2011), model human capital production requiring only the individual's time and current human capital stock. Other authors, such as Restuccia and Urrutia (2004), model human capital production where goods are the only input. In this paper, I have chosen a human capital production function requiring the both individual's time and goods. Is the relative weight of time versus goods important for the cross-country accounting exercise? To answer this question, I vary the parameter ν in both the U.S. and Norwegian versions of the economy from the benchmark value of 0.6 to a low of 0.2 and a high of 0.8. At lower values for ν , goods are more important for human capital production, and at higher values of ν goods become less important. Table 8 reports the results of these experiments.

Consider first the effect on intergenerational earnings elasticity. As seen in Table 8, the model accounts for about 10 – 11% of the data difference in intergenerational earnings elasticity, regardless of the value of ν . To understand why this is true, notice that when ν is lower the child's time is relatively less important and goods are relatively more important for human capital production. While this implies that public investments are more effective for improving the earnings prospects of low income, high ability children, it also means that parent's private education investments are also more effective. As a result, I find that as

Table 8: Results from Varying the Relative Weight of Time vs. Goods in Education

Value of ν	Intergenerational earnings elasticity			Pre-tax Gini coefficient		
	U.S.	Norway	$\frac{\Delta_{model}}{\Delta_{data}}$	U.S.	Norway	$\frac{\Delta_{model}}{\Delta_{data}}$
0.2	0.573	0.544	0.097	0.531	0.508	0.375
0.3	0.553	0.520	0.110	0.522	0.494	0.444
0.4	0.522	0.488	0.112	0.488	0.465	0.370
0.5	0.495	0.467	0.095	0.461	0.448	0.218
0.6	0.475	0.444	0.106	0.440	0.431	0.143
0.7	0.456	0.423	0.110	0.421	0.407	0.208
0.8	0.445	0.413	0.106	0.410	0.399	0.160

ν decreases, the private share of total education spending increases, particularly among higher income families. Thus, for all values of ν , moving from the U.S. to the Norwegian public education financing system has essentially the same effect – low income, high ability children are somewhat more likely to rise within the earnings distribution, but increased private education spending by high income parents offsets potentially larger declines in earnings persistence.

Turning to the effects of ν on earnings inequality, there is a different pattern. As ν decreases, the model is able to replicate more of the difference in pre-tax Gini coefficients seen in the data. Why is this the case? As discussed above, when ν decreases goods become relatively more important in human capital production, so private education spending increases. More importantly for understanding inequality, though, the variance of private education spending increases, which means the variance of total education spending also increases. This leads to greater earnings inequality in both countries, but the effect is smaller in the Norwegian version of the economy because average and marginal tax rates

are higher, which serves as a disincentive for private investment in human capital. Thus, the pre-tax Gini coefficient increases by a smaller amount than in the U.S. version.

Two main conclusions may be drawn from these experiments. First, the model results do not seem particularly sensitive to ν , and if anything the benchmark results may be a lower bound for the share of earnings inequality accounted for by the model. Second, the magnitude of private education spending is a major difference between the U.S. and Norway, and once again the option of private spending is shown to dampen what might otherwise be large cross-country differences in the model. This underscores the earlier point that understanding private education spending differences is a promising avenue for future research in accounting for cross-country differences in earnings inequality and persistence.

7.2 Cross-Country Differences in Post-Schooling Earnings Variance

In this model there are three sources of earnings variance: variance in innate ability, variance in education investments, and the “market luck” shocks. The main exercise assumes equal variance of the luck shocks in both the U.S. and Norway; however, this may be an invalid assumption due to cross-country differences in factors such as employment protection policies or unionization rates. For example, the OECD reports an employment protection index that ranges from zero to six, where higher numbers indicate that costs and procedures for dismissing workers are higher in that country. In 2008, the employment protection index for Norway was 2.7, whereas for the U.S. it was 0.7. This placed Norway among those OECD countries with the strictest employment protection laws, while the U.S. was among the least strict. Similarly, the OECD reports that in 2008, 53.3% of employees in Norway were unionized, but only 11.9% of U.S. employees were unionized. Based on statistics like these, it is reasonable to think that employees in Norway experience less uncertainty about their lifetime earnings once they complete school, which would show

Table 9: Results from Decreasing the Variance of Market Luck Shocks

Experiment	Value of σ_η	Intergenerational earnings elasticity	Pre-tax Gini coefficient
Norway Benchmark	0.530	0.444	0.431
10% decrease in σ_η	0.477	0.480	0.422
20% decrease in σ_η	0.424	0.507	0.412
30% decrease in σ_η	0.371	0.545	0.405
40% decrease in σ_η	0.318	0.580	0.400
50% decrease in σ_η	0.265	0.616	0.396

up in the model as lower variance of the market luck shocks. To investigate any effect this may have on the results, I incrementally decrease the variance of the market luck shock from its benchmark level in the economy with Norwegian public education spending and taxes. Table 9 reports the results for this experiment. As before, the first row repeats the benchmark intergenerational earnings elasticity and pre-tax Gini coefficients obtained in the Norwegian version of the economy. Subsequent rows show the effects from decreasing σ_η in 10% increments.

From Table 9 it is apparent that cross-country differences in post-schooling earnings shocks can not account for the remaining differences in earnings inequality and persistence. As σ_η decreases, the intergenerational earnings elasticity increases, but earnings inequality decreases. Why is this the case? First, the effect on inequality is simply mechanical, i.e., σ_η is a source of earnings variance, so when it decreases, earnings variance decreases. The effect on intergenerational persistence is slightly more subtle. As σ_η decreases, the other two sources of earnings variance – learning ability and investments in education – become relatively more important. Since both of these are positively correlated with parent earnings, the persistence of earnings across generations increases.

7.3 Cross-Country Differences in Variance of Learning Ability

Recall that the model begins with children at age five because that is approximately the age when children in both the U.S. and Norway enter the compulsory public education system. Furthermore, the ability endowment α is broadly interpreted to include not only innate factors, but also external influences prior to age five that affect the child's learning ability. Considering the U.S. and Norway, there are many reasons why the variance of learning ability may differ between the two countries. For example, the variance of learning ability may be positively related to the ethnic and cultural diversity in a population. As noted by Alesina et al. (2003) and Fearon (2003), the U.S. is much more heterogeneous in this respect than Norway. In addition, differences in early childhood education may affect the distribution of learning ability upon entrance to public compulsory schooling. Again, there is evidence that differences between the U.S. and Norway are substantial along this dimension. New mothers in Norway receive paid maternal leave for nearly a year, after which time most enroll their children in publicly subsidized pre-primary institutions. The OECD reports that in 2010, 95% of three year olds in Norway were enrolled in early childhood education, whereas only 51% of three year olds in the U.S. were enrolled.

How are the results affected if the variance of learning ability in the population of Norwegian five-year-olds is indeed smaller than in the United States? To answer this question, I take the model as previously calibrated and incrementally decrease the parameter σ_α in the version with Norwegian public education spending and tax functions. Table 10 reports the results from these experiments. The first row repeats, for purpose of comparison, the intergenerational earnings elasticity and pre-tax Gini coefficients obtained in the benchmark Norwegian model. Subsequent rows show the effects from decreasing σ_α in 10% increments. The results indicate that even small changes in the variance of learning ability can lead to large changes in the earnings distribution.

Table 10: Results from Decreasing the Variance of Ability

Experiment	Value of σ_α	Intergenerational earnings elasticity	Pre-tax Gini coefficient
Norway Benchmark	0.360	0.444	0.431
10% decrease in σ_α	0.324	0.387	0.378
20% decrease in σ_α	0.288	0.318	0.327
30% decrease in σ_α	0.252	0.242	0.285
40% decrease in σ_α	0.216	0.166	0.245
50% decrease in σ_α	0.180	0.093	0.222

Consider first the changes in the intergenerational earnings elasticity. As σ_α decreases, the ability distribution becomes more compressed. Then under the Norwegian public education system in which more funds are targeted to children in lower income households, it becomes more likely that low income, high ability children will surpass high income, low ability children in human capital production, and thus earnings. This increased “churning” decreases earnings persistence across generations.

A similar intuition can be applied toward understanding changes in the Gini coefficient. As σ_α decreases children are more similar in learning ability, so the resulting distribution of human capital and earnings exhibits less inequality. Recall that the Norwegian pre-tax Gini coefficient in the data is 0.377. This experiment indicates that just a 10% decrease in the variance of ability at age five will decrease the model’s predicted pre-tax Gini coefficient to 0.378, which is sufficient to account for essentially all of the differences in pre-tax inequality between the U.S. and Norway. Based on these exercises, it seems promising that cross-country differences in early childhood education policies may explain a large share of the remaining differences unaccounted for by public education spending and tax progressivity.

8 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 financial data at the school district level 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 taxes and public education spending at both compulsory and non-compulsory stages. Results in the case of the U.S. and Norway suggest that about 15% of differences in earnings inequality and about 10% of differences in intergenerational earnings persistence are due to differences in public education financing systems. I showed that these changes are primarily due to the distribution of public education spending across students, rather than cross-country differences in average public spending per student. Furthermore, I found that differences in public education spending are responsible for most of the model changes in intergenerational earnings persistence, whereas differences in tax progressivity are responsible for most of the model changes in earnings inequality. Promising channels for future work include a careful examination of the cross-country differences in private education spending and early childhood education policies.

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A Details on U.S. and Norway Data

U.S. data in Section 3 are obtained from the National Center for Education Statistics Common Core of Data and School District Demographics System. Norwegian data are obtained from the StatBank data service through Statistics Norway. For all graphs and tables in Section 3, U.S. data are from the year 2000, while Norwegian data are from 2002. Data are available for Norway beginning in 2000 as well, but there are many missing values in 2000 and 2001. In the graphs I use year 2002 data for Norway because it was the first year with complete data for nearly all districts; however, the patterns described are broadly consistent across all years since 2000.

In the U.S. data, total revenues are categorized as coming from local, state, and federal sources. In the Norwegian school district data, however, the sources are not defined this way, so I categorize total revenue into local and federal sources as follows. Local revenue is defined as the amount coming from user payments, revenues from sales and hiring, property tax, and other direct and indirect taxes. All other revenue sources are classified as federal.

The school district level 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. The school district level income measure for districts in Norway is median gross income for residents 17 and over, from Table 05671 in Statistics Norway's StatBank.

B 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:

$$\tau(\hat{y}) = \beta_0 + \beta_1\hat{y} + \beta_2\hat{y}^{\beta_3} \quad (12)$$

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.