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Accounting for cross-country differences in intergenerational earnings persistence: The impact of taxation and public education expenditure

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I document a strong negative cross-country correlation between intergenerational earnings persistence and measures of tax progressivity and level, and between intergenerational earnings persistence and public expenditure on tertiary education. To explain these correlations, I then develop an intergenerational lifecycle model of human capital accumulation and earnings that features progressive taxation, public education expenditure, and borrowing constraints among the determinants of earnings persistence. I calibrate the model to U.S. data and use it to decompose the contributions to earnings persistence from different model elements and to quantify how earnings persistence in the United States changes as I introduce tax and education expenditure policies from other countries. I find that individual investments in human capital account for 73% of the estimated intergenerational earnings persistence in the United States. Taxation, through its impact on investments in human capital, can explain 50% of the variation between the United States and 10 other countries, whereas borrowing constraints, which have received much attention in the literature, have a limited impact on earnings persistence.

Keywords. Intergenerational earnings persistence, taxation, public education expenditure.

JEL classification. E24, E62, H31, H52, J62, J68.

1. Introduction

In recent years, several empirical studies have been concerned with estimating and comparing the intergenerational persistence of earnings between fathers and sons in

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TABLE 1. Intergenerational earnings elasticity across countries.

Country	Estimated Earnings Elasticity
Denmark	0.15
Norway	0.17
Finland	0.18
Canada	0.19
Sweden	0.27
Germany	0.32
Spain**	0.40
France	0.41
Italy*	0.43
U.S.	0.47
U.K.	0.50

Note: This table displays the results from a meta study by Miles Corak (2006). *Taken from Piraino (2007). **Taken from Pla (2009). See Appendix A.1 for further details.

Western economies. The main finding of this literature is that intergenerational persistence is relatively high in the United States, Britain, and Southern Europe, and relatively low in Northern Europe and in Canada. Table 1 displays the results from a meta study of intergenerational earnings persistence across countries by Corak (2006),[1] supplemented with two recent studies from Italy and Spain.[2] The next question follows naturally: What are the reasons for these differences? Western economies differ greatly with respect to public expenditure on education and with respect to tax policies. Does the cross-country variation in public institutions explain the variation in earnings persistence?

Understanding why earnings mobility differs across countries is interesting, even if only for positive reasons. However, the question of whether economic fate is predetermined or whether it is influenced by public institutions may also have important policy implications. For instance, if the pattern we observe occurs because poor parents in some countries are borrowing-constrained and cannot invest optimally in their children's human capital, it may call for policy intervention.

Several explanations that could contribute to the observed cross-country pattern in intergenerational earnings persistence have been proposed in the economic literature, but there is little quantitative work in the area. To the best of my knowledge, there are no previous papers studying the impact of cross-country differences in policies on earnings persistence. In this paper, I start by documenting that there is a strong negative cross-country correlation between earnings persistence and measures of tax progressivity and tax level, and between earnings persistence and public expenditure on tertiary education. I then construct an intergenerational life-cycle model of human capital accumu-

[1]See also Blanden (2009) for an extensive summary of the empirical literature.

[2]There are many difficulties with comparing different studies of earnings persistence; see Appendix A.1. Table 1 is to be interpreted as a stylized fact.

lation and earnings to separate and quantify the determinants of earnings persistence. The model contains key elements that have been proposed as determinants of earnings persistence in the literature, namely progressive taxation, the efficiency of human capital investments, public education expenditure, borrowing constraints, partially inheritable abilities, inter vivos transfers from parents to children, and idiosyncratic wage shocks. I calibrate the model to U.S. data and decompose the contributions of the different model elements. I find that individual investments in human capital and inheritable abilities/family endowments are both important drivers of earnings persistence. Setting individual investments in human capital to zero in the model reduces earnings persistence by 73%, whereas setting the correlation of inheritable abilities to zero reduces earnings persistence by 53%.

Next I study how earnings persistence in the United States changes as I introduce policies from other countries into the model. I first use Denmark as an illustrating case study because it is the country in my sample with the highest and most progressive taxes and the greatest expenditure on tertiary education, as well as the lowest earnings persistence. I find that taxation and (to a smaller degree) public education expenditure have a significant impact on earnings persistence, and, therefore, are important contributors to the cross-country patterns that empirical researchers have found. More government expenditure on education and higher taxes reduce earnings persistence by reducing parental/individual incentives for investing in human capital, which leads to a weaker relationship between the parent's financial resources and the child's earnings. I find the impact of taxation to be quantitatively greater than the impact of education expenditure. Introducing a Danish tax system in the U.S. data reduces the intergenerational elasticity of earnings from 0.47 to 0.3, or about 53% of the difference between the United States and Denmark. In a sample with the United States and 10 other countries, taxation explains 50% of the variation in earnings persistence from the U.S. benchmark. I also study the quantitative importance of borrowing constraints in the model and conclude that they have little impact on earnings persistence.

The remainder of the paper is organized as follows: In Section 1.1, I discuss some possible explanations for cross-country differences in intergenerational earnings persistence in light of current theory and literature. In Section 2, I document a strong correlation between earnings persistence and tax progressivity, and between earnings persistence and spending on tertiary education. Section 3 studies the impact of taxation and public investment in education on parental investments in education in a simple analytical model. Section 4 presents the quantitative model. In Section 4.1, I discuss and justify some of the modeling choices. Section 5 discusses data and calibration. Section 6 decomposes the contributions to earnings persistence from the different model elements. In Section 7, I study the impact on earnings persistence from introducing Danish taxes and education expenditure into the U.S. economy. I also study the importance of borrowing constraints. Section 7.1 presents the results from a multi-country analysis. Section 8 concludes. Additional material is given in the Appendix and in a supplementary file on the journal website, http://qeconomics.org/supp/286/code_and_data.zip.

1.1 *Determinants of intergenerational earnings persistence: Theory and recent literature*

In classical human capital theory, it is usually assumed that the earnings of individuals depend on their level of human capital and on market luck, or random shocks. Two factors go into human capital formation: One is a fixed endowment, imperfectly inherited by children from parents; the other is investments in human capital, which can be made both by the parents and by the government; see Becker and Tomes (1979, 1986) and Solon (2004). Endowments here refer to everything from genetically inherited ability to knowledge acquired from the parents, family culture, and the parents' social connections. In my model below, I will refer to the family endowment as ability. The narrowest definition of human capital investment is investment in education, but many authors use broader definitions. It is also commonly assumed that parents care about their children's utility and that utility depends only on the consumption of goods that cannot be considered as investments in human capital; see, for instance, Becker and Tomes (1986). This way, the only reason to invest in children's human capital is to increase their future consumption through higher earnings. If there are diminishing returns to investment, there will be an optimal level of investment for each child.

From this theory, several explanations for cross-country differences in earnings persistence emerge. One possibility is that the inheritability of family endowments is stronger in some countries. There could be many underlying reasons for this. The degree of assortative mating does, for instance, differ across countries. In some countries, couples are more similar with respect to their education and family background, and since almost all research studies the correlation between fathers and sons, this will cause the sons to be more similar to their fathers. Indeed, there seems to be a somewhat higher correlation in spousal education in the United States and Italy than in Northern Europe, but Britain, which has relatively high earnings persistence, has a relatively low correlation in spousal education.[3]

Another possibility is that countries just differ in the returns to investments in human capital. In standard intergenerational models of earnings formation, earnings persistence increases with the returns to human capital investments; see, for instance, Restuccia and Urrutia (2004). Depending on modeling choices, there are several channels through which this may work, but I will mention just a common one: Optimal human capital investments are usually increasing in parental financial resources, as altruistic parents face a trade-off between their own consumption today and their children's future consumption. If human capital investments become more efficient, then for a given inequality of investments in children of high and low earners, the inequality of earnings outcomes will increase. This results in higher intergenerational earnings persistence.

Tax codes are also plausible explanations for the cross-country differences in earnings persistence, as they affect the incentives to invest in human capital. If taxes are progressive, it will have the effect that human capital investments become less attractive, particularly for someone with high ability. This will shrink the dispersion of human capital investments and cause smaller earnings persistence. In Section 2, I document

[3] See Fernandez, Guner, and Knowles (2005).

negative correlations between tax progressivity and earnings persistence, and tax level and earnings persistence.

If there are diminishing returns to human capital investments, and investments made by parents and the government are substitutes, then a parent's incentive to invest will be falling as the government invests more. As the government invests more, the difference between how much is invested in rich and poor children becomes smaller and earnings persistence will fall. Western economies differ with respect to public education expenditure. As I document in Section 2, the countries with low earnings persistence tend to spend more on public investments in education relative to gross domestic product (GDP) per capita. The difference is particularly large when it comes to spending on tertiary education.

Finally, one potential cause of earnings persistence that has received much attention in the literature is the presence of credit constraints. As mentioned above, there will usually be a direct relationship between parents' and children's earnings. This will be true even if the parents are not credit-constrained with respect to their own resources, and if markets are incomplete and human capital investments are risky; it may also be true even if they are not credit-constrained with respect to their children's future earnings. A stronger relationship may, however, occur if low earners with high ability/endowment children face binding credit constraints with respect to investing in their children's human capital. One potential source of cross-country differences in earnings persistence is the degree of credit market completeness. I do not have any good measure of credit market completeness across countries, but if the government heavily subsidizes education, it should reduce the number of credit-constrained parents. In my structural model below, I do, however, find that increasing or decreasing borrowing limits has very little quantitative impact on earnings persistence in the United States.

Empirical literature. The most commonly used measure of earnings persistence is the coefficient, often denoted β, from the regression of the logarithm of the son's earnings on the logarithm of the father's earnings and a constant, also called the intergenerational elasticity of earnings:

$$\log(y_{\text{son}}) = \alpha + \beta \log(y_{\text{father}}) + \varepsilon. \tag{1}$$

The relevant measure of earnings is lifetime or permanent earnings, but as this measure is rarely available, the best a researcher can do is often to average several years of earnings and control for the age at which the earnings were observed. What β tells us, in a purely statistical sense, is what percentage of a father's earnings advantage, relative to the mean in his generation, is, on average, transferred to the son. A β of 0 would represent the case in which the earnings of fathers and sons are completely unrelated, while a β of 1 would represent the case in which the earnings advantage of the father is perfectly transferred to the son. Hypothetically, one can also imagine β smaller than 0 or greater than 1. In practice, however, empirical studies have found β between 0 and 1, which implies that earnings tend to revert to the mean over generations.

The statistical literature, which estimates and compares the intergenerational elasticity of earnings for different countries, is by now quite large. Blanden (2009) provides a thorough discussion. There are some difficulties related to methodology and data, which makes it harder to compare different studies (see Appendix A.1). It is, however, clear that there are substantial differences between countries. Corak (2006) provides a meta study based on previous empirical studies of earnings persistence in different countries and current knowledge of data and methodological issues. Table 1 reproduces the main findings of his study, supplemented with two recent studies from Italy and Spain. It documents the pattern with relatively high earnings persistence in the United States, Britain, and Southern Europe, and relatively low earnings persistence in Northern Europe and in Canada.

Quantitative literature. In addition to the empirical work, there is also a theoretical literature, pioneered by Becker and Tomes, which gives us a framework for understanding the factors that may affect the correlation of children's and parents' earnings. The quantitative/structural literature, which takes models to the data, is, however, relatively sparse. I will briefly mention the papers that are closest in spirit to the work I am undertaking.

Han and Mulligan (2001) develop a very simple two-period/two-generation model in which parents care about their children, and have the opportunity to invest in their human capital and to give them monetary bequests. They calibrate their model to fit characteristics of the U.S. economy, including the intergenerational elasticity of earnings, β, which they take to be 0.4. They then study how β changes as they eliminate intergenerational borrowing constraints and increase the variance of shocks to ability. The authors conclude that eliminating borrowing constraints reduces β by at most 0.1, but they also find that β increases as the heterogeneity of family endowments increases. They suggest that if there is a greater variance of family endowments in the United States and Britain, perhaps because those countries are more racially and culturally diverse, then this result could be used to explain higher earnings persistence in those countries.[4]

It should be noted that in Han and Mulligan (2001), agents experience the same shocks to human capital and financial assets. It is, therefore, no insurance in holding both assets. An individual will invest in human capital until the return equals the return on financial assets and, if needed, will borrow financial assets to achieve this level of human capital investment. This may increase the importance of borrowing constraints.

Restuccia and Urrutia (2004) develop a model with infinite dynasties in which agents live for four periods: two as children and two as adults. Parents decide how much to invest in their children's elementary education and whether to send them to college. There is also a government that imposes taxes, runs a balanced budget, and invests the tax revenues in education. The focus of the paper is to determine whether investments in early or college education are quantitatively more important for earnings persistence. They

[4]The finding that a larger variance of family endowments leading to larger and not smaller persistence is not obvious. In the model in Section 4, this typically happens if the persistence of family endowments is greater than the persistence of earnings. However, in the calibrated model, the persistence of family endowments is smaller than the persistence of earnings, and increasing the variance of family endowments leads to lower earnings persistence.

find that early education matters more and that government investments in early education have a greater impact than government investments in college education. My results in Section 7.1 are consistent with the finding that an increase in government spending on early education has a greater impact on earnings persistence than an equally large increase in government spending on tertiary education.

Herrington (2013), in a contemporary paper, studies the importance of taxes and education expenditure in accounting for the difference in intergenerational earnings persistence between the United States and Norway. His paper is, apart from mine, the only paper to consider the impact of cross-country differences in policies. Similar to what I find in Section 7.1, he finds that introducing Norwegian taxes and education expenditure reduces earnings persistence. However, he finds the impact of education expenditure to be somewhat larger and the impact of taxes to be somewhat smaller than my results in Table 9.

With respect to education expenditure, Herrington is able to go a bit further than this paper, as he has data on the variation in education expenditure inside each country and not just aggregate measures of spending per student. Norway is shown to have a more progressive public education subsidy than the United States. Implementing progressive country-specific education subsidies may increase the importance of education expenditure in this paper. With respect to the impact of taxes, Herrington (2013) is missing some elements that are present in my paper and are likely to be of quantitative importance: financial assets and endogenous labor/leisure choice (see the discussion in Section 4.1). On the other hand, he is modeling continuous time investment in higher education. Time investment in education could be an interesting future extension of my paper.

Finally, Erosa and Koreshkova (2007) study the impact of replacing the U.S. tax code with a flat tax in a dynastic model of human capital investments. They also find that progressive taxes reduce earnings persistence. The magnitude of the effect may appear somewhat modest compared to the results in Section 7.1; however, the model and calibration strategy are also very different from those in this paper.

My paper is the first to conduct a multi-country analysis of the quantitative impact of cross-country differences in policies on β. It also offers a richer, more realistic model, combining some elements that are present in the papers above. In Section 4.1, I discuss the different model elements in detail and why they are important in a study of earnings persistence.

2. Stylized facts

It is difficult to summarize the tax system in a country with just one number. However, wedge-based measures of tax progressivity have been common in the literature. I adopt the tax progressivity wedge

$$\mathrm{PW}(y_1, y_2) = 1 - \frac{1 - \tau^m(y_2)}{1 - \tau^m(y_1)}, \tag{2}$$

which I construct in two ways: (i) using the marginal tax rate, $\tau^m(y)$, at income y and (ii) using the average tax rate, $\tau(y)$, at income y. In both cases, the measure takes values between 0 and 1 unless the tax schedule is regressive, and increases with the increase in the tax rate as earnings grow from y_1 to y_2. If there is a flat tax, then the progressivity wedge would be zero for all levels of y_1 and y_2. Analogous progressivity measures are used in the literature. Guvenen, Kuruscu, and Ozkan (2009) and Caucutt, Imrohoroglu, and Kumar (2003) use (2) with marginal tax rates.[5] Benabou (2002) and Heathcote, Storesletten, and Violante (2012) use a tax function, for which the parameter governing progressivity uniquely determines (2), constructed with average tax rates.[6]

When approximating the tax function as a polynomial, which I do in this paper, the measure may be more robust when constructed with average tax rates. Guner, Kaygusuz, and Ventura (2012) show that if the tax schedule is approximated by a polynomial, one will do relatively well in approximating the average tax rate at different incomes and do worse in approximating the marginal tax rate. This occurs because in the data, the marginal tax rate experiences sudden jumps, whereas the average tax rate does not.

For each country in Table 1, I use labor income tax data from the Organization for Economic Cooperation and Development (OECD) tax data base to fit tax functions; see Appendix A.2 for a detailed description. Different family types face different tax schedules. In this study, the unit under consideration will be dynasties of single males. However, in reality these males will often be married and will be facing a tax schedule for married people. I fit tax functions for single individuals, married individuals without children, and married individuals with one child. For married people, I assume that the male individual has a spouse, making 39.2% of his income (the average in the data). I then construct progressivity wedges of the form in (2). The progressivity wedges will generally be different for different values of y_1 and y_2. In Tables 13 and 14 in the Appendix, I display progressivity wedges for different family types at different income levels, using marginal and average tax rates.

Table 10 displays cross-country correlations between the progressivity wedges and intergenerational earnings persistence as well as between the tax rate at average earnings and intergenerational earnings persistence. As can be seen from the table, the correlation between earnings persistence and tax level at average earnings is about 0.5 for all family types. The correlation between earnings persistence and the measure of tax progressivity varies with income level. However, it is generally strong and approaching 0.8 for some income levels and family types, both when the measure is constructed with marginal taxes and with average taxes. At lower income levels, the correlation is generally stronger when the progressivity measure is constructed with marginal tax rates than when it is constructed with average tax rates. This is as we would expect. Marginal tax rates will increase before average tax rates.

In Figure 1, I graphically illustrate the correlation between tax progressivity and earnings persistence. I use 0.5 times average earnings, AE, in each country for y_1 and

[5]In Caucutt, Imrohoroglu, and Kumar (2003), taxes are flat but differ by skill group, so there is really no distinction between the average and marginal tax rate.

[6]When the tax function is given by $\tau(y) = 1 - \lambda_0 y^{-\lambda_1}$, then $\mathrm{PW}(y_1, y_2) = 1 - \frac{1-\tau(y_2)}{1-\tau(y_1)} = 1 - (\frac{y_2}{y_1})^{-\lambda_1}$.

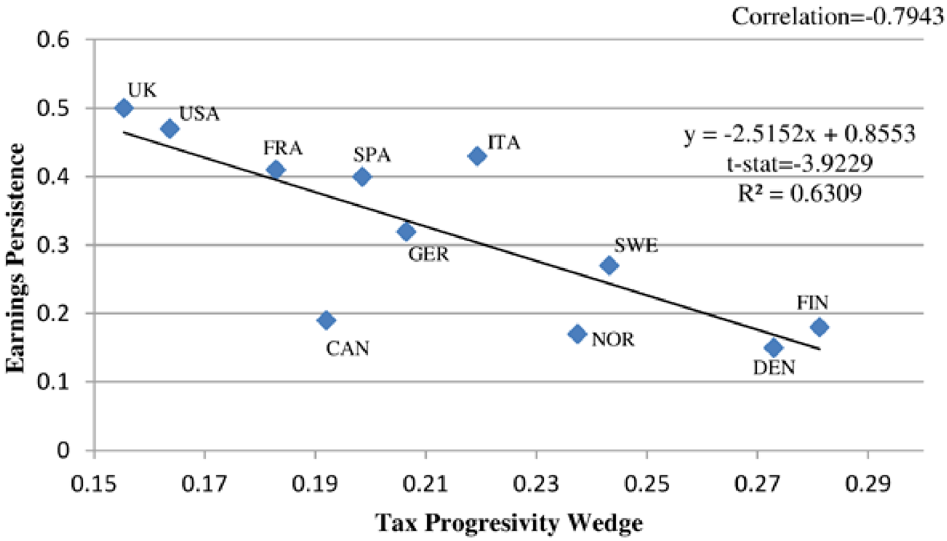

FIGURE 1. Correlation between tax progressivity and earnings persistence. Earnings persistence is taken from Table 1. The tax data are an average of the years 2001–2005, taken from the OECD tax data base. The progressivity wedges are constructed using marginal tax rates for a married individual without children, at incomes $y_1 = 0.5\text{AE}$, $y_2 = 2\text{AE}$. The regression coefficient is significant at the 1% level.

2 times average earnings for y_2. The taxes are for an individual who is married without children. I plot earnings persistence on the y-axis against the measure of tax progressivity, constructed with marginal tax rates, on the x-axis. The correlation between the two quantities is -0.79 and the regression coefficient is highly significant when earnings persistence is regressed on the progressivity wedges. A strong correlation between two variables need not imply, of course, that one has a causal effect on the other. However, this empirical observation motivates a further investigation of the impact of taxes on earnings persistence in a structural model with careful modeling of the tax systems.

In Figure 2, I plot the correlation between earnings persistence and public expenditure per student in tertiary education as a fraction of GDP per capita. The correlation between the two variables is -0.84, and the regression coefficient is highly significant when earnings persistence is regressed on education expenditure. This motivates the study below of the impact of public education expenditure on earnings persistence.

3. A simple model

To obtain an intuitive understanding of how taxation and public education expenditure qualitatively affect investments in human capital and earnings persistence, it is helpful to start with a simple model. I am extending the model of Solon (2004) to include risky human capital investments and a financial asset, two important elements that are also present in the quantitative model in Section 4. With these extensions, it is not possible

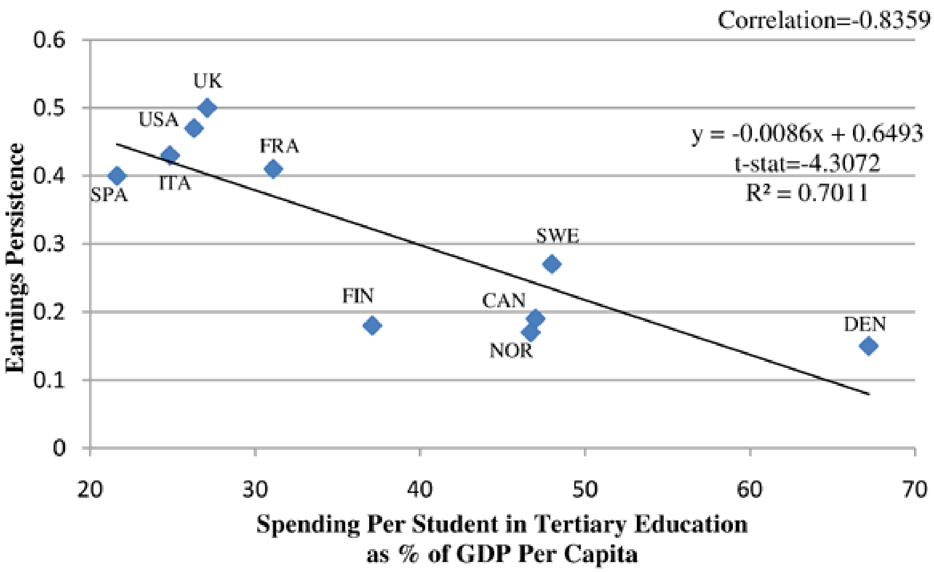

FIGURE 2. Correlation between public expenditure on tertiary education and earnings persistence. Earnings persistence is taken from Table 1. The education spending data are an average of the years 1999–2005, taken from the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics. The regression coefficient is significant at the 1% level.

to obtain analytical solutions for earnings or the regression coefficient when children's earnings are regressed on parents' earnings. However, we will be able to study the impact of taxes and government investments in education on human capital investments.

Assume that there is a continuum of infinitely lived single individual dynasties. Each individual lives for two periods: one as a child and one as an adult. Parents decide how much to consume, how much to invest in their child's human capital, and how much savings to leave for the child. Children do not make any economic decisions. Investments in human capital are risky and only pay a positive return with probability 1/2. This means that half the time, the child will have no labor income and will have to live from the bequests left by the parent. A parent's utility is a function of his consumption today, c_p, and his child's future after tax financial resources, which is the sum of after tax labor earnings, $\hat{y}_c = y_c(1-\tau)$, and the bequest from the parent, b:

$$U_p(c_p, \hat{y}_c, b) = \log(c_p) + \frac{\alpha}{2}\log(\hat{y}_c + b) + \frac{\alpha}{2}\log(b). \tag{3}$$

The parameter α measures how altruistic parents are with respect to their children. The earnings of the child are determined by his level of human capital. Human capital is a function of investments made by the parents, I_p, investments made by the government, I_g, and of the child's ability or family endowment, A_c:

$$y_c = A_c(I_p + I_g)^{\psi}. \tag{4}$$

Abilities are imperfectly transmitted from parent to child. I assume them to be log normally distributed, and follow an (autoregressive) AR(1) process:

$$\log(A_c) = \theta \log(A_p) + \nu, \quad \nu \sim N(0, \sigma_\nu^2). \tag{5}$$

The utility maximization problem of a parent can be written as

$$\begin{aligned} &\max_{c_p>0, I_p \geq 0, b} \log(c_p) + \frac{\alpha}{2}\log\big(y_c(1-\tau)+b\big) + \frac{\alpha}{2}\log(b) \\ &\text{s.t.} \quad c_p + I_p + b = y_p(1-\tau), \\ &\qquad y_c = A_c(I_p + I_g)^\psi, \end{aligned} \tag{6}$$

where y_p is the labor income of the parent. For simplicity, we will assume that the parent has no additional financial assets. Substituting for c_p and y_c gives a maximization problem in I_p and b:

$$\max_{0 \leq I_p, b} \log\big(y_p(1-\tau) - I_p - b\big) + \frac{\alpha}{2}\log\big(A_c(I_p+I_g)^\psi(1-\tau)+b\big) + \frac{\alpha}{2}\log(b). \tag{7}$$

I will assume an interior solution, where the first-order conditions with respect to both I_p and b hold with equality. If I_g is large, it could be that the optimal parental investment in education is 0. Furthermore, because the returns to human capital investments are diminishing, there will also be a point where the expected return on investment in the financial asset is equal to the expected return on investment in human capital. It will never be optimal for the parent to invest in education beyond that point, which is when $I_p = (1/2\psi A_c)^{1/(1-\psi)} - I_g$. However, assuming an interior solution where the first-order conditions hold with equality, we have

$$\frac{-1}{y_p(1-\tau) - I_p - b} + \frac{\alpha\psi A_c(1-\tau)(I_p+I_g)^{(\psi-1)}}{2(A_c(I_p+I_g)^\psi(1-\tau)+b)} = 0, \tag{8}$$

$$\frac{-1}{y_p(1-\tau) - I_p - b} + \frac{\alpha}{2(A_c(I_p+I_g)^\psi(1-\tau)+b)} + \frac{\alpha}{2b} = 0. \tag{9}$$

Equation (8) is the first-order condition with respect to investment in human capital and (9) is the first-order condition with respect to investment in the financial asset.

Proposition 3.1. *For interior solutions, where the first-order conditions with respect to I_p and b hold with equality, we have*

$$\frac{\partial I_p}{\partial y_p} > 0, \qquad \frac{\partial b}{\partial y_p} > 0, \qquad \frac{\partial I_p}{\partial I_g} < 0, \qquad \frac{\partial I_p}{\partial \tau} < 0, \qquad \frac{\partial I_p}{\partial \alpha} > 0. \tag{10}$$

For the proof, see Appendix A.3.

Proposition 3.1 says that as long as there is an interior solution, I_p and b are both increasing in the earnings of the parent, y_p. In other words, there is a direct impact of parental earnings on the child's earnings, beyond the correlation of abilities. The proposition also says that I_p is decreasing in the tax rate, τ, decreasing in government investment, I_g, and increasing in the altruism parameter, α.

How may the negative impact of taxes and education expenditure on investments in human capital translate into an effect on intergenerational earnings persistence? One reason that taxes and education expenditure affect earnings persistence is because there is a positive government investment in human capital, which is equal for all children. If private investments in education fall, due to a higher tax or more government investments, and public investments stay the same or increase, then the relative importance of parental investments compared to government investments decreases. The difference between how much is invested in rich and poor children becomes smaller in percent/log terms as taxes or government investments increase, and this leads to a fall in earnings persistence. The same effect will work in the opposite direction, when the altruism parameter, α, increases.

How may tax progressivity affect earnings persistence? If we make taxes more progressive by raising tax rates for high earners and lowering them for low earners, then high earners should decrease their investments in education and low earners should increase their investments. The difference between how much is invested in rich and poor children falls, and this should lead to lower earnings persistence.

The derivative of investments in human capital with respect to the human capital technology, ψ, is theoretically ambiguous in this model. The reason is that there are two opposing effects. On the one hand, when ψ increases, the child is better of compared to the parent who may respond by investing less. On the other hand, investments in human capital become more efficient and their impact on the child's earnings becomes larger.

In this section, in a simple model, we have seen that higher taxes and more government expenditure on education reduce parental investments in education. This should lead to lower intergenerational earnings persistence because the impact of parental earnings on the child's earnings becomes smaller. We will now turn to the study of a more realistic model with the purpose of quantifying the determinants of earnings persistence.

4. The quantitative model

Economic environment. The economy is populated by single-individual dynasties, where each individual lives for at least 70 years and at most 100 years. A model period is 5 years. For the first four periods, or 20 years, of his life, an individual is part of the parent's household and does not make any economic decisions. At age 20, a young individual moves out of his parent's house and forms his own household. At age 30, he has a child, and at age 65 he retires. The first decision a young adult must make is whether or not to enroll in college. All working age households, including college students, decide how much to work, consume, and save at a risk-free rate. College students also decide how much to invest in human capital production. There is a fixed time cost of attending college, and college students have to work at a low fixed wage, which is independent of

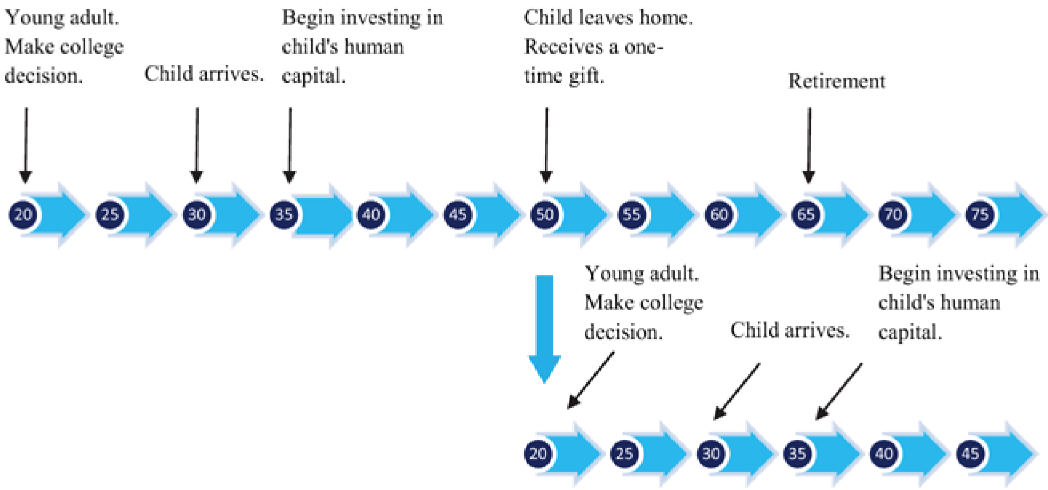

FIGURE 3. Household's life cycle.

their human capital. There is a probability of failing college, depending on the student's ability and prior level of human capital.

Households are altruistic and care about their children's utility. Households with a child, ages 5 to 19, decide how much to invest in the child's human capital. At the moment a child leaves home and begins his own household, the parent has the option of giving him a one-time gift of liquid assets to ensure that he gets a good start in life. This is, of course, a simplifying assumption, but it greatly reduces the complexity of the model. Empirically, the fact that the child receives a one-time gift at the beginning of his adult life can be motivated by the observation that many parents help their child pay for college or buy a first home. Figure 3 illustrates the life cycle of a household.

Wages and human capital. Worker productivity in this economy depends on human capital, college completion, labor market experience, and labor market luck. Since there is no unemployment in the model, experience is equal to potential experience, and is fully determined by age and whether a person attended college. Letting x denote the individual's experience level and letting h denote his level of human capital, his wage can be written

$$w = h\gamma_0 e^{\gamma_1^j x + \gamma_2^j x^2 + \gamma_3^j x^3 + u}, \tag{11}$$

$$u \sim N(0, \sigma_u^2), \tag{12}$$

where u is an idiosyncratic productivity shock and $j \in \{0, 1\}$ is an indicator for whether the individual is college educated. There are different age/experience paths for the wages of college- and high-school-educated workers. The human capital of a person must be built up during his childhood and during college. How much human capital a person accumulates depends on his ability, A, and how much is invested in his human capital in each time period by the parents, I_p, by the individual himself in college, I_s, and by the government, I_g:

$$\begin{aligned} h' &= h + A\big[h(I_p + I_g)\big]^{\psi_0} \quad \text{before college,} \\ h' &= h + A\big[h(I_s + I_g)\big]^{\psi_1} \quad \text{in college.} \end{aligned} \tag{13}$$

Here h' denotes human capital in the next time period. I follow the tradition in the literature on intergenerational earnings persistence (see Becker and Tomes (1979, 1986) and Solon (2004)) and think of human capital investments as investments of money or goods. However, while many definitions of what should be considered human capital investments have been suggested, I will think of it as investment in education. The ability or family endowment of the child is broadly defined to include things that do not have to be bought, like genetics, family culture, motivation, and knowledge acquired from the parents. Abilities are assumed to be log normally distributed and imperfectly inherited from parent to child according to an AR(1) process

$$\log(A_c) = \theta \log(A_p) + \nu, \quad \nu \sim N\big(0, \sigma_\nu^2\big). \tag{14}$$

Preferences. The momentary utility is a function of consumption in adult equivalents, $\frac{c}{e(t)}$, where $e(t)$ varies depending on whether there is a child in the household, and work hours, n:

$$u(c, n) = \frac{\left(\frac{c}{e(t)}\right)^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta}. \tag{15}$$

A household discounts the future by a factor δ. When the child leaves home, the parent cares about the child's utility, U^c, but discounts it by α. Thus a household's lifetime utility, U, is given by

$$U = \sum_{t=1}^{\text{death}} \delta^{t-1} u(c, n) + \delta^6 \alpha U^c. \tag{16}$$

Borrowing for college and probability of college completion. Individuals who attend college are allowed to borrow up to an amount z while in college. I require that they do not retire in debt, and in subsequent periods, I let the borrowing constraint, $\phi(j, t)$, be linearly decreasing between college and retirement. High school graduates are not allowed to borrow:

$$\phi(j = 1, t) = \max\big(0, z(9-t)/8\big), \qquad \phi(j = 0, t) = 0. \tag{17}$$

However, if someone took out a loan for college and failed to complete college, they would also be subject to the borrowing constraint for college graduates. The probability of success in college, $\pi(Ah)$, is a function of ability and acquired pre-college human capital:

$$\pi(Ah) = 1 - e^{\Omega Ah}. \tag{18}$$

Recursive formulation of the household's problem. A household can be in five different life stages; therefore, there are five different household maximization problems. The first decision a young household must make is whether or not to go to college. This is done at age 20, or $t = 1$. In both cases, he decides how much to consume, c, next period's capital, k', and how much to work, n. If he goes to college, he must also decide how much to invest in human capital, I_s. The state variables are age t, capital k, level of human capital h, ability A, and the productivity shock u. In all time periods, experience, x, will be equal to the current model period minus 4 for high-school-educated workers and equal to the current model period minus 5 for college-educated workers. Formally, the individual solves the Bellman problem

$$
\begin{aligned}
& W(k, h, t=1, A, u) = \max\{V(j=0, \cdot), V(j=1, \cdot)\}, \quad \text{where} \\
& V(0, k, h, t, A, u) = \max_{c,n,k'} u(c, n) + \delta E[V'(0, k', h, t', A, u')] \\
& \text{s.t.} \quad c(1+\tau_c) + k' = k(1+r) + wn(1-\tau(wn)) + \text{tr}, \\
& \qquad k' \geq 0, \qquad c > 0, \qquad w = h\gamma_0 e^{\gamma_1^0 x + \gamma_2^0 x^2 + \gamma_3^0 x^3 + u}, \quad u \sim N(0, \sigma_u^2), \\
& \qquad 0 \leq n \leq 1, \qquad t' = t+1, \\
& V(1, k, h, t, A, u) = \max_{c,n,k',I_s} u(c, n+\varpi) \\
& \qquad\qquad + \delta\pi(h, A) E[V'(1, k', h', t', A, u')] \\
& \qquad\qquad + \delta(1-\pi(h, A)) E[V'(0, k', h, t', A, u')] \\
& \text{s.t.} \quad c(1+\tau_c) + k' = k(1+r) + wn(1-\tau(wn)) - I_s + \text{tr}, \\
& \qquad h' = h + A[h(I_s + I_g)]^{\psi_1}, \\
& \qquad w' = h\gamma_0 e^{\gamma_1^j x + \gamma_2^j x^2 + \gamma_3^j x^3 + u}, \quad u \sim N(0, \sigma_u^2), \\
& \qquad I_s \geq 0, \qquad c > 0, \qquad w = w_c, \qquad k' \geq \phi(1, 1), \\
& \qquad 0 \leq n \leq 1 - \varpi, \qquad t' = t+1.
\end{aligned} \tag{19}
$$

Here, ϖ is the time cost of attending college, τ_c is a flat consumption tax, $\tau(wn)$ is a nonlinear labor income tax rate, and tr is a lump sum transfer from the government. Also note that while in college, an individual must work at the fixed wage, w_c, which is independent of his level of human capital. The problem of a working household without a child and at age 30 when no human capital investments are made is

$$
\begin{aligned}
& V(j, k, h, t, A, u) = \max_{c,n,k'} u(c, n) + \delta E[V'(j, k', h, t', A, u')] \\
& \text{s.t.} \quad c(1+\tau_c) + k' = k(1+r) + w(j, t, h, u)n(1-\tau(w(j, t, h, u)n)) + \text{tr}, \\
& \qquad k' \geq \phi(j, t), \qquad 0 \leq n \leq 1, \qquad c > 0, \\
& \qquad t' = t+1 \quad \text{for } t = 2, 3, 8, 9 \text{ (age} = 25, 30, 55, 60).
\end{aligned} \tag{20}
$$

At age 30, (20) is also a constraint, as the ability of the child will be revealed in the next period and the parent must have an expectation of his child's ability. Between ages 35 and 50, the parent must also decide on how much to invest in the child's human capital. He solves

$$
\begin{aligned}
& V(j,k,h_p,h_c,t,A,u) = \max_{c,n,k',I_p} u(c,n) + \delta E\big[V'\big(j,k',h_p,h_c',t',A,u'\big)\big] \\
& \text{s.t.} \quad c(1+\tau_c) + k' + I_p = k(1+r) + w(j,t,h,u)n\big(1-\tau\big(w(j,t,h,u)n\big)\big) + \text{tr}, \\
& \qquad I_p \geq 0, \qquad h_c' = h_c + A\big[h_c(I_p + I_g)\big]^{\psi_0}, \qquad k' \geq \phi(j,t) \\
& \qquad 0 \leq n \leq 1, \qquad c > 0, \qquad t' = t+1 \quad \text{for } 4 \leq t \leq 6 \ (35 \leq \text{age} \leq 50),
\end{aligned}
\tag{21}
$$

where h_p denotes the human capital of the parent and h_c denotes the human capital of the child. The parent must keep track of both as state variables. Now A is the ability of the child. There is no reason for the parent to know his own ability after the child's ability is revealed. When the parent is age 50 and the child is age 20, the child leaves the household and the parent has a one-time opportunity to give him a gift or an inter vivos transfer, b. The parent's problem is

$$
\begin{aligned}
& V(j,k,h_p,h_c,t=7,A,u) = \max_{c,n,k',b} u(c,n) + \delta E\big[V_p'\big(j,k',h_p,h_c',t=8,u_p'\big)\big] \\
& \qquad\qquad + \alpha E\big[W_c(b,h_c,t=1,A,u_c)\big] \\
& \text{s.t.} \quad c(1+\tau_c) + k' + b = k(1+r) + w(j,t,h,u)n\big(1-\tau\big(w(j,t,h,u)n\big)\big) + \text{tr}, \\
& \qquad k' \geq \phi(j,t), \qquad c > 0, \qquad 0 \leq n \leq 1, \qquad b \geq 0, \qquad t' = t+1,
\end{aligned}
\tag{22}
$$

where α controls the parent's degree of altruism. I assume that the parent does not observe the child's idiosyncratic shock before the size of the gift is decided. He must, therefore, take the expectation of the child's value function with respect to the idiosyncratic shock. A household in retirement simply solves

$$
\begin{aligned}
& V(j,k,h,t,A,u) = \max_{c>0,k'\geq 0} u(c,n=0) + \delta\Gamma(t)E\big[V'\big(k',t'\big)\big] \\
& \text{s.t.} \quad c(1+\tau_c) + k' = k(1+r) + T + \text{tr}, \\
& \qquad\quad \text{for } 10 \leq t \leq 16 \ (65 \leq \text{age} \leq 95),
\end{aligned}
\tag{23}
$$

where T is a constant amount of social security and $\Gamma(t)$ is an age-dependent probability of survival to the next period.

Government. The government taxes consumption and labor income, and runs a balanced budget. Some of the government's revenues are spent on pure public consumption goods, G, which enter separable in the utility function and, therefore, are not present in the household's problem, the social security payments T, and investment in education I_g. The remainder, TR, is distributed evenly to all households as transfers tr.

Let $Y^S(j, k, h_p, h_c, t, A, u)$ be the measure of households. The government budget can thus be written

$$\int \big(nw\tau(wn) + c\tau_c\big)\, dY = G + \mathrm{TR} + \int I_g\, dY + \int T\mathbb{1}_{[t\geq 65]}\, dY. \tag{24}$$

Equation (24) says that the sum of the tax revenues is equal to expenditure on pure public consumption goods, transfers, education expenditure, and social security payments.

4.1 *Discussion of modeling choices*

Life-cycle model with college decision. Using a life-cycle model with college decision allows us to study government expenditure on different levels of education. We can separate the effects of spending on primary, secondary, and tertiary education. Another argument for using a life-cycle model is that when studying the impact of parents' earnings on the earnings of children, we are interested in the financial resources available to parents at the time when there are children in the household. There is a literature documenting that even after controlling for parents' lifetime income, the income of the parents during the childhood years matters for the children's income; see Cunha and Heckman (2007) for a survey.

Human capital production. Equation (13) is the same functional form as in Ben-Porath (1967), except that Ben-Porath allowed for different exponentials on the human capital and goods inputs. It is known that the efficiency of human capital investments varies by age (see Cunha and Heckman (2007)), and this is the rationale for specifying different technologies before college and in college. One could have used a different technology at every age, but this would complicate the model.

Some would argue that parental time also belongs in the production function for human capital. It has been the tradition in the literature on intergenerational earnings persistence to assume that parental time is included in the family endowment, which I refer to as ability. Becker and Tomes (1979), Becker and Tomes (1986), Solon (2004), Han and Mulligan (2001), and Restuccia and Urrutia (2004) all make this assumption, which is, however, a simplification. Explicitly modeling parental time as an input in human capital production could be an interesting extension. A paper that models investment of both goods and parental time is Erosa and Koreshkova (2007); however, they do not have correlated family endowments.

With respect to the policy experiments in Section 7, it is more clear how they would affect goods investment than how they would affect time investment. For goods investment, higher taxes reduce both the parents' available resources to invest and the incentive to invest (the return on the investment becomes smaller). With time investment, one may invest more as a response to the tax, because the opportunity cost has became smaller, or one may invest less, because the return on the investment is smaller. Which effect would dominate is ultimately a quantitative question.

The effect of public education expenditure may also be different with investment of parental time. If government investments are viewed as goods and complement parental time, increased government investment could actually lead to more parental investments. However, if more government investments mean that the child is spending more time away from the parents, the effect may be to weed out the investment of parental time.

Finally, it should also be mentioned that a production function similar to the one in (13) has been used in some recent studies involving human capital accumulation later in life; see, for instance, Huggett, Ventura, and Yaron (2007), Ionescu (2009), or Guvenen, Kuruscu, and Ozkan (2009). These studies do, however, ignore the input of goods in the production of human capital and focus on the human capital input, which is modeled as the product of previous human capital and time. These studies focus on human capital accumulation during work life and/or college, whereas in my model, human capital accumulation starts at age 5. In my model, the input of the child's time is kept constant, although still augmented by the child's human capital. Parental time is assumed to be included in the family endowment.

Financial assets and inter vivos transfers. I will argue that in a realistic quantitative model developed to study intergenerational earnings persistence, it is important to have financial assets and a mechanism for transfers from parent to child, in addition to human capital. The presence of assets in the model affects how much is invested in a child's human capital in various ways. In a model without financial assets, parents will divide their resources between their own consumption today and their children's future consumption or, equivalently, their children's human capital. This may create a too strong correlation between the earnings of the parent and the child's human capital, as the optimal investment in the child will always be increasing in the earnings of the parent. If there are financial assets and diminishing returns to human capital investments, there will be a point at which the return on capital is strictly higher than the return on human capital, and this will put a cap on human capital investments. The effect of an increase in taxes on human capital investments may be stronger when financial assets are present, because parents will choose to help their children by giving them more financial assets and will invest less in education when the returns to education fall.

Children with low ability but rich parents will earn more in a world with no financial assets, because the only way to help them is to invest in their human capital. With assets in the model, their parents will rather give them some financial assets. Furthermore, since there is uncertainty in the model, parents would like to accumulate some assets to insure against negative shocks, even when the expected return on human capital investments is higher than the return on financial assets. This will take resources away from human capital investments. Finally, a popular explanation both for earnings persistence (see, for instance, Han and Mulligan (2001)) and for college enrollment in the literature is the existence of borrowing constraints. To study the impact of borrowing constraints, it is crucial that the model have financial assets.

Endogenous labor supply. Allowing agents in the model to choose their work hours affects the returns to human capital investments and will be important for the shape of the optimal investment policy as a function of capital. In Figure 4, I illustrate this point

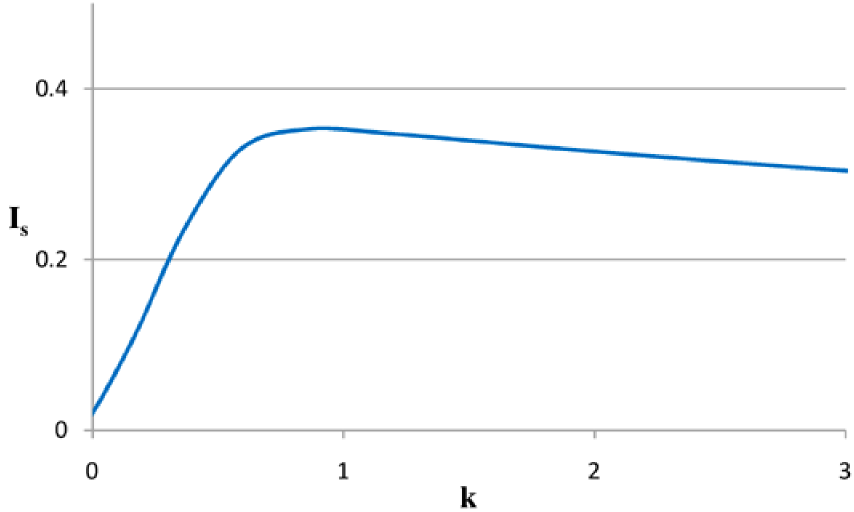

FIGURE 4. Human capital investment for a model college student.

by plotting the optimal investment in human capital for an individual in college. As can be seen from the figure, the optimal investment peaks at some point and starts sloping downward. This is because, as the agent becomes wealthier, he will enjoy more leisure in the future and the returns to investing in human capital are falling. Some families accumulate a lot of physical capital, but the fact that they enjoy leisure and can control their labor supply will affect the shape of their optimal human capital investments.

Labor supply is also potentially important for college enrollment and for the importance of borrowing constraints with respect to human capital investments; see Garriga and Keightley (2007) and Keane and Wolpin (2001). If a poor person cannot borrow to invest in his child, he may choose to compensate by working a bit more. Equivalently, if a college student cannot borrow, he may choose to take a part-time job. Having labor choice in the model reduces the importance of borrowing constraints. If a college student has no other way to raise money than to borrow, borrowing constraints are more likely to be important.

5. Calibration

Many of the parameters can be obtained without solving the model. I calibrate 27 model parameters to their empirical counterparts. The remaining 11 parameters are estimated jointly using an exactly identified simulated method of moments approach. Tables 2 and 3 summarize the parameters calibrated outside and inside the model. The main source of data for the estimated parameters—6 out of the 11 data moments—is employed males from the Panel Study of Income Dynamics (PSID) (1999–2005). I use employed males because most of the literature on intergenerational earnings persistence is based on the relationship between father and son, and the analysis is carried out on working individuals. In addition, there is no unemployment in my model. I use the years 1999–2005 because these are the years for which I also have data on education spending

Table 2. Parameters calibrated outside of the model.

Parameter	Value	Description	Target
r	0.011	Risk-free interest rate (annual)	3-month T-bill minus inflation (1947–2008)
σ	2	$u(c,n)=\frac{(c/e(t))^{1-\sigma}}{1-\sigma}-\chi\frac{n^{1+\eta}}{1+\eta}$	Browning, Hansen, and Heckman (1999)
η	3		
e	1.0 or 1.3		OECD modified equivalence scale
γ_1^0, γ_2^0, γ_3^0	0.221, −0.029, 0.001	$w=h\gamma_0 e^{\gamma_1^j x+\gamma_2^j x^2+\gamma_3^j x^3+u}$	PSID (1968–1997)
γ_1^1, γ_2^1, γ_3^1	0.295, −0.052, 0.003		
τ_{1s}, τ_{1m}, τ_{1mc}	−1.183, −0.595, −1.513	$\tau(wn)=\tau_1(wn/\text{AE})^{0.2}+$	OECD tax data (2001–2005)
τ_{2s}, τ_{2m}, τ_{2mc}	3.181, 1.637, 3.474	$\tau_2(wn/\text{AE})^{0.4}+\tau_3(wn/\text{AE})^{0.6}+$	
τ_{3s}, τ_{3m}, τ_{3mc}	−2.253, −1.008, −2.235	$\tau_4(wn/\text{AE})^{0.8}$	
τ_{4s}, τ_{4m}, τ_{4mc}	0.513, 0.197, 0.470		
τ_c	0.084	Consumption tax	Vertex Inc. (2002)
ϖ	0.110	Time spent studying in college	American Time Use Survey
w_c	$11.14/h	Wage rate in college	CPS (1999–2005)
$I_g(t)$	Primary: $4522	Public spending per student	UNESCO (1999–2005)
	Secondary: $5295		
	Tertiary: $10,672		
z	$24,856	College borrowing limit	Lochner and Monge-Narajano (2011)
T	$13,094	Old age Social Security	Social Security Administration (1999–2005)
G	31% of revenue	Public consumption	2 × military spending + interest payments
$\Gamma(t)$	Varies	Death probabilities	NCHS (1991–2001)

Note: Dollar amounts in annual 2005 dollars.

TABLE 3. Parameters estimated endogenously.

Parameter	Value	Description	Data Moment
γ_0	0.215	$w = h\gamma_0 e^{\gamma_1^j x+\gamma_2^j x^2+\gamma_3^j x^3+u}$	$\bar{w}$, skilled workers
h_0	1.670	Starting level of human capital	$\bar{w}$, unskilled workers
ψ_0	0.440	$h' = h + A(hI)^{\psi_0}$ before college	$\bar{I}_p$, elementary school
ψ_1	0.800	$h' = h + A(hI)^{\psi_1}$ in college	$\bar{I}_s$, in college
σ_u	0.407	$u \sim N(0, \sigma_\nu^2)$	Std. dev. of $\log(w)$
θ	0.335	$\log(A_c) = \theta \log(A_p) + \nu$	β
σ_ν	0.300	$\nu \sim N(0, \sigma_\nu^2)$	College enrollment
Ω	−0.246	$\pi(Ah) = 1 - e^{\Omega Ah}$	College failure rate
α	0.358	Parental altruism	$\bar{k}$, age 25–29
χ	117.4	$u(c,n) = \frac{(c/e(t))^{1-\sigma}}{1-\sigma} - \chi\frac{n^{1+\eta}}{1+\eta}$	$\bar{n}$
δ	1.005	Discount factor	$\bar{k}$, age 50–54

and taxes. Below I describe the data used in the calibration of each parameter as well as the estimation approach.

Preferences. The momentary utility function is the standard constant relative risk aversion (CRRA) utility function in (15), with consumption measured in adult equivalents, $(\frac{c}{e(t)})$. I use the so-called OECD modified adult equivalence scale, and set $e(t) = 1.3$ when there is a child in the household and use $e(t) = 1.0$ when there is not. Consistent with a survey of the empirical literature in Browning, Hansen, and Heckman (1999), I set the coefficient of relative risk aversion, σ, equal to 2, and the inverse of the Frisch elasticity of labor supply, η, equal to 3. The elasticity of substitution between consumption and labor, χ, the time discount factor, δ, and the altruism parameter, α, are among the estimated parameters. The corresponding data moments are average hours worked for employed males 25–64, asset holdings of employed males 50–54, and asset holdings of employed males 25–29 in the PSID (1999–2005). Consistent with the American Time Use Survey (2003), I assume that the day has 15 hours not needed for personal care and I normalize hours so that working 15 hours per day is equivalent to a labor supply of 1 in the model.

Risk-free interest rate. Given the partial equilibrium nature of the model, I take the risk-free rate as fixed and calibrate it using data. I set the risk-free rate equal to the average of 3-month T-bill rates minus inflation over the period 1947–2008 based on data from the Federal Reserve Bank of St. Louis.[7]

Wages. I calibrate the life-cycle profile of wages exogenously, using the entire PSID from 1968–2005. I regress wages on model potential experience and control for the year of observation. I estimate different experience paths for college graduates and non-college graduates. For the data moments used in the structural estimation, I use only the years 1999–2005. I take the average wage of college graduates, the average wage of high school

[7] Series TB3MS and GDPDEF.

graduates, and the variance of log wages as the corresponding data moments to estimate the following parameters: the market return to human capital, γ_0, the starting level of human capital, h_0, and the standard deviation of the idiosyncratic earnings shock, σ_u. In the PSID, individuals are observed only every second year from 1999–2005, while they are observed every year until 1997. To get an estimate of the variance of 5-year wages in the time period from 1999–2005, I assume that the ratio between the variance of 5-year and 1-year wages in this time period is the same as it was in the period 1991–1997.

Production of human capital/investment in education. The data moments that correspond to the parameters of the human capital production function, ψ_0, and ψ_1, are private spending on elementary and college education. In addition, I must know public spending per student at each level of education, $I_g(t)$. I follow Restuccia and Urrutia (2004) and think of education spending by local governments in primary and secondary education as private spending, while I take state and federal education spending as public spending. The rationale behind this is that local government spending is financed by local taxes and that parents, when they choose which neighborhood to live in, choose the level of local government education spending. Public schools receive both local and state/federal funding, and schools in wealthier neighborhoods have larger budgets due to more local funding; see also Fernandez and Rogerson (1996) and Fernandez and Rogerson (1998).

In one way, counting all local government spending as parental investment in education may be a strong assumption that leads to a high level of private education spending relative to public spending. On the other hand, defining education spending as the only form of monetary investment that parents make in human capital is very conservative. To construct the relevant calibration targets for each level of education under the above assumption, I use data on public expenditure per student as fraction of GDP per capita from the UNESCO Institute for Statistics (1999–2005) and data on private expenditure as a fraction of total expenditure, as well as local government's share of public expenditure from the OECD (1999–2005).

Intergenerational correlation of ability. The intergenerational correlation of ability, θ, obviously has an impact on the intergenerational persistence of earnings, and I use that as the calibration target for this parameter. I obtain the value of 0.47 for the intergenerational earnings persistence from a meta study by Corak (2006). This also happens to be the same value as found by Grawe (2004), the latest study, using data from the PSID.

Time spent studying in college, college enrollment, failure, and borrowing. To calibrate the fixed time cost of attending college, ϖ, I use data from the American Time Use Survey (2004–2008). College students spend, on average, 3.3 hours per day on educational activities on weekdays. I assume that they attend two 13-week semesters per year and that they also study 3.3 hours per day on weekends. While this may be a bit optimistic, many students also attend summer school.

I use college enrollment as the data target for the standard deviation of abilities, σ_ν, and the college failure rate as the target for the parameter Ω, which determines the probability of failing college. I compute these targets from the fraction of males with college degrees in the PSID (1999–2005) and data on college survival probability from the OECD (2000, 2004).

I obtain the college borrowing limit from Lochner and Monge-Narajano (2011). This is the borrowing limit for the federal loan program called Stafford loans, which is what most students are eligible to receive. There is another loan program called Perkins loans, which can provide further loans to the students with greatest financial need, but in practice, few students make use of this program. Below I study the effect of relaxing the borrowing constraint.

Taxes. The labor income tax schedule is a polynomial function of an individual's earnings relative to the average earnings, AE:

$$\tau(wn) = \tau_1\left(\frac{wn}{\mathrm{AE}}\right)^{0.2} + \tau_2\left(\frac{wn}{\mathrm{AE}}\right)^{0.4} + \tau_3\left(\frac{wn}{\mathrm{AE}}\right)^{0.6} + \tau_4\left(\frac{wn}{\mathrm{AE}}\right)^{0.8}. \tag{25}$$

As described in more detail in Appendix A.2, I fit this polynomial to labor income tax data from the OECD tax data base (2001–2005). These data are constructed by the OECD based on tax laws from different countries. It is well suited for cross-country comparisons; see also Guvenen, Kuruscu, and Ozkan (2009). Coming up with an accurate estimate of consumption taxes in the United States is complicated by the fact that there are local county-level taxes in addition to state taxes. Vertex Inc. (a consulting company) estimated that the average consumption tax in the United States was 8.4% in 2002 and I use that number. For simplicity, I abstract from capital taxes. I do this because different types of capital are taxed differently, and this also differs across countries. Households do, for instance, have about half of their wealth in their homes, wealth that may or may not be taxed. In the United States, interest income is taxed as labor income, while dividends and capital gains are subject to capital gains tax. The return on capital is, however, set very conservatively in the calibration. It is set equal to the return on risk-free bonds, which was 1.1% over the past 60 years.

Pure public consumption. I assume that the government spends a fraction of its tax revenues on pure public consumption goods, G. I assume that this fraction is equal to two times military spending[8] plus average interest rate payments in the data over the period from 2001 to 2005. This amounts to 31% of tax revenues and leaves 69% of tax revenues to be spent on education, social security, and lump-sum redistribution.

Death probabilities and social security. I assume that all retirees receive the same constant Social Security benefit. I obtain the average benefit for males from the Annual Statistical Supplement to the Social Security Bulletin (1999–2005). I obtain the probability that a retiree will survive to the next period from the National Center for Health Statistics (1991–2001).

[8]Prescott (2004) assumes that 2 times military spending is pure public consumption. I also add average yearly interest payments to this number.

Table 4. Estimation statistics.

Statistic	Data	Model
Mean hours worked	0.417	0.417
Mean wages of workers without college degrees	1.000	1.001
Mean wages of workers with college degrees	1.757	1.751
Std. dev. of log(wage)	0.570	0.566
Investment in elementary school	0.038	0.037
Investment in college	0.121	0.124
Fraction of workers enrolling in college	0.588	0.610
Fraction failing college	0.400	0.407
Intergenerational earnings elasticity	0.470	0.470
Mean assets of people ages 25–29	0.092	0.090
Mean assets of people ages 50–54	0.525	0.531

Estimation method. Eleven model parameters are calibrated using an exactly identified simulated method of moments approach. I minimize the squared percentage deviation of simulated model statistics from the eleven data moments in Table 4. Let $\Sigma = \{\gamma_0, h_0, \psi_0, \psi_1, \sigma_u, \theta, \sigma_\nu, \Omega, \alpha, \chi, \delta\}$ and let $g(\Sigma) = (g_1(\Sigma), \dots, g_{11}(\Sigma))'$ denote the vector where $g_i(\Sigma) = \frac{\bar{m}_i - \hat{m}_i(\Sigma)}{\bar{m}_i}$ is the percentage difference between empirical moments and simulated moments. Then

$$\hat{\Sigma} = \min_{\Sigma} g(\Sigma)' g(\Sigma). \tag{26}$$

Table 3 summarizes the estimated parameter values. As can be seen from Table 4, I get relatively close to matching all of the moments. Because five of the empirical moments have unknown variance, it is not possible to compute any standard errors in this exercise.

6. Decomposing earnings persistence in the model

There are four main model elements that govern earnings persistence and that can be easily shut on and off: the process by which abilities are inherited from parents to children, the variance of idiosyncratic productivity shocks, inter vivos transfers from parents to children, and investments in human capital. Human capital investments are made by parents (individuals in college) and the government. Parental/individual investments and inter vivos transfers will be affected by the size of the government investments, returns to human capital investments, taxation, and borrowing constraints. To quantify how the different model elements affect earnings persistence, I shut them down one by one; see Table 5. We cannot set human capital investments to zero because everyone would get a zero wage, so we will keep government investments constant, relative to average earnings in the economy, and set parental investments to zero, inter vivos transfers to zero, the correlation of abilities to zero, and the variance of the idiosyncratic shock to zero. I keep the variance of the shocks to the log of abilities, σ_ν, and the parameters of the human capital production function, ψ_0 and ψ_1, constant in this exercise.

TABLE 5. Earnings persistence with different model elements present.

Earnings Persistence	Correlated Abilities	Idiosyncratic Shocks	Private Investments	Inter vivos Transfers
0.470	X	X	X	X
0.220		X	X	X
0.538	X		X	X
0.126	X	X		X
0.449	X	X	X	
0.255			X	X
−0.022		X		X
0.249		X	X	
0.271	X			X
0.499	X		X	
0.139	X	X		
−0.006				X
0.249			X	
0.000		X		
0.275	X			

The main conclusion from Table 5 is that both parental/individual investments and the correlation of abilities make significant positive contributions to intergenerational earnings persistence. The link between earnings persistence and private human capital investments comes from the fact that the optimal parental/individual human capital investment policy functions are usually upward sloping in financial resources; the exception is for very wealthy individuals.[9]

The case when all model elements are present except private investments in human capital is particularly interesting. The intergenerational earnings elasticity is then 0.126, or well below the Scandinavian countries. One way to interpret this is as if private investments in human capital accounts for 73% of the estimated intergenerational earnings persistence in the United States. In the context of the present model, policy reforms that eliminate private human capital investments could potentially explain the low earnings persistence in Scandinavia. However, more likely policy is one out of several factors responsible for the discrepancy in earnings persistence between the United States and Scandinavia.

When all model elements are present, the effect of leaving out inter vivos transfers is to reduce the intergenerational earnings elasticity from 0.47 to 0.449. Inter vivos transfers affect intergenerational earnings persistence in three ways. The absence of transfers limits the ability of children with rich parents to invest in college education, and this would negatively impact earnings persistence. Another effect is that if there are no inter vivos transfers, the only way a wealthy parent can help the child is to invest more in human capital. This will increase earnings persistence, as the difference between how much is invested in rich and poor children increases. However, introducing inter vivos

[9]Figure 4 displays an example investment policy function for a model college student. In the simulated model, almost all individuals would be on the upward sloping part of the graph.

transfers alone in the model yields a negative intergenerational earnings elasticity. This is because of the negative income effect on labor supply. Children of high earners get larger transfers and work less, which causes a negative correlation between the earnings of parents and children.

With all elements present in the model, removing the idiosyncratic shocks causes the intergenerational earnings elasticity to increase from 0.47 to 0.538. The effect of introducing idiosyncratic wage shocks in the model is generally to reduce earnings persistence. This is because the shocks are random and not correlated across generations, like abilities and investments in human capital. However, there is an exception when only inter vivos transfers are present in the model. Introducing shocks that are log normally distributed around zero has the effect of making the society richer and causing parents to give larger transfers. In the case with only inter vivos transfers present, larger transfers lead to a stronger negative correlation between the earnings of parents and children.

Introducing correlated abilities alone while shutting down the other three model elements leads to an intergenerational earnings elasticity of 0.3271. One might have expected it to be equal to the correlation of the log of abilities, 0.333, but there is a nonlinear relationship between ability and earnings. Having parental/individual investments alone in the model gives an earnings elasticity of 0.256.

7. Evaluating the importance of policies for earnings persistence

In Section 2, I documented a strong cross-country correlation between intergenerational earnings persistence and tax progressivity and level, and between intergenerational earnings persistence and public spending on tertiary education. This motivates the study, in this section, of the impact of country policies on earnings persistence. I also study the impact of relaxing and tightening the borrowing constraints. For country policies, I first use Denmark as a case study, because out of the countries in Table 1, Denmark has the highest and most progressive[10] taxes and they spend the most on tertiary education (see Figures 1 and 2). Denmark is also the country with the lowest earnings persistence. Results for more countries are presented in Section 7.1.

The impact of taxation and public education expenditure. In this subsection, I study the impact of replacing the U.S. tax system and public education expenditure policies with their Danish equivalents. When I perform the policy experiments, I keep public education expenditure and taxes as functions of average earnings in the economy. In this way, if the society becomes richer or poorer because of a policy change, education expenditure and taxes will adjust accordingly. The reader should also note that because the government budget balances, the lump-sum transfer to households, tr, changes as I change the policies.

Table 6 displays how selected model statistics change with the introduction of Danish policies. As can be seen from the fourth row of the table, the greatest reduction in intergenerational earnings persistence comes from introducing a Danish tax system in the

[10] The progressivity ranking is somewhat sensitive to income level.

Table 6. Policy experiments.

Statistic	Bench-mark	Danish Taxes	Danish Educ. Subsidies	Danish Subsidies + Taxes	Tax With U.S. Level, Dan. Prg.	Flat Tax With Dan. Level
Average hours worked	0.417	0.402	0.408	0.396	0.413	0.410
Std. dev. of log(wages)	0.566	0.473	0.601	0.504	0.512	0.563
Fraction completing college	0.362	0.307	0.502	0.436	0.334	0.368
Intergen. earnings elasticity	**0.47**	**0.299**	**0.439**	**0.298**	**0.406**	**0.447**
$\bar{I}_p$ age 5–9	$4000	$461	$5380	$790	$1884	$2912
$\bar{I}_p$ age 10–14	$5089	$673	$6723	$1112	$2479	$3792
$\bar{I}_p$ age 14–19	$5766	$747	$5007	$463	$2779	$4352
$\bar{I}_s$ in college	$15,172	$1451	$10,981	$744	$5790	$13,691
$\bar{I}$ (all ages)	$5083	$579	$5656	$668	$2255	$4017
$\bar{b}$	$83,107	$4761	$108,644	$8000	$27,448	$74,758
tr	$5247	$10,195	$6252	$11,403	$4610	$12,607
Average earnings	$61,791	$47,287	$68,363	$51,586	$53,866	$59,401
$\frac{\bar{I}_{\text{private}}}{\bar{I}_{\text{total}}}$	0.528	0.147	0.428	0.112	0.366	0.450
Corr(college, $\log(y_{\text{parent}})$)	0.181	0.127	0.161	0.122	0.146	0.175

Note: The third column displays the results when introducing a Danish tax system into the model. The fourth column shows the results when introducing Danish public education expenditure policies. The fifth column shows the results when introducing Danish taxes and education spending at the same time. The sixth column displays the results from introducing a tax system with the US average tax rate but with Danish progressivity. The last column displays the results when introducing a flat tax equal to the average tax rate in Denmark. The dollar amounts are in annual 2005 dollars.

U.S. model. Introducing a Danish tax system in the U.S. model reduces the intergenerational earnings elasticity by 17 percentage points, to 0.30, or about 53% of the difference between the United States and Denmark; see Table 1. The higher and more progressive taxes greatly reduce the incentives for private investment in education, and this leads to lower earnings persistence. We observe that higher and more progressive taxes also lead to lower college completion and less cross-sectional inequality. The lump-sum transfer to households more than doubles, from about $5000 to $10,000.

A higher tax level has the effect of reducing the levels of private human capital investments and private investments' share of total investments falls. Thus, for a given percentage increase in private investments, the percentage increase in total investments is smaller. This weakens the relationship between the parent's financial resources and the child's earnings, and leads to lower earnings persistence. The effect of more progressive taxes is to disproportionately reduce the incentives for human capital investments for wealthy and/or high-ability individuals. This compresses the distribution of private human capital investments and leads to lower intergenerational earnings persistence.

To investigate the quantitative impact of tax progressivity versus tax levels on earnings persistence, I impose a tax system with the same average labor income tax rate as in the United States but with the same progressivity as in Denmark, as measured by (2).[11] The sixth column of Table 6 displays the results from this experiment. The intergenerational persistence of earnings is now 0.406. We can interpret this as if about 37% of the

[11]See Appendix A.5 for details.

difference in earnings persistence between the benchmark economy and the economy with a Danish tax system is due to increased tax progressivity and about 63% is due to the increased tax level.

In the last column of Table 6, I display the results from an experiment where I introduce a flat tax at the average tax rate in the Danish tax experiment (43.5%). This results in an intergenerational earnings elasticity of 0.447, which is considerably higher than in the case with a Danish tax schedule. Cross-sectional inequality, labor supply, investment in education, tax revenues, and the transfer, tr, are all higher with the flat tax.

Introducing a Danish public education expenditure scheme lowers the intergenerational earnings elasticity by 3.1 percentage points, to 0.439. This is explained by increased public expenditure reducing the incentives for parental/individual expenditure on education in relative terms. Total private education expenditure actually increases in absolute terms but this is because the society has become richer and average earnings have increased by about 11%. Private education expenditure's share of total education expenditure does, however, fall from 53% to 43%.

Secondary and tertiary private education spending decreases with Danish public expenditure, while private spending on elementary education increases. This is because the Danish public investments are very large for tertiary and secondary education (see Table 7), and at about the same level as in the United States for elementary education. Therefore, parents move their investments from late to early education. Not surprisingly, greatly increasing public expenditure in tertiary education increases college enrollment. The correlation between college completion and parental earnings decreases.

Introducing both Danish public education expenditure and taxation at the same time further decreases earnings persistence by only 0.1 percentage point, to 0.298, relative to the case with just a Danish tax. There are several potentially competing effects here, and we cannot necessarily expect the effects from the tax and education expenditure policy experiments to add onto each other. On the one hand, private investment in education has become smaller relative to public investment and this should lead to lower earnings persistence, all else being equal. On the other hand, when public education spending increases, more people go to college and this could positively affect both the variance and persistence of income. Another effect pointing in the direction of higher earnings persistence is that the society has become richer and, therefore, people invest more in human capital, in addition to the government investing more. When to-

Table 7. Public education expenditure per student as percentage of GDP per capita.

Education Level	U.S.	Denmark
Primary	11.1	9.6
Secondary	13.0	19.5
Tertiary	26.3	67.1

Note: Based on data from UNESCO (1999–2005) and OECD (1999–2005).

tal human capital investments increase, human capital becomes more important for the log of earnings relative to the idiosyncratic shocks.

We conclude that Danish tax and education expenditure policies significantly impact earnings persistence. Taxation is quantitatively most important. Whether having low earnings persistence in the society is good or bad is naturally a different question. Higher and more progressive taxation as a stand-alone policy reduces human capital accumulation and leads to a poorer society, while increased public education expenditure has the opposite effect. When I introduced Danish education spending, the net change in tax revenues was actually positive. This implies that spending more on education is Pareto improving in steady state; however, a study of optimal policy should also take into account the transition between the steady states. Yet another issue is, of course, general equilibrium effects. I will leave the study of optimal policies to future research.

The impact of borrowing constraints. The importance of borrowing constraints both for intergenerational earnings persistence and college enrollment has received much attention in the literature. In this section, I study the effect of tightening and relaxing the college borrowing constraint, as well as relaxing the assumption that borrowing is allowed only if one attends college. Finally, I allow for negative inter vivos transfers; that is, the parents can pass on debt to their children. Table 8 displays the results from these experiments.

As can be seen from Table 8, relatively large changes to the borrowing constraint have relatively little impact on intergenerational earnings persistence. Completely eliminating borrowing for college reduces college completion by 8%; however, it is those who have the least to gain from college who drop out. Average earnings in the economy fall only by 0.9%. Intergenerational earnings persistence actually falls by 0.4 percentage point (a very small change). Letting people borrow more also has little impact both on earnings persistence and on college enrollment. Human capital investments in college increase slightly and average earnings increase slightly when more borrowing is allowed.

Table 8. The impact of borrowing constraints.

Statistic	Benchmark	0 × BC	2 × BC	2 × BC w/o College	Negative Transfers
Fraction completing college	0.362	0.340	0.393	0.395	0.303
Intergen. earnings elasticity	**0.470**	**0.466**	**0.465**	**0.466**	**0.464**
Average human capital inv. in college	$15,172	$14,601	$15,482	$15,462	$16,619
Average gift from parent to child	$83,107	$85,491	$83,411	$82,266	$39,070
Average earnings	$61,791	$61,291	$62,680	$62,740	$61,869

Note: The second and third columns display the results when setting the college borrowing constraint to 0 and doubling the college borrowing constraint, to $49,712. The college borrowing constraint is linearly decreasing between college and retirement. The fourth column displays the results when people who do not attend college are also allowed to borrow up to twice the original college borrowing constraint, or $49,712, in all time periods before retirement. The fifth column displays the results when the borrowing constraint is 2 times the original college borrowing constraint in all time periods prior to retirement and parents are allowed to pass on debt to their children.

The obvious reason for why relaxing the borrowing constraint has little effect on earnings persistence is simply that most individuals are not borrowing-constrained from investing in human capital. Most individuals begin to accumulate positive asset holdings at a young age to save for retirement and for their children's college education. Thus, there are no binding constraints stopping them from investing more in human capital. It does, however, turn out that in the benchmark economy, the college borrowing constraint binds for about 21% of those who enroll in college. Two mechanism contribute to reducing the impact of these borrowing constraints: first, as we can see from Table 8, parents compensate by giving larger transfers when the borrowing constraint tightens; second, individuals in college can compensate by working more.

The last two columns of Table 8 display the results from experiments in which everyone, not just those who attend college, can borrow up to twice the original college borrowing constraint in all time periods prior to retirement. In the last column, parents are also allowed to give their children negative inter vivos transfers. Allowing for borrowing against children's earnings leads to a very slight decrease in intergenerational earnings elasticity, from 0.466 to 0.464, relative to the experiment in the fifth column with identical borrowing constraints for parents but only positive transfers to children allowed. Allowing parents to pass on debt to their children is bad for children with poor parents. Many parents choose to borrow toward their children's earnings. The loan is not used for human capital investments but is rather added to the parents' retirement savings. This leads to a society in which the average holdings of capital are lower and the average transfer from parent to child falls by about $44,000 relative to the experiment in the fifth column with identical borrowing constraints for parents but only positive transfers to children allowed. There is a significant drop in college enrollment; however, average earnings decrease only slightly. It is those who would get marginal gains from college who drop out, and those who have large gains from college are able to invest almost the same amount as before. The average human capital investment in college actually increases, but this is because college completion is lower and those who drop out were investing little.

7.1 *Earnings persistence and policies across countries*

Above, I looked closely at the effect of introducing Danish tax and education expenditure policies into the U.S. model on earnings persistence. In this section, I present similar results for all the countries for which I have the data; see Table 9. Unfortunately, public education expenditure at all three levels of education is only available for 8 of the 11 countries in Table 1.

The third column in Table 9 displays the simulated earnings persistence in the model after introducing the fitted tax policy from each country in Table 1 into the U.S. model. The fourth column displays the fraction of the difference between the actual earnings persistence in the United States and each country that is explained by introducing the tax policy from that country into the U.S. model. Tax policies explain 50% of the variation in earnings persistence between the United States and country i as measured by the

Table 9. The impact of country policies on intergenerational earnings persistence.

		Taxation		Educ. Exp.		Taxation & Educ. Exp.		U.S. Tax Level & Country i Tax Prog.	
Country	Actual β_i	β	$\%\lvert\beta_{US}-\beta_i\rvert$ Explained	β	$\%\lvert\beta_{US}-\beta_i\rvert$ Explained	β	$\%\lvert\beta_{US}-\beta_i\rvert$ Explained	β	$\%\lvert\beta_{US}-\beta_i\rvert$ Explained
Denmark	0.15	0.299	0.534	0.439	0.096	0.298	0.538	0.406	0.200
Norway	0.17	0.404	0.219	0.458	0.040	0.407	0.209	0.435	0.117
Finland	0.18	0.375	0.328	0.468	0.007	0.395	0.259	0.409	0.210
Canada	0.19	0.463	0.026	–	–	–	–	0.450	0.070
Sweden	0.27	0.382	0.438	–	–	–	–	0.429	0.204
Germany	0.32	0.384	0.574	–	–	–	–	0.455	0.100
Spain	0.4	0.481	−0.157	0.439	0.448	0.454	0.226	0.460	0.146
France	0.41	0.443	0.447	0.432	0.633	0.403	0.884	0.455	0.249
Italy	0.43	0.438	0.795	0.425	0.879	0.376	−0.346	0.446	0.597
U.S.	0.47	0.470	–	0.470	–	0.470	–	0.470	–
U.K.	0.5	0.467	−0.093	0.477	0.217	0.476	0.201	0.463	−0.240
Average	0.317	0.419	0.311	0.451	0.331	0.410	0.282	0.443	0.165
R^2			0.498		0.123		0.545		0.284

Note: The table displays the impact on earnings persistence from introducing the tax and education expenditure policies from each country into the U.S. model.

coefficient of determination:

$$R^2 = \frac{\sum_i(\beta_{i\text{data}} - \beta_{i\text{model}})^2}{\sum_i(\beta_{i\text{data}} - \beta_{\text{US}})^2}. \tag{27}$$

In Figure 5, I plot the simulated earnings persistence in the model after introducing the tax policy from each country into the U.S. model against the earnings persistence for each country in the data. The correlation between actual and simulated earnings persistence is 0.69. If we had been able to explain 100% of the difference between the United States and each country with taxes, all the dots in Figure 5 should have been on the diagonal.

The ninth column in Table 9 displays the simulated earnings persistence in the model after introducing a tax system with the same average labor income tax rate as in the United States but with the same progressivity as in country i, as measured by (2).[12] Tax progressivity explains 28% of the variation in earnings persistence between the United States and country i as measured by R^2. We can interpret this as if the total impact of taxes is 43% due to tax level and 57% due to tax progressivity.

The results from introducing the public education expenditure policies from each country, where data are available, into the U.S. model are displayed in the fifth column of Table 9. On average, education expenditure explains 33% of the difference between country i and the United States. However, education expenditure does a good job of explaining the difference between the United States and the countries where earnings per-

[12] See Appendix A.5 for details.

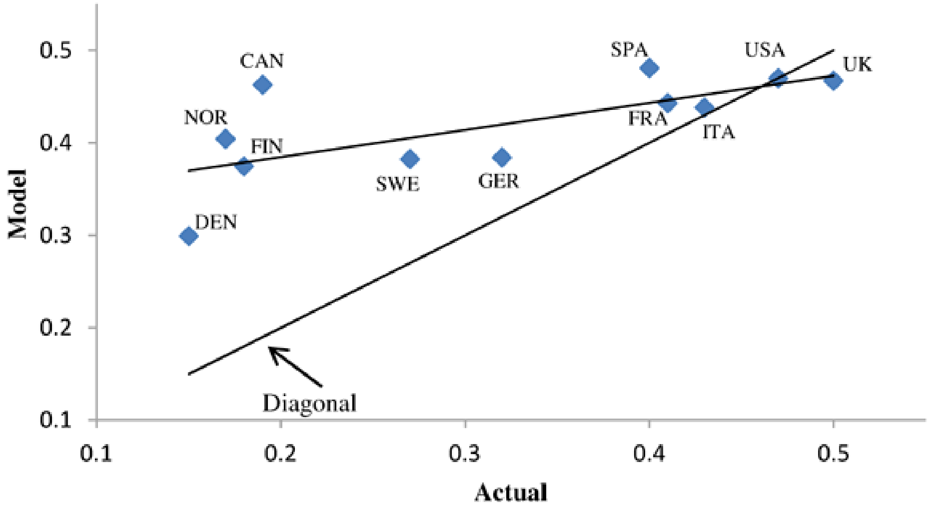

FIGURE 5. The impact of taxation on intergenerational earnings persistence. Replacing the U.S. tax system with the tax system from country i explains 50% of the variation in intergenerational earnings persistence between the United States and the other countries in Table 1. Corr(actual, model) = 0.69.

sistence in the data is not that different from in the United States (United Kingdom, Italy, France, Spain), but it cannot explain the large differences between the United States and the Nordic countries (Denmark, Norway, Finland). As measured by R^2, it explains 12% of the variation between the United States and seven countries. It should be noted in this context that the quantitative impact of public expenditure on early education is greater than the impact of expenditure on college education.[13] The Nordic countries have very high public spending on tertiary education while relatively moderate spending on early education.[14] It should also be noted that a potential issue when studying the impact of education expenditure on earnings persistence is that countries may differ with respect to the degree of redistribution in education expenditure schemes. However, I do not have information on this.

The seventh column in Table 9 displays the results from introducing, at the same time, both the tax and public education expenditure policies from each country into the U.S. model. On average this explains 28% of the difference between the United States and country i. Relative to just introducing the education expenditure policy from each country into the U.S. model, we now do a little better in explaining the Nordic countries, where earnings persistence is significantly lower than in the United States, but we do worse in explaining the difference between the United States and some of the other countries. As measured by R^2, we explain 54% of the variation in earnings persistence

[13] A similar result is found in Restuccia and Urrutia (2004).

[14] This is dependent on making the same assumption for these countries as I did for the United States, namely to count public education expenditure raised by local taxes as private spending.

between the United States and these seven countries with taxes and education expenditure. The corresponding R^2 for taxes alone is 56%, meaning that education expenditure does not increase our explanatory power after controlling for taxes.

8. Conclusion

In this paper, I develop an intergenerational life-cycle model of human capital accumulation and earnings that features taxation, public education expenditure, borrowing constraints, partially inheritable abilities, inter vivos transfers from parent to child, and idiosyncratic wage shocks as determinants of intergenerational earnings persistence. I calibrate the model to U.S. data, and use it to decompose the contribution to earnings persistence from different model elements and to quantify how earnings persistence in the United States changes as I introduce policies from other countries. I find that individual investments in human capital can account for 73% of the estimated intergenerational earnings elasticity in the United States. Taxation and public education expenditure have a significant impact on earnings persistence through their impact on individual investments in human capital and are significant contributors to the cross-country patterns that empirical researchers have found. Taxation is found to be quantitatively more important for cross-country differences. Taxation explains 50% of the variation in earnings persistence between the United States and 10 other countries. I also find that borrowing constraints, which have received much attention in the literature, have a limited impact on earnings persistence.

Future research in this area may hope to include data from more countries, especially when it comes to education expenditure. One important mechanism that could affect the results in this study and should be investigated further is time investment in children's human capital. In this study, I assumed that time investment is included in the family endowment. Another potentially important source of earnings persistence which I have assumed to stay constant throughout this study is the production technology for human capital. It will affect both earnings persistence and cross-sectional inequality. Future research may focus on estimating human capital production functions from different countries. An extension is also to explicitly model the supply of educational services. Then tax and education expenditure policies would directly impact the human capital production functions. Finally, within such a general equilibrium framework, it would be interesting to study optimal education expenditure and tax policies.

Appendix

A.1 *Discussion of difficulties with comparing different studies of earnings persistence*

There are some difficulties related to comparing different studies of intergenerational earnings persistence. Solon (1992) and Blanden (2009) provide more in-depth discussions of some of the methodological issues. One problem in the estimation of (1) is the measure of earnings. Ideally the measure of earnings used in (1) should be permanent or lifetime earnings. Since this measure is rarely available, the econometrician will either use earnings observed in a single year or, preferably, take the average of several years of earnings. This will generally be an inaccurate measure of permanent earnings. It is easy to show that an inaccurate measure of the father's earnings in (1) will lead the estimate of β to be biased downward. A first step toward reducing this measurement error is controlling for age in (1), and this is done in pretty much every study. However, if more years of earnings are averaged, the measurement error is reduced, and this is a source of discrepancies between different studies. Another obvious source of discrepancies between studies is the quality of the data. If the sample is too homogeneous, i.e., the variance of earnings is too small, as is typical for unrepresentative data samples, the problem with measurement error is compounded; see Solon (1992).

A possible solution to the problem with measurement error in the father's earnings is the use of instrumental variables. The instruments must be uncorrelated with the measurement error and, in addition, uncorrelated with the son's earnings. The problem with the instrumental variable approach is that most variables related to father's earnings may also have an independent impact on the son's earnings. Solon (1992) shows that in this case, the estimate of β will be biased upward. The instrumental variables approach is nonetheless becoming more popular in the literature.

Finally, the age at which father's and son's earnings are observed may have a substantial impact on the estimates of β; see Haider and Solon (2006) and Grawe (2003). Controlling for age in the regression does not solve this problem, since high and low earners have different life-cycle earnings profiles. Often the earnings of young sons are regressed on the earnings of old fathers, which is found to cause a downward bias in the estimate of β. Haider and Solon (2006) find that the years around 40 will be the best proxies for lifetime earnings.

Corak (2006) provides a cross-country meta study of intergenerational earnings persistence that tries to take into account how many years of the father's earnings were used as a measure for permanent earnings, whether an instrumental variable (IV) approach was used, and the age of the father at the time of observation. Table 1 displays the results from this study supplemented with earnings persistence from Italy and Spain, which I take from Piraino (2007) and Pla (2009). I adjust the number for Italy using a formula provided in Corak (2006). I cannot do the same for Spain, because I do not know the average age of the fathers in that study. Pla (2009) reports one earnings elasticity using sons aged 30–40 and one earnings elasticity using sons aged 40–50. The number listed is the average of the two. Given the many problems with comparing different studies of intergenerational earnings persistence, it is clear that Table 1 should be interpreted as a stylized fact.

A.2 *Fitting tax functions based on data from the OECD*

For every country in Table 1, I fit the polynomial in (25). I use this functional form because it generally gives me a very good fit, R^2 above 99.9%, and because I get functions that are strictly increasing and well behaved on a relatively wide range of labor income.

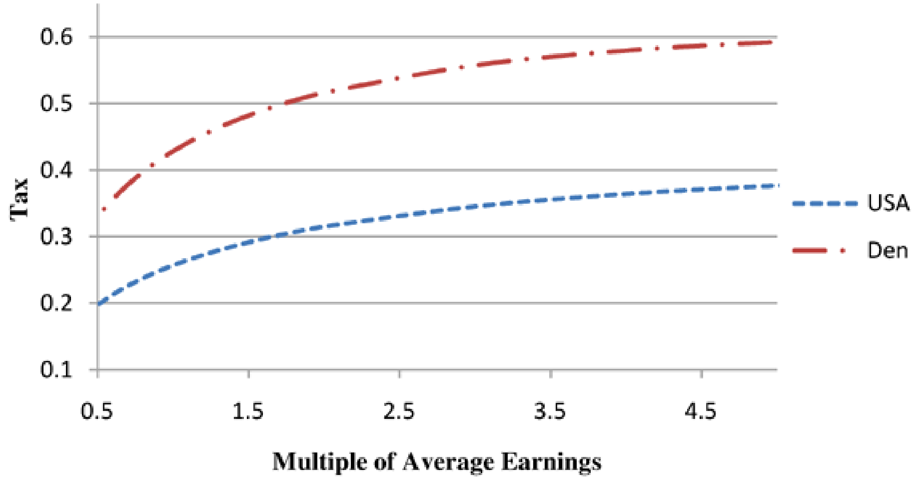

Figure 6. Labor income tax functions for the United States and Denmark (singles without children).

I use labor income tax data from the OECD tax-benefit calculator.[15] These data are constructed by the OECD based on tax laws from different countries.

The OECD tax–benefit calculator gives the gross and net (after taxes and benefits) labor income at every percentage of average labor income by year and by family type, starting in 2001. I use every data point in the range from 50% of average earnings to 400% of average earnings, where a substantial fraction of the population is located. I then add data points at 30%, 450%, 500%, 550%, 600%, 650%, 700%, 750%, 800%, 850%, 900%, 950%, 1000%, 1100%, 1200%, 1400%, 1500%, and 2000% to ensure a reasonable tax schedule for very low and very high earners. I take an average of the years 2001–2005 and fit tax schedules for three different family types; single without children, married couple without children, and married couple with one child. My model is of single males; however, in reality most males who father children will be married for a large part of their working life. During the married years, I assume that each man has a wife, who makes 39.19% of his earnings (the average in the data). Table 12 displays the country tax functions, while Figure 6 plots the tax functions for singles without children in the United States and Denmark.

A.3 *Proof of Proposition* 3.1

We can rearrange (8), the first-order condition with respect to investments in human capital, as

$$\frac{-2b}{(1-\tau)} + A_c(I_p + I_g)^{(\psi-1)} * \bigl(-2(I_p + I_g) + \alpha\psi\bigl(y_p(1-\tau) - I_p - b\bigr)\bigr) = 0. \qquad (28)$$

[15]An interactive version is available at www.oecd.org/document/18/0,3343,en_2649_34637_39717906_1_1_1_1,00.html.

Applying the implicit function theorem to (28) yields

$$\frac{\partial I_p}{\partial y_p} = \frac{(I_p + I_g)\alpha(1-\tau)}{I_g(2+\alpha) + \alpha(y_p(1-\tau) - b)(1-\psi) + I_p(2+\alpha\psi)} > 0,$$

$$\frac{\partial b}{\partial y_p} = \frac{A_c(I_p + I_g)^{\psi}\alpha(-1+\tau)^2\psi}{2I_g + 2I_p + A_c(I_p + I_g)^{\psi}\alpha\psi(1-\tau)} > 0,$$

$$\frac{\partial I_p}{\partial I_g} = -\frac{2I_g + I_p(2+\alpha(-1+\psi)) + \alpha(b + y_p(-1+\tau))(-1+\psi)}{I_g(2+\alpha) + \alpha(b + y(-1+\tau))(-1+\psi) + I_p(2+\alpha\psi)} < 0,$$

$$\frac{\partial I_p}{\partial \tau} = -\frac{(I_g + I_p)^{(1-\psi)}(2b(I_g + I_p) + A(I_g + I_p)^{\psi} y_p \alpha(-1+\tau)^2\psi)}{A(-1+\tau)^2\psi(I_g(2+\alpha) + \alpha(b + y_p(-1+\tau))(-1+\psi) + I_p(2+\alpha\psi))}$$

$$< 0,$$

$$\frac{\partial I_p}{\partial \alpha} = \frac{(I_g + I_p)(y_p(1-\tau) - I_p - b)}{(I_g(2+\alpha) + \alpha(b + y(-1+\tau))(-1+\psi) + I_p(2+\alpha\psi))^2} > 0. \qquad \square$$

A.4 *Computational details*

Computation of optimal policies. I put boundaries on the capital and human capital space, and pick a grid in each dimension. I pick 40 grid points in $K = [k^{\min}, k^{\max}]$ and 16 grid points in $H = [h^{\min}, h^{\max}]$. The grid points for capital are taken to be the scaled zeros of a 40th-order Chebyshev polynomial, while the grid points for human capital are taken to be the scaled zeros of a 16th-order Chebyshev polynomial. Following the method outlined by Tauchen (1986), I approximate the processes for the idiosyncratic productivity shock, u, and ability, A, as finite state Markov processes. I use 7 equally spaced states for u in $U = [-2\sigma_u, 2\sigma_u]$ and use 13 equally spaced states for A in $\bar{A} = [-3\sigma_A, 3\sigma_A]$. Let $J = \{0, 1\}$ be the state space for whether an individual is college educated. The maximum size of the state space occurs in periods 5–7, or ages 40–50, when there are six state variables apart from time. The state space is then $J \times K \times H \times H \times \bar{A} \times U$ or 1,863,680 grid points. I compute the household's optimal policies for each grid point in each time period by iterating backward. I start from age 100, the last period of life. In that period, the next period's value function is 0 and the optimal policy is to consume as much as possible. Knowing the value function at age 100, I can compute optimal policies and value functions for age 95, and so on. Reaching age 50, when the child leaves home, I need to know both the parent's value function at age 55 and the child's value function at age 20 to compute the optimal policies. The first time around, I use an educated guess for the child's value function at age 20. When I reach age 20, I get a new $V(\text{age} = 20, \cdot)$ and start over again from age 50. I continue this iteration until V converges.

To solve for the optimal policies in each time period, I use the routine called LCONF from the International Mathematics and Statistics Library (IMSL) Fortran library. It is based on M. Powell's method for solving linearly constrained optimization problems; see IMSL documentation for details. To interpolate the value function outside of the grid, I use Chebyshev collocation; see Judd (1998) and Heer and Maussner (2004). When there is a child in the household and the parent is investing in the child's human capital, the next period's value function must be interpolated in the $K \times H$ space. The value function is then represented as a polynomial with $40 \times 16 = 640$ coefficients. At one point in time, when the agent chooses whether or not to attend college, I am taking the max of two value functions. When these two value functions overlap, the value function considered by the parent, before the child makes the college decision, will generally not be concave. However, what the parent needs to consider is the expectation of the value function over the idiosyncratic shock. It turns out that the expectation of the value function is concave, although there is no theoretical guarantee for it. To be absolutely sure that I am finding a global max, I am multiply starting the solver from points that are far apart.

Simulation. Knowing today's state, the policy functions, and drawing shocks, u and ν, I can find the next period's state. I make 200,000 draws from a random initial distribution of 20 year olds and run the simulation for 200 generations (enough to reach a stationary distribution). In the simulation, the policy functions must be interpolated on the $K \times H \times H$ space as both the child's and the parent's human capital may be outside of the grid. I use linear interpolation.

Hardware and software. I use Intel Fortran version 13.0 and a computer with 2X Intel Xenon X5690 processors. To speed up the computation, I use OpenMP to parallelize the code on the 24 threads.

A.5 *Introducing a tax system with U.S. level and progressivity like in country i*

I follow an approach similar to Guvenen, Kuruscu, and Ozkan (2009). Whether we define the progressivity wedge in (2) with marginal or average taxes, it is the same transformation of the tax function, which will hold progressivity constant while changing the tax level. We want to introduce a new tax function, $\tilde{\tau}(y)$, which has the same average tax rate as in the United States but where progressivity, as defined in (2), is the same as in the tax system of country i, $\tau_i(y)$. We must have

$$1 - \frac{1 - \tilde{\tau}^m(y_2)}{1 - \tilde{\tau}^m(y_1)} = 1 - \frac{1 - \tau_i^m(y_2)}{1 - \tau_i^m(y_1)} \quad \Rightarrow \quad \frac{1 - \tilde{\tau}^m(y_2)}{1 - \tau_i^m(y_2)} = \frac{1 - \tilde{\tau}^m(y_1)}{1 - \tau_i^m(y_1)} \tag{29}$$

for all levels of y_1 and y_2. Letting the fraction $\frac{1-\tilde{\tau}^m(y)}{1-\tau_i^m(y)}$ be equal to a constant, Λ, for all levels of y, and rearranging (29), we have

$$1 - \tilde{\tau}^m(y) = \Lambda\big(1 - \tau_i^m(y)\big) \quad \Rightarrow \quad \tilde{\tau}^m(y) = 1 - \Lambda + \Lambda \tau_i^m(y). \tag{30}$$

Observing that $\int_0^y \tau^m(y) = y\tau(y)$, we can integrate on both sides and obtain

$$\tilde{\tau}(y) = 1 - \Lambda + \Lambda \tau_i(y). \tag{31}$$

We must solve for Λ in the context of the model to obtain the same average tax level as in the United States. If we instead replace the marginal tax rate, $\tau^m(y)$, with the average tax rate $\tau(y)$ when constructing the progressivity measure, then (30) would read

$$1 - \tilde{\tau}(y) = \Lambda\big(1 - \tau_i(y)\big) \quad \Rightarrow \quad \tilde{\tau}(y) = 1 - \Lambda + \Lambda \tau_i(y) \tag{32}$$

without integrating.

A.6 *Additional tables*

TABLE 10. Correlations between intergenerational earnings persistence and tax measures.

	Family Type		
Correlation( )	Single	Married (0 Children)	Married (1 Child)
β, τ^m(AE)	−0.550	−0.543	−0.610
β, PW^m(0.5AE, AE)	−0.685	−0.623	−0.631
β, PW^m(0.5AE, 2AE)	−0.804	−0.794	−0.745
β, PW^m(0.5AE, 4AE)	−0.727	−0.649	−0.731
β, PW^m(AE, 2AE)	−0.787	−0.715	−0.784
β, PW^m(AE, 4AE)	−0.549	−0.457	−0.426
β, PW^m(AE, 6AE)	−0.376	−0.172	−0.198
β, τ(AE)	−0.503	−0.515	−0.500
β, PW^a(0.5AE, AE)	−0.376	−0.399	−0.529
β, PW^a(0.5AE, 2AE)	−0.498	−0.515	−0.581
β, PW^a(0.5AE, 4AE)	−0.658	−0.692	−0.672
β, PW^a(AE, 2AE)	−0.612	−0.628	−0.636
β, PW^a(AE, 4AE)	−0.751	−0.788	−0.742
β, PW^a(AE, 6AE)	−0.780	−0.783	−0.794

Note: τ^m(AE) and τ(AE) are the marginal and average tax rates at average earnings. PW$^m(y_1, y_2)$ and PW$^a(y_1, y_2)$ are the progressivity wedges between incomes y_1 and y_2, constructed with marginal and average tax rates.

TABLE 11. Consumption tax by country (OECD 2001–2005).

Country	Consumption Tax
Denmark	25.0%
Norway	23.7%
Finland	22.0%
Canada	7.0%
Sweden	25.0%
Germany	16.0%
Spain	16.0%
France	19.9%
Italy	20.0%
U.S.*	8.4%
U.K.	17.5%

Note: *From Vertex Inc. (2002).

Table 12. Country tax functions.

Country	τ_1	τ_2	τ_3	τ_4	R^2
			Married (0 children)		
Denmark	−0.8340821	2.653975	−1.782215	0.3727709	0.9999
Norway	−0.9151925	2.357054	−1.436	0.2768166	0.9999
Finland	−1.786036	4.210806	−2.709563	0.5645917	0.9993
Canada	−1.004608	2.383766	−1.467924	0.2944103	0.9996
Sweden	0.0435576	0.2558834	0.117199	−0.1021613	0.9998
Germany	−2.341808	6.033008	−4.321287	0.9888285	0.9998
Spain	−0.695431	1.482619	−0.724988	0.1047873	0.9999
France	−0.0659207	0.5232531	−0.2436658	0.0372464	0.9999
Italy	−2.199901	5.172168	−3.501398	0.7705837	0.9999
U.S.	−0.5952387	1.636844	−1.007828	0.1970667	0.9998
U.K.	−1.751862	4.313386	−3.016562	0.6846306	0.9986
			Married (1 child)		
Denmark	−2.737235	6.483092	−4.328906	0.9324725	0.9994
Norway	−1.687183	3.881035	−2.436887	0.4949357	0.9996
Finland	−3.258404	7.108649	−4.592615	0.9685161	0.9986
Canada	−3.044256	6.512615	−4.210616	0.8934768	0.9968
Sweden	−1.89896	4.382775	−2.78672	0.5725898	0.9995
Germany	−2.831994	6.707468	−4.575432	1.004294	0.9994
Spain	−0.8535222	1.800009	−0.9442255	0.1558268	0.9999
France	0.145302	−0.2255823	0.4825532	−0.1739126	0.9995
Italy	−2.972545	6.547168	−4.289763	0.9156697	0.9995
U.S.	−1.512787	3.473651	−2.235034	0.4697056	0.9997
U.K.	−3.387389	7.400429	−4.917345	1.06676	0.9938
			Single (0 children)		
Denmark	−1.851625	4.995183	−3.491631	0.7754541	0.9998
Norway	−0.9186265	2.453045	−1.511725	0.2899294	0.9999
Finland	−2.314598	5.579046	−3.775753	0.826796	0.9992
Canada	−0.3056732	0.8059581	−0.2546371	−0.0145851	0.9997
Sweden	−0.8620883	2.485298	−1.601609	0.3224937	0.9996
Germany	−1.278933	3.923879	−2.909065	0.6716755	0.9995
Spain	−0.7455719	1.710186	−0.924621	0.155641	0.9997
France	−0.6403266	1.995908	−1.385199	0.3145717	0.9997
Italy	−2.33939	5.629314	−3.884271	0.8666075	0.9999
U.S.	−1.18305	3.181103	−2.252743	0.5132841	0.9997
U.K.	−1.815518	4.588508	−3.26912	0.7516708	0.9957

Table 13. Country progressivity wedges (marginal tax rates) between multiples of average earnings.

Country	τ(AE)	(0.5, 1)	(0.5, 2)	(0.5, 4)	(1, 2)	(1, 4)	(1, 6)
				Married (0 children)			
Denmark	0.534	0.155	0.273	0.332	0.140	0.209	0.130
Norway	0.402	0.127	0.237	0.311	0.126	0.211	0.176
Finland	0.433	0.159	0.281	0.343	0.145	0.219	0.150
Canada	0.313	0.103	0.192	0.256	0.100	0.171	0.160
Sweden	0.414	0.119	0.243	0.347	0.141	0.259	0.227
Germany	0.502	0.148	0.206	0.160	0.069	0.014	−0.141
Spain	0.270	0.099	0.198	0.284	0.110	0.205	0.209
France	0.331	0.086	0.183	0.288	0.106	0.221	0.299
Italy	0.386	0.135	0.219	0.237	0.097	0.118	0.036
U.S.	0.319	0.087	0.164	0.219	0.084	0.145	0.131
U.K.	0.342	0.099	0.155	0.161	0.062	0.069	0.022
				Married (1 child)			
Denmark	0.544	0.222	0.365	0.394	0.183	0.220	0.184
Norway	0.401	0.150	0.270	0.336	0.141	0.219	0.232
Finland	0.437	0.205	0.348	0.395	0.179	0.238	0.222
Canada	0.336	0.161	0.271	0.308	0.132	0.175	0.165
Sweden	0.429	0.164	0.290	0.352	0.151	0.225	0.230
Germany	0.479	0.178	0.271	0.253	0.114	0.092	0.030
Spain	0.266	0.102	0.201	0.285	0.111	0.204	0.243
France	0.318	0.100	0.220	0.347	0.134	0.275	0.344
Italy	0.384	0.167	0.275	0.298	0.130	0.157	0.131
U.S.	0.317	0.112	0.198	0.244	0.097	0.149	0.161
U.K.	0.348	0.159	0.251	0.252	0.109	0.111	0.073
				Single (0 children)			
Denmark	0.353	0.087	0.140	0.154	0.058	0.073	0.073
Norway	0.581	0.191	0.302	0.307	0.137	0.144	0.102
Finland	0.328	0.102	0.204	0.285	0.114	0.204	0.229
Canada	0.463	0.135	0.242	0.300	0.124	0.191	0.199
Sweden	0.513	0.114	0.155	0.110	0.046	−0.004	−0.061
Germany	0.300	0.102	0.201	0.280	0.110	0.198	0.231
Spain	0.368	0.099	0.147	0.138	0.053	0.043	0.024
France	0.419	0.140	0.216	0.213	0.089	0.085	0.055
Italy	0.376	0.093	0.173	0.239	0.088	0.160	0.203
U.S.	0.435	0.135	0.246	0.311	0.129	0.204	0.214
U.K.	0.480	0.174	0.285	0.312	0.135	0.166	0.149

TABLE 14. Country progressivity wedges (average tax rates) between multiples of average earnings.

Country	τ^m(AE)	(0.5, 1)	(0.5, 2)	(0.5, 4)	(1, 2)	(1, 4)	(1, 6)
			Married (0 children)				
Denmark	0.410	0.129	0.248	0.343	0.138	0.247	0.291
Norway	0.283	0.102	0.204	0.294	0.114	0.214	0.261
Finland	0.280	0.129	0.251	0.349	0.140	0.252	0.298
Canada	0.206	0.084	0.169	0.245	0.092	0.175	0.215
Sweden	0.314	0.085	0.183	0.283	0.106	0.216	0.273
Germany	0.359	0.144	0.256	0.311	0.130	0.195	0.199
Spain	0.167	0.074	0.157	0.240	0.089	0.179	0.227
France	0.251	0.064	0.138	0.222	0.079	0.169	0.225
Italy	0.241	0.121	0.226	0.298	0.120	0.202	0.228
U.S.	0.231	0.073	0.146	0.212	0.079	0.150	0.185
U.K.	0.230	0.097	0.178	0.231	0.090	0.148	0.166
			Married (1 child)				
Denmark	0.349	0.177	0.332	0.440	0.189	0.320	0.360
Norway	0.252	0.121	0.237	0.334	0.133	0.242	0.288
Finland	0.226	0.162	0.309	0.417	0.176	0.305	0.351
Canada	0.151	0.133	0.255	0.344	0.140	0.243	0.279
Sweden	0.270	0.132	0.257	0.357	0.144	0.259	0.305
Germany	0.304	0.156	0.285	0.362	0.153	0.244	0.262
Spain	0.158	0.077	0.161	0.245	0.091	0.181	0.229
France	0.228	0.066	0.150	0.250	0.090	0.197	0.262
Italy	0.201	0.141	0.265	0.352	0.145	0.246	0.278
U.S.	0.196	0.095	0.186	0.259	0.100	0.181	0.215
U.K.	0.162	0.138	0.257	0.333	0.138	0.226	0.249
			Single (0 children)				
Denmark	0.581	0.191	0.302	0.307	0.137	0.144	0.102
Norway	0.435	0.135	0.246	0.311	0.129	0.204	0.214
Finland	0.480	0.174	0.285	0.312	0.135	0.166	0.149
Canada	0.328	0.102	0.204	0.285	0.114	0.204	0.229
Sweden	0.463	0.135	0.242	0.300	0.124	0.191	0.199
Germany	0.513	0.114	0.155	0.110	0.046	−0.004	−0.061
Spain	0.300	0.102	0.201	0.280	0.110	0.198	0.231
France	0.376	0.093	0.173	0.239	0.088	0.160	0.203
Italy	0.419	0.140	0.216	0.213	0.089	0.085	0.055
U.S.	0.353	0.087	0.140	0.154	0.058	0.073	0.073
U.K.	0.368	0.099	0.147	0.138	0.053	0.043	0.024

References

Becker, G. and N. Tomes (1979), "An equilibrium theory of the distribution of income and intergenerational mobility." *Journal of Political Economy*, 87, 1153–1189. [388, 398, 401]

Becker, G. and N. Tomes (1986), "Human capital and the rise and fall of families." *Journal of Labor Economics*, 4, S1–S39. [388, 398, 401]

Ben-Porath, Y. (1967), "The production of human capital and the life cycle of earnings." *Journal of Political Economy*, 75, 352–365. [401]

Benabou, R. (2002), "Tax and education policy in a heterogeneous agent economy: What levels of redistribution maximize growth and efficiency?" *Econometrica* (70), 481–517. [392]

Blanden, J. (2009), "Intergenerational income mobility in a comparative perspective." In *Education and Inequality Across Europe* (P. Dolton, R. Asplund, and E. Barth, eds.), Edward Elgar, Cheltenham. [386, 389, 417]

Browning, M., L. Hansen, and J. Heckman (1999), "Microdata and general equilibrium models." In *Handbook of Macroeconomics* (M. Woodford and J. Taylor, eds.), Elsevier, New York. [404, 405]

Caucutt, E. M., S. Imrohoroglu, and K. B. Kumar (2003), "Growth and welfare analysis of tax progressivity in a heterogeneous-agent model." *Review of Economic Dynamics*, 546–577. [392]

Corak, M. (2006), "Do poor children become poor adults? Lessons for public policy from a cross country comparison of generational earnings mobility." In *Dynamics of Inequality and Poverty*, Research on Economic Inequality, Vol. 13, 143–188, Emerald, Bingley. [386, 390, 406, 418]

Cunha, F. and J. Heckman (2007), "The technology of skill formation." Working Paper 12840, NBER. [401]

Erosa, A. and T. Koreshkova (2007), "Progressive taxation in a dynamic model of human capital." *Journal of Monetary Economics*, 54 (3), 667–685. [391, 401]

Fernandez, R., N. Guner, and J. Knowles (2005), "Love and money: A theoretical and empirical analysis of household sorting and inequality." *Quarterly Journal of Economics*, 120, 273–344. [388]

Fernandez, R. and R. Rogerson (1996), "Income distribution, communities, and the quality of public education." *Quarterly Journal of Economics*, 111, 135–164. [406]

Fernandez, R. and R. Rogerson (1998), "Public education and income distribution: A dynamic quantitative evaluation of education-finance reform." *American Economic Review*, 88, 813–833. [406]

Garriga, C. and M. P. Keightley (2007), "The technology of skill formation." Working Paper 2007-051A, Federal Reserve Bank of St. Louis. [403]

Grawe, N. (2003), "Lifecycle bias in the estimation of intergenerational income mobility." Working Paper 207, Statistics Canada Analytical Studies Branch. [418]

Grawe, N. (2004), "Intergenerational mobility for whom? The experience of high- and low earning sons in international perspective." In *Generational Income Mobility in North America and Europe* (M. Corak, ed.), Cambridge University Press, Cambridge. [406]

Guner, N., R. Kaygusuz, and G. Ventura (2012), "Income taxation of US households: Facts and parametric estimates." Discussion Paper 9078, CEPR. [392]

Guvenen, F., B. Kuruscu, and S. Ozkan (2009), "Taxation of human capital and wage inequality: A cross-country analysis." Working Paper 15526, NBER. [392, 402, 407, 421]

Haider, S. and G. Solon (2006), "Life-cycle variation in the association between current and lifetime earnings." *American Economic Review*, 96, 1308–1320. [418]

Han, S. and C. Mulligan (2001), "Human capital, heterogeneity and estimated degrees of intergenerational mobility." *The Economic Journal*, 111, 207–243. [390, 401, 402]

Heathcote, J., S. Storesletten, and G. Violante (2012), "Redistribution in a partial insurance economy." Working paper. [392]

Heer, B. and A. Maussner (2004), *Dynamic General Equilibrium Modeling*. Springer, Berlin. [420]

Herrington, C. (2013), "Public education financing systems, earnings inequality and intergenerational mobility." Working paper, Arizona State University. [391]

Huggett, M., G. Ventura, and A. Yaron (2007), "Sources of lifetime inequality." Working Paper 13224, NBER. [402]

Ionescu, F. (2009), "The federal student loan program: Quantitative implications for college enrollment and default rates." *Review of Economic Dynamics*, 12, 205–231. [402]

Judd, K. (1998), *Numerical Methods in Economics*. MIT Press, Cambridge, MA. [420]

Keane, M. and K. Wolpin (2001), "The effect of parental transfers and borrowing constraints on educational attainment." *International Economic Review*, 42, 1051–1103. [403]

Lochner, L. and A. Monge-Narajano (2011), "The nature of credit constraints and human capital." *American Economic Review*, 101, 2487–2529. [404, 407]

Piraino, P. (2007), "Comparable estimates of intergenerational income mobility in Italy." *The B.E. Journal of Economic Analysis & Policy*, 7. [386, 418]

Pla, M. (2009), "Measuring intergenerational earnings mobility in Spain: A selection-bias-free approach." [386, 418]

Prescott, E. C. (2004), "Why do Americans work so much more than Europeans." *Federal Reserve Bank of Minneapolis Quarterly Review*, 28 (1), 2–13. [407]

Restuccia, D. and C. Urrutia (2004), "Intergenerational persistence of earnings: The role of early and college education." *American Economic Review*, 94, 1354–1378. [388, 390, 401, 406, 416]

Solon, G. (1992), "Intergenerational income mobility in the United States." *American Economic Review*, 82, 393–408. [417, 418]

Solon, G. (2004), "A model of intergenerational mobility variation over time and place." In *Generational Income Mobility in North America and Europe* (M. Corak, ed.), Cambridge University Press, Cambridge. [388, 393, 398, 401]

Tauchen, G. (1986), "Finite state Markov-chain approximations to univariate and vector autoregressions." *Economics Letters*, 20, 177–181. [420]

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