How Do Taxes Affect Human Capital?
The Role of Intergenerational Mobility

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Existing studies of the effects of taxation on human capital accumulation are based on models with extreme intergenerational mobility properties. One strand of the literature uses life-cycle models, in which intergenerational mobility is perfect. Another strand relies on models of infinitely lived dynasties, in which intergenerational persistence is perfect. Hendricks (1999) shows that the predicted tax effects differ in important ways across the two model classes, in large part due to the extreme mobility properties implied by standard infinite horizon and life-cycle models. It is therefore important to study the effects of taxes in environments with *realistic* intergenerational mobility properties.

To this end, this paper develops an overlapping generations model of taxation and human capital accumulation which matches features of the intergenerational transmission of earnings and education estimated from a panel of U.S. workers. The main finding is that abstracting from the intergenerational transmission of human capital, as is typically done in life-cycle models, has little impact on the predicted effects of tax reforms. In contrast, models with extreme degrees of intergenerational persistence, as implicit in infinite horizon models, generate very different outcomes. This finding cautions against the use of infinite horizon models of human capital accumulation.

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1. Introduction

How do income taxes affect human capital accumulation? The literature studying this question has employed two classes of models: overlapping generations models and models of infinitely lived dynasties.[1] Until recently, their properties were commonly believed to be very similar. For example, Lucas (1990, pp. 295-6) remarks that infinite horizon and life-cycle models "have very different theoretical structures, yet in practice, for the kind of tax problem under study here, seem to yield quite similar results." However, recent research suggests that infinite horizon models tend to generate substantially larger tax effects than do life-cycle models (Hendricks 1999). In large part, the differences are due to implicit assumptions about intergenerational mobility. Life-cycle models typically abstract from all intergenerational links so that intergenerational mobility is perfect. By contrast, infinite horizon models implicitly assume that children inherit their parents' physical and human capital, which implies complete intergenerational persistence.

Of course, in the data neither persistence nor mobility are perfect. This raises two questions: (*i*) How large are the effects of income taxes in models with *realistic* intergenerational mobility properties? (*ii*) How well do infinite horizon or life-cycle models *approximate* the properties of such models? This paper offers answers to these questions.

Addressing these issues requires a quantitative theory of lifetime earnings inequality and intergenerational mobility that is consistent with key features of the data. Since little is known about how intergenerational mobility varies with parental characteristics, such as schooling and ability, the paper constructs a dataset of matched parents and children and develops a set of stylized intergenerational mobility facts. I then develop a model that can quantitatively account for these stylized facts. It combines the features of a conventional life-cycle model with a theory of the intergenerational transmission of education and ability along the lines of Becker and Tomes (1986). The model is calibrated to U.S. data and numerical simulations are used to measure the effects of moving from a progressive to a flat income tax. The predictions are compared for varying degrees of intergenerational mobility.

The main finding is that conventional life-cycle models, which abstract from all intergenerational links, closely approximate the properties of models with realistic

[1] Important studies using life-cycle models include Davies and Whalley (1991) and Heckman, Lochner, and Taber (1998, hereafter HLT). Infinite horizon models are used, for example, in Trostel (1993) and in many endogenous growth models such as Stokey and Rebelo (1993).

intergenerational mobility. By contrast, imposing very strong intergenerational persistence, as is implied by infinite horizon models, leads to exaggerated tax effects. This finding cautions against the common practice of studying human capital accumulation in the context of infinite horizon models.

A second contribution of the paper is to quantify how moving to a flat income tax affects intergenerational mobility and lifetime earnings inequality. I find that the flat tax reduces intergenerational persistence only minimally. The common concern that the flat tax erodes "equality of opportunity" may therefore be unfounded. However, moving to a flat tax leads to a polarization of education: the propensity to attend college increases for high income households, but decreases for low income households. This substantially increases lifetime earnings inequality.

This paper contributes to two strands of the literature. First, it contributes to the literature on intergenerational mobility (e.g., Mulligan 1997). An empirical contribution is to characterize the joint transmission of education and ability, providing the stylized facts required to develop an empirically successful theory of intergenerational mobility. A theoretical contribution is to construct a quantitative model of the intergenerational persistence of education and earnings. To my knowledge, this is the first attempt at quantifying how taxes affect intergenerational mobility.[2]

The paper also contributes to the emerging literature studying how taxes affect earnings inequality. Most existing studies have abstracted from human capital accumulation (e.g., Castaneda et al. 1998). Notable exceptions are HLT and Knowles (1999). This paper extends HLT's work mainly by allowing for intergenerational transmission of education and ability. The paper closest to the present one is Knowles (1999), who studies the effects of redistributive tax policies on inequality in a model with realistic intergenerational mobility properties. In his model intergenerational persistence is due to two features that are most relevant for poor households: fertility choice and borrowing constraints. His work should therefore be viewed as complementary to mine.

The rest of this paper is organized as follows. Section 2 illustrates how the effects of income tax reforms depend on the intergenerational transmission of human capital using a simple analytical example. Section 3 summarizes the intergenerational mobility observations that motivate the model developed in section 4. The choice of model parameters is given in section 5, followed by simulation results in section 6. The final section concludes.

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[2] Becker and Tomes (1986) and Mulligan (1997) develop qualitative results.

2. Tax Effects With Intergenerational Persistence

This section selectively reviews existing research on the effects of taxes on human capital accumulation. Two findings emerge that motivate the present paper: (*i*) Tax effects differ significantly between infinite horizon and lifecycle models. (*ii*) A large part of these differences can be traced to assumptions about intergenerational mobility implicit in the two frameworks.

Existing results about the effects of income taxes on human capital differ widely. In a lifecycle model, Davies and Whalley (1991) find that labor income taxation has almost no effect on human capital accumulation. Perroni (1995) has a similar result in a slightly more general model. By contrast, using an infinite horizon model, Trostel (1993) finds that a one percentage point increase in income taxes reduces human capital by 0.97 percent. A similar divide between lifecycle and infinite horizon models is found in the literature studying the growth effects of taxes in models of human capital accumulation (see Hendricks 1999b for details).

One key aspect in which these models differ is the way in which generations are linked. In lifecycle models, the human and physical capital endowments of new agents are typically taken as exogenous. As a consequence, parental background does not affect child outcomes and intergenerational mobility is perfect. Infinite horizon models, by contrast, can be represented as lifecycle models in which children inherit their parents' human and physical capital. Integenerational persistence is then perfect.

To identify how much assumptions about intergenerational persistence contribute to differences in the effects of taxes on human capital, Hendricks (1999) develops a framework that nests a conventional lifecycle model similar to Davies and Whalley (1991) and an infinite horizon model similar to Trostel (1993) as special cases. Transforming the lifecycle model into its infinite horizon counterpart, changing one assumption at a time, allows to quantify the role played by each individual model feature.

The main finding is that most of the differences in tax effects are accounted for by assumptions about intergenerational persistence. For example, the lifecycle model generates a tax elasticity for human capital of +0.09 (a 10% increase in income taxes leads to a 0.9% *increase* in steady state human capital), whereas the infinite horizon version yields an elasticity of –0.58. Two-thirds of this difference is due to assumptions about intergenerational links. Specifically, removing the assumption that children inherit human and physical capital from their parents reduces the tax elasticity from the infinite horizon value of –0.58 to –0.14.

Overall, the experiments reported in Hendricks (1999) show that income taxes affect human capital more strongly in infinite horizon models than in lifecycle models. The intuition for this finding is that the intergenerational transmission of human capital generates multiplier effect. Holding prices constant, imposing an income tax reduces the rate of return to human capital. Households respond by reducing human capital investment. In a lifecycle model, this leaves the human capital endowments of new generations unaffected. However, in a model with intergenerational persistence there is an additional feedback effect. As parents reduce their human capital investment, their children's human capital endowments decline as well. This in turn reduces the endowments of the grandchildren, and so on. As a consequence, the total drop in human capital is larger, especially in the long run. The appendix demonstrates how this intuition can be made precise in an analytical example.

These findings establish that the effects of taxes depend in important ways on the modeling of intergenerational mobility. However, since existing studies have focussed on the extreme cases of perfect mobility of perfect persistence, little is known about tax effects in environments with *realistic* intergenerational mobility. The subsequent analysis attempts to fill this gap. Of particular interest is the question whether one of the extreme cases closely approximates the properties of a model with realistic mobility.

3. Intergenerational Mobility Facts

This section provides estimates of the intergenerational persistence of earnings and education for a sample of U.S. workers. A number of stylized facts are documented that provide the basis for the model presented in section 4. Only an outline of the empirical approach is presented here together with the main findings. Details are provided in the appendix.

3.1 Empirical Approach

The data are taken from the 1968 to 1992 waves of the Panel Study of Income Dynamics (PSID). For an individual to be included, he/she has to satisfy the following criteria: At least 10 years with positive earnings must be observed at ages between 18 and 70 while the individual is "head" or "wife" of the household. Education must be reported in at least one year after the age of 30 (to make sure that reported education does not change at some later age). Annual work hours must lie between 500 and 4000. The individual must have positive sample weight.

Estimating intergenerational mobility from observations that combine men and women is difficult because it is not clear whether the gender earnings gap reflects differences in human capital, the disruption of female work histories during child-rearing, or discrimination. All results presented here are therefore obtained from all-male samples.[3]

It is assumed that individual earnings are determined by unmeasured ability, education, age, sex, and a transitory idiosyncratic shock. Abilities are divided into $q = 1, \ldots, n_q$ classes with equal mass in each ($\Pr(q) = 1 / n_q$).[4] The choice of n_q is determined by two opposing considerations. On the one hand, a larger n_q yields a more precise description of the earnings distribution. On the other hand, it reduces the number of observations in each ability/education cell and makes the results harder to understand. The results reported here are therefore based on $n_q = 5$, but varying n_q between 4 and 7 makes little difference. Educational attainment is divided into $n_s = 2$ classes, where $s = 1$ represents up to 12 years of schooling and $s = 2$ represents more than 12 years of schooling. I refer to the each group by the highest degree attained by the typical group member (high school graduates and college graduates, respectively).

The first step characterizes the *distribution of lifetime earnings* in each education/sex group. This is accomplished by estimating earnings regressions of the form

$$\ln(y_{a,i}) = \chi_i + \beta_1 a + \beta_2 a^2 + \xi_{a,i} ,$$

separately for each group. Here y denotes annual earnings in 1992 dollars, i indexes the individual, a is age, and ξ is an i.i.d. disturbance.[5] Denote by $\hat{\chi}_i$ the intercept χ_i purged of cohort effects using a linear regression of the χ_i on birth years. Each individual is assigned a present value of earnings proportional to $e^{\hat{\chi}_i}$:

$$E_i = \sum_{a=a_s+1}^{a_R} \exp\left(\hat{\chi}_i + \beta_1 a + \beta_2 a^2\right) / D_a ,$$

where $D_a = 1.035^{a-16}$ is cumulative discount factor based on an interest rate of 3.5%, which is close to the one generated by the model below. Note that the age at which earnings begin differs by schooling class, but earnings are discounted to a common age of 16 for all individuals. This is important for capturing the main cost of attending college: foregone

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[3] Allowing for daughters in addition to sons changes the findings little. However, mothers are found to affect the earnings and education of their offspring much less than fathers.

[4] Throughout the paper, the notation $\Pr(q, s)$ is used to denote the joint distribution of q and s. $\Pr(q)$ denotes the marginal distribution, and $\Pr(q \mid s)$ is the conditional distribution.

[5] In a more general ARMA model, Moffitt and Gottschalk (1993) show that the serial correlation of transitory component of earnings is very small.

earnings. Given that the sample includes at least 10 years of observations for each individual (and in many cases more than 20 years), it seems preferable not to use instrumental variables in the estimation of lifetime earnings.

The result is a joint distribution of the present values of earnings and schooling in each group. An algorithm described in the appendix is then used to assign households to ability classes, which allows to estimate the mean present values of earnings in each (q, s) class, $E_{q,s}$ together with the population share of each class $\Pr(q,s)$.

The second step matches parents with their children and constructs intergenerational *transition probabilities*, $\Pr(q \mid q^P, s^P)$ and $\Pr(s \mid q, s^P)$, where the superscript P indicates parental variables. For example, $\Pr(q \mid q^P, s^P)$ is estimated as the fraction of children of ability q of all children whose parents have ability q^P and schooling s^P. Since the characteristics of parents and children are not identical, the estimated transition probabilities are not consistent with the model's requirement that the distribution of (q, s) be stationary. The transition probabilities are therefore adjusted such that they generate the observed distribution $\Pr(q, s)$ as the stationary distribution (see the appendix for details).

3.2 Empirical Findings

Average lifetime earnings by ability and education ($E_{q,s}$), measured in 19+++ dollars, are shown in table 1. Two important insights emerge. Variation in ability determines most of the variation in earnings. The top quintile earns more than 3 times more than the bottom quintile, whereas a college education increases earnings by at most 13%. This is consistent with the common finding that education accounts for only a small fraction in lifetime earnings variation (e.g., Fullerton and Rogers 1993). The second finding is that obtaining a college degree increases the present value of earnings substantially only for the highest q class. This finding appears surprising at first, but is supported by HLT based on different data and estimation procedures. Attaining college increases peak earnings for all q, but the present value of earnings increases by less than peak earnings because college attendance postpones the start of work life by four years. An important implication is that lower taxes may lead low ability households to *reduce* college attendance.

Transition probabilities for schooling are shown in table 2. The main observation is that, even controlling for the child's ability, parental schooling substantially increases the probability that the child attains college. This strongly suggests that schooling is transmitted to the child independently of ability.

Transition probabilities for abilities are shown in table 3. There is considerable persistence in abilities. For example, for a parent with college degree the probability of having a child in the top ability class is 57% for $q^P = 5$ compared with 12% for $q^P = 1$. However, it is not only the parent's ability that determines the child's ability, parental schooling also has a strong effect. These findings motive how the intergenerational transmission of earnings is modeled below.

4. The Model

The model combines a conventional life-cycle model along the lines of HLT with a theory of the intergenerational transmission of human capital along the lines of Becker and Tomes (1986). There are three types of agents: households, firms, and a government. Only steady states are considered.

4.1 Households

At each date a cohort of unit measure is born which lives for a_L periods. The household is inactive until age a_0, engages in full-time schooling until age a_S, works until age a_R and is retired thereafter. Each household gives birth to a single child at age a_B.

Households are endowed with an ability parameter $q \in \{1,2,\ldots,n_q\}$ and schooling cost parameters for each education level, p_s, $s \in \{1,\ldots,n_s\}$. These represent non-pecuniary costs of schooling and are drawn independently across households from a continuous distribution. Each household chooses the schooling level, s, and an age profile of job training investments so as to maximizes the present value of lifetime earnings net of education costs. The household then chooses a lifetime profile of consumption subject to a present value budget constraint. Household variables are therefore indexed by birth date, age, ability and education. For example, consumption at a particular age would be denoted $c_{b,a}^{q,s}$. However, in what follows I suppress the (q,s) superscripts where there is no risk of confusion.

It is convenient to solve the household in two parts: First, the households chooses education and training so as to maximize the present value of earnings. Then it chooses consumption subject to a present value budget constraint.

4.1.1 Earnings Maximization

At the beginning of active life, at age a_0, the household is endowed with an ability level q and schooling cost parameters p_s. First, the household chooses between n_s discrete schooling levels corresponding to different values of a_s, p_s, and flow tuition costs d_s. As a result of choosing education level s a worker with ability q begins work life with a human capital endowment of

$H_{q,s}$. Then, at ages a_s+1 through a_R, the household chooses job training investments in the form of time (v) and purchased goods (x). The objective is to maximize the present value of earnings net of taxes and education costs

$$\max_s E_{q,s} - p_s ,$$

where

$$E_{q,s} = \max \sum_{a=a_S+1}^{a_R} \{\omega^S_{b+a-1}(1-v_{b,a})\, h_{b,a} - x_{b,a} - T_w(b,a)\} / D_{b,a} - \sum_{a=a_0}^{a_S} d_s / D_{b,a}$$

subject to the law of motion for human capital

$$h_{b,a+1} = (1-\delta_h)\, h_{b,a} + G(h_{b,a}, x_{b,a}, v_{b,a}, q)$$

with initial condition $h_{b,a_S+1} = H_{q,s}$.

Here, ω^s_{b+a-1} is the pre-tax wage rate per efficiency unit of labor of type s at date $b+a$–1 (when the household born at b is age a). The labor tax function depends on pre-tax earnings and is assumed to be differentiable. Slightly abusing notation, I write

$$T_w(b,a) = T_w(\omega^s_{b+a-1}(1-v_{b,a})\, h_{b,a} - x_{b,a}) .$$

The cumulative discount factors are

$$D_{b,a} = \prod_{\hat{a}=a_0}^{a} R_{b+\hat{a}-1} ,$$

where R is the gross rate of return on capital after taxes. Note that E is computed from pre-tax prices because total tax payments cannot be computed from marginal tax rates. However, the discount factor uses the after-tax interest rate r.

p_s is normalized to zero for the lowest schooling level and drawn from a normal distribution with mean $\mu(q, s^P)$ and standard deviation $\sigma(q, s^P)$ for s = 2. The dependence of μ on parental schooling creates intergenerational persistence in schooling.

4.1.2 Consumption Choice

Given optimal levels of schooling and job-training, the household chooses a consumption path that maximizes the discounted sum of utilities

$$V_b = \sum_{a=a_C}^{a_L} \beta^a\, u(c_{b,a}) ,$$

where $\beta > 0$ is a discount factor. Consumption begins at age a_C. The household starts with asset holdings of $k_{b,a_0} = 0$. The flow budget constraint is

(1) $$k_{b,a+1} = k_{b,a}\, R_{b+a-1} + \omega^{s}_{b+a-1}\,(1 - v_{b,a})\, h_{b,a} - x_{b,a} - T_w(b,a) - c_{b,a} - d^{s}_{b,a} + z_{b,a}$$

with terminal condition $k_{b,a_L+1} = 0$. z is a lump-sum transfer. Optimal consumption is governed by a standard Euler equation.

(2) $$u'(c_{b,a}) = \beta\, R_{b+a}\, u'(c_{b,a+1})$$

4.1.3 Solution to the Household Problem

A solution to the household problem is a list of age profiles $\{c, k, h, x, v\}$ and a scalar s that satisfy (*i*) the conditions for optimal job training; (*ii*) the consumption Euler equation (2) and (*iii*) the budget constraint (1); (*iv*) the law of motion for h; (*v*) the choice of s maximizes the present value of earnings.

4.2 Intergenerational Transmission of Ability

The modeling of the intergenerational persistence of earnings is based on the seminal work of Becker and Tomes (1986). They propose a Galton-style regression to the mean equation for the intergenerational transmission of abilities of the form

$$\ln(Q) = \bar{q} + \alpha \ln(Q^P) + \varepsilon,$$

where ε is an i.i.d. disturbance. This setup may be labeled "pure nature" because it most appropriately describes a *genetic* transfer of abilities, which is independent of parental behavior.

The pure nature setup has two implications that are difficult to reconcile with the data. The first implication is that the children's q's are independent of parental behavior. This is inconsistent with the fact documented above that parental education has a strong impact on child ability, even after controlling for parental ability. The second problem is that an extensive literature suggests that acquired, not only genetic, traits are transferred from parents to children, a fact explicitly acknowledged by Becker and Tomes (1986, p. S4): "Both biology and culture are transmitted from parents to children."

I therefore adopt an alternative specification which I call "pure nurture" that allows for the transfer of *acquired* skills from parents to children. The ability parameter of a child with a parent who has human capital h^P at the time the child is born is governed by

(3) $$\ln(\hat{Q}) = \bar{q} + \alpha(s^P)\ln(h^P) + \varepsilon,$$

where ε is an i.i.d. disturbance term with distribution N(0, σ_ε) and $\bar{q}$ may be normalized to zero. Parental abilities and schooling determine h^P and are therefore transmitted to the children. Permitting the transmission parameter α to depend on parental schooling as well allows the model to replicate the empirical transition probabilities slightly better, but is not important for the quantitative results (the difference between α(1) and $\alpha(n_s)$ in the calibrated model is less than 0.07).

Since $\hat{Q}$ is a continuous variable, whereas computational restrictions require a finite number of ability types, the child is assigned is the largest grid point below $\hat{Q}$: $Q = \max\{Q_q | Q_q \le \hat{Q}\}$. For a given parent, the probability that the child has $\ln(\hat{Q}) < \ln(Q_q)$ is

$$\Theta\left(q \mid q^P, s^P\right) = \Pr\{\varepsilon < \ln(Q_q) - \alpha(s^P)\ln(h^P)\} = \Phi\left(\ln(Q_q) - \alpha(s^P)\ln(h^P)\right)$$

where Φ is the normal cdf with standard deviation σ_ε. Define Θ(0|.,.) = 0. The transition probabilities are then

(4) $$\Pr(q \mid q^P, s^P) = \Theta(q \mid q^P, s^P) - \Theta(q-1 \mid q^P, s^P)$$

Discussion. The motivation for this setup is to remain as close as possible to the model of Becker and Tomes (1986), which is arguably the leading theory of intergenerational mobility, while at the same time being consistent with the stylized facts pointed out in section 3. The proposed specification abstracts from a number of features that have been suggested in the literature. Allowing for parental investment in children's human capital would not change any results. As pointed out by Becker and Tomes (1986), if parents are altruistically motivated, whether human capital investment is chosen by parents or children makes no difference; both maximize the children's lifetime earnings. Borrowing constraints could invalidate this result, but Cameron and Heckman (1998) suggest that these are not empirically important. Allowing for parental fertility choice, as suggested by Knowles (1999), might be important, especially for the poorest households, and should be explored in future research.

A possible concern about this setup is that a pure nurture model may overstate the importance of intergenerational persistence. In the data, it is likely that both genetic and acquired abilities are transmitted to children, although their relative importance is controversial. To the extent that intergenerational transmission is genetic, it does not respond to incentives and is therefore irrelevant for the effects of taxes (a pure nature model is isomorphic to a model without intergenerational links, except in the intergenerational mobility statistics it generates). Adopting a pure nurture approach therefore overstates the importance of intergenerational persistence. However, this only strengthens the main finding that a model with realistic intergenerational mobility properties is very similar to a model that abstracts from intergenerational persistence (such as a conventional life-cycle model).

4.3 Firms

Firms produce output according to the constant returns to scale production function

$$Y_t = F(K_t, L_t^1, \ldots, L_t^{n_S}),$$

where K is capital input and L^s denotes labor input of schooling level s. Firms rent all inputs from households and maximize period profits. The first order conditions are standard:

$$r_t = F_K(t), \quad \omega_t^s = F_{L^s}(t)$$

4.4 Government

The government imposes capital and labor income taxes on households. All tax revenues are rebated in lump-sum fashion to tax payers in proportion to their individual tax payments. The government therefore has zero net revenues, which ensures that the tax reform has no direct redistributional effects. The capital tax rate is exogenous, τ_K. The labor tax rate is determined by the tax function T_w.

4.5 Equilibrium

There are $n_q \cdot n_s$ household classes. Within each class, all households behave identically. Let $\Pr_b(q,s)$ be the mass of households with ability q and schooling s in cohort b. A competitive equilibrium consists of a sequence of prices (r_t, ω_t^s, R_t), a sequence of aggregate quantities (Y_t, K_t, L_t^s), a distribution of household types $\Pr_b(q,s)$, transition matrices $\Pr_b(q,s \mid q^P, s^P)$, and a sequence of household age profiles

$$(c_{b,a}^{q,s}, x_{b,a}^{q,s}, v_{b,a}^{q,s}, h_{b,a}^{q,s}, k_{b,a}^{q,s}, d_{b,a}^{q,s}, z_{b,a}^{q,s}, \lambda_{b,a}^{q,s}, E_b^{q,s}).$$

These satisfy the following conditions. (*i*) factor prices (r_t, ω_t^s) are consistent with the firm's first-order condition. (*ii*) The after tax rate of return is $R_t = 1 + (1-\tau_{K,t})(r_t - \delta_k)$. (*iii*) Household age profiles solve the household problem, where transfers rebate all tax payments:

$$z_{b,a}^{q,s} = T_w\left(\omega_{b+a-1}^s (1 - v_{b,a}^{q,s})\, h_{b,a}^{q,s} - x_{b,a}^{q,s}\right) + \tau_{K,b+a-1}(r_{b+a-1} - \delta_k)\, k_{b,a}^{q,s}.$$

(iv) The distribution of types is consistent with the household's optimal education choice of $\Pr(s \mid q, s^P)$ and with (4). (v) Goods markets clear:

$$F = C + X + K_{t+1} - (1-\delta_k) K_t .$$

(vi) Factor markets clear:

$$L_t^s = \sum_q \sum_{a=a_S+1}^{a_R} \Pr_{t-a+1}(q,s)(1-v_{t-a+1,a}^{q,s})\, h_{t-a+1,a}^{q,s}$$

$$K_t = \sum_{q,s} \sum_{a=a_0}^{a_L} \Pr_{t-a+1}(q,s)\, k_{t-a+1,a}^{q,s} .$$

In what follows, the analysis is restricted to steady states, in which all variables are constant over time.

5. Parameter Choices

Parameters are chosen based on aggregate U.S. observations and on the intergenerational mobility facts documented in section 3.

5.1 Households

Agents die at age $a_L = 75$ and retire at age $a_R = 64$. Schooling begins at age $a_0 = 7$ (based on enrollment data in Cohn and Geske 1990, table 1.2). Children are born when parents are aged $a_B = 30$. Consumption begins at age $a_C = 16$. The utility function is assumed to be of the form $u(c) = c^{1-\sigma}/(1-\sigma)$ with a conventional value of $\sigma = 2$. β is chosen to match a capital-output ratio of 2.5.

5.1.1 Schooling

The parameters to be chosen for each schooling level are: a_s, d^s, $H_{q,s}$, and the parameters that govern the distribution of schooling costs. There are $n_s = 2$ schooling levels corresponding to high school completion ($a_S = a_0 + 11$) and college graduation ($a_s = a_0 + 15$). The amounts of human capital produced by each schooling level, $H_{q,s}$, are chosen to replicate observed relative earnings levels ($E_{q,s}$). If labor of different types are perfect substitutes, then $H_{1,1}$ is normalized to one, while the other $H_{1,s}$ are then chosen to replicate earnings relative to $E_{1,1}$. Otherwise, $H_{1,s}$ is normalized to 1 for all s and the relative earnings of various s types are governed by parameters of the production function.

Schooling costs. The cost of attending high school is normalized to $p_1 = 0$. For parsimony, mean college costs are assumed to be of the form

$$\mu(q, s^P) = \mu(q) + abs(\mu(q)) \cdot \nu(s^P).$$

$\mu(q)$ are chosen to replicate the fraction of college graduates in each earnings class in the data, $\Pr(s \mid q)$. I normalize $\nu(1) = 0$ and choose $\nu(2) < 0$ to replicate the difference in college attendance between children of parents who are college graduates as opposed to high school graduates, $P(s = 2 \mid s^P = 2) - P(s = 2 \mid s^P = 1)$.

The standard deviation of p_s is chosen such that a change in college tuition induces (partial analytic) changes in the fractions of agents enrolled that are consistent with the data. Kane (1994) estimates that a $1000 increase in tuition reduces enrollment by 4.6% for the lowest family income class, but by only 1.2% for the highest. The average change across all households is 3.2%. $\sigma(p_s)$ is chosen to replicate the 4.6% figure for the lowest ability class and an average response of 3.2%. Translating $1000 into model units requires to express it as a fraction of average per capita earnings. In 1990 median weekly earnings of one-earner households are $455, so that $1000 represent approximately 4% of annual median earnings (Statistical Abstract 1993, table 672).

Tuition. The tuition variable represents the annual direct cost of attending college. This should include all privately paid costs, except forgone earnings. There is no tuition for high school, reflecting the fact that 90% of the direct cost of high school education is paid for by the public sector (Cohn and Geske 1990). In 1990, tuition and fees for colleges and other higher education amounted to $37.4 billion or 0.67% of GDP. It is hard to say whether this figure understates or overstates the private cost of attending college. On the one hand there are additional direct costs, on the other hand a fraction of tuition and fees is paid for by the public sector. The ratio of aggregate college tuition to output is therefore set to 0.7% for college.

5.1.2 Job Training

As is conventional in this literature, the production function for human capital is assumed to be of the form $G = B_s \, h_{q,s} \, (v\,h)^{\varphi} \, x^{\psi}$. The parameters to be chosen are then B, φ, ψ, and δ_h. Following HLT δ_h is set to 0. There is a range of parameter estimates in the literature for φ and ψ. An intermediate value for returns to scale is $\varphi + \psi = 0.75$. At least half of the total cost of job training is due to time inputs, which suggests $\varphi = 0.45$ and $\psi = 0.3$. Learning productivity is chosen so as to replicate earnings growth between the ages of 25 and 48 as implied by the estimated earnings equations described above.

5.1.3 Intergenerational Mobility

The grid points (Q_q) are chosen to match the desired Pr(q). The transmission coefficients in the Galton equation [$\alpha(s^P)$] are chosen to replicate the stationary transition probability that high ability parents have high ability children, $\Pr(q \geq 4 \mid q^P \geq 4, s^P)$. The variance of ε is normalized to one. This is possible because changing σ_ε, $\alpha(s^P)$, and $\ln(Q_q)$ by a common factor leaves the equilibrium unchanged.

5.2 Firms

The production function is of the form $F = K^\theta L^{1-\theta}$ where L is a labor aggregator. The depreciation rate δ_K is chosen to replicate a capital output ratio of 2.5 and an investment share in GDP of $I/Y = 0.2$. In steady state $K = (1-\delta_K)K + I$. Therefore,

$$\delta_K = (I_K/Y)(Y/K) = 0.08. \tag{5}$$

The parameter θ is chosen to match a capital share of rK/Y = 0.34, which yields a steady state interest rate of $r - \delta_K = 0.34/(K/Y) - \delta_K = 0.056$.

In the baseline case, L is a CES aggregator of labor of different schooling levels:

$$L = \left(\upsilon_1 (L^1)^\rho + \upsilon_2 (L^2)^\rho\right)^{1/\rho}$$

with $\upsilon_1 + \upsilon_2 = 1$. The elasticity of substitution between high school and college labor is taken from HLT: $1/(1-\rho) = 1.441$. The weights υ_s are set to match the average ratio of college to high school present value of earnings. I also explore the case where the different types of labor are perfect substitutes: $L = L^1 + L^2$. The parameters υ_s and ρ are then dropped.

5.3 Tax Rates

Following HLT, the capital tax rate is set to 0.15. For flat taxes the tax function is simply $T_w(\hat{y}) = \tau_w \hat{y}$. With progressive taxes, the wage tax combines a deductible with the requirement that the marginal tax rate is continuous. Define net earnings as $\hat{y} = y - y^*$ where y^* is a deductible. For progressive taxes the wage tax function is

$$T_w(\hat{y}) = \begin{cases} \mathrm{T}_0 & \text{if} \quad \hat{y} < y_0 \\ \tau_1 \hat{y} + 0.5\tau_2 \hat{y}^2 & \text{if} \quad y_0 \leq \hat{y} \leq y_1 \\ \mathrm{T}_3 + \tau_{\max} \hat{y} & \text{if} \quad \hat{y} > y_1 \end{cases}$$

The marginal labor tax schedule is piecewise linear in earnings:

$$T_w'(\hat{y}) = \begin{cases} 0 & if \quad \hat{y} < y_0 \\ \tau_1 + \tau_2\,\hat{y} & if \quad y_0 \le \hat{y} \le y_1 \\ \tau_{\max} & if \quad \hat{y} > y_1 \end{cases} .$$

Given the choice of range boundaries below, this simplifies to

$$T_w'(\hat{y}) = \max\{0, \min\{\tau_{\max},\ \tau_1 + \tau_2\,\hat{y}\}\}$$

The range boundaries are defined such that the average tax schedule is continuous:

(6) $$\tau_1\, y_0 + 0.5\,\tau_2\, y_0^2 = \mathrm{T}_0$$

(7) $$\mathrm{T}_3 + \tau_{\max}\, y_1 = \tau_1\, y_1 + 0.5\,\tau_2\, y_1^2$$

The slope coefficients are defined so that the marginal tax schedule is continuous

$$\tau_1 + \tau_2\, y_0 = 0$$

$$\tau_1 + \tau_2\, y_1 = \tau_{\max}$$

In addition, I require a marginal tax rate at zero net earnings of τ_1. The income level at which maximum taxes are reached is specified exogenously (y_1).

Based on IRS (1998) data, τ_1 and τ_2 are chosen to match marginal tax rates of 0.15 at $y = y^*$ and the maximum marginal tax rate of $\tau_{\max} = 0.36$ at $y_1 = \$70,000$. This neglects the fact that in the U.S. tax code an additional tax bracket exists. It has a marginal tax rate of 39.6% for AGI's over $278,000. The model does not have households with earnings that high. The deductible is $y^* = \$9,660$ (see HLT). Average earnings per adult are set to $30,000.

6. Simulation Results

This section presents numerical experiments that shed light on how the aggregate effects of tax reforms depend on the intergenerational transmission of human capital. The experiments compare two steady states. The *progressive tax* steady state is parameterized so as to replicate U.S. data including the progressive income tax system. The *flat tax* steady state is obtained by replacing the progressive labor income tax by a flat tax. The capital income tax is held constant at $\tau_K = 0.15$, while the flat wage tax rate τ_w is chosen to maintain government revenues unchanged.[6] The findings are compared for three versions of the model that differ only in the

[6] This is the same experiment as the one studied in HLT.

intergenerational persistence of ability and education. The experiments also shed light on the effects of the flat tax on lifetime earnings inequality and intergenerational mobility, which are of independent interest.

6.1 Benchmark Case: Complete Intergenerational Mobility

As a benchmark case, consider a version of the model that has no intergenerational transmission of human capital, as is typically assumed in life-cycle models. Apart from the intergenerational mobility statistics, the properties of this model are identical to those of a model with purely genetic intergenerational transmission ("pure nature") as in Becker and Tomes (1986). This case is implemented by setting $\alpha = 0$ and $\nu(2) = 0$. The aggregate effects of moving to a flat tax are shown in column 3 of table 4.

The changes are mostly driven by the responses of human capital investment to reduced marginal tax rates. These responses differ between highly able ($q = 5$) and other ($q < 5$) households. The highly able initially face a strongly progressive wage tax. Their marginal tax rate therefore drops significantly under the flat tax. They respond by investing more in job training and by increasing college attendance. Correspondingly, the fraction of high ability households that attain a college degree rises by 9.7% and their human capital at age 30 increases by 3.2 to 7.7%, depending on education. The implied increase in college labor supply causes output to rise by 1.1% while the relative wage ω^2 / ω^1 drops by 3.1%. The physical capital stock falls as rich workers substitute human for physical capital, so that the interest rate rises.

The response of households with $q < 5$ is very different. They face only slightly progressive taxes in the initial steady state, so that the direct incentive effect of the flat tax is small. The drop in tax rates increases the payoffs as and the costs of job training in roughly equal proportions, so that job training remains nearly unchanged. The main impact on these households is an indirect one: the drop in the college wage rate and the increase in the interest rate reduce their college attendance. The overall effect of the tax reform is therefore to reduce the fraction of college educated workers (by 2.4%) while the effective supply of college labor increases.

The opposing changes in college attendance by the highly able compared with the less able are the driving force behind the changes in *earnings inequality* (table 5). The ability composition of the college educated population improves because the highly able attend college more often and because the less able attend college less often. As a consequence, the college premium increases by 8.3%.[7] In addition, high ability households invest more in training and education, while low ability households invest less. Both changes contribute to increase of the quintile ratio of lifetime earnings by 9.8%.

The changes in inequality are much larger than in models without human capital. For example, Castaneda et al. (1998) find that moving to a flat tax has virtually no effect on earnings inequality in a model with fixed human capital but variable labor supply. On the other hand, the changes are considerably smaller than inequality variations that are observed across countries or even over time within countries. For example, the U.S. college premium for workers with up to 5 years experience fluctuated between 31% and almost 70% during the period 1970-87 (Murphy and Welch 1989). Given the fundamental nature of the tax experiment, this finding suggests that differences in income tax systems account for only a fraction of the observed cross-country variation in earnings inequality.

To summarize, moving to a flat tax increases human capital investment by the highly able, but reduces investment by the majority of households. This leads to greater aggregate labor supply and thus to greater output. It also increases the polarization of education and therefore earnings inequality.

6.2 Intergenerational Persistence of Human Capital

The next step is to examine how the results of the benchmark model are modified, if human capital is transmitted from parents to children. This is done in two steps. The first extension of the model allows for intergenerational transmission of education. The second extension allows in addition for intergenerational transmission of abilities.

Column 2 of table 4 shows the changes in aggregates caused by a move to a flat tax, if parents transmit education, but not ability to their children. In this experiment $\nu(2)$ is chosen so as to replicate the observed difference in college attainment of children with college educated parents compared with other children.

The results are nearly identical with the benchmark case. The main difference is a slightly stronger stratification of education. If high ability parents are more often college educated (table 1), their children are also more like to attain college. The reverse holds for low ability parents. This positive feedback loop leads to greater stratification. As a consequence, the

[7] The college premium is defined as the ratio of average lifetime earnings of all college educated workers to average lifetime earnings of all others.

college premium increases by an additional percentage point. The changes in aggregates are very similar to the benchmark case.

Column 1 of table 4 shows the results for the case where parents transmit ability and education to their children. This is the baseline version of the model, which has realistic intergenerational mobility properties. Here, $\alpha(s^P)$ is chosen so as to replicate the probability that a high ability parents ($q^P > 3$) has a high ability child ($q > 3$). The changes in aggregates are again close to the benchmark case. For example, aggregate output increases by 1.3% compared with 1.1% in the benchmark case. The polarization of education is again slightly stronger, which leads to a higher college premium. One might expect that stronger polarization of education leads to a larger increase in the quintile ratio as well, but in fact it increases by slightly less than in the benchmark case. The reason is that attending college less often *increases* earnings for the less able.

The similarity of the results for the three cases leads to the main finding: Abstracting from intergenerational persistence, as is commonly done in lifecycle models, leads to findings that are very close to those obtained from models with realistic intergenerational mobility properties. In order to understand this result, it is useful to examine the changes in *intergenerational persistence* caused by the flat tax. As shown in table 6, measures of intergenerational persistence change only slightly. The Galton coefficient for earnings is almost unchanged (+0.01), the one for schooling actually falls. The probability of placing a child in college falls by 1 to 2 percentage points depending on the parent's education level. These changes are small compared with the differences observed across major industrial countries or even across samples within the U.S. (e.g., Mulligan 1997, table 7.5).

The reason why mobility changes little is that the behavioral responses of high and low ability households tend to offset each other. Note first that the intergenerational transmission probabilities for ability, $\Pr(q \mid q^P, s^P)$ generally change very little. For a parent of a given type (q^P, s^P), the probability of having a child with high ability depends on the parent's human capital at age 30. As argued above, h^P changes very little for most household types because all inputs to job training are tax deductible. As a consequence, the probability of having a gifted child ($q > 3$) increases by less than 0.01. The only exception is the highest ability class ($q^P = 5$), who find their marginal tax rates considerably reduced under the flat tax and who therefore invest more in job training.

It follows that the changes in the distribution of the children's abilities must be caused, in large part, by changes in parental schooling choice. Given that these are quite large, it may appear surprising that the changes in the children's abilities are so small. In particular, the fraction of children with q = 5 increases by only 0.2 percentage points (table 4).

The key to understanding this result is to note that the behavioral changes of high ability households are largely offset by counteracting changes of other households. In particular, households with q = 5 increase their probability of college attainment by 10.4 percentage points and thereby improve their chances of placing a child in the highest ability class by 2.1 percentage points. However, all other households reduce their college participation and thereby reduce the chances of having highly able offspring. Therefore, the total fraction of children with high ability changes little.

One might expect that the stronger stratification of education should lead to higher earnings persistence. Since the children of parents with high earnings are more likely to be educated, earnings persistence increases for the rich. Similarly, the children of the poor are less educated, but this *reduces* earnings persistence for the poor because the college premium for low ability workers is negative. Again, the behavioral changes of high and low ability parents tend to cancel each other and overall earnings persistence increases only moderately.

To summarize, allowing for realistic intergenerational persistence of education and abilities does not alter the aggregate or the distributional effects of moving to a flat tax in important ways. The stratification of education already found in the benchmark case is only slightly amplified. The key reason for this finding is that the flat tax induces more human capital investment by the highly able, but less investment by all other households. The overall effect on the human capital transmitted to children is therefore small.

6.3 Sensitivity Analysis

This section examines the robustness of the previous findings. Since intergenerational persistence is not precisely estimated, an important question is how the findings change, if persistence is greater than estimated. I therefore construct two additional experiments. The first experiment increases the persistence of abilities by doubling the baseline value of $\alpha(s^P)$. In this case the probability that a high ability parent ($q^P > 3$) has a high ability child rises from 70% (the empirical value replicated by the baseline experiment) to 79%. The Galton coefficient for earnings rises to 0.64, which exceeds the largest value reported in Mulligan's (1997, table 7.5) survey of the literature.

The second experiment increases the schooling cost for children of parents without college degrees [$\nu(2)$] so that education is nearly perfectly transmitted. This raises the Galton coefficient for education to 0.64 compared with a maximum value of 0.45 reported by Mulligan (1997, table 7.4).

In both cases, the effects of moving to the flat tax on the aggregates reported in table 4 and on inequality are similar to the baseline case. Aggregate output increases by at most 1.4%, compared with 1.3% in the baseline case. The college premium and the quintile ratio increases by somewhat larger amounts (up to 13%) because the stratification of education becomes slightly stronger. These findings suggest that sensible increases in intergenerational persistence do not overturn the main finding that conventional life-cycle models closely approximate the properties of models with realistic persistence properties.

However, imposing extremely strong persistence, as implied by infinite horizon models, substantially changes the findings. To illustrate this point, I construct an experiment which combines the modifications of the two previous ones: both abilities and education are now highly persistent. This experiment has a Galton coefficient for earnings of 0.94 compared with around 0.4 in the data.

In this case college attendance by low ability households drops so strongly that aggregate output *falls* by 1.5% under the flat tax. The reason is that with almost complete persistence the strong transmission of schooling amplifies the direct effect of the tax reform on education more strongly than with realistic intergenerational mobility. The fact that parents reduce their education reduces their probability of having highly able children. This creates a positive feedback loop. Less able children acquire less schooling and have children with even lower abilities, and so forth.

Taken together these findings show that models that abstract from intergenerational persistence, such as conventional lifecycle models, closely approximate the properties of models with realistic intergenerational mobility properties. By contrast, models with near complete persistence, such as infinite horizon models, lead to very different tax effects, which cautions against the use of infinite horizon models for the study of human capital accumulation.

Experimentation with variations of other parameters, such as the substitution elasticity between labor types or the age at which human capital is transmitted from parents to children, did not yield significant changes in any of the results and are therefore not reported.

7. Conclusion

Recent research has shown that the intergenerational transmission of human capital affects the outcomes of tax reforms in important ways. This finding casts doubt on existing studies of tax reforms, which have used shortcuts in modeling intergenerational persistence. Studies using life-cycle models have abstracted from all intergenerational links, so that intergenerational mobility is perfect. By contrast, studies using infinite horizon models implicitly assume inheritance of human capital and therefore imply perfect persistence. As a consequence, the predicted effects of tax reforms differ substantially across model frameworks.

An important question is therefore: How large are the effects of taxes in models with realistic intergenerational mobility properties? This paper develops a quantitative model of intergenerational earnings mobility which allows to answer this question. The main finding is that models which abstract from intergenerational persistence closely approximate the properties of model with realistic intergenerational mobility. However, imposing very high persistence leads to substantially different outcomes. These findings support the results obtained from conventional life-cycle models, but caution against the use of infinite horizon models for the study of human capital accumulation.

The paper provides additional results of independent interest by quantifying the effects of recent flat tax proposals (see HLT and Altig et al. 1997) on lifetime earnings inequality and intergenerational mobility. The main finding is that moving to a flat tax induces a substantial polarization of educational attainment. High ability workers attain college more frequently, whereas low ability workers reduce college attendance. As a result lifetime earnings inequality, as measured by the quintile ratio, increases by 9.8%. However, the effects on intergenerational mobility are small, suggesting that concerns about equality of opportunity may be unfounded.

There are important ways in which the paper should be extended. The empirical basis for choosing the functional forms that govern the intergenerational transmission of skills is weak (Aiyagari et al. 2000). This paper has followed the traditional approach of positing a Galton regression to the mean equation, but alternatives should certainly be explored. Allowing parents to invest in the human capital of their children might make a difference. If parents invest the efficient amount (as in Becker and Tomes 1986), abstracting from such investment is a harmless simplification. However, parents may deviate from the efficient investment, perhaps due to borrowing constraints or because they value education in itself. If their investment is sensitive to future earnings (a point on which no evidence exists), taxes may have stronger effects on intergenerational mobility.

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9. Tables

Table 1. Distribution of lifetime earnings

	$q = 1$	$q = 2$	$q = 3$	$q = 4$	$q = 5$
Present value of earnings ($E_{q,s}$)					
$s = 1$	243,459	426,187	557,218	686,362	898,293
$s = 2$	155,495	398,056	553,492	694,303	987,759
College premium	-36.1	-6.6	-0.7	1.2	10.0
Fraction with college	15.0	19.1	22.6	31.7	53.3

Notes: The present value of earnings is measured in 1992 dollars. The college premium is defined as (average earnings of all college graduates) / (average earnings of all others).

Table 2. Probability that a child attends college

	$q = 1$	$q = 2$	$q = 3$	$q = 4$	$q = 5$
$s^P = 1$	9.5	12.0	17.3	16.2	31.4
$s^P = 2$	36.8	57.5	39.7	65.5	78.1

Notes: The table shows $100 \cdot \Pr(s = 2 \mid q, s^P)$.

Table 3. Transition probabilities for child ability

		$q = 1$	$q = 2$	$q = 3$	$q = 4$	$q = 5$
$q^P = 1$	$s^P = 1$	37.4	23.0	19.7	17.6	7.8
	$s^P = 2$	32.5	1.1	36.7	25.2	9.3
$q^P = 4$	$s^P = 1$	14.4	1.8	25.3	21.7	34.4
	$s^P = 2$	4.5	3.0	7.2	30.6	47.0

Notes: The table shows $100 \cdot \Pr(q \mid q^P, s^P)$.

Table 4. Changes in aggregates

	Baseline	Only transmission of schooling	No intergenerational transmission
Output	1.3	1.1	1.1
Capital stock	-1.4	-1.6	-1.6
Labor input	2.5	2.2	2.2
High school labor input (L^1)	0.7	0.5	0.4
College labor input (L^2)	5.4	5.1	5.3
High school wage rate (ω^1)	0.1	0.0	0.1
College wage rate (ω^2)	-3.1	-3.0	-3.1
Interest rate [%]	0.3	0.3	0.3
Fraction with college [%]	-2.8	-2.5	-2.4
$q = 1$	-5.5	-4.7	-4.3
$q = 5$	10.4	9.7	9.7
Fraction among college educated with $q = 1$ [%]	-3.1	-2.6	-2.3
with $q = 5$	12.9	11.3	10.9
Fraction with $q = 5$ [%]	0.2	0.0	0.0

Notes: Changes in percent for the top part of the table. Changes in percentage points for the bottom half.

Table 5. Inequality measures

	Levels		Changes (%)		
	Data	Baseline	Baseline	Only transmission of schooling	No intergenerational transmission
College premium	31.2	30.3	11.3	9.3	8.3
Quintile ratio		2.9	9.8	10.1	10.2

Table 6. Intergenerational mobility

	Levels		Changes		
	Data	Baseline	Baseline	Only transmission of schooling	No inter-generational transmission
Galton earnings	0.29	0.33	0.01	– –	– –
Galton schooling		0.45	-0.02	– –	– –
$\Pr(s = 2 \mid s^P)$					
$s^P = 1$	16.1	15.6	-1.2	0.5	-2.4
$s^P = 2$	61.0	60.5	-2.5	-6.9	-2.4
$\Pr(s = 2 \mid q^P)$					
$q^P = 1$	0.0	17.8	-5.4	-2.4	-2.4
$q^P = 5$	0.0	43.5	4.2	0.2	-2.4
$\Pr(q = 5 \mid q^P)$					
$q^P = 1$	8.0	6.4	-0.1	– –	– –
$q^P = 5$	41.1	34.5	2.1	– –	– –

Changes are in percentage points (not percentage changes)