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Tax Reform and Human Capital Accumulation: Evidence from an Empirical General Equilibrium Model of Skill Formation

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Abstract

The progressivity of the tax system has a potentially large disincentive effect on human capital accumulation. It is thus surprising that Heckman, Lochner, and Taber (1998b, 1999a,b) represent the only previous empirical work on this important topic. I build on their work a) by accounting for the tax system when estimating the model, b) by performing welfare analysis, c) by examining the transition from one steady state to another, and d) by adding a number of robustness checks. I first estimate a dynamic general equilibrium model of schooling and on-the-job training on micro data. The estimates are then used to measure the extent to which the progressivity of the tax system distorts human capital. I find a small long run effect of progressivity on schooling. I find larger short run effects, but that they are short lived. The impact of the reform on human capital acquired on the job depends on how it is measured. Under one measure the effect is large, but the consequence of this on earnings seems to be small. Perhaps surprisingly, the welfare effects are typically favorable for progressive wage taxes (with flat capital taxation) versus a flat income tax in the long run. The welfare effects are different when I examine a progressive income tax as virtually all workers prefer the flat income tax to it. I also build on Heckman, Lochner, and Taber's (1998b,1999a,b) evidence on the extent to which taxation of physical capital favors human capital investment. These simulations also yield small long run effects on schooling and on human capital stocks.

KEYWORDS: Human Capital, Tax, General Equilibrium, Structural Model

1 Introduction

A large literature in public economics studies the effects of taxation on labor market outcomes. At the same time, an enormous amount of work in labor economics studies various aspects of human capital. The lack of empirical work on the effects of taxation on human capital accumulation is therefore surprising. This paper helps fill this gap with a general equilibrium model of skill formation that is estimated on micro data. These estimates are then used to simulate the effects of tax reform on human capital accumulation in a modified version of the Heckman, Lochner, and Taber (1998a) model.

This paper focuses on two specific goals. The first and primary goal is to measure the effect of the progressivity of the current U.S. tax schedule on schooling and human capital investment on the job. Under a progressive regime, an individual who invests in human capital has a marginal tax rate that rises. This effect should discourage human capital investment. Heckman, Lochner, and Taber (1998b,1999a,1999b) represent the only previous attempts to measure the extent of this potentially important disincentive.

The second goal is to measure the effect of changing the tax base on human capital investment. Both academic circles and the popular press have discussed switching to a consumption based tax system. It is well known that this type of policy encourages physical capital investment. However, most of the existing literature has ignored the fact that this increase in physical capital investment should come in part at the expense of human capital investment. An individual can save between periods through either human capital or physical capital investment. A switch to a consumption tax will tend to favor physical capital as a form of savings. Once again we have virtually no empirical evidence on this effect other than the papers by Heckman, Lochner, and Taber (HLT).

Heckman, Lochner, and Taber (1998b) is the first paper to attempt to measure the effects of progressivity on human capital. They use estimated parameters from HLT (1998a) to simulate the effect of tax reform on schooling and on-the-job training (OJT). They find substantial effects on human capital in a partial equilibrium environment. However, their general equilibrium steady state analysis yields very small effects on schooling and OJT.[1] Then HLT (1999a) extend these results to an open capital market environment with similar conclusions.

I build on this important earlier work in several ways. First, the tax system was ignored when the empirical estimates in HLT(1998a) were obtained. In this paper, I estimate the parameters of the model accounting for the U.S. tax system. This allows the environment in which the model is simulated to coincide with the maintained assumptions during estimation. Second, I consider the welfare implications of the changes.[2] Third, HLT is limited to a steady state analysis. This paper examines the transition from one regime to the next. Fourth, the space devoted to discussion of tax changes in the previous papers is short, allowing for only a few simple simulations.[3] This type of general equilibrium analysis by its nature requires many strong assumptions for tractability. As a result substantial sensitivity analysis that explores the robustness of the results to various assumptions greatly increases the value of the exercise. A major goal of this paper is to provide a substantial amount of sensitivity analysis along many dimensions. These include estimation of a model that incorporates changes in the wage structure and tax structure over time and consideration of a broader set of tax changes.

As in Heckman, Lochner, and Taber (1998b), I find small long run effects of both reforms on schooling. The short run effects on schooling are considerably larger than the long run effects, but are still fairly modest. In contrast, the effect of taxes on human capital acquired on the job depend on how that human capital is measured. Under one measure the effect is potentially large in both the short and long run. However, the consequence of this human capital for earnings seems to be small. The welfare effects vary across specifications. Perhaps surprisingly, the welfare effects are typically favorable for progressive *wage* taxes (with a flat capital tax) in the long run. In the base case simulation, even the highest ability individuals prefer a progressive *wage* tax to the flat tax. This is consistent with the Nielson and Sorensen (1997) conjecture that in a model with human capital, some progressivity is optimal. The welfare effects are

[1] Heckman Lochner and Taber (1999b) summarizes the results from HLT(1998b).

[2] In the HLT papers, the functional form of utility that was used (utility of schooling measured in consumption rather than utility units) led to an awkward welfare analysis. As a result the welfare results were not reported for those simulations.

[3] Heckman, Lochner, and Taber (1998b) is a short paper. Heckman, Lochner, and Taber (1999a) is substantially longer, but estimation of the effects of tax policy is not the primary emphasis.

different when I examine a progressive *income* tax, as virtually all workers prefer the flat income tax to it. The additional welfare effects that come from the consumption tax are consistent with the previous work on the subject (see e.g. Altig et. al., 2001).

In the next section, I review the literature on taxes on human capital accumulation. Section 3 presents the model, and section 4 discusses the data. In section 5, I discuss the estimation of the parameters of the model. Section 6 presents the simulation to a flat income tax, while section 7 presents the switch to a consumption tax. Finally, I conclude in section 8.

2 Previous Literature

While the effects of taxes on human capital has been subject to almost no empirical work, a moderate amount of theory has been published. Perhaps the lack of empirical work on this subject results from Boskin's (1975) realization that in the simplest model in which all human capital investment is foregone earnings, a flat wage tax is neutral. In this case, investments in human capital are implicitly tax deductible, so a wage tax imposes no distortions. However, when the investment consists of both foregone earnings and tuition that is not tax deductible, an increase in a flat wage tax may discourage human capital investment. In this case, the tax increase reduces the benefits of human capital investment more than the costs.

Heckman (1976) investigates the impact of taxation on human capital production for a single worker with a leisure choice. He again assumes that the sole input into human capital production is tax-deductible foregone earnings. Given this assumption, an income tax (as opposed to a wage tax) stimulates human capital, because it reduces the after-tax interest rate on physical capital. In a partial equilibrium framework, Driffill and Rosen (1983) show that this effect could be large. In addition, Heckman (1976) shows that when labor supply is endogenous, taxes have an ambiguous net effect on market time and hence on human capital due to the lower after-tax return on human capital. Sgontz (1982) summarizes the basic model and extends it to progressive taxes. He shows that a progressive income tax has an ambiguous effect on human capital accumulation. The direct effect is to reduce human capital investment because the rate of tax on the benefit (additional earnings) is higher than the rate for deducting the cost (foregone income). The overall effect is ambiguous, however, because the effect on the after-tax interest rate is ambiguous.

A number of papers expand these basic results in different directions. Eaton and Rosen (1980) show that the effects of an earnings tax on human capital becomes ambiguous when uncertainty is incorporated into the model. Nerlove et. al. (1993) demonstrate that if the full costs of human capital investment were a goods cost (i.e. tuition), then physical capital would be tax-advantaged over human capital because depreciation can be deducted. Nielson and Sorensen (1997) show that with an income tax, some progressivity in the tax system may be desirable to discourage human capital investment since an income tax typically favors human capital relative to physical capital. Quigley and Smolenski (1990) provide a nice discussion of the overall tax treatment of training and schooling.

Many dynamic general equilibrium models have taxes, and some of these models include human capital.[4] Of particular relevance, Davies and Whalley (1991) find small steady-state effects of replacing an income tax with a wage or a consumption tax in an overlapping generations model with human capital. In their general equilibrium framework, they show that physical capital adjusts so that the change in the after-tax interest rate is much smaller than in the partial equilibrium analysis of Driffill and Rosen (1983). A short-lived increase in physical capital is due to a switch from an income tax to a consumption tax, but the level of human capital remains largely unchanged during the transition.[5]

Very little empirical work has studied the effects of taxation on human capital. Typically this work has not incorporated progressivity in the tax system (which is the main goal of this paper).[6] Dupor et. al. (1996) perform some rough partial equilibrium simulations that suggest the effects of progressivity on human

[4]Examples include Kotlikoff and Summers (1979), Lucas (1990), Lord and Ranzagas (1991, 1998), Jones, Manuelli, and Rossi (1993), Pecorino (1993), Trostel (1993), and Jones and Manuelli (1999).

[5]Lord (1989) also examines the transition from a payroll to a consumption base. He finds that human capital investment is higher in the consumption regime.

[6]Examples of empirical work without progressive taxes includes Heckman (1976), Rosen (1982), and Heckman, Lochner, and Cossa (2002).

capital investment may be substantial for some individuals. The only other work is by Heckman, Lochner, and Taber (1998b,1999a,b) and has been discussed above.

3 The Model

In this section I present the modified HLT model. At the level of the individual consumer, it is a standard human capital model generalizing Ben-Porath (1967). A good survey of the literature on this class of models is provided by Weiss (1986). The only major difference between this model and Ben-Porath(1967) is that the human capital production function for schooling differs from the production function for human capital produced using on-the-job training (OJT). Instead, schooling is treated here as a binary choice (some college/no college). Individuals may also receive nonpecuniary benefits (or costs) of schooling. This individual lifecycle model is imbedded in an Auerbach and Kotlikoff (1987) style full certainty overlapping generations framework. The model has two sources of *ex ante* heterogeneity. First, individuals differ in ability. Individuals with higher ability may begin life with more human capital and may be more efficient at producing human capital. Second, individuals are born at different points in times. The distribution of ability is identical across birth cohorts. However, different cohorts face different skill prices and tax systems, which lead to different distributions of investment and wage profiles *ex post*.

In order to keep track of individuals, I need four subscripts. A person is "born" upon graduating from high school (at actual age 18), at which point they begin to make their own economic decisions. Let b denote this "birth" year and t the current year. Individuals may differ in terms of their ability type, so I assume a finite number of types, J, and index type by j. Finally, students make schooling decisions denoted by s, where s is 0 for high school graduates and 4 for college graduates. Thus, human capital level H_{sjbt} denotes the human capital level at time t of an individual born at date b, of ability type j, who chooses schooling level s.

The Individual's Problem

Individuals live for T years and retire exogenously after $T_R < T$ years. I allow for two levels of schooling, high school and college. In the first portion of the lifecycle, a prospective student decides whether or not to attend college. In making that schooling decision, he or she chooses the option that yields the highest level of lifetime utility incorporating nonpecuniary benefits of college.

The optimal lifecycle problem can be solved in two stages. I first condition on schooling and solve for the optimal path of consumption and OJT for each schooling level. Individuals then select between the two schooling levels to maximize lifetime welfare. Since the last subscript represents calendar time, and b is the calendar year someone is "born," a worker enters the labor force at time $b+s$ and has initial level of human capital H_{sjbb+s}. OJT is modelled as in Ben-Porath (1967). I do not include leisure in the main specification of the model.[7] After entering the labor force, a worker's time can be decomposed into time spent investing in human capital and time spent producing the final good. Let I_{sjbt} represent the fraction of work time devoted toward on-the-job training (at time t, for an individual of ability level j, born at b, who chose schooling level s). If the worker did not invest in human capital during time period t at all, he would receive the wage $R_{st}H_{sjbt}$, where the rental rate on skill, R_{st}, varies across time and school levels but not across cohorts and ability groups. As in Ben-Porath (1967), workers implicitly pay for the work time devoted to training through lower wages. Thus, they will be compensated only for the time devoted towards producing the final good so they earn $R_{st}H_{sjbt}(1 - I_{sjbt})$.

Human capital is produced according to the human capital production function,

$$H_{sjbt+1} = A_{sj} I_{sjbt}^{\alpha_s} H_{sjbt}^{\beta_s} + H_{sjbt}, \tag{1}$$

which depends on parameters A_{sj}, α_s,and β_s. Note that with this specification, if a worker did not invest in on-the-job training ($I_{sjbt} = 0$), his level of human capital would not change. Thus, I do not allow wage growth early in the lifecycle to occur exogenously as a result of either learning by doing or the aging process.

[7] In the appendix I discuss the issues involved in incorporating leisure into this model.

In this sense my estimates represent an upper bound on the amount of wage growth due to human capital investment.

While I model investment in human capital as purely a time cost, this specification can also represent other types of investment. One possibility is that goods are an input into investment. Haley (1976) shows how one can reinterpret I_{sjbt} as a goods-time investment composite.[8] In this case the cost of the investment good would be originally paid for by the firm, but then passed on to the worker through lower wages. This investment time could also represent learning by doing where the amount of learning depends on alternative jobs and people change jobs over the lifecycle, foregoing income early in life to take a job with a higher rate of learning (See Rosen, 1972 or Heckman, Lochner, and Cossa 2002).

Heterogeneity in ability enters the model both through the constant parameter in the human capital production function, A_{sj}, and through the initial level of human capital, H_{sjbb+s}. These parameters represent ability to "earn" and ability to "learn," respectively. The α_s and β_s parameters are also permitted to depend on the schooling level.

Define K_{sjbt} and C_{sjbt} as the levels of physical capital holdings and consumption at time t by a person born at b of type j and schooling level s. Borrowing is not constrained, so individuals may hold negative capital stocks. Wage income is taxed along a progressive schedule, and I denote income net of taxes by the function $NT(\cdot)$. In the primary specification of the work that follows, I assume that capital income is taxed at a flat tax τ_r. This yields the budget constraint,

$$K_{sjbt+1} \leq K_{sjbt}(1 + (1 - \tau_r)\, r_t) + NT\left(R_{st} H_{sjbt}(1 - I_{sjbt})\right) - C_{sjbt}, \tag{2}$$

where r_t is the rental rate on physical capital at time t gross of taxes and ignoring depreciation. Workers begin life with capital, κ_0, which does not depend on schooling or type. It is received as an exogenous transfer from one generation to the next.[9]

Using constant relative risk aversion parameter, γ, and discount factor δ, one obtains the following Bellman's equation,

$$\begin{aligned} V_{sjbt}(H_{sjbt}, K_{sjbt}) &= \max_{C_{sjbt}, I_{sjbt}} \frac{C_{sjbt}^{\gamma}}{\gamma} + \delta V_{sjbt+1}(H_{sjbt+1}, K_{sjbt+1}), \\ &\quad \text{subject to (1) and (2).} \end{aligned} \tag{3}$$

Given the parameters of the model, the prices facing the agents, and the tax system, one can solve for the optimal levels of consumption and human capital investment during the lifecycle for each schooling level for the model defined above.

Now consider the schooling decision. Ben-Porath (1967) makes no fundamental distinction between schooling and OJT. In the HLT model, they differ from each other in three ways. The production function is not restricted to be the same, schooling is a binary choice, and it allows for nonpecuniary benefits or costs of schooling. After graduating from high school, the student decides between entering the work force immediately ($s = 0$) or attending "college" for four years ($s = 4$).[10] While in college the student must pay an annual tuition of level D (which varies across individuals in the data). During college the student faces the budget constraint,

$$K_{sjbt+1} \leq K_{sjbt}(1 + (1 - \tau_w)\, r_t) - C_{sjbt} - D, \tag{4}$$

and thus tuition will enter the value function for college. In addition individuals have idiosyncratic nonpecuniary benefits or costs of schooling, ε, measured in utility units. I assume that

$$\varepsilon \approx N(\mu_j, \sigma_\varepsilon^2), \tag{5}$$

[8] This is irrelevant for the investor in partial equilibrium. However, this type of cost would change the general equilibrium model somewhat in that some goods would be allocated to human capital investment rather than consumption.

[9] It is transferred from the older generation at the time of retirement.

[10] I am assuming here that individuals do not return to college after entering the labor force. I relaxed this restriction for my initial simulations (HLT did not), but nobody chose to return to college. I now impose it to simplify the computation.

so that tastes for schooling vary within ability types, but the mean may differ across ability types. Thus, an individual chooses to attend college if

$$V_{4jbb}(H_{4jbb+4}, \kappa_0 - PVT) + \varepsilon > V_{0jbb}(H_{0jbb}, \kappa_0), \tag{6}$$

where PVT is the present discounted value of tuition for college graduates, while high school graduates incur no direct costs for their schooling. Given optimal investment in physical capital, schooling, investment in job-specific human capital, and consumption, I calculate the path of savings. For a given return on capital and rental rates on human capital, the solution to an individual's optimization problem is unique given concavity of the human capital production function in terms of I_{sjbt}, $(0 < \alpha_s < 1)$, and H_{sjbt}, $(0 < \beta_s < 1)$, that investment is in the unit interval $(0 \leq I_{sjbt} \leq 1)$, and concavity of utility in terms of consumption $(\gamma < 1)$. This completes the specification of the agent's problem.

Aggregating the Model

The market treatment of schooling and on-the-job training differ. In contrast to most general equilibrium models, HLT do not assume that college graduate human capital is perfectly substitutable with high school graduate human capital. For computational reasons, however, they do assume that the human capital of two members of the same education groups is perfectly substitutable. Thus two high school graduates at different ages rent their human capital out at the same market rate, R_{0t}, but college graduates rent their human capital out at a different rate, R_{4t}.

In order to compute rental prices for capital and for the different types of human capital, it is necessary to construct aggregates for each of the school groups. I embed the human capital model into an overlapping generations framework in which the population at any given time is composed of T overlapping generations.

Let N_{sjb} be the fraction of individuals of type j, born at time b, who choose schooling level s. Each cohort has a fraction μ_j of each ability type for $j = 1, ..., J$. In this notation, the aggregate stock of employed human capital for schooling s at time t is cumulated over the non-retired cohorts in the economy at time t,

$$\bar{H}_{st} = \sum_{b=t-T_R}^{t} \left[\sum_{j=1}^{J} H_{sjbt}(1 - I_{sjbt}) N_{sjb} \mu_j \right]. \tag{7}$$

The aggregate capital stock is the capital held by persons of all ages,

$$\bar{K}_t = \sum_{b=t-T}^{t} \left[\sum_{j=1}^{J} \left(K_{0jbt} N_{0jb} + K_{4jbt} N_{4jb} \right) \mu_j \right]. \tag{8}$$

Rational Expectations Equilibrium Conditions

To close the model, it is necessary to specify the aggregate production function $F(\bar{H}_t^1, \bar{H}_t^2, \bar{K}_t)$, which is assumed to exhibit constant returns to scale. The equilibrium conditions require that marginal products equal pre-tax prices,

$$R_{0t} = F_1(\bar{H}_{0t}, \bar{H}_{4t}, \bar{K}_t), \tag{9}$$

$$R_{4t} = F_2(\bar{H}_{0t}, \bar{H}_{4t}, \bar{K}_t), \tag{10}$$

$$r_t = F_3(\bar{H}_{0t}, \bar{H}_{4t}, \bar{K}_t). \tag{11}$$

In the two-skill economy estimated below, I specialize the production function to the form used by HLT,

$$F(\bar{H}_{0t}, \bar{H}_{4t}, \bar{K}_t) = a_3 \left(a_1 \bar{H}_{0t}^{\rho} + (1 - a_1) \bar{H}_{4t}^{\rho} \right)^{a_2/\rho} \bar{K}_t^{1-a_2}. \tag{12}$$

When $\rho = 1$, the two human capital types are perfect substitutes, yielding a standard Cobb-Douglas production function in terms of capital and labor. Irrespective of the value of ρ, this specification of F delivers a model consistent with the constancy of capital's share.

I assume that the government collects taxes to satisfy a fixed revenue requirement. Apart from collecting taxes, activities of the government are not central to this analysis.

Table 1

Summary Statistics

Variable	Mean	Standard Deviation	Sample Size
College Enrollment	0.47	0.50	2242
Wage	11.23	6.88	22954
Tuition	1.02	0.50	2242
AFQT Type 1(lowest):			
College Enrollment	0.11	0.32	559
Wage	9.04	5.35	6310
AFQT Type 2:			
College Enrollment	0.34	0.48	557
Wage	10.70	5.66	6092
AFQT Type 3:			
College Enrollment	0.56	0.50	553
Wage	11.81	6.45	5619
AFQT Type 4(highest):			
College Enrollment	0.86	0.35	573
Wage	14.04	8.67	4933

(1) College Enrollment is a dummy variable for whether the individual completed one year of college.

(2) Wages are measured in terms of 1992 dollars per hour.

(3) Tuition is measured in terms of thousands of 1992 dollars per year at two year colleges in the state of residence at age 17.

4 The Data

My data come from the National Longitudinal Survey of Youth (NLSY), which is a representative panel data set begun in 1979 with youth aged 14 to 22. The survey is conducted annually and respondents are questioned on a large range of topics, including schooling, earnings, and family background. This research was conducted using white male civilians from the cross-sectional sample only. The main motivation in using white males was to abstract from labor supply decisions that would substantially complicate the model. Previous work has shown the key parameters of the analysis (α_s, β_s, and σ_ε) are similar for women and men (see Browning, Hansen, and Heckman, 1998). Thus, ignoring women may not be a major problem, but since other parameters such as those governing labor supply do vary, one can not tell for sure.

A very convenient aspect of the NLSY data is that in 1980, 94% of the respondents were administered the Armed Services Vocational Aptitude Test (ASVAB), which consists of ten standardized tests used by the armed forces to assess a variety of skills. Four of these tests are combined to form the Armed Forces Qualifying Test (AFQT), which is used as a criterion for admission into the armed forces. I assign individuals into different ability groups on the basis of their AFQT score. Following HLT, I use AFQT as a measure of ability in order to incorporate heterogeneity into the model in a simple way.[11] Specifically, I partition the sample into four subsets of equal size.

Table 1 presents sample means and standard deviations for the key variables. The first three rows contain summary statistics for the full sample, and the next set of rows condition on the four ability types. The sample size for “college” and for “wages” differs because I am using panel data. The sample has 2242 individuals and 22,954 wage observations.

[11] An alternative is to estimate the distribution of ability. I attempted to do this using Heckman-Singer(1984) style heterogeneity, but this problem proved to be computationally burdensome.

Another key variable in the analysis is tuition. This variable is constructed from the Department of Education's annual HEGIS and IPEDS "Institutional Characteristics" surveys. Tuition measures are enrollment-weighted averages of public two-year institutions in the respondent's state of residence at age 17. It does not generally come from the school that the student actually attended. This variable is also presented in the table. It is measured in thousands of 1992 dollars.

One issue that arises with this data set is that I only observe young individuals, so I cannot capture the full age-earnings profile. I use data up to 1994 in which the oldest members of the sample are 37. By that point in the lifecycle the vast majority of earnings growth has taken place (see e.g. Murphy and Welch, 1990). While these data do not identify the full age earnings profile, they do identify the most important portion. The one parameter that is not well identified with this type of data is the depreciation of human capital, which can be identified primarily from the slope of the age-earnings profile late in life. Since I cannot estimate it, I set depreciation to zero in this model, which is consistent with what is reported in the literature (see Browning, Hansen, and Heckman, 1998). It is also consistent with the lack of any peak in life cycle wage-age profiles reported in the literature (See Meghir and Whitehouse, 1996).[12] Most importantly, in the appendix I demonstrate that the results of the simulation are not sensitive to this assumption.

The fact that I do not observe the full lifecycle is a disadvantage of the NLSY, but I have no obviously superior alternative. I do not know of a longitudinal U.S. data set that covers individuals for a full 45 years. The PSID, which is closest, follows only a small number of respondents for thirty years.[13] While the CPS is not longitudinal, one could use the repeated cross section to follow a few cohorts for 30 years. However, use of either the PSID or CPS would be problematic for a number of reasons. First, I could not use the AFQT score for heterogeneity. Second, while the changing wage structure is a problem in the current set up, it would be even more of a problem for the full 30-year period. Third, the NLSY is longitudinal while one must rely on repeated cross sections in the CPS.

5 Estimation and Calibration of the Initial Steady State

Overview of the Approach

The goal of this paper is to estimate the effect of two different types of tax reform on human capital accumulation. I begin with an initial steady state that is intended to represent the U.S. economy and tax system in 1994. An unanticipated tax change that eliminates progressivity is then announced, and I simulate the transition from this initial steady state to the new steady state. I examine two types of tax reform: a switch to a flat income tax and a switch to a flat consumption tax. This section of the paper details the estimation of the parameters of the model and the calibration of the initial steady state. Once the parameters governing the initial steady state are set, I can analyze the impact of policy changes on the economy.

A fundamental problem arises in implementing the strategy discussed above. In the simulations, I assume that the economy is in steady state. In reality, however, the labor market is clearly not in steady state because of well documented changes in the labor force (see e.g. Autor and Katz, 1999). Additionally, the tax system has changed over time. In an ideal world, I would estimate a version of the model that incorporates learning about the wage structure and tax system that would use worker behavior to estimate their predictions about future wages and taxes. However, the data are not sufficiently rich to identify this full process. While making progress on this problem is an important avenue for future research, it is beyond the scope of this paper. An obvious single best solution to this problem does not exist. One could estimate the model assuming that the economy is in steady state (as in HLT) and that taxes do not change, but this is at odds with the data. Alternatively, one could estimate the model accounting for the changes in the wage structure and tax changes over time, but this leads to an inconsistency between the assumptions maintained during estimation and those maintained during simulations. I address this problem not by choosing one single "best" specification, but by using a range of specifications. I estimate the model under alternative assumptions about future

[12] Although other papers such as Fullerton and Rogers (1993) do find evidence of a peak in life cycle earnings.

[13] The advantage of the PSID is that one can observe some people for a long period of time. If one is interested in the full lifecycle earnings profile as in e.g. Fullerton and Rogers (1993), the PSID is preferable. However, the main goal of this paper is to study human capital. The advantage of the NLSY is that it focuses on young people. Since two-thirds of earnings growth occurs within the first 10 years (Murphy and Welch, 1990), the NLSY is better suited for this study.

prices and tax schedules and show that the basic results are insensitive to these assumptions. Thus, this inconsistency between the model and the data does not appear to drive the main results on the sensitivity of human capital investment to progressivity of the tax system.

The parameters and other elements of the model needed for determining the initial steady state are the following:

- Tax system at initial steady state: $NT(\cdot)$ in equation (2)
- Steady state prices (interest rate and human capital rental rates): r_0, R_{00}, R_{40} in equations (9)-(11)
- Human capital production function parameters: $A_{sj}, \beta_s, \alpha_s$, for $j = 1, ..., 4$,and $s = 0, 4$ in equation (1)
- Initial level of human capital: H_{jsbb+s}, for $j = 1, ..., 4$,and $s = 0, 4$ in equation (1)
- Preference parameters: γ, δ in equation (3)
- Parameters of distribution of tastes for schooling: $\sigma_\varepsilon, \mu_j$ for $j = 1, ..., 4$ in equation (5)
- Transfer from old generation to young generation: κ_0 in equation (2)
- Parameters of aggregate production function: ρ, a_1, a_2, a_3 in equation (12)

In determining the steady states, some of the parameters are estimated while the others are either calibrated or fixed. I estimate the parameters that are most important for the question at hand, namely the parameters of the human capital production function and of the tastes for schooling. These parameters dictate the way in which human capital investment responds to incentives. In the appendix, I present a sensitivity analysis for the nonestimated parameters. The initial steady state was determined using the following procedure,

Stage 0: Choose some initial parameters ($NT(\cdot)$, $r_0, R_{00}, R_{40}, \gamma, \delta, \rho$).[14]

Stage 1: Estimate the parameters of the human capital production function and the initial level of human capital ($A_{sj}, \beta_s, \alpha_s, H_{jsbb+s}$).

Stage 2: Estimate schooling taste parameters ($\sigma_\varepsilon, \mu_j$) and calibrate transfers from old to young (κ_0).

Stage 3: Solve for values of a_1, a_2,and a_3 that are consistent with the steady state.

I now describe each of these stages in detail.

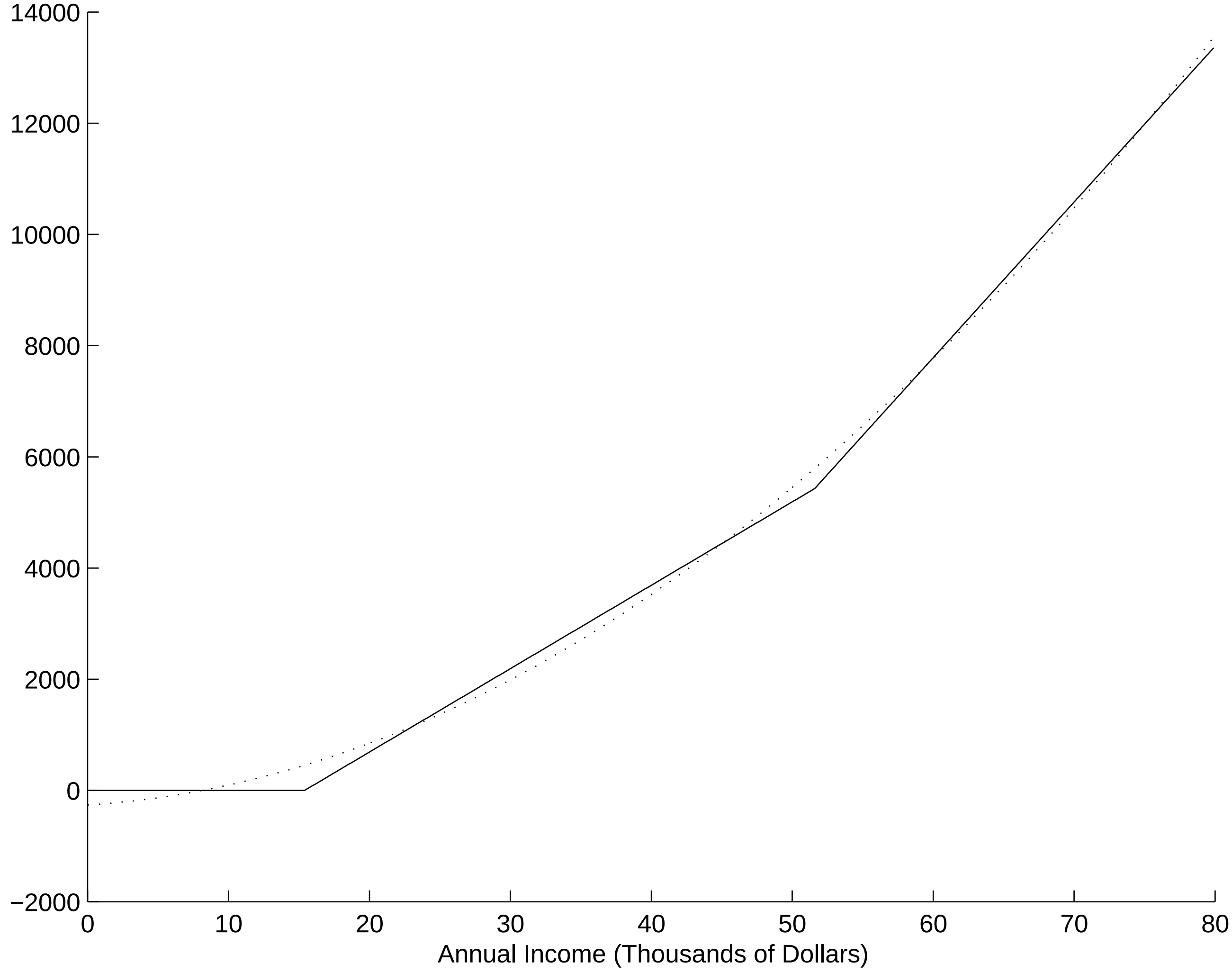
Stage 0: Initial Parameters and Tax System

In the initial steady state I impose a tax system that approximates the federal income tax system of the United States. I begin by obtaining the level of taxes paid for any level of taxable income for the years 1977-1994 for single individuals and for married couples from published tax tables. I assume that the families take the standardized deduction and that the married couple only has two children. For each year, I then smooth this schedule by taking a second-order polynomial approximation obtained through a least squares regression of taxes paid on taxable income. This regression yields a very accurate approximation of the schedule with levels of R^2 above 99.5% every year. This can be seen in Figure 1, which presents the true and approximated schedule for married couples with two children in 1994.

In my primary specification, I allow the schedule and number of deductions that an individual faces to vary across the life cycle with demographics. Specifically, I calculate the distribution of single individuals and incorporate the number of children living at home for each schooling group and for each age. I then let the tax schedule change with these demographics in a smooth way. For the married couples I assume that each male worker is married to a woman who earns exactly eighty percent of what he earns. In the results

[14] I call this stage 0 rather than stage 1 becuase it does not involve any actual estimation or calibration. It does involve some numerical approximaton as a quadracic approximation to the tax schedule is obtained through least squares.

Figure 1
Actual and Approximated
1994 U.S. Income Tax Schedule
Taxes Payed by Taxable Income
(Married Couples with Two Children)



Solid Line True Schedule
Dotted Line Approximate Schedule

that follow, I estimate and simulate the model both by using this approach and by assuming individuals are married with two children throughout their lives. The results are very similar between the two.

The base case uses the 1994 tax system, but some specifications allow the tax system to change over time. I use the procedure above to approximate the tax schedule for each year from 1976-1994. I then smooth across years as well by taking a weighted moving average of the approximated tax rates. In creating the moving average, I put weight 0.4 on the current year, 0.2 on adjacent years, and 0.1 on the schedule two years removed.

In the estimation, I follow Altig et. al. (2001) by approximating the tax system assuming a constant tax rate on capital and a progressive tax on labor earnings. I fix the capital tax rate at 15%.[15] I also relax this assumption and simulate a more traditional progressive income tax below.

Since I do not have data on consumption in the NLSY, it is necessary to make some assumptions about time preference (δ) and the intertemporal elasticity of substitution for consumption (governed by γ). Given the levels of human capital investment implied by the estimates from the model and levels of initial assets for each individual, I obtain consumption and savings under the assumption that $\delta = 0.96$ and $\gamma = -3$. In the appendix, I show that the results are not sensitive to these assumptions. I also assume throughout that people retire 47 years after graduating from high school and die 15 years later. Thus if all individuals graduate from high school at age 18, then they would all retire at age 65 and die at age 80.

HLT estimate a production function in a manner completely consistent with their micro-framework. Though my model differs somewhat from theirs, it is identical at the aggregate level, so HLT's (1998a) estimates can be used here directly. They find that $\rho \approx 0.306$, which yields an elasticity of substitution between skill types of 1.441, very close to other estimates (e.g. Katz and Murphy, 1992). This parameter plays a key role in the general equilibrium effects of taxes on schooling attainment. In the appendix, I show how the results change when ρ is close to one.

Since the level of human capital is not well defined, I can normalize the rental rates on human capital R_{00} and R_{40} to any value. I choose to normalize them each to two. Since H_{sjbt} is measured in units of hourly wages, and individuals work approximately 2000 hours per year, $R_{s0} = 2$ implies that $R_{s0}H_{sjbt}$ has the interpretation of annual income measured by thousands of dollars per year. I set the after tax interest rate to 0.05 in the initial steady state and show that the results are not sensitive to this benchmark.

Stage 1: Estimating The Human Capital Production Functions

My first empirical goal is to estimate the parameters of the human capital production functions. For the reasons describe above, I experiment with a number of different assumptions about the tax system and about future prices. This work extends the previous empirical work on these models by allowing the rental rates on human capital for college and high school workers to change and by estimating under progressive taxes that may also change over time.

For each ability-schooling (j, s) type, the relevant parameters are $(\alpha_s, \beta_s, A_{sj}, H_{sjbb+s})$. I assume that, conditional on measured ability, no selection bias results from the schooling decision.[16] As discussed in the data section, I divide the sample into four quartiles based their AFQT score.

Let τ_{st} denote the schedule of taxes that individual of schooling type s faces at time t.[17] For any particular set of parameters $(\alpha_s, \beta_s, A_{sj}, H_{sjbb+s})$, any path of human capital rental rates $\widetilde{R}_{sb} = (R_{sb}, ..., R_{sb+T_R})$, and any path of tax schedules $\widetilde{\tau}_{sb} = (\tau_{sb}, ..., \tau_{sb+T_R})$, I can simulate the model to form log wage profiles. Denote these predicted log wages for an individual of type j with schooling s at age a as $W_{sja}(\alpha_s, \beta_s, A_{sj}, H_{sjbb+s}; \widetilde{\tau}_{sb}, \widetilde{R}_{sb})$. Let W^*_{ia}, $s(i)$, $j(i)$, and $b(i)$ denote the log wage, schooling level, ability level, and birth cohort respectively for

[15] Many factors are involved in choosing this rate when one's primary interest is human capital accumulation. For example, since borrowing and saving are treated symmetrically for computational purposes, this rate is also the rate at which interest is deducted. One cannot deduct the interest on Guaranteed Student Loans, but one can deduct the interest for college if parents finance it through a second mortgage. I did not perform sensitivity analysis on this variable *per se* because I also check robustness using the progressive income tax regime in results presented in Table 6. It also is fixed in the primary simulations (Table 4 and Table 5), so it is not particularly important.

[16] This is broadly consistent with the literature on the returns to schooling. See Card (1999) for a recent survey. Both IV estimates and twins estimates are reasonably close to the OLS estimates. In particular, in virtually all studies the 95% confidence interval of the IV estimate includes the OLS point estimate.

[17] Taxes vary across schooling because the demographics used to approximate the schedule vary by schooling group.

individual i in the sample at age a. I estimate $(\alpha_s, \beta_s, A_{sj}, H_{sjbb+s})$ by nonlinear least squares, minimizing the distance between the predicted wage profiles and the actual ones,

$$\sum_i \sum_a \{W^*_{ia} - W_a(\alpha_{s(i)}, \beta_{s(i)}, A_{s(i)j(i)}, H_{s(i)j(i)bb+s(j)}; \widetilde{\tau}_{sb}, \widetilde{R}_{sb})\}^2, \tag{13}$$

and constraining $0 \leq \alpha_s \leq 1$, $0 \leq \beta_s \leq 1$, and $A_{sj} \geq 0$ for each schooling and ability group. I use Huber-White type heteroskedastic consistent standard errors for panel data.[18] This puts no restriction on the relationship for wages between years for a given person, but assumes that the error term for one individual is uncorrelated with the error term for another.

The results from this procedure are presented in Table 2. The Type 1 group comes from the lowest quartile of AFQT ability, while Type 4 represents the highest. To test the sensitivity of the estimates to different assumptions, I estimate the model using a number of different strategies. The simplest is to ignore the progressivity of the tax system and changes in the wage structure and assume the economy is in steady state.[19] This approach is essentially identical to HLT and the previous empirical work on the Ben-Porath model (see Browning, Hansen and Heckman, 1998 for a discussion of this literature).[20] The results of this procedure are presented in the first column of Table 2. The second and third columns also assume that the economy is in steady state, but use the approximation of the 1994 tax code described above. The specification in column (3) allows for the tax code to change over the lifecycle with demographics, while the specification in column (2) fixes the tax schedule to be that for a married couple with two children.[21]

The results in the first three columns are similar across these different specifications. For both the high school and college educated workers, α_s is large and precisely measured. In contrast, β_s is much less precisely estimated and varies across specifications. The A_{sj} parameters also vary across specifications and have large standard errors, but this is in large part do to the close relationship between β_s and A_{sj}. If β_s were fixed, the values of A_{sj} would be much more robust and precisely estimated.[22] Within schooling groups, the constant parameter A_{sj} increases with ability. This is consistent with the notion that high skill individuals not only earn more, but are also more efficient at human capital investment. As one would expect, initial human capital is also increasing with type.

In column (4), I present results from a specification in which I allow the tax schedule to change across time and cohorts. Column (5) allows for both tax changes and human capital rental rate changes.[23] In these columns, one can see that the value of β_s declines to zero, but the α_s parameters remain high.[24] The A_{sj} parameters increase to compensate for the lower value of β_s. The estimation procedure for this model is substantially more complicated than the previous two because I need to solve for separate investment paths for all eight NLSY cohorts while constraining the initial value of human capital to not vary across cohorts. As a result, the objective function was not nearly as smooth. In estimation I use a simplex routine rather than a gradient method. Relatedly, since I could not obtain a reasonable numerical estimate of the derivative of the objective function, I could not obtain reasonable estimates of the standard errors of the model. Note that this is a numerical problem, not an econometric problem. I can think of no reason why the standard errors in the fourth and fifth columns would substantially differ from those in the first three columns, but it is impossible to tell for sure.

It is not at all obvious which of these estimates one should prefer. It depends on one's priors about individual's beliefs on the changing wage structure and changes in the tax structure. My primary specifi-

[18] The implicit assumption here is that differences in wages across individuals of the same ability type represents measurement error.

[19] If taxes are linear, human capital investment and thus wage profiles are not affected by the tax rate. As a result, these results are perfectly robust to any level proportional taxes or to the complete absence of taxation of labor income.

[20] The data set is somewhat different than HLT as I use more recent years of the NLSY data and a different wage measure.

[21] That is, in column (2), I use one tax schedule at all ages, married with two children. In column (3), the tax code changes over age and is a weighted average of the single schedule and the married schedule with various levels of children. The weights depend on the sample proportion of each type at each age.

[22] In results not shown, I have experimented informally with various specification assuming either Ben-Porath neutrality ($\alpha_s = \beta_s$), fixing $\beta_s = 1$, or fixing $\beta_s = 0$. All three yield the pattern described in the text.

[23] I allow price changes in a simple way by taking a linear approximation to the price trend during the 1980s using HLT's estimates of human capital prices. Their series contains a large increase in the college price and a large fall in the high school price that is consistent with the literature on the changing wage structure (e.g. Katz and Murphy, 1992).

[24] Unfortunately, given imprecision in estimation of β_s, I have no obvious explanation for this.

Table 2

Estimated Parameters for Human Capital Production Function Under Alternative Assumptions (Standard Errors in Parentheses)

	(1)	(2)	(3)	(4)	(5)
High School:					
α	0.944(0.007)	0.969(0.011)	0.963(0.013)	0.921	0.791
β	1.000(-)	0.731(0.252)	0.751(0.277)	0.000	0.000
A Type 1	0.055(0.0003)	0.101(0.054)	0.095(0.056)	0.475	0.565
A Type 2	0.055(0.0002)	0.109(0.064)	0.103(0.067)	0.603	0.724
A Type 3	0.056(0.0002)	0.115(0.071)	0.108(0.073)	0.686	0.835
A Type 4	0.056(0.0002)	0.118(0.074)	0.111(0.076)	0.716	0.877
H_0 Type 1	7.939(0.140)	7.852(0.140)	7.723(0.140)	7.927	7.523
H_0 Type 2	9.530(0.181)	9.429(0.180)	9.544(0.180)	9.491	8.907
H_0 Type 3	10.294(0.246)	10.224(0.250)	10.606(0.248)	10.208	9.522
H_0 Type 4	10.371(0.481)	10.372(0.504)	10.065(.498)	10.242	9.497
Sample Size (Wages)	13965	13965	13965	13965	13695
College:					
α	0.942(0.008)	0.970(0.021)	0.965(0.023)	0.956	0.952
β	1.000(-)	0.286(0.296)	0.303(0.321)	0.000	0.000
A Type 1	0.057(0.0005)	0.341(0.253)	0.325(0.262)	0.674	0.591
A Type 2	0.057(0.0002)	0.376(0.288)	0.358(0.298)	0.767	0.673
A Type 3	0.057(0.0002)	0.404(0.317)	0.384(0.327)	0.839	0.739
A Type 4	0.058(0.0001)	0.456(0.375)	0.433(0.386)	0.977	0.865
H_0 Type 1	10.550(0.690)	10.325(0.700)	10.338(0.697)	10.344	10.456
H_0 Type 2	11.791(0.375)	11.571(0.396)	11.580(0.393)	11.567	11.654
H_0 Type 3	12.561(0.357)	12.333(0.368)	12.339(0.364)	12.301	12.417
H_0 Type 4	14.343(0.372)	14.163(0.380)	14.165(0.375)	14.073	14.214
Sample Size (Wages)	8989	8989	8989	8989	8989
Progressive Taxes	No	Yes	Yes	Yes	Yes
Demographics	No	No	Yes	Yes	Yes
Changing Tax Code	No	No	No	Yes	Yes
Changing Wages	No	No	No	No	Yes

(1) The estimates in specification (1) do not incorporate progressive taxes.

(2) Specification (2) incorporates progressive taxes with 1996 U.S. Tax Code.

(3) Specification (3) uses 1996 U.S. tax code incorporating demographics over lifecycle.

(4) Specification (4) uses cohort-specific U.S. tax code incorporating demographics over lifecycle.

(5) Specification (5) uses cohort-specific U.S. tax code incorporating demographics over lifecycle and changes in wage structure.

(6) I calculate Huber/White panel standard errors.

(7) Accurate standard errors for cases (4) and (5) could not be obtained due to non-smoothness of the objective function.

cation will use the specification associated with column (3) because it yields the cleanest experiment. The simulations assume that the economy begins in steady state with progressive taxes. Only columns (2) and (3) estimate the model under these assumptions.[25] As a result, these specifications yield an initial steady state that is closest to the U.S. population (as represented by the NLSY data). To check the robustness of the results, I have simulated the tax changes in all five specifications, and I demonstrate the extent to which the basic results differ among them.

Stage 2: Estimating the Probability of Attending College

My next empirical goal is to obtain estimates of the parameters governing the schooling decision. Recall that an individual attends college if

$$V_{4jbb}(H_{sjbb+4}, \kappa_0 - PVT) + \varepsilon > V_{0jbb}(H_{sjbb}, \kappa_0), \tag{14}$$

where V_{4jbb} is the lifetime utility from consumption for a college graduate of type j from cohort b who must pay present value of tuition PVT, and V_{0jbb} is the lifetime utility that individual would obtain if he chose not to attend college. I assume that $\varepsilon \sim N(\mu_j, \sigma_\varepsilon^2)$ where the expected value of the tastes for schooling depends on the individual's type. Letting Φ denote the cdf of a standard normal random variable, the probability of attending college for individual i who faces tuition level PVT_i is

$$\Phi\left(\frac{V_{4jbb}(H_{sj(i)b(i)b(i)+4}, \kappa_0 - PVT_i) - V_{0jbb}(H_{sj(i)b(i)b(i)}, \kappa_0) + \mu_{j(i)}}{\sigma_\varepsilon}\right). \tag{15}$$

I first construct V_{4jbb} and V_{0jbb} by simulating the model using the parameters estimated in Stage 1. I calculate PVT_i by taking the present value of tuition payments that individual i would face if he attended college for four years.[26] I then run a probit to estimate the parameters. It is well known that a probit model requires a scale normalization that is typically imposed by setting the variance of the error term to one. I have already implicitly imposed a scale normalization on the model through my choice of utility function that identifies the variance of the error term.[27]

One can see from (15) that σ_ε plays a crucial role in determining the response of schooling to tax changes. Changes in the tax system influence the probability of attending college through the term $V_{4jbb+4} - V_{0jbb+4}$. Since the coefficient on this difference in the probit is $1/\sigma_\varepsilon$, a large σ_ε implies that schooling is insensitive to tax changes. One can also see in (15) that variation in $V_{4jbb+4} - V_{0jbb+4}$ within each ability type is necessary to identify σ_ε and μ_j. The variation in $V_{4jbb+4} - V_{0jbb+4}$ within ability group arises only through the variation in tuition across state of residence and cohorts. Thus, the elasticity of college attendance with respect to a change in the present value of earnings is identified through the elasticity of college attendance with respect to tuition.

An additional complication arises at this stage. When using reasonable values for discount rates and interest rates, I do not obtain enough lifecycle savings in this model to be consistent with the U.S. economy. That is, if a college student starts with zero initial wealth, he will borrow during college and eventually pay it off, but he does not accumulate enough wealth during his lifecycle to account for the amount of savings we see in the data. To address this problem I impose an exogenous transfer from the old to the young (κ_0).[28] The level of this transfer does not vary across individuals. I calibrate κ_0 to yield a capital output

[25] Columns (2) and (3) represent very similar specifications with similar results. Since (3) is more general in allowing for the tax schedule to change with demographics, I focus on it rather than on (2).

[26] As described above, this is the average tuition at a two year college in the state in which they lived at age 17. The fact that I am using 2 year college tuition, but assuming four years of college is awkward, but allowing for a richer schooling would complicate the model substantially.

[27] Alternatively I could reparameterize the model by assuming that one goes to college if

$$\alpha\left[V_{4jbb}(H_{4jbb+4}, \kappa_0 - PVT) - V_{0jbb}(H_{0jbb}, \kappa_0)\right] + \varepsilon > 0.$$

Then I could normalize the variance of ε to 1 as is standard and estimate by a probit. This alternative is equivalent to my normalization in (15) when $\alpha = 1/\sigma_e$. In fact, in practice I estimate the parameters by running a probit of college attendance on $V_{4jbb} - V_{0jbb}$ and dummy variables indicating each of the four types. This gives a coefficient on $V_{4jbb} - V_{0jbb}$ equal to $1/\sigma_\varepsilon$ and coefficients on each dummy variable μ_j/σ_ε. I then calculate the structural parameters from these estimated coefficients.

[28] Fullerton and Rogers (1993) also use this device to help explain the existing capital stock in their model.

Table 3

Estimated Distribution of Tastes for College Measured in Terms of 1/10000 of a Utility Point (Standard Errors in Parentheses)

	Estimated Coefficient	Average Derivative)
Mean Type 1 (μ_1)	-5.284(2.436)	-0.504(0.068)
Mean Type 2 (μ_2)	0.124(0.842)	-0.013(0.082)
Mean Type 3 (μ_3)	2.064(0.357)	0.229(0.095)
Mean Type 4 (μ_4)	2.524(2.155)	0.223(0.075)
Standard Deviation (σ_ε)	3.500(2.027)	-3.004(1.733)
Transfer	52.866(0.492)	-
Sample Size	2242	

(1) These results are from the specification incorporating progressive taxes, the 1996 tax code, but not changing wages.

(2) For the standard deviation, the average derivative corresponds to the change in the probability of attending college for a $1000 change in tuition. For the mean terms it measures the difference in the probability of attending college for somebody with the mean tastes versus no nonpecuniary benefits.

ratio in the initial steady state equal to four. Since the capital/output ratio depends on schooling, and since lifetime utility and thus the parameters of the schooling decision depend on the level of the transfer, I must simultaneously estimate the schooling parameters and calibrate the transfer. That is, I estimate the transfer and the parameters of the schooling decision jointly by maximizing the probit likelihood function subject to the constraint that the resulting capital/output ratio be four.[29]

I have estimated this model using a number of different assumptions about changing taxes and skill prices, but I focus on the main results from the steady state model with progressive taxes that account for demographics (column (3) in Table 2). These results are presented in Table 3. The parameters themselves are somewhat hard to interpret, since they are measured in utility units. What can be seen is that the point estimates for the tastes for schooling are monotonically increasing in ability type. The estimated standard deviation of the tastes for school is 3.5, so the mean for the lowest ability type is about 1.5 standard deviations lower than the mean for the second group. The mean for the highest two are close to each other and about 2/3 of a standard deviation higher than the previous group. To aid interpretation, I present average derivatives of the probit in the second column. For the standard deviation, this shows that a $1000 increase in tuition per year lowers the probability of attending college by three percentage points. This is a large effect, but well within the range of those estimated in the data (see Leslie and Brinkman, 1988). The average derivative for each μ_j presents the difference in the probability of attending college for someone with the mean tastes for schooling versus no nonpecuniary benefits or costs ($\varepsilon = 0$). For instance the first row states that if one could shift the mean nonpecuniary benefit of the lowest group from -5.284 to 0, their schooling probability would increase by 50 percent. This is a very large amount. Tastes for schooling (as opposed to differences in the returns to schooling) explain much of the difference in college attendance rates between ability groups that are shown in Table 1. The model was also estimated using the parameters from

[29] In practice, for each potential transfer level, I can estimate the probit and simulate the capital/output ratio. I then solve for the value of the transfer level that yields a capital/output ratio of four. This procedure worked very well.

the other specifications, and the basic results (not shown) are similar.[30]

Stage 3: Solving for $a_1, a_2,$ and a_3

So far, I claim the model is a steady state, but I have chosen the skill prices rather than solved for them within the model. To this point, the supply of skill to the market is consistent with the prices: given $r = 0.05$ and $R_{00} = R_{40} = 2$, I can solve for steady state aggregate levels of physical and human capital. What I have not done to this point is show that these prices and levels of human capital are consistent with a steady state. I solve for the remaining parameters of the aggregate production function (a_1, a_2, a_3) so that the derivatives yields these prices. This guarantees that the prices are consistent with a steady state, and thus that the initial steady state is consistent with the U.S economy (as measured by NLSY data).

6 Simulation of Switch to a Flat Income Tax

Armed with the estimates of the model, I am ready for the main goal of the paper: simulating the impact of tax policy on human capital accumulation. In my base specification, the steady state consists of a flat 15% tax on capital income and a progressive tax on labor income. The government suddenly announces a change to a flat income tax system in which the tax rate on capital remains fixed at 15%, but a proportional tax rate on labor income with a rate that balances the government's budget. That is, the present value of taxes over the transition into the steady state is equal to the present value of a fixed series of government expenditure. That series is dictated by the initial tax system. I also present results from an initial steady state with a progressive tax on income from both labor and capital. I then simulate the result of a transition to a new steady state with a flat income tax, where again the government budget constraint is balanced. Interest paid on debt is deducted in both cases. I simulate the model using a Gauss-Sidal algorithm as in Auerbach and Kotlikoff (1987).[31]

I present the first set of simulations in Table 4 and in Figure 2, using the base set of estimates of the model (summarized in column (3) of Table 2 and in Table 3). In the first set of rows of Table 4 (labelled "Changes Across Cohorts"), the first column labelled "One Year" corresponds to the cohort who makes their schooling decision immediately following the new tax change, "Five Years" corresponds to the cohort who makes their schooling decision four years after that, ... and "Long Run" represents a cohort in the new steady state. The rows at the bottom of the table (labelled "Changes of Aggregates Over Time") present results that vary by time rather than by birth cohort. In this case, the column for "One Year" shows aggregates for the year immediately following the change.

As a measure of schooling, I compute the fraction of people that attend college. As can be seen from the first row in the table, the long run effect of this tax change is actually slightly negative; enrollment falls by 0.6% (from 0.468 to 0.465). In this simulation, the rental rates on human capital adjust so that essentially the same fraction of students attend college in the new steady state as the old one. This result is consistent with HLT's finding that taxes have small effects on schooling in the long run. As in HLT, the partial equilibrium effects (not shown) are quite large: when I simulate the model but do *not* allow prices to change, I find that college attendance rises by about 12%.

The short run effects on enrollment are positive and much larger in magnitude than the long run effects, but they are short lived. The first cohort increases their schooling by 4.71%, the fifth by 2.82%, but by the tenth cohort, the schooling increase is down to 1.14%. The positive effects in the short run disappear over time as the college premium and interest rate adjust.

[30] In all of these specifications, I use the parameters estimated in Stage 1 but assume that the economy is in steady state. I also tried to estimate the schooling parameters using the variation across cohorts in schooling returns for identification. This did not work at all, as the sign on the returns is actually negative. This result in itself is not surprising. Most individuals in the NLSY were making their schooling decisions during the 1970s when schooling premia were falling, and college attendance fell as well. The failure here is likely due to the strength of the perfect foresight assumption-high school students making schooling decision in the 1970s did not anticipate the large increase in the returns during the 1980s.

[31] Basically, I start with a guess of the tax rate and a set of prices for the new steady state and transition. Given this guess, I can simulate the human and physical capital investment by consumers. Plugging these into the first order conditions for the aggregate production function and into the government budget constraint, I obtain a new tax rate and prices. This procedure is iterated until convergence.

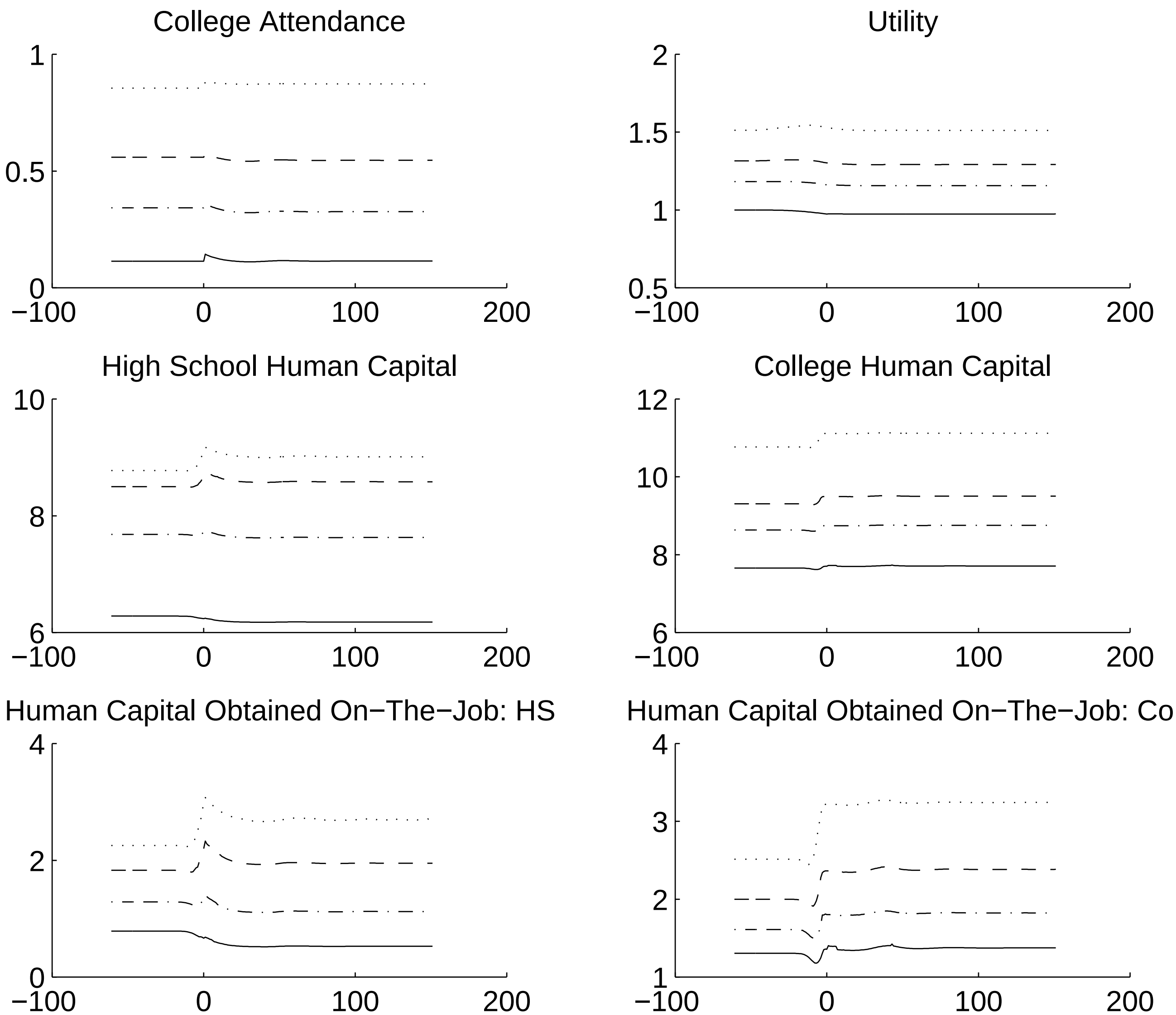
Table 4

Progressive Wage Tax to Flat Wage Tax
Holding Flat Capital Tax Rate Constant,
Comparison across Cohorts and Time,
Percentage Change in Outcomes,
Base Case

	One Year	Five Years	Ten Years	Fifty Years	Long Run
Changes Across Cohorts:					
College Enrollment	4.71	2.82	1.14	-0.26	-0.60
HC Stock Per HS Grad	2.14	2.33	2.46	2.74	2.78
HC Stock Per Coll Grad	0.90	0.54	0.14	-0.42	-0.39
Type 1:					
College Enrollment	26.12	16.77	8.86	1.89	0.51
HC Stock Per HS Grad	-0.59	-0.87	-1.22	-1.62	-1.61
HC Stock Per Coll Grad	0.87	0.86	0.55	0.71	0.69
OJT HC High School	-12.99	-18.44	-25.80	-33.06	-32.93
OJT HC College	7.15	7.05	3.31	5.59	5.41
Utility	-2.44	-2.50	-2.56	-2.61	-2.62
Type 2:					
College Enrollment	4.82	1.42	-1.64	-4.27	-4.89
HC Stock Per HS Grad	0.85	0.41	-0.09	-0.69	-0.67
HC Stock Per Coll Grad	1.33	1.30	1.28	1.39	1.39
OJT HC High School	9.15	3.04	-4.76	-12.79	-12.63
OJT HC College	11.90	11.45	11.76	13.25	13.33
Utility	-1.48	-1.63	-1.77	-1.94	-1.96
Type 3:					
College Enrollment	2.57	0.86	-0.73	-1.99	-2.35
HC Stock Per HS Grad	2.97	2.38	1.80	0.96	0.99
HC Stock Per Coll Grad	2.06	2.05	2.00	2.13	2.13
OJT HC High School	27.53	21.36	15.16	6.55	6.74
OJT HC College	18.29	18.08	17.62	19.24	19.28
Utility	-0.76	-0.96	-1.15	-1.36	-1.39
Type 4:					
College Enrollment	3.20	2.80	2.44	2.20	2.11
HC Stock Per HS Grad	4.54	4.02	3.51	2.64	2.67
HC Stock Per Coll Grad	3.24	3.21	3.18	3.28	3.29
OJT HC High School	36.23	31.34	26.75	19.28	19.48
OJT HC College	28.28	28.03	27.70	28.87	29.04
Utility	0.64	0.42	0.21	-0.03	-0.07
Changes of Aggregates Over Time:					
High School HC Stock	-1.72	-0.61	-0.23	0.15	0.13
College HC Stock	-4.22	-1.21	0.13	2.36	2.16
Skill Price HS HC	-0.24	-0.40	-0.51	-0.73	-0.80
Skill Price College HC	1.57	0.02	-0.75	-2.22	-2.17
Physical Capital Stock	0.00	-1.64	-2.72	-5.12	-5.24
Interest Rate	-2.34	0.56	2.10	5.16	5.18
Aggregate Output	-2.35	-1.00	-0.67	-0.22	-0.34

(1) Each entry represents a percentage change in a variable from the original steady state.
(2) Changes across cohorts compare each cohort with a cohort in the initial steady state. “One Year” represents the cohort making schooling decisions right after the policy change is enacted.
(3) Changes across time compares a time period with a corresponding time period of the original steady state. “One Year” represents the first year after the policy change is enacted.

Figure 2
Change in Human Capital and Utility
with a Shift From a Progressive Wage and Flat Capital Tax
to a Flat Consumption Tax
(By Cohort on the Horizontal Axis)



Solid Line Ability Group 1

Dot-Dash Line Ability Group 2

Dashed Line Ability Group 3

Dotted Line Ability Group 4

For individual ability groups, the effects of progressivity on schooling are larger than in aggregate. In the long run, schooling of the first and fourth group are affected positively by the change, while schooling of the second and third are affected negatively. Since enrollment increases for the highest ability group, even though total enrollment falls, the stock of college human capital rises in the long run relative to high school (as can be seen by looking at the high school and college human capital stocks towards the bottom of the table). The disaggregate short run effects largely mirror the aggregate short run effects. The one exception appears to be the low ability group for whom enrollment increases by 26% the first year. However, one should keep in mind that only 11% of them attend college, so the 26% increase in college represents a change from 11% to 14%. These basic results on schooling can be seen in the first panel of Figure 2 as well.

Human capital acquired on the job is more complicated to analyze because it is less obvious how to measure it. The "HC Stock Per Coll Grad," which I also call the stock measure, gives the total (non-discounted) stock of college human capital supplied to the market for each cohort. Formally, for the aggregate I use

$$\frac{\sum_{t=b}^{b+T_R} \sum_{j=1}^{J} H_{sjbt}(1-I_{sjbt})N_{sjb}\mu_j}{\sum_{t=b}^{b+T_R} \sum_{j=1}^{J} N_{sjb}\mu_j}, \tag{16}$$

and for each individual ability/school group I use

$$\sum_{t=b}^{b+T_R} H_{sjbt}(1-I_{sjbt}). \tag{17}$$

In a steady state, (16) would be a measure of the aggregate supply of human capital to the workforce conditional on schooling, which is why I refer to it as the stock measure. The tax effect on this variable can be seen most clearly when conditioning on ability types. Again the long run results show only small responses of human capital investment to changes in the progressivity of the tax system ranging from a fall of 1.61% to a rise of 3.29%. The short run effects are of a similar order of magnitude as the long run effects with no obvious pattern.

The small level of change in this variable is somewhat misleading. I have used average human capital levels to measure on-the-job training. If most human capital were acquired prior to labor force entry, the effect of OJT on this measure might be small. Thus, it is possible that taxes actually have a large effect on OJT investment, but that the effect of this additional OJT on human capital stocks is small. To address this possibility, I present an alternative human capital measure. I call label it "OJT HC" in the tables and figures. It measures the difference between human capital at labor force entry and human capital at retirement, $(H_{sjbb+T_R} - H_{sjbb})$. One can see that the effect of taxes on OJT appears to be much larger when this measure is used. The tax change has two effects that go in opposite directions. The direct effect of elimination of the progressivity yields more investment, while the increase in the interest rate through general equilibrium counteracts this effect. As a result, some groups experience large increases in OJT human capital (e.g. 29% for type 4 college graduates) and others experience large decreases (e.g. -33% for type 1 high school graduates). Two things should be kept in mind when interpreting these results. First, the model was estimated under the assumption that the full rise in wages over the lifecycle is due to human capital investment as opposed to learning-by-doing or random job matching, so in a sense these results represent an upper bound on the effect of progressivity on OJT. Second, schooling and human capital are treated quite differently in the aggregate production function. When college enrollment increases, skill prices adjust moderating the effects particularly in the long run. In contrast, high OJT workers are assumed to be perfect substitutes for low OJT workers so a margin for skill prices to adjust does not exist (although interest rates can adjust). Relaxing the perfect substitutability could easily lead to much smaller long run effects, but this is beyond the scope of this study. Together, these two points suggest that the results on "OJT HC" in Table 4 and Figure 2 are upper bounds of the effects of progressivity on OJT. These results demonstrate that these effects could be very large.

Table 4 and Figure 2 also show the effects of changing the tax system on the utility of the agents measured in consumption equivalence units. The number reported represents the percentage that consumption would have to be raised for members of the pre-reform economy to yield the same level of utility as in the post-reform economy, for individuals in the given cohort.[32] In doing this calculation, I account for the nonpecuniary benefits of schooling. Interestingly, when I eliminate the progressivity I find that utility for all four groups falls in the long run, and that aggregate output also falls (by 0.34%).[33] This is consistent with the result of Nielsen and Sorensen (1997). When the tax on capital is positive, human capital is favored over physical capital, so they show that some progressivity in the tax system is desired to encourage physical capital formation. Also, since older workers (i.e. before retirement) tend to make more money than young workers, progressive taxes in part transfer money from older generations to younger generations. Abolishing progressive taxes may make future generations worse off at the benefit of those alive today.

Table 5 presents simulations of the same tax reform using parameters from alternative empirical specifications. The basic patterns are very similar to the base case. I consistently find very small long run effects on schooling with moderate short run effects, but quick transitions. When OJT is measured using the stock measure, the tax changes again lead to very small changes in the short and long run. Using the "OJT HC" measure, the effects are much less robust. Some results are as large as in Table 4, and some are smaller. The welfare effects are very similar (except that the long run utility effect for the type 4 workers changes from a very small negative effect to a very small positive effect in the first and third simulation).

In the appendix I demonstrate the basic results are robust to a number of different model specifications. I discuss the sensitivity to alternative parameterizations of the discount factor (δ), the risk aversion parameter (γ), heterogeneity in ability, the initial interest rate, and the schooling elasticity of substitution (ρ). For all but the last parameter, the results are very robust. The fact that the results differ with ρ is not surprising. When the high school and college human capital become highly substitutable ($\rho = 0.99$ in the simulation), the results are much closer to the partial equilibrium results. However, when ρ remains close to its estimated value (and within the range of estimates in the literature) the results are robust. The appendix also discusses an ultimately unsuccessful attempt to include labor supply in the model.

Table 6 and Figure 3 present results from the simulation that starts from a progressive income tax regime and switches to a flat income tax with the same tax rate on both labor and capital income. In calibrating the initial steady state, I use exactly the same tax schedule approximation and parameters as before. The only difference is that capital income is included in the calculation of tax rates. It is not at all obvious that this specification is preferable to the previous one, as both greatly simplify the tax treatment of lifecycle savings. Given lack of data on savings and tax returns in the NLSY, a more complete treatment is beyond the scope of this paper. The hope here is that these two specifications represent the extremes about taxation of capital income and the truth lies somewhere between. The first experiment is also cleaner in terms of isolating the effect of progressivity on human capital; eliminating the progressive income tax (as presented in Table 6) also changes the after-tax interest rate.

For schooling, the basic pattern is similar to the results in Table 4. The long run effect is still small (1.81%). However, the short run effects are substantially higher than in Tables 4 and 5. As in Table 4, the stock measures of human capital are small in the short and long run. The "OJT HC" measures are quite large, as before, but in this case they are consistently negative. Table 6 also reveals an interesting pattern between high school and college workers. For college students of all four types, OJT human capital becomes less negative over time, while for high school graduates of all four types it becomes more negative. This results from the change in the skill prices, which are falling for college graduates and rising for high school graduates. To see why, consider the comparison between high school educated workers during the transition versus at the final steady state. The fact that rental rates rise during the transition encourages human capital investment (OJT) since the cost of investment (wages today) falls relative to the benefit (wages tomorrow). Thus OJT investment should be higher for high school educated workers during the transition than during the final steady state when rental rates do not change.

Even though aggregate output rises only slightly, all four groups are made better off by this tax change. The differences between Table 6 and Table 4 are due to differences in the tax treatment of capital, as we

[32]That is, I assume that consumption for the pre-reform cohorts is increased (or decreased) by a constant fraction in all periods. I present the percentage that the initial steady state consumption in all periods must be raised to yield the post-reform utility.

[33]Utility falls more than output because the interest rate rises. The undiscounted level of consumption over the lifecycle remains essentially unchanged (-0.34%). Since the interest rate rises, however, more of this consumption occurs late in life. Since it is discounted, utility falls.

Table 5

**Progressive Wage Tax to Flat Wage Tax
Holding Flat Capital Tax Rate Constant,
Comparison across Cohorts and Time,
Percentage Change in Outcomes,
Alternative Parameter Estimates**

	(1)		(2)		(3)	
	Five Years	Long Run	Five Years	Long Run	Five Years	Long Run
Changes Across Cohorts:						
College Enrollment	3.64	0.53	2.54	-0.11	1.55	1.03
HC Stock Per HS Grad	0.29	-0.19	0.24	-0.03	1.36	1.24
HC Stock Per Coll Grad	0.64	1.05	1.74	1.97	0.01	-0.06
Type 1:						
College Enrollment	21.45	7.58	15.48	3.28	20.83	18.33
HC Stock Per HS Grad	-0.20	-0.66	-0.22	-0.52	0.57	0.45
HC Stock Per Coll Grad	0.14	0.27	0.92	0.66	-0.29	-0.37
OJT HC High School	-5.30	-14.83	-4.60	-8.58	2.19	1.71
OJT HC College	1.46	4.29	8.08	5.40	-15.33	-18.93
Utility	-2.08	-2.22	-2.42	-2.58	-2.40	-2.5628
Type 2:						
College Enrollment	2.77	-2.75	0.79	-4.04	-0.06	-1.01
HC Stock Per HS Grad	0.42	-0.17	0.31	-0.05	1.25	1.11
HC Stock Per Coll Grad	0.46	0.56	1.21	1.19	-0.18	-0.28
OJT HC High School	6.48	-4.34	1.40	-2.23	4.49	4.00
OJT HC College	8.33	10.47	11.08	10.97	-8.73	-12.21
Utility	-1.13	-1.41	-1.50	-1.84	-1.45	-1.70
Type 3:						
College Enrollment	1.68	-1.33	0.67	-1.89	-1.61	-2.15
HC Stock Per HS Grad	1.02	0.30	0.95	0.52	1.90	1.76
HC Stock Per Coll Grad	0.76	0.90	1.61	1.58	0.05	-0.07
OJT HC High School	15.67	3.71	5.64	2.30	6.12	5.65
OJT HC College	13.83	16.96	13.64	13.58	-0.78	-4.21
Utility	-0.52	-0.87	-0.84	-1.26	-0.83	-1.12
Type 4:						
College Enrollment	2.89	2.13	2.74	2.18	1.69	1.63
HC Stock Per HS Grad	1.41	0.60	1.46	0.97	2.29	2.14
HC Stock Per Coll Grad	1.09	1.24	2.26	2.22	0.39	0.25
OJT HC High School	20.51	7.98	7.88	4.62	6.75	6.32
OJT HC College	21.74	25.04	19.60	19.39	6.81	3.80
Utility	0.70	0.31	0.46	-0.00	0.38	0.06
Changes of Aggregates Over Time:						
High School HC Stock	-0.62	-0.66	-0.48	0.06	-0.92	0.32
College HC Stock	-0.42	1.59	-0.92	1.86	-0.12	0.97
Skill Price HS HC	0.04	-0.06	-0.31	-0.73	0.20	-0.95
Skill Price College HC	-0.10	-1.60	0.00	-1.95	-0.36	-1.39
Physical Capital Stock	-0.64	-3.20	-1.31	-4.79	-0.85	-4.25
Interest Rate	0.11	2.95	0.47	4.63	0.25	3.88
Aggregate Output	-0.54	-0.35	-0.85	-0.38	-0.60	-0.53

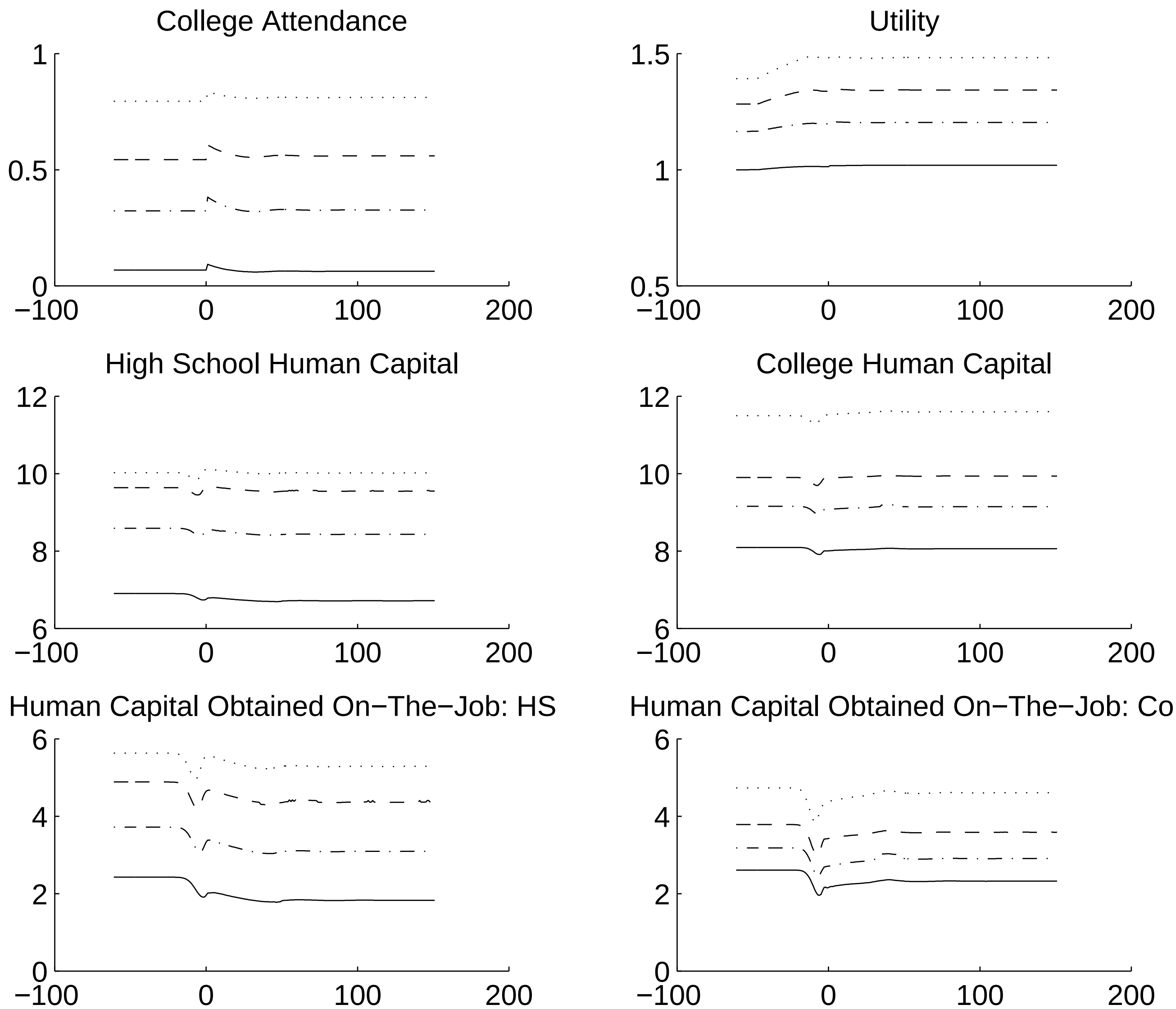
(1) See notes to Table 4.

(2) Specification (1) estimates the OJT production function parameters without taxes.

(3) Specification (2) estimates them with changing tax code.

(4) Specification (3) estimates them with changing tax code and wage structure.

Figure 3
Percent Change in Human Capital and Utility
with a Shift From a Progressive Income Tax
to a Flat Income Tax
(By Cohort on the Horizontal Axis)



Solid Line Ability Group 1

Dot-Dash Line Ability Group 2

Dashed Line Ability Group 3

Dotted Line Ability Group 4

Table 6

Progressive Income Tax to Flat Income Tax, Comparison across Cohorts and Time, Percentage Change in Outcomes Base Case

	One Year	Five Years	Ten Years	Fifty Years	Long Run
Changes Across Cohorts:					
College Enrollment	10.91	8.20	5.51	2.27	1.81
HC Stock Per HS Grad	-1.50	-1.32	-1.38	-2.16	-2.07
HC Stock Per Coll Grad	-0.74	-0.43	-0.12	0.57	0.61
Type 1:					
College Enrollment	37.14	23.59	10.49	-5.76	-7.47
HC Stock Per HS Grad	-1.65	-1.57	-1.75	-2.78	-2.70
HC Stock Per Coll Grad	-1.03	-0.93	-0.83	-0.42	-0.43
OJT HC High School	-16.95	-16.52	-17.91	-25.09	-24.59
OJT HC College	-16.40	-15.40	-14.54	-10.94	-10.93
Utility	1.75	1.76	1.80	1.93	1.93
Type 2:					
College Enrollment	18.44	13.40	8.32	2.06	1.22
HC Stock Per HS Grad	-0.53	-0.55	-0.87	-1.89	-1.83
HC Stock Per Coll Grad	-0.84	-0.71	-0.59	-0.10	-0.11
OJT HC High School	-9.02	-9.24	-11.10	-17.09	-16.78
OJT HC College	-14.52	-13.50	-12.55	-8.59	-8.63
Utility	3.26	3.18	3.09	3.02	2.99
Type 3:					
College Enrollment	11.53	9.00	6.43	3.45	2.96
HC Stock Per HS Grad	0.24	0.19	-0.04	-0.97	-0.93
HC Stock Per Coll Grad	-0.14	-0.05	0.04	0.37	0.38
OJT HC High School	-4.36	-4.74	-5.97	-10.81	-10.66
OJT HC College	-9.30	-8.62	-7.95	-5.33	-5.23
Utility	3.92	3.85	3.74	3.66	3.63
Type 4:					
College Enrollment	5.18	4.24	3.30	2.25	2.06
HC Stock Per HS Grad	0.84	0.75	0.54	-0.09	-0.10
HC Stock Per Coll Grad	0.22	0.33	0.43	0.86	0.86
OJT HC High School	-1.21	-1.72	-2.81	-6.01	-6.06
OJT HC College	-7.26	-6.51	-5.81	-2.74	-2.67
Utility	5.00	4.95	4.87	4.81	4.78
Changes of Aggregates Over Time:					
High School HC Stock	0.66	0.48	-0.23	-3.53	-3.42
College HC Stock	-0.66	0.62	1.18	2.84	2.43
Skill Price HS HC	-0.45	0.36	1.28	3.79	3.68
Skill Price College HC	0.47	0.27	0.30	-0.71	-0.47
Physical Capital Stock	0.00	1.90	3.91	6.27	6.41
Interest Rate	0.00	-1.02	-2.55	-4.86	-5.06
Aggregate Output	0.01	0.86	1.26	1.10	1.02

(1) Each entry represents a percentage change in a variable from the original steady state.

(2) Changes across cohorts compare each cohort with a cohort in the initial steady state. “One Year” represents the cohort making schooling decisions right after the policy change is enacted.

(3) Changes across time compares a time period with a corresponding time period of the original steady state. “One Year” represents the first year after the policy change is enacted.

also see a large increase in the capital stock.

I will briefly summarize the findings in this section. The results of switching from a progressive tax to a flat tax on schooling are robust across specifications. I find small long run effects, moderate short run effects, and a quick transition. In contrast, the effect of this reform on OJT is much less robust. I consistently find small effects when using the stock measure, but the "OJT HC" measure produces fairly large changes even in the long run. The sign of these changes varies across groups and specifications. Perhaps surprisingly, the welfare effects are typically favorable for progressive wage taxes in the long run. In the simulation in Table 4 even the highest ability individuals (very slightly) prefer the progressive wage tax to the flat tax. The welfare effects are different in Table 4, as virtually all workers prefer the flat income tax to the progressive income tax.

7 Simulation of Switch to a Flat Consumption Tax

The goal of this section is to estimate the effects on human capital accumulation of a switch from the current regime to a flat consumption tax. The simulations start from the same initial steady states as the simulations in section 5 and the methodology for simulating the change is identical. The taxing authority issues a once and for all switch to a new tax regime in which only consumption is taxed at a flat rate. The new tax rate balances the present value of government revenue with expenses. HLT (1998b, 1999a,b) represent the only previous work that has analyzed the effects a change in progressivity combined with a change in the tax base on human capital. I again generalize their results in a number of dimensions including looking at the transition rather than just steady states, using parameter estimates that coincide with the underlying model, and analyzing the welfare implications.

Table 7 and Figure 4 present the results of this simulation for the base case parameters. The long run change in the tax base leads to an increase in physical capital accumulation of approximately ten percent. This increase in physical capital comes only in small part at the expense of human capital accumulation. In the long run, college enrollment falls only slightly (1.25%), and within schooling groups human capital increases slightly for college graduates (1.11%) and falls by 2.74% for high school graduates.

The transition is complicated, as a number of phenomena occur simultaneously. To understand it, first consider the variables documented at the bottom of Table 7. The physical capital stock increases fairly slowly, and this increase in the capital stock leads to falling interest rates over time and rising skill prices. However, the high school skill price initially falls and then rises much more rapidly than the college price. Taking prices as given and focusing on the supply of human capital, four separate effects influence human capital acquisition. First, eliminating the progressivity of the income tax encourages human capital investment. Second, the switch to a consumption tax favors physical capital over human capital. Third, the increase in physical capital lowers interest rates, which encourages human capital investment. Fourth, the changing skill prices influence schooling and OJT in several different ways. The changes in the relative skill price between college and high school encourage schooling at first and then discourage schooling in the long run. The fact that both skill prices rise over time encourages human capital investment during the transition because raises the later benefit relative to the current cost (i.e. foregone earnings).[34] One can see in Table 7 and Figure 4 that different effects dominate for different cohorts, school types, and ability types. Schooling changes moderately over the transition. As in the previous tax reform, I find very large changes in the difference measure for on-the-job training human capital, but this time it is consistently negative and large for high school graduates. Finally, looking at the stocks of the two types of human capital one can also understand why these prices are consistent with the equilibrium.

Aggregate output rises over time in Table 7, although utility falls for most individuals. This occurs because the after-tax interest rate falls. While the total amount of consumption rises over the lifecycle, relatively more consumption takes place at the end of the lifecycle. Since later consumption is discounted, lifetime utility falls. One can also compare the consumption tax reform in Table 7 to the flat tax reform in Table 4. All individuals that are documented in these tables prefer the consumption reform to the income reform. What is not shown in Table 7, but can be seen by comparing Figure 4 with Figure 2, is that the

[34] See HLT (1998a) for more discussion of this issue.

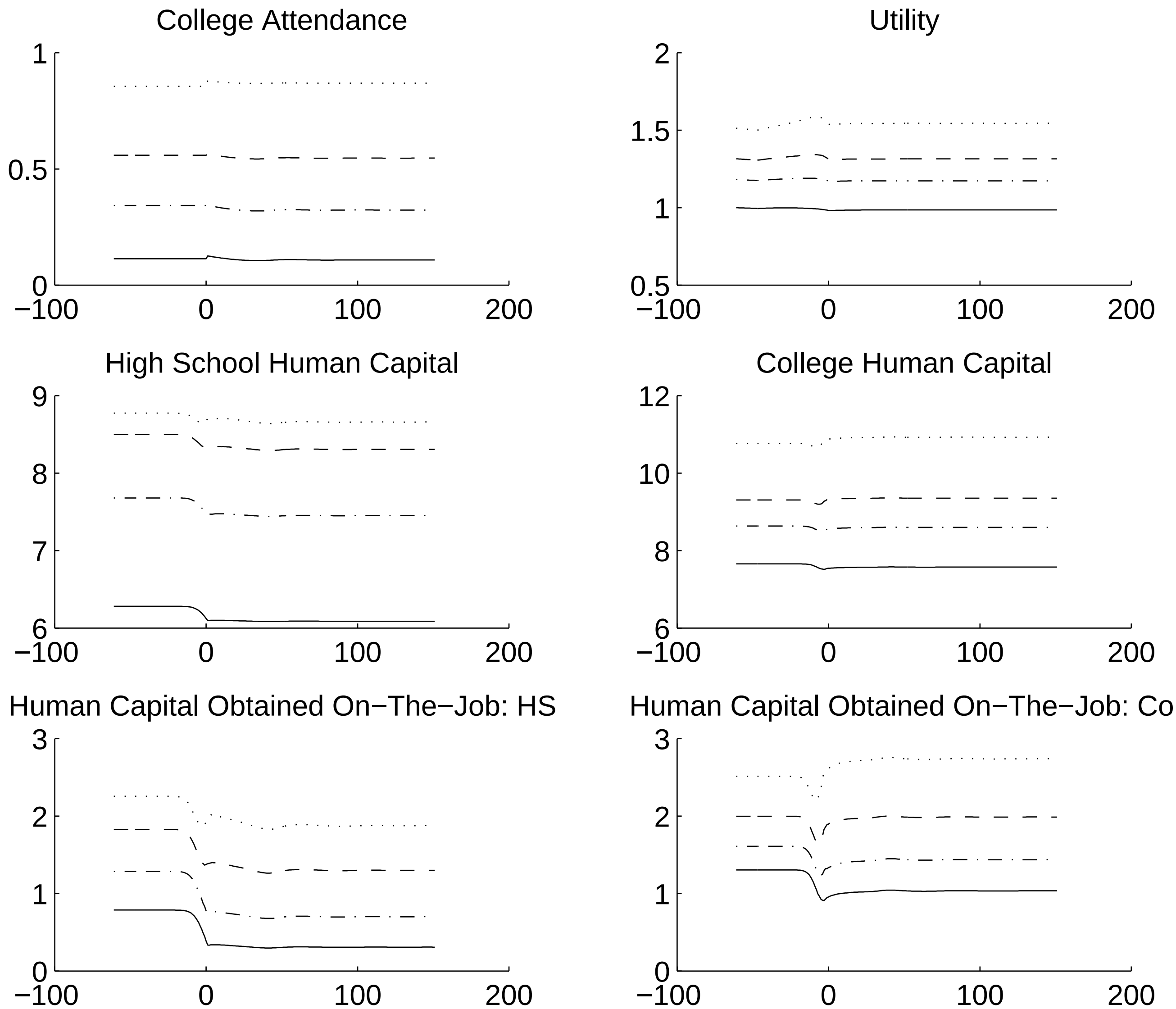
Table 7

Progressive Wage and Flat Capital Tax to Flat Consumption Tax, Comparison across Cohorts and Time, Percentage Change in Outcomes, Base Case

	One Year	Five Years	Ten Years	Fifty Years	Long Run
Changes Across Cohorts:					
College Enrollment	2.14	1.28	0.33	-1.01	-1.25
HC Stock Per HS Grad	-2.62	-2.54	-2.50	-2.80	-2.74
HC Stock Per Coll Grad	0.37	0.60	0.78	1.09	1.11
Type 1:					
College Enrollment	10.42	6.47	2.28	-3.94	-4.85
HC Stock Per HS Grad	-2.92	-2.87	-2.88	-3.10	-3.07
HC Stock Per Coll Grad	-1.45	-1.32	-1.23	-1.07	-1.08
OJT HC High School	-57.46	-56.98	-57.32	-61.19	-60.80
OJT HC College	-25.97	-24.17	-22.96	-20.61	-20.68
Utility	-1.88	-1.74	-1.62	-1.45	-1.44
Type 2:					
College Enrollment	0.21	-1.24	-2.90	-5.29	-5.70
HC Stock Per HS Grad	-2.70	-2.70	-2.66	-3.02	-2.98
HC Stock Per Coll Grad	-0.85	-0.68	-0.57	-0.37	-0.39
OJT HC High School	-41.31	-41.08	-41.06	-45.97	-45.47
OJT HC College	-16.54	-14.48	-13.08	-10.60	-10.71
Utility	-1.01	-0.86	-0.74	-0.61	-0.61
Type 3:					
College Enrollment	0.77	0.04	-0.81	-1.98	-2.22
HC Stock Per HS Grad	-1.91	-1.83	-1.85	-2.32	-2.26
HC Stock Per Coll Grad	0.20	0.31	0.38	0.52	0.51
OJT HC High School	-24.29	-23.58	-24.38	-29.47	-28.90
OJT HC College	-4.28	-2.95	-2.15	-0.52	-0.53
Utility	-0.42	-0.26	-0.14	-0.02	-0.02
Type 4:					
College Enrollment	2.71	2.42	2.11	1.73	1.65
HC Stock Per HS Grad	-0.83	-0.71	-0.80	-1.40	-1.31
HC Stock Per Coll Grad	1.07	1.23	1.32	1.50	1.49
OJT HC High School	-12.19	-11.33	-12.11	-17.44	-16.82
OJT HC College	4.48	6.21	7.14	8.99	8.96
Utility	0.89	1.07	1.20	1.34	1.33
Changes of Aggregates Over Time:					
High School HC Stock	1.91	1.17	0.48	-1.73	-1.67
College HC Stock	-0.43	-0.05	0.11	-0.01	-0.16
Skill Price HS HC	-1.01	0.17	1.22	3.05	3.02
Skill Price College HC	0.59	1.01	1.48	1.82	1.93
Physical Capital Stock	0.00	3.19	6.20	9.65	9.74
Interest Rate	0.50	-1.99	-4.29	-7.38	-7.48
Aggregate Output	0.49	1.14	1.65	1.56	1.54

(1) Each entry represents a percentage change in a variable from the original steady state.
(2) Changes across cohorts compare each cohort with a cohort in the initial steady state. “One Year” represents the cohort making schooling decisions right after the policy change is enacted.
(3) Changes across time compares a time period with a corresponding time period of the original steady state. “One Year” represents the first year after the policy change is enacted.

Figure 4
Change in Human Capital and Utility
with a Shift From a Progressive Wage and Flat Capital Tax
to a Flat Consumption Tax
(By Cohort on the Horizontal Axis)



Solid Line Ability Group 1

Dot-Dash Line Ability Group 2

Dashed Line Ability Group 3

Dotted Line Ability Group 4

oldest generations alive at the time of the policy switch prefer the income tax switch to the consumption tax switch.[35]

I next consider the robustness of the results in Table 7. Table 8 is analogous to Table 5 by using alternative parameter estimates, but it presents the results of a consumption tax reform. The basic results in Table 8 are very similar to Table 7, although some effects switch from being slightly negative to slightly positive or vise versa. In the appendix I show that the main findings are robust to various other specifications as well.

Table 9 and Figure 5 present simulations that start from a regime with a progressive tax on both capital and labor income and then switches to a flat consumption tax. The magnitudes of the effects are much larger in this case than in the previous simulation. In the long run, capital increases by 21%. As before the long run effect on schooling is very small, but in this case the short run effect is large. On-the-job training human capital falls substantially, particularly for high school workers. The welfare comparisons indicate that all workers shown in the table prefer the new regime to the old one. However, comparing Table 9 with Table 6, the later cohorts prefer the consumption tax base, but the earlier cohorts tend to favor the income tax base. These results are not surprising given previous work on the effects of switching the tax base (see e.g. Altig, et. al., 2001).

The results in this section are similar to those in section 5 in that I find small long run effects on schooling enrollment and moderate short run effects. Once again stock measures of OJT shows small effects. In contrast, the "OJT HC" measures show large changes that are typically negative in both the short and long run with magnitudes that vary across specifications. All four types of individuals prefer the consumption switch to the income switch in the long run. The highest ability workers prefer the flat consumption regime to the progressive wage regime, while the lower ability workers prefer the progressive wage regime. All four ability types prefer the flat consumption regime to the progressive income regime in the long run.

8 Summary and Conclusions

Heckman, Lochner, and Taber (1998b, 1999a,b) represent the only previous work that attempts to estimate the effect of the progressivity of the tax system on human capital accumulation. I build on their work a) by accounting for the tax system when estimating the model, b) by performing welfare analysis, c) by examining the transition from one steady state to another, and d) by adding a number of robustness checks. I first estimate a dynamic general equilibrium model of human capital accumulation on micro data. I test for robustness by estimating the model under a number of different assumptions. These estimates are then incorporated into the general equilibrium framework, and several tax reforms are simulated. My primary focus is to estimate the extent to which progressivity of the U.S. income tax distorts human capital decisions. I measure this distortion by simulating a switch from a progressive income tax regime to a flat income tax regime. I also simulate a switch to a flat consumption tax regime. I use many specifications to check the robustness of the results.

Given the roughness of the simulations, it is not surprising that the levels of the effects vary across the different specifications. However, the orders of magnitude are similar; the aggregate long-run effects of both tax reforms on college enrollment are small, consistently less than 2%. When I disaggregate the data, I find moderate long-run effects with some ability groups increasing their schooling and others decreasing schooling. The short-run effects are larger, but these effects are short lived, affecting only a small number of cohorts.

The magnitude of the effects of taxes on human capital acquired on-the-job depends crucially on the way it is measured. Measuring it as the difference in human capital between retirement and labor force entry, I find large effects that tend to go in different directions for different groups. (In some simulations these effects are over 50% for some ability types.) However, the contribution of this extra human capital to the stock of human capital is small. In particular, when I measure human capital as the amount of human capital supplied to the labor force during a worker's career, the policy effect is typically less than 3%.

I also estimate the welfare effects of these tax changes. The effects of the reform on the agents' well-being may be somewhat surprising. Table 4 shows that all four ability types prefer the progressive wage/flat capital tax system to the flat income tax regime in the long run. In contrast, workers prefer a flat income tax to a progressive income tax. I also verify conventional wisdom and previous work in showing that workers prefer

[35]The reason for this is that during retirement workers have positive consumption, but no labor earnings.

Table 8

Progressive Wage and Flat Capital Tax to Flat Consumption Tax, Comparison across Cohorts and Time, Percentage Change in Outcomes, Alternative Parameter Estimates

	(1)		(2)		(3)	
	Five Years	Long Run	Five Years	Long Run	Five Years	Long Run
Changes Across Cohorts:						
College Enrollment	1.87	0.29	0.76	-0.45	1.37	0.96
HC Stock Per HS Grad	-2.02	-1.95	-1.31	-1.43	-0.22	-0.34
HC Stock Per Coll Grad	-1.14	-0.74	0.23	0.32	-1.23	-1.27
Type 1:						
College Enrollment	10.61	3.15	4.36	-1.06	15.26	13.42
HC Stock Per HS Grad	-2.05	-2.03	-1.52	-1.67	-0.80	-0.93
HC Stock Per Coll Grad	-1.56	-1.32	-1.18	-1.18	-1.09	-1.14
OJT HC High School	-44.17	-44.06	-23.92	-25.96	-4.85	-5.39
OJT HC College	-34.22	-29.42	-21.32	-21.29	-54.04	-56.29
Utility	-1.24	-0.78	-1.74	-1.59	-2.01	-1.99
Type 2:						
College Enrollment	0.24	-2.26	-2.14	-4.25	-0.44	-1.22
HC Stock Per HS Grad	-1.93	-1.92	-1.27	-1.44	-0.25	-0.38
HC Stock Per Coll Grad	-1.35	-1.10	-0.77	-0.77	-1.18	-1.24
OJT HC High School	-37.64	-37.52	-16.37	-18.13	-2.27	-2.78
OJT HC College	-30.49	-25.32	-15.28	-15.10	-47.87	-50.02
Utility	-0.22	0.27	-0.87	-0.73	-1.06	-1.03
Type 3:						
College Enrollment	0.65	-0.61	-0.50	-1.57	-1.10	-1.49
HC Stock Per HS Grad	-1.83	-1.80	-0.89	-1.08	0.29	0.15
HC Stock Per Coll Grad	-1.20	-0.93	0.10	0.07	-1.24	-1.32
OJT HC High School	-32.85	-32.60	-10.69	-12.23	-0.30	-0.83
OJT HC College	-26.61	-21.12	-5.27	-5.52	-38.96	-41.15
Utility	0.38	0.88	-0.29	-0.16	-0.48	-0.45
Type 4:						
College Enrollment	2.16	1.52	2.27	1.90	1.87	1.77
HC Stock Per HS Grad	-1.81	-1.78	-0.58	-0.78	0.61	0.45
HC Stock Per Coll Grad	-0.90	-0.62	0.56	0.53	-1.09	-1.18
OJT HC High School	-30.26	-30.10	-7.60	-9.04	0.57	0.06
OJT HC College	-21.52	-15.70	-0.41	-0.67	-30.67	-33.14
Utility	1.59	2.10	0.97	1.12	0.71	0.76
Changes of Aggregates Over Time:						
High School HC Stock	0.93	-2.20	0.66	-1.05	0.13	-1.18
College HC Stock	0.82	-0.46	0.06	-0.12	0.70	-0.33
Skill Price HS HC	0.62	3.81	0.40	2.45	0.82	2.24
Skill Price College HC	0.69	2.54	0.82	1.78	0.42	1.63
Physical Capital Stock	3.72	12.51	3.03	8.59	3.10	7.69
Interest Rate	-2.10	-9.51	-2.00	-6.51	-2.00	-6.06
Aggregate Output	1.53	1.82	0.97	1.52	1.03	1.17

(1) See notes to Table 4.

(2) Specification (1) estimates the OJT production function parameters without taxes.

(3) Specification (2) estimates them with changing tax code.

(4) Specification (3) estimates them with changing tax code and wage structure.

Table 9

Progressive Income Tax to Flat Consumption Tax, Comparison across Cohorts and Time, Percentage Change in Outcomes, Base Case

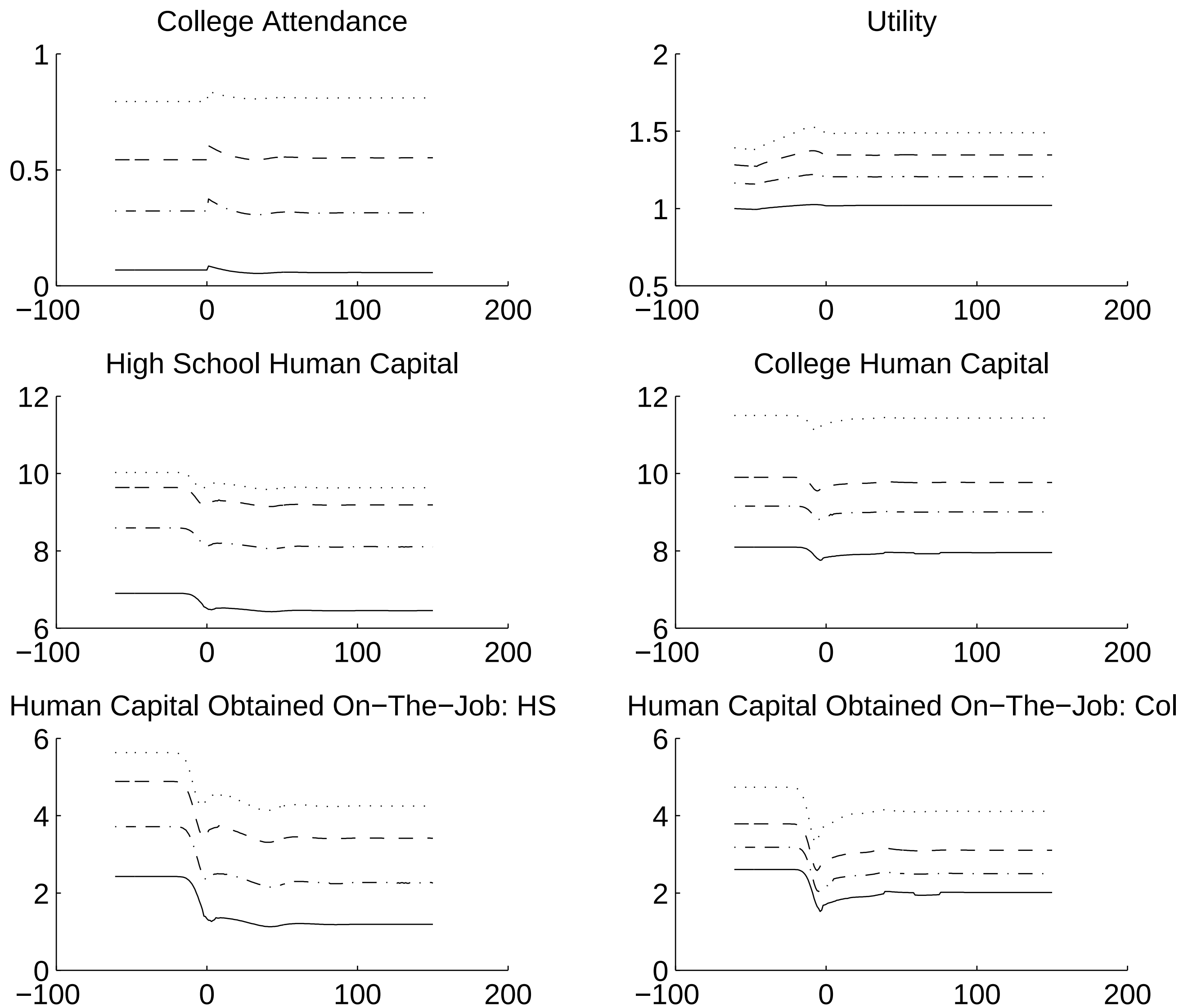
	One Year	Five Years	Ten Years	Fifty Years	Long Run
Changes Across Cohorts:					
College Enrollment	10.08	7.49	4.68	0.85	0.30
HC Stock Per HS Grad	-5.91	-5.37	-5.01	-6.00	-5.82
HC Stock Per Coll Grad	-2.62	-2.08	-1.61	-0.77	-0.7411
Type 1:					
College Enrollment	26.01	15.74	3.96	-14.00	-15.80
HC Stock Per HS Grad	-5.99	-5.85	-5.50	-6.64	-6.50
HC Stock Per Coll Grad	-3.20	-2.90	-2.62	-1.73	-1.74
OJT HC High School	-46.65	-46.07	-44.06	-51.76	-50.95
OJT HC College	-33.63	-31.82	-29.61	-22.73	-22.81
Utility	1.74	1.74	1.81	2.03	2.04
Type 2:					
College Enrollment	16.11	11.19	5.96	-1.49	-2.47
HC Stock Per HS Grad	-5.31	-4.70	-4.56	-5.91	-5.71
HC Stock Per Coll Grad	-2.90	-2.18	-2.02	-1.64	-1.65
OJT HC High School	-36.25	-33.07	-32.88	-40.28	-39.37
OJT HC College	-31.20	-25.67	-24.34	-21.28	-21.37
Utility	3.14	3.13	3.14	3.19	3.17
Type 3:					
College Enrollment	11.18	8.56	5.76	2.12	1.52
HC Stock Per HS Grad	-3.89	-3.66	-3.54	-4.74	-4.67
HC Stock Per Coll Grad	-2.23	-2.00	-1.80	-1.30	-1.33
OJT HC High School	-25.91	-24.47	-24.38	-30.32	-30.04
OJT HC College	-24.41	-22.80	-21.35	-17.81	-17.95
Utility	3.73	3.78	3.81	3.86	3.83
Type 4:					
College Enrollment	5.52	4.55	3.48	2.20	1.96
HC Stock Per HS Grad	-3.16	-2.62	-2.88	-3.97	-3.94
HC Stock Per Coll Grad	-1.80	-1.45	-1.13	-0.57	-0.57
OJT HC High School	-20.38	-18.34	-19.55	-24.61	-24.52
OJT HC College	-21.01	-18.89	-16.78	-13.12	-13.15
Utility	4.79	4.92	5.02	5.15	5.13
Changes of Aggregates Over Time:‡					
High School HC Stock	5.43	2.90	0.77	-6.06	-6.01
College HC Stock	2.95	1.91	1.39	0.08	-0.44
Skill Price HS HC	-1.77	0.73	3.00	7.71	7.61
Skill Price College HC	-0.13	1.41	2.55	3.07	3.39
Physical Capital Stock	0.00	7.14	13.59	21.16	21.39
Interest Rate	3.21	-3.38	-8.53	-15.69	-15.99
Aggregate Output	3.20	3.51	3.89	2.15	2.01

(1) Each entry represents a percentage change in a variable from the original steady state.

(2) Changes across cohorts compare each cohort with a cohort in the initial steady state. "One Year" represents the cohort making schooling decisions right after the policy change is enacted.

(3) Changes across time compares a time period with a corresponding time period of the original steady state. "One Year" represents the first year after the policy change is enacted.

Figure 5
Percent Change in Human Capital and Utility
with a Shift From a Progressive Income Tax
to a Flat Consumption Tax
(By Cohort on Horizontal Axis)



Solid Line Ability Group 1

Dot-Dash Line Ability Group 2

Dashed Line Ability Group 3

Dotted Line Ability Group 4

the flat consumption tax to the flat income tax in the long run. In a comparison of the long run effects of the consumption tax regime with the progressive wage tax (and flat capital tax) regime, higher ability types prefer the former while lower ability types prefer the latter.

Given the limited amount of research on the effects of progressivity on human capital accumulation, much more work can be done. This paper has made a number of strong assumptions for computation tractability, and it is important to know how sensitive the results are to these assumptions. Extensions may include incorporating labor supply, additional schooling groups, treating different levels of human capital as different inputs to the production function, and uncertainty. The combination of this paper and Heckman, Lochner, and Taber (1998b,1999a,b) provides a useful framework for expanding in these directions.

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Appendix: Sensitivity Analysis

This appendix considers the robustness of the results presented in Table 4 and Table 7 along a number of different dimensions. These results are presented in Table A1. Before describing the different experiments, I will first briefly explain the table. In each row I present two simulations: the flat tax reform (as in Table 4) and the consumption tax reform (as in Table 7). For each reform I present results for the first cohort, the tenth cohort, and the long run. To preserve space I document only the aggregate effects on college enrollment and the stock measure of OJT human capital.

Discount Factor My first experiment is to use different discount factors. I recalibrate the steady state to account for these new values, but change nothing else. Rather than a discount factor of 0.96, I try 0.97 and 0.94. The results are remarkably insensitive to this change.

Risk Aversion I next explore sensitivity to the utility parameter γ. I again recalibrate the model with this new value, but change nothing else. Moving γ from -3 to 0.1 and then to -6, the results are insensitive to the values.

Heterogeneity My next experiment is to ignore heterogeneity in ability. I re-estimate all of the parameters of the model without conditioning on AFQT quartile, and then recalibrate and simulate the model. Once again the aggregate measures are not sensitive.

Interest Rate In this case I re-estimate and recalibrate the model using an interest rate of 0.03 rather than 0.05. The estimates are not quite as close as in the previous cases, but the basic implications of moderate short run effects and small long run effects on schooling remain. The effects on human capital investment are of similar magnitudes as previous results.

Schooling Elasticity of Substitution I next change the elasticity of substitution between high-school-educated workers and college-educated workers. I do this by changing the parameter ρ in the aggregate production function. With this functional form, $\rho = 1$ corresponds to perfect substitutes. The results in the text set ρ to its estimated value of 0.306, but here I try $\rho = 0.99$. This matters substantially as the long run effect on schooling is now 6% rather than slightly negative. Given the difference between the partial and general equilibrium effects, it is not surprising that making college and high school workers highly substitutable changes the effect. I next experiment with ρ closer to the HLT estimate of 0.3. Setting $\rho = 0.25$ (elasticity of 1.33) and $\rho = 0.50$ (elasticity of 2) yield results very similar to those in Tables 4 and 7.

Depreciation The model I have described and estimated did not allow for any depreciation in human capital. I re-estimate and recalibrate the model assuming that human capital depreciates by 2% per year. These results are very similar to those in the base case.

Labor Supply Labor supply is by far the most difficult extension of the model that I consider in this appendix. I did not include it in the main model for two reasons. First, it can be added in a number of different ways, and figuring out precisely the right way is a paper in its own right. One's first inclination may be to assume that human capital is not an input into leisure and that people do not invest in human capital during leisure time. Neither of these assumptions seems reasonable when leisure is defined as time out of the labor force and out of school. For example, in terms of this model, I would want to treat job matching as a type of human capital: people spend time and effort in an activity that raises their wages. The low levels of labor supply that we see early in the lifecycle are partially picking up time spent investing in matching capital, which I would want to treat as part of human capital investment. As a another example, just by changing the term from "leisure" to "home production," one can see why one might be worried about assuming that human capital is useless for non-workers. As a back-of-the-envelope calculation, many women went to college in the fifties even though they had very low subsequent labor force participation. Measuring the extent to which human capital is an input into leisure and vise versa is an important topic, but is well beyond the scope of this paper.

Table A1

Sensitivity of Simulation Results to Alternative Assumptions, Comparison across Cohorts and Time, Percentage Change in Outcomes

	Flat Income Tax			Flat Consumption Tax		
	One Year	Ten Years	Long Run	One Year	Ten Years	Long Run
$\delta = 0.94$						
College Enrollment	4.70	1.16	-0.54	1.89	0.07	-1.45
HC Stock Per HS Grad	0.93	0.23	-0.25	-3.07	-2.97	-3.18
HC Stock Per Coll Grad	2.19	2.53	2.87	0.09	0.47	0.75
$\delta = 0.97$						
College Enrollment	4.72	1.12	-0.64	2.26	0.46	-1.15
HC Stock Per HS Grad	0.88	0.11	-0.47	-2.37	-2.24	-2.50
HC Stock Per Coll Grad	2.11	2.42	2.73	0.52	0.94	1.30
$\gamma = 0.1$						
College Enrollment	4.85	1.60	-0.02	3.91	1.55	-0.28
HC Stock Per HS Grad	1.61	1.35	1.07	0.54	0.63	0.12
HC Stock Per Coll Grad	2.97	3.29	3.68	2.53	2.89	3.26
$\gamma = -6$						
College Enrollment	4.52	1.09	-0.66	1.48	0.07	-1.39
HC Stock Per HS Grad	0.93	0.09	-0.55	-3.03	-2.97	-3.23
HC Stock Per Coll Grad	1.93	2.26	2.57	-0.13	0.25	0.56
No Heterogeneity						
College Enrollment	3.07	1.85	-0.01	2.00	1.06	-0.74
HC Stock Per HS Grad	1.44	-0.00	-1.20	-3.56	-3.26	-3.80
HC Stock Per Coll Grad	2.73	2.60	3.07	0.34	0.72	1.39
$r = 0.03$						
College Enrollment	7.24	2.50	0.59	6.04	1.98	0.00
HC Stock Per HS Grad	1.17	0.55	0.16	-0.89	-0.93	-1.20
HC Stock Per Coll Grad	0.68	1.17	1.47	-0.02	0.48	0.76
$\rho = 0.90$						
College Enrollment	8.30	7.13	5.87	2.75	3.70	3.44
HC Stock Per HS Grad	-0.36	-0.74	-1.12	-3.25	-3.09	-3.22
HC Stock Per Coll Grad	2.09	1.84	1.89	0.55	0.49	0.41
$\rho = 0.50$						
College Enrollment	4.60	1.57	-0.24	1.97	0.59	-0.99
HC Stock Per HS Grad	0.75	0.11	-0.42	-2.71	-2.54	-2.77
HC Stock Per Coll Grad	2.17	2.39	2.72	0.44	0.77	1.06
$\rho = 0.25$						
College Enrollment	4.71	1.14	-0.60	2.14	0.33	-1.25
HC Stock Per HS Grad	0.90	0.14	-0.39	-2.62	-2.50	-2.74
HC Stock Per Coll Grad	2.14	2.46	2.78	0.37	0.78	1.10
Depreciation 2%						
College Enrollment	5.67	1.92	0.65	2.41	0.65	-0.16
HC Stock Per HS Grad	0.11	0.09	-0.00	-1.21	-1.26	-1.40
HC Stock Per Coll Grad	0.73	1.00	1.17	-0.13	0.01	0.04

The second main reason that I did not include leisure in the model it is unlikely that the basic results of this paper would be sensitive to inclusion of leisure if it were done correctly. The measured effects of taxes on labor supply vary from small to moderate. It is not clear precisely what the effects of labor supply on human capital would be, but if human capital investment during leisure time is similar to human capital investment on the job, and if human capital is useful for home production, then the effect may be small. Putting these together will probably yield a small *partial equilibrium* effect of taxes on human capital through labor supply. Given that the general equilibrium effects on schooling are an order of magnitude smaller than the partial equilibrium effects, it seems unlikely that labor supply would change things by very much. It also seems unlikely that adding labor supply would fundamentally change the OJT results.

Despite my reservations, I incorporate leisure into the model in a simple way by assuming that no human capital investment takes place during leisure time and that leisure affects utility directly.[36] In particular, I assume that utility has an additively separable functional form, where period-specific utility has a power form and the discount rate is the same as for consumption. I estimate the model using the same basic strategy as in the rest of the paper. This did not work well. Essentially, the problem is that identification of the intertemporal elasticity of labor supply comes from the low levels of labor supply at the beginning of the lifecycle (since I only have young workers). In this type of Ben-Porath model, the shadow value of time is very high in the first few periods, so the relatively small amounts of labor supply at the beginning of life yields a very high intertemporal elasticity of labor supply. When I simulate the tax reform with this value I ran into problems. First, the model was very difficult to solve, and I had trouble with numerical convergence. Second, the results were not believable. For example, in one simulation those with the highest ability spend the first fourteen years of their working life with zero wages (they have high leisure and high human capital investment). In the last fifteen years of their working life they work 3000 hours a year (which I constrained to be the maximum time spent working in order to obtain convergence). I experimented with alternative specifications and obtained similar types of strange behavior. In the end, I think that incorporating labor supply into this model is important, but one must be very careful in doing it. In particular, incorporating search and matching likely could have a major impact on the interpretation of the low levels of labor supply early in the working life and likely would yield more reasonable results. Again, this type of study would be very important in its own right, but is well beyond the scope of this paper.

[36] Heckman (1975) also uses this specification.