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6 Taxes and Capital Formation: How Important Is Human Capital?

James Davies and John Whalley

6.1 Introduction

Work on how taxes affect both capital formation and welfare has produced a wide variety of conclusions spanning the range from little or no effect (Harberger 1964, Wright 1969), to large effects (Summers 1981), to intermediate (Ballard, Fullerton, Shoven, and Whalley 1983, Auerbach, Kotlikoff, and Skinner 1983 [AKS]), to random (King and Fullerton 1984). Despite, or perhaps because of this wide variety of conclusions, the study of tax effects on capital formation has been one of the most active areas of public finance research over the last ten or so years.

In this paper, we reevaluate some of this work in light of the fact that little of it explicitly considers how tax factors enter when accumulation of both human and nonhuman capital occurs. We motivate the paper by recognizing the potential quantitative dominance of human relative to nonhuman capital, and build on a limited but still important taxation and human capital literature. This begins with Boskin (1975) who argues that human capital is taxed on a consumption tax basis and is tax preferred relative to nonhuman capital; and Kotlikoff and Summers (1979) (KS) who show how interasset (human/nonhuman) substitution effects in a growth model can change the way taxes affect steady-state behavior. It also includes Driffill and Rosen (1983) (DR) who analyze the effects of taxes for a single consumer life-cycle optimization prob-

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lem with both human and nonhuman capital. Their simulation results show that in a partial equilibrium setting welfare costs of income taxes rise when human capital is also taken into account.[1]

Our analysis departs from this work both in considering a full dynamic model in which human and nonhuman capital substitution effects on the production side and trading in nonhuman assets among overlapping generations occur, and in computing transition paths following tax changes as well as steady states. We also develop clear intuition as to the ways in which the presence of human capital affects tax analysis. We stress both the sequential nature of asset accumulation over the life-cycle and the implications that follow for assessments of the effects of taxes on capital formation.

Compared to models that do not separately identify human and nonhuman capital, there is an additional welfare cost associated with taxes on the return to financial assets since they not only change the time profile of consumption over the lifetime as in a one-asset model, but in addition affect asset accumulation decisions. The resulting welfare losses are in addition to those emphasized in existing single asset work. Furthermore, taxes on the income return to savings affect the composition of savings, with substitution out of nonhuman capital into human capital. Therefore, two substitution margins affect financial savings rather than one as in a traditional life-cycle model. Savings in aggregate falls, in the presence of an income tax, but savings in the form of human capital rises.

We use a numerical simulation model based on earlier joint work (Davies, Hamilton, and Whalley 1989) into which we incorporate human capital to analyze how these effects interact. Human capital is incorporated into a 50-period lifetime, overlapping generations equilibrium structure. Simple, and familiar, functional forms are used: consumers have constant relative risk aversion (CRRA) utility functions, and the aggregate production function is Cobb-Douglas. A constant elasticity human capital production function is also used. The model is calibrated to a stylized data set for the U.S. economy in the mid-1970s, closely related to that used by Summers (1980, 1981). Sensitivity of the results to alternative parameter values is also examined.

Our central-case results indicate that, in a dynamic one-sector economy of the Summers type, unlike the partial equilibrium analysis of Driffill and Rosen, incorporating human capital may not change the full dynamic welfare impact of alternative tax experiments markedly. For a move from an income to either a consumption or wage tax there is almost no change in long-run welfare effects from incorporating human capital. On the other hand, *impact* effects on savings are larger, and the transition to a new balanced growth path with endogenous human capital is more rapid since stocks of both factors can adjust. We therefore find ourselves in disagreement with the partial equilibrium conclusion that welfare costs of income taxes are larger with endogenous human capital. This conclusion is, in part, a reflection of the well-known result that in full dynamic equilibrium analysis the importance of distortionary tax wedges tends to be eclipsed by gains due to movement toward the golden rule capital intensity. However, it also reflects the fact that *in steady-state comparisons* we find that there is little distortion in the pattern of human capital investment.

The paper is organized as follows. The next section reviews the effects of taxes on human capital accumulation in a 2-period framework, and discusses how insights from partial equilibrium analysis need to be modified in light of full dynamic equilibrium analysis. Section 6.3 then lays out the formal structure of a multiperiod life-cycle model of consumption, leisure, and human capital accumulation. The implementation of this general structure in our simulations, which for computational simplicity endogenize human capital but take leisure as fixed, is explained in section 6.4. Results of the simulations are presented in section 6.5.

The conclusion to the paper emphasizes how a number of features that potentially complicate tax analysis are not captured in the simulation model presented here. Especially important is the omission of endogenous labor—leisure choice since there is an important mutual interaction between labor supply and human capital investment plans. Also important is progressivity in the income tax, which for computational reasons we do not incorporate. Liquidity constraints have also not been modeled, and we assume that all human capital reflects accumulation of general rather than job-specific training. Alternative models of the educational process, such as screening, in which education has only redistributive effects rather than increasing the productivity of workers either by enhancing their skills or producing information of value in job-worker matching (both of which are captured by the human capital approach), are not considered. Also, we have not estimated the possible effect of rationing of access to either publicly funded or prestige maximizing educational institutions, under which tax effects on human capital formation have a lump-sum element. Finally, we have not examined the role of intergenerational links within the family in helping to determine patterns of human capital formation. Our analysis is, therefore, a first foray into an area of investigation from which most public finance economists have generally kept their distance. Further work may therefore alter the thrust of the results presented here, although we believe our insights on both partial equilibrium effects and differences between partial and full dynamic equilibrium analysis will endure.

6.2 Human Capital and the Analysis of Tax Treatment of Capital Income

Human capital is best thought of as the accumulation of a future income stream through the investment of time to provide for higher income in the future. As an asset, it is different from real capital. In the absence of slavery, individuals cannot purchase others' human capital or sell any which they accumulate themselves. Adjustments to the stock can only occur at a limited rate—in the case of additions sometimes at a fairly quick rate, but in the opposite direction only at the rate of depreciation. Being individual specific, human capital can also not be bequeathed or given away.[2]

Analyzing the ways in which human capital affects the standard literature analysis of the tax treatment of capital is complicated by the fact that human capital occurs in both "general" and "specific" form. General human capital consists of skills that are portable across firms, whereas specific human capital consists of skills that are only useful while working for a particular employer. While it is relatively easy to model the accumulation of human capital when all skills are general, this is not the case where skills are job-specific to some degree. Human capital theory merely predicts that the costs of and returns to investment in specific human capital (usually acquired on the job) will be shared between worker and employer, with the precise outcome being determined by implicit bargaining between the two.[3]

To the extent that firms bear some of the costs of specific training, human capital accumulation may also be directly affected by business taxes, and in particular the corporate income tax. Under the latter, training costs are fully deductible and the returns to the firm fully taxable. Neglecting the imperfect utilization of tax losses, this means that the employer's portion of investment in specific training receives cash-flow tax treatment at the corporate level. Unfortunately, there is no consensus on the determinants of how employers and employees share the costs of specific training. The result is that the present study, like previous work incorporating human capital in the public finance literature, is mostly confined to the analysis of general human capital.

There are also complex issues concerning the relationship between schooling and screening (see, e.g., Spence 1973). In the extreme, if education represents entirely unproductive signaling it is a wasteful activity and ought to be discouraged.[4] More sophisticated models, recognizing that signals may either represent useful skills or play a useful role in job matching, have less draconian policy implications. However, to the extent that education represents signaling there is usually an argument that private markets generate "too much" education. Tax systems that encourage human capital investment therefore appear especially inappropriate. In the remainder of this paper, for the most part we put these complications on one side, treating human capital as general rather than specific and rejecting the pure screening interpretation of schooling.

As pointed out by Boskin (1975), in his notes on the tax treatment of human capital, human capital basically receives consumption tax treatment. Investors in human capital forgo other uses of time when investing, which is equivalent to forgoing gross of tax income to save in the form of human capital. Supplying labor and changing consumption between periods via human capital accumulation, therefore, only involves single taxation as under a consumption tax, rather than double taxation as under an income tax. Investment in the asset is treated much like a tax shelter, with investment implicitly yielding a tax break. Taxes only apply to the income return to the asset.[5]

In the traditional 2-period consumption diagram commonly used to show how taxes influence capital accumulation and savings, human capital can be seen to complicate the analysis and, if anything, amplify the welfare cost of intertemporal tax distortions. How this occurs is shown in figures 6.1 and 6.2. In figure 6.1 (the no-tax case), the individual is endowed with an "unimproved" earnings stream E lying on the 45° line. By forgoing consumption in period 1 (C_1), the individual can transform consumption opportunities between periods according to the transformation frontier AD. The curvature of this frontier reflects the diminishing marginal rate of return to human capital investment.[6]

Given the interest rate the individual faces, optimizing behavior involves moving from the endowment point A to the tangency B (which maximizes lifetime wealth) through human capital investment. Utility maximization implies moving from point B to consumption point C by accumulating financial assets in period 1 (saving) and then reselling them in period 2. Note that the horizontal intercept of the effective budget constraint, ZZ, gives the discounted present value of lifetime earnings; that is, it is a measure of *human*

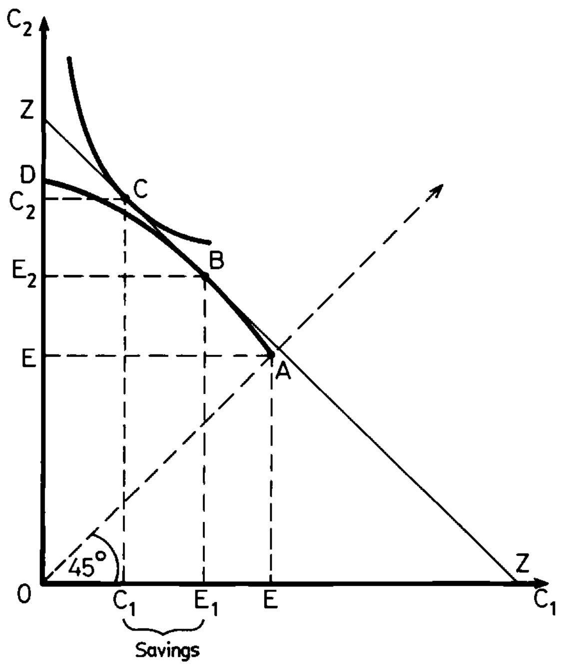

Fig. 6.1 Two-period intertemporal consumption smoothing in the no-tax case

wealth. It is important to distinguish the latter, which is a value, from *human capital*, which is a physical stock.

Optimizing behavior thus implies a two-stage process. Human capital accumulation occurs up to the point where the rate of return on human capital equals the interest rate, *r*. Accumulation or decumulation of financial assets then occurs, as needed, to smooth the modified earnings stream, *B*, into the desired consumption stream, *C*. Although figure 6.1 illustrates a case with positive saving, an outcome where positive accumulation of human capital occurs in the early years of the life-cycle, but there is net borrowing, could also occur.[7]

The effects of an interest income tax that applies only to the return to financial assets in this framework are shown in figure 6.2. The budget constraint *ZZ* from figure 6.1 becomes more shallowly sloped in the presence of the tax, as represented by *Z'Z'* in figure 6.2 This results in more accumulation of human capital (represented by the movement from *B* to *B'* for wealth-maximizing human capital accumulation), smaller total savings, and considerably smaller financial savings because of the substitution effect. The inter-asset distortion created by the tax yields an additional welfare cost beyond that recognized in existing dynamic tax analyses (i.e., the tax-induced over-accumulation of human capital) and acts to reduce savings as conventionally

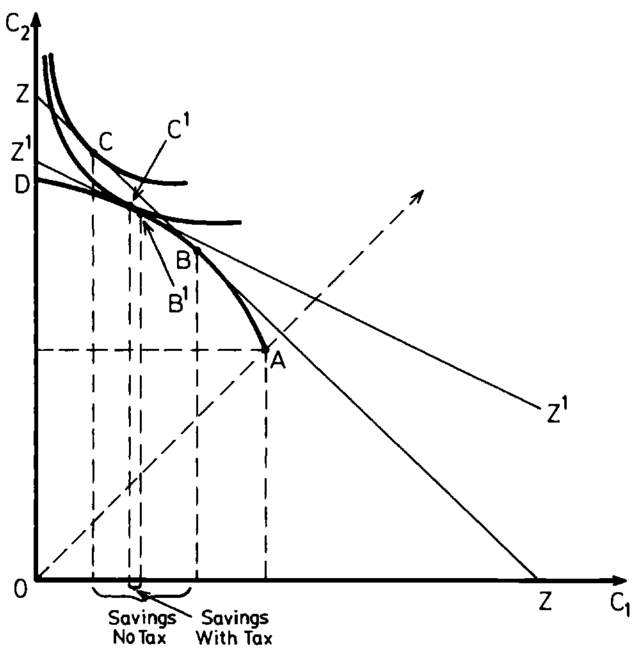

Fig. 6.2 Two-period intertemporal consumption smoothing in the presence of an interest income tax

measured, that is, in the form of accumulation of financial assets. This additional effect of taxes on saving is not widely recognized in the literature.

Diagrams of this type can also be used to illustrate the impact of wage or consumption taxes (see Davies and St-Hilaire 1987, 77–82). Either a proportional wage or consumption tax will radially shift the earnings transformation frontier, *AD*, inward. Although savings in the form of nonhuman capital will be reduced, the optimal human capital investment plan will be unchanged, and if revenues are returned to the individual via lump-sum transfers, the budget constraint will revert to its pretax position, *ZZ*. Savings in nonhuman form may, however, still differ from their pretax value if the transfer payments alter the timing of income receipts over the lifetime. A proportional wage tax used to finance social security payments in the second period, for example, would leave human capital investment unchanged but would reduce private saving.

Progressivity of either wage or consumption taxes would also alter this simple picture. With smoothly increasing marginal tax rates under a wage tax, the slope of the *AD* locus in figure 6.1 would be lower in absolute value at all points (except *A*). The result would be reduced human capital investment. Human capital investment would also be distorted somewhat under a simple progressive annual expenditure tax, but there would be no distortion under a *Blueprints*—style lifetime consumption tax (see again Davies and St.-Hilaire 1987, 79–82).

Note that if human capital is considerably larger in value terms than real capital, as many believe, and if there is significant substitution between the two, then in percentage terms, the differential impact of taxes on savings from either including or not including human capital in the analysis will be correspondingly larger.[8] Also, as one moves outside of the partial equilibrium analysis represented by figures 6.1 and 6.2, one might expect that the rate of return on the smaller real capital stock from the production side of the economy would be largely dictated by the rate of return on the larger human capital stock. Thus, the rate of return on real capital might be dictated largely by the rate of return on human capital, and changes in the tax treatment of financial assets would have relatively little impact on its own net of tax rate of return since human capital is the dominant factor of production. In a dynamic context, if the elasticity of substitution in production between human and nonhuman capital were high and intertemporal consumption elasticities were small, then changes in the tax treatment of real capital would largely affect the composition of wealth rather than its size. Thus, arguments that current tax treatment of real capital substantially increases consumption and reduces capital accumulation need revision once endogeneity of gross of tax rates of return on real assets is included.

As we stress above, despite the various effects of income taxes on intertemporal behavior and resource allocation in the presence of human capital, there has been relatively little work analyzing them. Kotlikoff and Summers (1979) (KS) and Driffill and Rosen (1983) (DR) have made the most important contributions. KS analyze steady-state tax incidence in an overlapping generations growth model with a schooling choice for young people and a labor-leisure (i.e., "retirement") choice for old people. They show that capital income taxes are partly shifted onto labor by induced increases in human capital accumulation. On the other hand, if wage taxes reduce labor supply (i.e., induce earlier retirement), they are partly shifted onto capital since labor supply declines and the capital stock increases as a result of increased saving for the now-longer retirement period. KS do not analyze the welfare costs of alternative taxes. Our paper extends their work by moving beyond steady-state comparisons to include the transition between steady states, by using a multi-period framework, and by using specific functional forms to simulate both tax incidence and welfare costs in a growth model incorporating human capital.

DR explicitly investigate the welfare effects of capital income taxes with endogenous leisure choice and human capital formation, but in a partial equilibrium single consumer setting. They use the continuous-time human capital life-cycle analysis of Blinder and Weiss (1976) but utilize specific functional forms. Several points emerge from their work. Proportional income taxes increase human capital accumulation. An increase in income taxes reduces net of tax earnings, which reduces consumption of leisure and increases time devoted to training. Also, an income tax reduces the net of tax interest rate, which increases human capital accumulation. Their results suggest that the excess burden of income taxes is lower if human capital formation is (incorrectly) treated as exogenous. A failure to explicitly model human capital accumulation decisions leads to an overestimate of tax revenues because increased human capital investment implies a smaller income tax base. DR also find that consumption taxes have a lower excess burden than proportional income taxes, and a failure to take human capital explicitly into account downward biases estimates of efficiency gains from moving from an income to a consumption tax.[9]

Ideally, analyses of the tax treatment of human capital should also take into account progressivity in the income tax and the effects of public subsidies covering the direct costs of formal education. Individuals typically invest in human capital in years in which they are in low marginal brackets but generate a higher return to labor in years when they are in higher brackets. Although such progressivity effects have been substantially weakened by recent tax reforms in the United States and elsewhere, they nonetheless ought to discourage human capital formation. One cannot be sure whether the result of adding more "realism" would be to show that taxes and transfers are less encouraging to human capital formation than the proportional tax analysis would suggest, however, since there are very heavy public subsidies to educational institutions.[10] These likely imply a rate of subsidy to the direct costs of formal education exceeding significantly the relevant marginal tax rate for young people. The extent to which such subsidies offset the discouraging effect of progressivity in the tax system is unclear.

All the above analysis is, however, dependent both on partial equilibrium assumptions and, implicitly, the assumed perfect substitution between human and physical capital in production. The questions we address are how significant all these effects are in dynamic general equilibrium. How large are the additional welfare costs of tax distortions of savings when we move to a more standard formulation with imperfect substitution of factors in production? How much do induced changes in the rental rate on human and nonhuman capital tend to dampen behavioral responses? How serious a problem is the mismeasurement of the effects of taxes on savings?

6.3 A Life-Cycle Growth Model with Endogenous Human Capital Formation

The model we use to investigate the effects of incorporating human capital into analysis of taxes on capital formation is an extension of the overlapping generations life-cycle simulation models that, following Summers (1980, 1981) and Auerbach, Kotlikoff, and Skinner (1983) (AKS), are now widely used in the literature. In order to achieve comparability across models we adopt the same structure as Summers, even to the point of largely using the same set of base parameters in model simulations. We simulate the effects of various tax changes, and present both transitional and steady-state results. As in Summers (1980), for simplicity we assume myopic expectations along the transitional path. We differ in allowing endogenous investment in (general) human capital.

In this section we set out the structure of the now-standard model of consumption, leisure and human capital choice for an isolated individual, and indicate how it would, ideally, be embedded in a life-cycle growth model. This allows us to discuss some of the theoretical background behind the consequences of alternative taxes for capital formation and welfare that are captured in the simulations reported later, as well as effects that are not possible in our fixed-leisure simulations. The approach we describe can be used in alternative variants in which human capital and/or leisure can be fixed. Human capital fixed but leisure variable is the AKS case; in Summers's case both are fixed. Our numerical simulations reported in section 6.5 are only for the fixed-leisure case, since this is the simplest to compute.

6.3.1 Life-Cycle Optimizing Behavior

In a more general model with leisure endogenous, individuals each seek to maximize an intertemporal utility function:

$$(1) \qquad U(C_1, \ldots, C_T; \ell_1, \ldots, \ell_T),$$

where C_t and ℓ_t represent consumption and the fraction of time spent in leisure in period t, respectively.[11] Without taxes, the lifetime budget constraint is given by:

(2)
$$\sum_{t=1}^{T} \frac{C_t}{(1+r)^{t-1}} \leq \sum_{t=1}^{T} \frac{E_t}{(1+r)^{t-1}},$$

where E_t is earned income in year t, and r is the interest rate. Each household assumes r is time invariant (under the assumed myopic expectations) and, additionally, implicitly assumes that the price of consumption goods does not change over time. In order to introduce taxes, let E_t be net of wage or income taxes, replace r by the net of tax interest rate r_n, allow a proportional consumption tax at rate u, and assume revenues are redistributed as lump-sum transfers R_t. The budget constraint then becomes:

(2′)
$$\sum_{t=1}^{T} \frac{C_t(1+u)}{(1+r_n)^{t-1}} \leq \sum_{t=1}^{T} \frac{E_t + R_t}{(1+r_n)^{t-1}}.$$

Earnings are proportional to the stock of human capital, H_t, and the time available for earning:

(3)
$$E_t = W_t^n H_t (1 - s_t - \ell_t) \quad t = 1, \ldots, T,$$

where W_t^n is the net of tax rental rate on human capital in period t, and s_t is the proportion of time spent in human capital accumulation via schooling or on-the-job training. Here H_t is the (depreciated) sum of endowed human capital, H_1, and all additions to the human capital stock made in the past, h_τ:

(4)
$$H_t = \begin{cases} H_1 & t = 1 \\ \dfrac{H_1}{(1+\delta)^{t-1}} + \displaystyle\sum_{\tau=1}^{t-1} \frac{h_\tau(s_\tau, H_\tau)}{(1+\delta)^{t-\tau}} & t = 2, \ldots, T, \end{cases}$$

where δ is the depreciation rate. For convenience, we assume δ to be constant over time.

To understand how life-cycle optimizing behavior operates in this framework, it is helpful to first consider how any household would solve the above problem if the time path of ℓ_t were fixed at the optimal level ℓ_t^*, since if ℓ_t is fixed, the human capital investment problem and the intertemporal utility maximizing problem decompose.

With fixed leisure, optimal human capital investment is simply that which maximizes the value of lifetime earnings. Given optimal human capital investment, the individual then maximizes $U(C_1, \ldots, C_T; \ell_1^*, \ldots, \ell_T^*)$ subject to (2) where the E_ts are now fixed, that is, finding the optimal consumption path reduces to a familiar (and simple) problem.

Neglecting the possibility of corner solutions, and taking the special case where, for simplicity, H_t does not affect h_t, the solution to the wealth-maximizing human capital investment problem is characterized by the first-order conditions:

(5) $$\frac{\partial h_t}{\partial s_t} \sum_{\tau=t+1}^{T} \frac{W_\tau^n(1-s_\tau-\ell_\tau^*)}{[(1+r_n)(1+\delta)]^{\tau-t}} = W_t^n H_t \quad t = 1, \ldots, T,$$

which imply that the marginal benefit of spending additional time in schooling (the left-hand side) must equal forgone earnings (the wage rate, $W_t^n H_t$) at each time t.

In equation (5) depreciation plays the same analytical role as r_n; that is, both affect the discounted present value of the returns to human capital investment in the same way. Also, we can see that by reducing r_n, interest income taxes raise the (private) marginal benefit of human capital investment and thereby distort human capital investment decisions (see Heckman 1976, S27). We also note that a proportional wage tax would have no effect on human capital investment in the absence of any change in the optimal ℓ_t, since equal proportional changes in the values of W_t^n leave (5) unchanged. Heavier wage taxes later in life under a progressive tax reduce investment in human capital, however, since they lower W_t^n early in life less than later in life in the left-hand side of (5).

The wealth-maximizing human capital investment plan tends to produce large but falling investment in human capital in early years. At some point before retirement (or the end of the life if there is not a fixed retirement age), human capital reaches a peak, where gross investment in human capital has declined to annual depreciation. Beyond this peak there is a decline in the human capital stock, but despite the fact that there is no scrap value, the stock typically remains large at the retirement point since decumulation is limited by the rate of depreciation. (This typical pattern appears in our simulation results discussed below.)

The age profile of earnings produced by this optimal human capital plan differs considerably from that assumed in some previous work in the public finance literature. Summers (1980, 1981), for example, has all workers paid the same amount at a particular date, irrespective of age. The only reason for earnings growth over the life-cycle is that there is labor-augmenting technical progress. In contrast, earnings growth due to human capital investment generates a concave age profile of earnings. Given a particular age profile of desired consumption, and holding the present value of lifetime earnings constant, such a concave profile is less conducive to saving in early years and just before retirement. Aggregate saving will therefore generally differ between models where wage growth is generated solely by technical progress and those where human capital investment enters.

Changes in taxation may alter the age profile of earnings due to induced changes in human capital investment. An interest income tax, for example, encourages human capital investment and makes the age profile of earnings steeper. Holding the consumption profile constant, this tends to reduce saving in nonhuman form.[12]

In order to see how the labor-leisure choice is determined over time in this model, assume that the human capital investment plan has been fixed on an initially optimal path, $H_1^*, \ldots, H_T^*$. Associated with $H_1^*, \ldots, H_T^*$ are optimal values of $s_1^*, \ldots s_T^*$, which we will also treat as fixed for the moment. Given these, one can maximize (1) subject to (2′), where the E_ts are given by:

$$E_t = W_t^n H_t^* (1 - s_t^* - \ell_t) \quad t = 1, \ldots, T. \tag{3'}$$

Assuming an interior solution, the first-order conditions are given by:

$$\left.\begin{cases} \text{(a) } U_{1t} + \dfrac{\lambda(1+u)}{(1+r_n)^{t-1}} = 0 \\ \text{(b) } U_{2t} + \dfrac{\lambda W_t^n H_t^*}{(1+r_n)^{t-1}} = 0 \end{cases}\right\} t = 1, \ldots, T, \tag{6}$$

where U_{1t} and U_{2t} indicate partials with respect to consumption and leisure respectively in year t. If the optimal solution for any period were that $\ell_t = 1$ for that period, (6b) would become the inequality:

$$U_{2t} > \frac{\lambda W_t^n H_t^*}{(1+r_n)^{t-1}}. \tag{6b'}$$

The first-order conditions yield the following set of relationships:

$$\left.\begin{cases} \text{(i) } \dfrac{U_{2t}}{U_{1t}} = W_t^n H_t^*/(1+u) \\ \text{(ii) } \dfrac{U_{1t}}{U_{1t'}} = (1+r_n)^{(t'-t)} \\ \text{(iii) } \dfrac{U_{2t}}{U_{2t'}} = (1+r_n)^{(t'-t)} \dfrac{W_t^n H_t^*}{W_{t'}^n H_{t'}^*} \end{cases}\right\} t = 1, \ldots, T. \tag{7}$$

Here (7i) indicates that the marginal rate of substitution (MRS) between goods and leisure in any period equals the net wage rate deflated by the rate of consumption taxation. The Euler relationship, (7ii), indicates that the marginal utility of consumption must decline at a rate equal to r_n, and (7iii) indicates that the MRS between leisure in different time periods is related to r_n in the same way as the MRS for consumption, except that changes in the wage rate alter the opportunity cost of leisure as well and need to be taken into account.

In general, the greater the amount of leisure taken over the lifetime, the less is the inducement to human capital accumulation, as can be seen in (5). Thus in models like KS, where both leisure and human capital are endogenous, taxes that tend to reduce labor supply are likely to also reduce investment in human capital, producing a second-round decline in the effective supply of labor. The age profile of earnings becomes less steep, leading to increased saving. Thus there is a tendency for the capital-labor ratio to rise a fortiori, so that, for example, a wage tax may end up largely shifted onto capital (see KS).

On the other hand, from (6) and (7) human capital investment has a major impact on the time path of leisure, via its influence on the wage rate. Thus, features of the tax or education systems that encourage human capital investment, such as interest income taxes or subsidies to higher education, produce substitution away from leisure toward consumption of goods, as well as leisure substitution between periods to the extent that the age profile of net wage rates is altered. By making the age profile of earnings steeper, they also lead to reduced saving.

There are also potentially important interactions between leisure and consumption of goods. Taking the household production view, home time and goods may be regarded as inputs in a home production function, where the output is a bundle of *commodities*. A rising price of time (i.e., a higher wage rate) leads to substitution in household production away from time toward goods within a period (7i), but also to substitution away from consumption of commodities in periods when they are made relatively more expensive by the higher wage (7iii). It appears that the latter influence tends to dominate, since it is widely observed that both expenditures on goods and wage rates are hump shaped over the life-cycle, but leisure time has a U-shaped profile.

The simulation model, whose results are reported later in this paper, has so far only been implemented with exogenous leisure. One implication is that we are unfortunately not able to examine computationally the consequences of the interaction between tax effects on labor supply and human capital investment, some of which we have outlined above. In addition, with CRRA preferences the model generates constant proportional desired growth of consumption over the lifetime, which differs both from the observed pattern, and what would be expected on the basis of the full model sketched above. Given a particular age profile of earnings, quite a different pattern of savings is likely to be generated. Also, tax experiments can only affect the *level* of the consumption profile and not its shape, so that, for example, the rich consequences of interactions between goods and leisure cannot be captured.

6.3.2 The Production Side and the Aggregate Economy

As in Summers (1981) and AKS (1983) we assume a constant rate of substitution (CRS) aggregate production function that produces a single commodity that can be used for either consumption or capital accumulation. However, inputs are no longer labor and capital, but instead are human and physical capital:

$$(8) \qquad Y_t = F(H_t^m, K_t).$$

Note that the stock of human capital employed in production, H_t^m, is only part of the overall stock, $\bar{H}_t$, since the latter can also be employed in leisure or training.

Aggregate use of these factors in any period must equal the economy's endowment, $\bar{K}_t$ and $\bar{H}_t$. In the simple case of constant population the latter evolve according to the equations of motion:

$$(9)\qquad \begin{cases} \text{(i) } \bar{K}_t = \bar{K}_{t-1} + \sum_{j=1}^{T+1} (K_t^j - K_{t-1}^{j-1}) \\ \text{(ii) } \bar{H}_t = \bar{H}_{t-1} + \sum_{j=1}^{T+1} (H_t^j - H_{t-1}^{j-1}), \end{cases}$$

where K_t^j and H_t^j represent the physical and human capital held by the generation of age j in period t. For each of the 50 overlapping generations identified in the model, if $(K_t^j - K_{t-1}^{j-1})$ is positive, generation j is a saver in period t, if negative a dissaver. The term $H_t^j - H_{t-1}^{j-1}$ is bounded from below since dissaving in any period can only occur through depreciation. We define $K_t^0 = H_t^0 = H_t^{T+1} = 0$. $K_t^{T+1} = 0$ is a consequence of nonsatiation in a life-cycle context.

The full employment conditions in this economy are somewhat more complex than in one-asset growth models, since time can be devoted to two nonmarket uses (schooling and leisure). Effective units of human capital available to the labor market are

$$(10)\qquad \bar{H}_t^m = \sum_{j=1}^{T} (H_t^j)(1 - s_t^j - \ell_t^j),$$

where the j superscript again indicates the values for members of the various age groups. Full employment conditions are thus

$$(11)\qquad \begin{Bmatrix} \text{(i) } K_t = \bar{K}_t \\ \text{(ii) } H_t^m = \bar{H}_t^m \end{Bmatrix}.$$

We allow technical progress at rate g, and population grows at rate n. Thus, in a steady-state solution the rental rate on human capital will be constant, but aggregate stocks will grow at rate $(n + g)$.

In equilibrium, a zero-profit condition for the aggregate production function must be satisfied:

$$(12)\qquad Y_t = W_t H_t^m + r_t K_t,$$

where Y_t is aggregate output, and W_t and r_t are *gross* of tax rates of return to human and nonhuman capital. Output is the numeraire. An equilibrium in period t, finally, is given by values of the rental rates W_t and r_t, such that (11) and (12) are satisfied. Furthermore if

$$(13)\qquad W_{t+1} = (1+g)W_t;\ r_{t+1} = r_t,$$

then such an equilibrium lies on a balanced growth path.[13] Revenues raised through taxes are redistributed in lump-sum form to each of the 50 generations paying taxes.

6.4 Implementing the Model Approach

In order to use the structure outlined above for capital income tax simulation analysis, we have made some simplifying assumptions and have chosen specific functional forms. As explained earlier, in the simulations reported in this paper we have ignored leisure. Like Summers (1981) we assume that all individuals work for 40 years and retire for 10. The first 40 years of the lifetime can be used for earning or learning. The extra leisure in retirement is not assumed to affect utility. Using the constant relative risk aversion (CRRA) utility function we therefore have the simple (and familiar) preferences:

(1′) $$U = \sum_{t=1}^{T} \left[\frac{C_t^{1-\alpha}}{1-\alpha}\right] \frac{1}{(1+\rho)^{t-1}},$$

where α is the inverse of the intertemporal elasticity of substitution, σ. With this choice (7) reduces to:

(7′) $$\frac{C_{t'}}{C_t} = \left[\frac{1+r_n}{1+\rho}\right]^{(t'-t)/\alpha} \qquad t = 1, \ldots, T,$$

so that C_t simply grows at a constant proportional rate that rises with r_n, and falls with ρ and α.[14]

The choice of a human capital investment function, h_t, is also critical in the model. In general h_t would depend on the inputs s_t and H_t:

(14) $$h_t = h(s_t, H_t).$$

However, important special cases are provided by

(14′) $$h_t = h(s_t),$$

and

(14″) $$h_t = h(s_t H_t).$$

The latter formulation embodies the "neutrality" hypothesis of Ben-Porath (1967).[15] On the other hand, (14′) provides the computationally helpful simplification of making $\partial h_t / \partial s_t$ independent of H_t. In the simulations reported here we use the constant elasticity form:

(15) $$h_t = A s_t^{\theta}.$$

Although constant elasticity is typically assumed in the empirical literature on the human capital production function,[16] (15) is, of course, a simplified formulation.

Although available empirical evidence is limited (see, e.g., Heckman 1975; and Haley 1976), there are strong a priori grounds for expecting the stock of general human capital to enter the human capital production function. It has been suggested, for example, that learning skills are likely one of the most important forms of general human capital. If H_t enters (14), tax effects on human capital investment will compound through time. Despite the absence of such compounding, (15) turns out to produce realistic age profiles of training time, human capital, and earnings, as discussed in the next section. The partial equilibrium impact of tax changes on human capital investment also turn out to be large, so that the absence of compounding in (15) does not lead to insensitivity of s_t with respect to taxes.

Finally, on the production side we use the Cobb-Douglas production function:

(16) $$Y_t = H_t^{m\gamma} K_t^{1-\gamma}.$$

6.4.1 Parameterization

To implement the model approach described above, we choose particular values for the parameters appearing in all the functions given above by calibrating the model to a base-case balanced growth path. This growth path is much the same as used by Summers (1981), and, by extension, Davies, Hamilton, and Whalley (1989).

The basic parameter set is displayed in table 6.1, where taste, technology, and tax parameters are reported. Following Summers, we use a unitary intertemporal elasticity of substitution, σ, and rate of time preference, $\rho = .03$. While our share parameter of labor in the aggregate production function, γ, and population growth rate, n, are also set at Summers's values (.75 and .015, respectively), we have used a lower productivity growth rate, g (.01). Sum-

Table 6.1 **Base-Case Parameter Values**

Parameter		Value
Tastes:		
Intertemporal elasticity of substitution	(σ)	1.000
Rate of time preference	(ρ)	.030
Technology:		
Share parameter of labor in production function	(γ)	.750
Human capital production function:	(θ)	.500
	(δ)	.010
Population growth rate	(n)	.015
Productivity growth rate	(g)	.010
Taxes:		
Capital income tax		.500
Labor income tax		.200

mers used $g = .02$, but we found that we could not calibrate the human capital production function successfully unless a lower value was chosen for g.[17]

Our calibration of the human capital production function proceeds as follows. First, we choose arbitrary values of δ and θ. Next we iterate until we find a value of the scale parameter, A, in the human capital production function which produces a steady state with the base-case parameter values in which the ratio of rental rates, r/w, and the capital-labor ratio, K/H^m, are the same as in the one-commodity version of Davies, Hamilton, and Whalley (1989), which is similar to Summers's base case. Thus the human capital production function is calibrated by requiring that the rental rates and capital-labor ratio should be the same in the base case as in previous work, which ignores human capital. Finally, we look at the age profiles of human capital, training time, and earnings produced by the model in order to confirm that these are realistic. In principle, if the profiles were not realistic we would experiment with alternative values of δ and θ until they were. However, our initial choice, $\delta = .01$ and $\theta = .5$, proved satisfactory and further rounds of the process were unnecessary.[18]

The age profiles of human capital, training time, and earnings produced by the model are shown in figures 6.3 and 6.4. Figure 6.3 indicates that new labor-market entrants (aged, say, 20 biologically) spend about 32% of their time in human capital investment. This fraction declines at a falling rate. About halfway through the working lifetime only about 10% of available time is being spent in training. (This pattern is fairly similar to that estimated, e.g., by Heckman 1975.) The age profiles of both human capital and earnings display a shape that is familiar from both the theoretical and empirical human capital literature going back at least to Mincer (1974) (see also Weiss 1986, and Willis 1986).

Labor and capital income tax rates in the base case are set at 20% and 50%, respectively, as in Summers (1980, 1981). Following the methodology of Shoven and Whalley (1973), and unlike Summers, the revenues collected are returned to the taxpayers as lump-sum transfers. For simplicity the distribution scheme is assumed to be uniform and unrelated to age.[19]

The tax experiments we perform involve replacing initial taxes by wage and consumption taxes alternatively. The government's revenue requirement, and therefore transfer payments, are maintained on a period-by-period basis in all experiments. Tax rates adjust to yield the required revenue, with a balanced budget in every period.

In order to perform tax replacement experiments, we need to specify how expectations of future prices, tax rates, and transfer payments are formed. Like Summers (1980), we have adopted the computationally simple assumption of myopic expectations. Everyone expects that the current period rental and tax rates and transfer payments will continue unchanged indefinitely. (Note that for transfer payments, this myopic expectation always turns out to

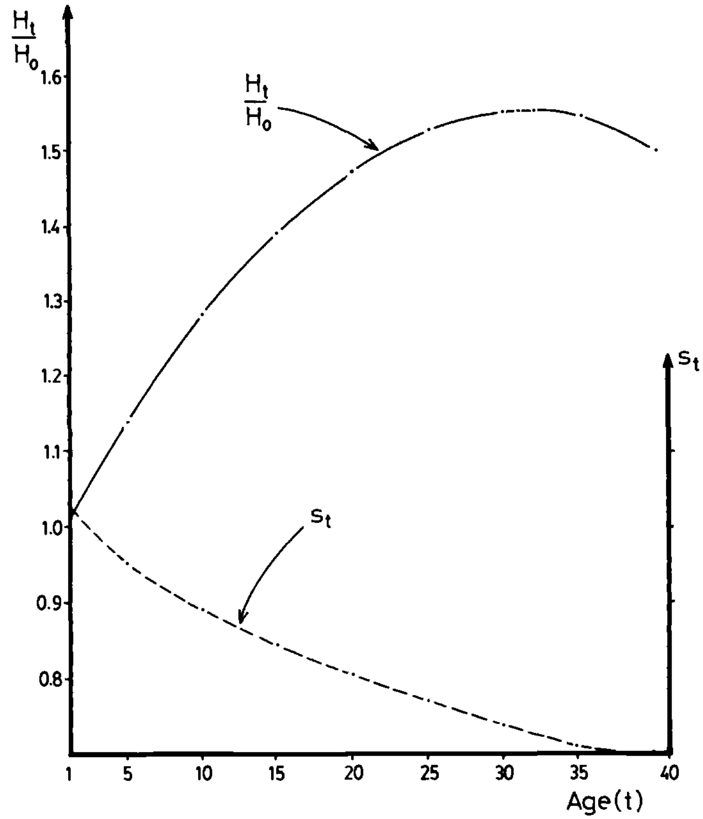

Fig. 6.3 Human capital accumulation (*H*) and training time (*s*) in base-case steady state

have been correct.) This assumption contrasts with the perfect foresight approach used, for example, by AKS and Auerbach and Kotlikoff (1983, 1987).

The main effect of using myopic expectations in the simulations performed here is that the economy converges more rapidly to the new steady state than with perfect foresight. This is because when capital income taxes are reduced, households do not anticipate that the gross rate of return on capital will decline in the future. Not surprisingly, the capital stock converges to its new, higher, steady-state level more rapidly than it would if households could foresee perfectly the declining gross rate of return.

There is some evidence on the quantitative significance of using myopic expectations for results from models such as we use. In their simulations of capital income tax reforms, based on a model similar to Summers's, but with perfect foresight, Auerbach and Kotlikoff (1983) find that the capital stock has adjusted halfway to its new steady-state level between 10 and 15 years after the policy change. In contrast, we find here that the same degree of con-

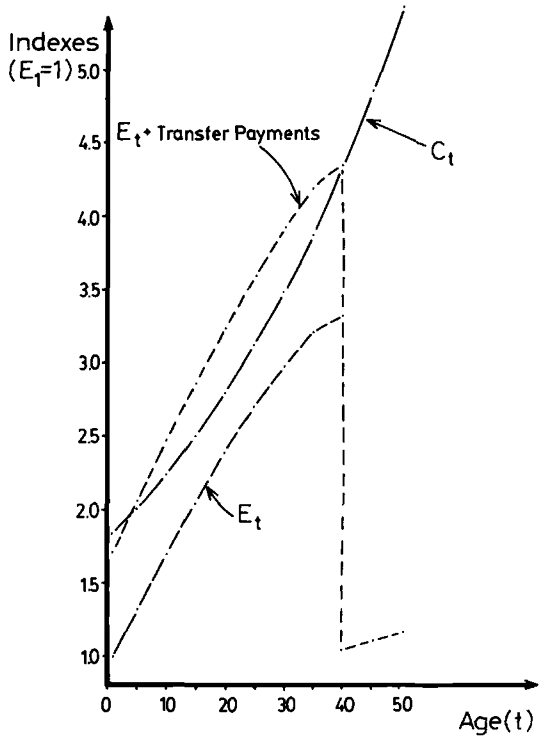

Fig. 6.4 Earnings (*E*), transfer payments, and consumption over the life-cycle in the base case

vergence has occurred after just five or six years. The latter result is similar to the findings of Summers (1980).

Our simulations thus yield base-case balanced growth scenarios for the economy and alternative time paths of behavior under changed policies. This allows for full welfare comparisons between base and revise cases, including both transitional as well as long-run effects.

6.5 Results

We have used the model described in the previous sections in two alternative modes, which we then use to evaluate the effects of alternative capital income tax changes. One is a move to a wage tax, in which the tax on interest income is removed and labor tax rates are revised upward to preserve revenues. The other is a move to a consumption tax, in which taxes on both labor income and interest income are set equal to zero and replaced by an equal-yield sales tax. As in Summers, yield equality applies on a period-by-period basis. The two alternative model analyses have human capital endogenously determined in one and exogenous in the other (effectively, the Summers case of labor growth at rate n). In both cases, an endogenous labor-leisure choice is excluded from the modeling framework for reasons of simplicity.

In table 6.2 we report results from comparisons of sequences of equilibria under a move from an income tax to a wage tax and a move from an income tax to a consumption tax. Most of the results describe the change between the base and the new steady states achieved under wage and consumption taxes. For example, we report the steady-state welfare gains, with human capital alternatively assumed endogenous and exogenous, in the second line of both panels A and B (for wage and consumption taxes, respectively). The most striking aspect of these steady-state welfare gains, as of the steady-state changes in capital intensity, rate of return, per capita consumption, and human capital stock, is the similarity of results whether human capital is endogenous or exogenous. Under the wage tax, steady-state welfare rises a little *less* when human capital is endogenous, apparently due to the operation of Summers's postponement effect.[20]

While steady-state characteristics are of interest, more important are the full dynamic welfare gains shown in the first line of each part of table 6.2. These capture the impact effects, the effects along a transitional path to a new balanced growth path, and comparisons across balanced growth paths. Welfare effects are reported in terms of the discounted present value of the period-by-period change in consumption plus the change in the value of the terminal

Table 6.2 **Equilibrium Sequence Comparisons for Capital Income Tax Changes**

	Changes Relative to Base Case (%)	
	Human Capital Endogenous	Human Capital Exogenous
A. Wage Tax:		
Present value of consumption and terminal capital stock	5.2	5.7
Steady state:		
Welfare	5.1	5.3
K/H^m	92.2	87.9
r	−38.7	−37.7
Consumption	11.7	12.6
Human capital stock	−3.2	.0
B. Consumption tax:		
Present value of consumption and terminal capital stock	6.2	6.3
Steady state:		
Welfare	9.8	9.8
K/H^m	111.7	107.7
r	−45.0	−42.5
Consumption	14.0	14.5
Human capital stock	−2.1	.0

capital stock. Adding transitional effects reduces the gains under the consumption tax, reflecting the considerable losses of the old in the early transition years previously identified, for example, by AKS. In addition, transitional welfare changes are slightly more favorable with human capital exogenous under both tax experiments.[21]

These results are very different than those obtained using partial equilibrium assumptions by Driffill and Rosen (1983) (DR). However, they are not *inconsistent* with the DR results. The partial equilibrium welfare gains from either the wage or consumption tax experiment here, as measured by the equivalent variation (EV), are 4.4% greater here when human capital is made endogenous.[22] (Gains are the same under wage and consumption taxes since they are equivalent in the partial equilibrium context.) This difference is smaller than obtained by DR with their quite different functional forms, but it is still substantial—in fact, of the same order of magnitude as the full dynamic welfare gains in our model. Alternative parameterizations increase the partial equilibrium differential markedly without altering the conclusion suggested by the full dynamic results. For example, in the $\theta = .75$ run reported in table 6.5 partial equilibrium gains are 9.1% higher when human capital is made endogenous, but the full dynamic welfare gains are again little affected.

The reason for these results can be seen from tables 6.3 and 6.4. The impact effect under either change in tax treatment is to increase savings, as predicted by traditional analysis. In long-run dynamic equilibrium, with a move to a new balanced growth path, the rate of return on nonhuman capital reverts to approximately its original net of tax value in both experiments. Thus, with a 50% tax rate on capital income, a 10.6% gross of tax rate of return, r, in the original base case implies a net of tax value of 5.3%, which is not too much lower than the new long-run balanced growth values of 6.5% and 6.0% in the wage and consumption tax case, respectively (with endogenous human capital). In long-run balanced growth the net of tax rate of return on assets is largely unchanged, and there is, therefore, little long-run effect on human capital formation.

Thus, the effects which results by DR highlight, from including human capital in tax analysis of saving behavior, including the interasset substitution effect between human and nonhuman capital and the larger effect on savings that we describe in the earlier part of this paper, turn out to be transitional rather than long-run effects. Also, in the long run the impacts on welfare are largely unchanged.

The feature that the gross of tax rate of return on nonhuman capital falls to approximately the net of tax rate of return in the new balanced growth path is a property common to both our model and the Summers (1981) model without endogenous human capital, which uses a similar parameterization. The similarity of outcomes is hardly an accident. We have calibrated our human capital production function to produce an optimal age-earnings profile in the base case that will generate aggregate saving equal to that obtained with the

Table 6.3 Transitional Effects of a Move from an Income Tax to a Wage Tax

Year	K/H^m	r	C/C_{BC}	$\bar{H}/\bar{H}_{BC}$	S/Y
A. Human capital endogenous:					
0	3.140	.106	1.0	1.0	.059
1	2.887	.113	.700	1.0	.382
2	3.357	.101	.765	.993	.339
3	3.779	.092	.820	.987	.301
4	4.150	.086	.866	.982	.270
5	4.471	.081	.904	.978	.243
10	5.512	.070	1.021	.967	.161
20	6.162	.064	1.098	.963	.108
50	5.988	.065	1.118	.968	.096
100	6.035	.065	1.117	.968	.097
B. Human capital exogenous:					
0	3.140	.106	1.0	1.0	.059
1	3.140	.106	.710	1.0	.333
2	3.492	.098	.764	1.0	.301
3	3.808	.087	.810	1.0	.275
4	4.088	.083	.850	1.0	.252
5	4.338	.080	.885	1.0	.233
10	5.219	.072	1.002	1.0	.169
20	5.954	.066	1.103	1.0	.116
50	5.857	.066	1.127	1.0	.093
100	5.901	.066	1.126	1.0	.095

Note: In part A, it takes six years for K/H^m to converge halfway to its new steady-state value. The comparable figure for part B is 7 years. C/C_{BC} = ratio of aggregate consumption to that which would be observed if the base case had continued undisturbed. $\bar{H}/\bar{H}_{BC}$ = ratio of aggregate human capital stock to that which would be observed if the base case had continued undisturbed. S/Y = ratio of aggregate savings (i.e., in physical capital) to national income.

Summers-type exponential age-earnings profile. Suppose that in the Summers-type model the steady-state gross of tax rate of return fell exactly to the base-case net rate of return under either the wage or consumption tax experiment. Would we expect a similar drop in the steady-state gross rate of return in *our* model? The same drop in the gross rate of return would give a human capital investment plan under the wage or consumption tax exactly the same as in the base case. The shape of the steady-state age-earnings profile would not be affected by the tax regime. Now, would such an unchanged age-earnings profile allow the same capital deepening and, therefore, the same change in rate of return as simulated by Summers? If so, our wage or consumption tax steady-states *would* feature the gross rate of return falling to the net. Given that our age-earnings profile has been chosen to give a base-case saving pattern similar to that in the Summers model, it would not be surprising if it also gave a saving pattern similar to the Summers model under the wage or consumption taxes. Thus, the fact that in our model wage and consumption tax experiments produce similar capital deepening, and a similar drop in the gross rate of return as in Summers' model, is not unintuitive.

Table 6.4 Transitional Effects of a Move from an Income Tax to a Consumption Tax

Year	K/H^m	r	C/C_{BC}	$\overline{H}/\overline{H}_{BC}$	S/Y
A. Human capital endogenous:					
0	3.140	.106	1.0	1.0	.059
1	2.887	.113	.532	1.0	.531
2	3.567	.096	.641	.993	.452
3	4.157	.086	.729	.987	.389
4	4.663	.079	.801	.983	.338
5	5.090	.074	.859	.980	.291
10	6.366	.062	1.032	.973	.177
20	6.885	.059	1.135	.974	.108
50	6.598	.061	1.138	.980	.106
100	6.646	.060	1.140	.979	.104
B. Human capital exogenous:					
0	3.140	.106	1.0	1.0	.059
1	3.140	.106	.558	1.0	.476
2	3.677	.094	.649	1.0	.414
3	4.146	.086	.725	1.0	.365
4	4.553	.080	.788	1.0	.325
5	4.904	.076	.841	1.0	.292
10	6.055	.065	1.016	1.0	.189
20	6.739	.060	1.141	1.0	.113
50	6.463	.062	1.142	1.0	.103
100	6.523	.061	1.145	1.0	.103

Note: C/C_{BC} = ratio of aggregate consumption to that which would be observed if the base case had continued undisturbed. $\overline{H}/\overline{H}_{BC}$ = ratio of aggregate human capital stock to that which would be observed if the base case had continued undisturbed. S/Y = ratio of aggregate savings (i.e., in physical capital) to national income.

Thus, the result here that the new steady-state human capital investment plan is not much different from the initial plan under the income tax reflects those aspects of a Summers-type model that make savings increase sufficiently under wage or consumption tax experiments to bring the steady-state gross of tax rate of return down to about its initial net-of-tax value. There are no doubt many alternative models in which savings would be less sensitive to tax changes, with the result that the gross of tax rate of return would not fall to the net, and effects on human capital investment would persist in steady state.

Tables 6.3 and 6.4 provide more details on the transitional paths for the human capital endogenous and exogenous models under the two alternative tax changes. They suggest a more rapid transitional process when human capital is endogenous. In both wage tax and consumption tax experiments, the short-run stimulus to saving in nonhuman form is larger when human capital is endogenous. Savings ratios in the impact year are .333 and .476 in the wage and consumption tax experiments with human capital exogenous, but are .382 and .531 when human capital is endogenous. This reflects a very substantial accompanying decline in human capital investment, which shows up in a

0.7% depletion of the human capital stock after just one year under both of the new tax regimes.[23] The result of the larger savings response is that the capital-labor ratio converges much closer to its new long-run value after five years when human capital is endogenous than when it is exogenous.

Intercohort redistributive effects follow a familiar pattern in our simulations. As in AKS, under the wage tax the most substantial gains go to those who are old in the impact year, and under the consumption tax the reverse is true. These redistributive effects show only a small amount of sensitivity to the endogeneity of human capital. The largest effect is in the wage tax case where those aged 40 and above experience welfare gains up to 0.7% more when human capital is endogenous, and younger cohorts experience up to 0.7% smaller gains. The additional benefit for older workers and retirees can be traced to the slower decline of the interest rate in the initial years of transition with endogenous human capital, while the reduced gain for younger workers appears to reflect the harm done to their lifetime optimization by myopic expectations and the emerging postponement effect.

Table 6.5 reports some of the sensitivity analysis we have done with the model. The first three rows show changes with respect to which our central-case results on welfare gains from the various tax experiments are highly robust. The first change raises the θ parameter in the human capital production function to .75. By itself, a move to $\theta = .75$ leads to a solution with almost no human capital investment taking place. Recall that we calibrated the base-case model by finding a value for the scale parameter, A, in the human capital production function, that would give human capital investment plans that would generate an overall capital-labor ratio, and gross of tax rate of return r, equal to those in the base case of Davies, Hamilton, and Whalley (1989). We have recalibrated in the $\theta = .75$ run, choosing a new value of the parameter A to once again have $r = .106$ in the base case. The second and third changes also (necessarily) involve a recalibration of the model. Here we find new values of A that generate initial steady states with the gross interest rate 2.0 percentage points below and above the central-case value of 10.6% alternatively.

The last three rows of table 6.5 display more sensitivity, although none of these experiments disturbs the similarity of results with human capital endogenous versus exogenous. Using a lower value of σ (.5), which many would now consider more "realistic" than $\sigma = 1$, reduces the full dynamic welfare gains somewhat. Setting the Cobb-Douglas share parameter in the aggregate production function, γ, equal to 0.6, instead of the central-case value of 0.75, produces an approximate doubling in welfare gains. Behind this is a somewhat greater increase in the capital-labor ratio under the various tax experiments than observed in the central-case runs. With human capital endogenous, the capital-labor ratio rises 102% when the income tax is replaced by a wage tax and 138% under the consumption tax replacement. The corresponding figures in the central case were 92% and 112%. An interesting feature of the $\gamma = 0.6$ results is that human wealth bulks significantly smaller as a proportion of overall wealth. Now human wealth in the initial steady state is

Table 6.5 Dynamic Welfare Gains from Tax Experiments with Altered Parameter Values (% changes relative to base case)

	Replacing Income Tax by			
	Wage Tax		Consumption Tax	
	Human Capital Endogenous	Human Capital Exogenous	Human Capital Endogenous	Human Capital Exogenous
Central case	5.2	5.7	6.2	6.3
Parameter changes:				
$\theta = .75$	5.3	5.6	6.1	6.3
$r = .086$	5.3	5.3	6.3	6.3
$r = .126$	5.5	5.8	6.2	6.3
$\gamma = .6$	9.8	10.2	12.2	12.4
$\sigma = .5$	4.3	4.6	5.4	5.6
Tax rates = 28	1.3	1.0	1.6	1.5

Note: In the $\theta = .75$ run and the $r = .086$ and .126 runs, the human capital production function is recalibrated. With $\theta = .75$ the parameter A is chosen so that initial $r = .106$, as in the base case. The $r = .086$ and $r = .126$ runs necessitate a new choice of A given the calibration procedure described in section 6.4 of the text.

about 72% of total wealth, in contrast to the figure of 80% in the central-case runs. This may represent confirmation of the intuition about the impact of the relative size of the human capital stock (discussed in app. A) on the results of intertemporal tax analysis which we briefly outlined in section 6.2.

Finally, the last row of table 6.5 indicates how our results would have differed if we had assumed equal tax rates of 28% on labor and capital income in the base case. This run is motivated by recent U.S. tax reform. Reducing the assumed rate of tax on capital income from the 50% of the central case dramatically reduces the percentage of welfare gains from wage or consumption tax experiments. However, it is interesting to note that even in this case the annual welfare gains from the move to wage or consumption taxes would equal about \$63 billion and \$77 billion, respectively, in current U.S. terms. (For comparison, in the second quarter of 1988 U.S. GDP was running at an annual rate of \$4.8 trillion.)

6.6 Conclusion

This paper discusses how the analysis of the effects of taxes on capital formation is changed by the explicit incorporation of human capital. While there has been much discussion in recent public finance literature of the effects of intertemporal tax distortions on capital formation and welfare, little of this has explicitly incorporated human capital. In the paper we show how the impact effects of incorporating human capital suggest important and neglected tax induced interasset effects and larger effects on savings (as conventionally measured), consistent with earlier partial equilibrium analysis of Driffill and

Rosen (1983). We also present a framework for dynamic long-run equilibrium analysis in the tradition of Summers (1980, 1981), but with endogenous human capital formation.

Using this framework, we perform numerical simulation analyses designed to explore how incorporating human capital affects the welfare analysis of tax distortions of savings. For the numerical specification we use, estimates of intertemporal distorting costs of taxes are little affected by including human capital, in contrast to the conclusion offered by Driffill and Rosen from their partial equilibrium analysis. While the impact effect of removing these tax distortions is to increase savings by more in the human capital endogenous case for a move from an income tax to a consumption or wage tax and to generate an additional interasset effect, in the long run the net of tax rate of return on nonhuman capital is largely unchanged because of interasset substitution effects between human and nonhuman capital. As a result, long-run welfare analysis produces values for the discounted present value of consumption plus change in the value of terminal capital, which are similar. Our paper therefore suggests that static partial equilibrium analysis focusing on how human capital changes the analysis of tax distortions of savings can be misleading when compared to full dynamic equilibrium analysis, which captures endogenous effects on interest rates through interasset substitution effects.

These findings must, however, be qualified by the fact that some potentially important features of human capital formation and its tax treatment are neglected in our analysis. Our simulation model has exogenous leisure and does not incorporate liquidity constraints, progressivity in the income tax, or job-specific human capital. We have also not modeled rationing of access to educational institutions, and the lump-sum effects that taxes on the associated pure rents would create. Intergenerational links within the family that may affect human capital formation are also not incorporated. A further qualification is that, as in all such work, our results are contingent on specific functional forms and parameter values. Work with more general production functions for both aggregate output and human capital is an important avenue for future research. Thus, although we feel that our paper takes an important step in clarifying the impact of incorporating human capital in life-cycle simulations of tax effects in dynamic equilibrium, it should be regarded as a first foray in this area.

Appendix

Estimates of the Size of the Human Capital Stock

There are two approaches commonly used to measure the stock of human capital in the literature, and they yield different results. One uses cumulated past investments of time to measure the value of the current stock of human capital. The other calculates the present value of the stream of future incremental earnings attributable to human capital. In principle, as we argue below, the latter research (used, e.g., by Bowman 1974) is superior.

If the first approach is used, results are sensitive to a number of differences in procedure. These include the calculation of a depreciation factor for invested funds and the classification of expenditures that are allocated to human capital accumulation. Examples of papers that use this approach are Kendrick (1976) and Schultz (1960).

To us, the second approach seems analytically superior. In the absence of an explicit market, the value of human capital must equal the discounted present value of the earnings stream that it generates. In general, this is likely to differ from the accumulated cost of inputs into human capital investment because the rate of return on inframarginal investments exceeds the discount rate.

A series of factors also affects estimates generated by the second approach, however. These include the method used to approximate the profile of future earnings for workers, the choice of discount rate used to compute the present value of earnings streams, and the choice of the wage rate of "nonimproved labor." An attractive feature of work in this group of studies, however, is that calculations can be related to explicit models of the human capital accumulation process. For example, previous work on earnings functions has been used to develop models explaining earnings that can then be estimated and subsequently simulated to produce a sequence of future earning returns to workers of different type. Incremental earnings returns can then be discounted back to compute the net present value. Examples of papers that use this approach are Graham and Webb (1979) and Kroch and Sjoblom (1986).

The earliest attempt to value the stock of human capital is by Schultz (1960). Schultz's motivation for calculating the size of the human capital stock was to evaluate the contribution of education to economic growth. He wished to be able to compare the value of investments in human and nonhuman capital, the stocks of human and physical capital, and the relative rates of return to these two investment vehicles.

Schultz calculated the human capital stock by cumulating educational expenditures. Direct costs and forgone earnings vary between elementary, secondary, and higher education. Forgone earnings were calculated by determining the number of weeks per year that a student is voluntarily out of the labor market, and multiplying this by the current average weekly wage in manufacturing (forgone earnings are typically at least 50% of the costs of education). Schultz determined the educational capital stock by summing together the product of total numbers of years of each type of education and its estimated cost. Schultz calculated that in 1957 the educational capital stock for the labor force aged over 14 was approximately 30% of the total capital stock; a relatively small number.

Kendrick (1976) also provided estimates of capital investment and cumulated stocks for various types of capital, including human capital. Human capital was separated into two categories: tangible and intangible human wealth. The former includes costs such as "rearing costs" incurred in raising children to working age (14 years). Only direct costs (i.e., not the opportunity cost of parent's time) is included. Intangible investments include expenditure on education, employee training, medical, health, safety, and mobility. Of the categories of human wealth considered by Kendrick, expenditures on education and employee training are of a discretionary nature and subject to tax effects.

Various sources, such as surveys and published data, were used by Kendrick to determine expenditures, and deflators were obtained to derive real expenditure. For educational expenditures, the procedure was to first estimate the average real expenditures per head by single age groups up to age 95, then cumulate per capita lifetime expenditures for each cohort for each year covered in the calculation. This is then multiplied by the number of persons in each age group each year and summed across age groups. A depreciation adjustment was applied to education investments beginning at age 28.

While it is not possible to compare exactly the calculations of Kendrick and Schultz, the estimates appear to be close since, according to Kendrick, the ratio of human to total wealth is approximately 28% in 1957.

Unlike the calculations of Kendrick and Schultz, Graham and Webb (1979) estimate the size of the stock of human wealth by capitalizing the flow of returns to human capital. The use of this approach is motivated by the observation that the services of human capital are priced in labor markets, in contrast to the services of physical capital goods.

The basis for their calculation is 1970 Public Use Survey data, collected from detailed census questionnaires. Their methodology involves assuming that all agents in the same age cohort with the same number of years of education are the same. Agents are assumed to engage in no postschool investment in human capital. To calculate lifetime expected earnings, a secular earnings growth rate is applied to earnings of workers currently possessing t years of schooling. This means that a younger person will have a higher earnings profile than an older person with the same level of education. Their earnings streams are based on expected earnings, which are weighted by probabilities of being alive at various ages derived from life tables. Present values of earnings for a representative agent of alternative ages and with various years of schooling are calculated. These are then multiplied by the number of agents and then summed over all values of age and schooling to find the aggregate human capital stock.

Graham and Webb present numerous graphs displaying the behavior of the human capital stock over time. The pattern of lifetime human wealth increases initially, followed by a decline to zero at retirement. The peak in the wealth series generally occurs at around age 40. The point at which depreciation begins depends on the number of years of schooling.

The size of the males-only capital stock is calculated by the authors for 1969, using a discount rate of 7.5%. Their estimates of $7.2 trillion compare to Kendrick's total nonhuman capital stock figure of $3.7 trillion. A 20% discount rate, however, lowers the figure to $2.9 trillion. Using the $7.2 trillion figure for human capital means that their estimate of the male human capital stock would be roughly twice the nonhuman capital stock reported by Kendrick.

A further paper by Kroch and Sjoblom (1986) also uses a present discounted earnings approach similar to that employed by Graham and Webb. Under their approach, the stream of earnings for a representative agent with given characteristics is constructed by first fitting an earnings function model of the type suggested by Mincer (1974) to longitudinal earnings data. Their earnings function depends on years of schooling, time worked, experience, vintage effects for persons, and various interaction terms (e.g., the product of experience and schooling, to allow for different effects of experience given different levels of schooling). This earnings function is then simulated to produce earnings profiles for given types of individuals. The resulting earnings streams provide a measure of returns to human capital, and these can then be aggregated over all individuals. An attractive feature of this work is that it focuses on schooling wealth, that is, the capitalized value of improvements made to labor. A separate estimate is reported for human wealth, which is schooling wealth plus the present value of the return to unimproved labour (the wage with zero years of schooling).

Using a discount rate of 4%, the authors report values of schooling wealth that are dramatically larger than the educational wealth estimates of Kendrick and Schultz. For 1980, the stock of human wealth is calculated to be $26.5 trillion, while schooling wealth is $18 trillion. For comparison, the Federal Reserve Board measure of the aggregate value of real capital was approximately $9.6 trillion. They suggest the gap between these measures has widened markedly since the early 1970s.

Finally, Jorgenson and Pachon (1983) obtain much higher values for the human capital stock by making an allowance for the value of home production. Their conclusion is that human capital may represent as much as 96% of the total capital stock of the United States. While one may wish to discount such a high figure, it is nonetheless clear that one underestimates considerably the value of the flow of services produced by human capital if one ignores household outputs.

The literature, therefore, exhibits considerable variability as to estimates of the value of the human capital stock. The divergence in results between the first approach (cumulating costs of investment) and the second (discounting future earnings) is explicable in terms of the latter capturing the impact of high inframarginal returns to human capital investment. We prefer the second approach on theoretical grounds, and therefore conclude that the literature supports the view that human capital is substantially larger in aggregate value than the physical capital stock. Some might feel that this is evident from the national accounts, which show that the return to human capital in the form of earnings is about three times capital income. The issue, however, is how much of the return to labor one attributes as a return to human capital.

Notes

1. A review of the literature should also mention Lord (1989), which uses a model in many ways similar to ours. Lord's paper came to our attention after this paper was completed. While our analysis focuses on the impact of income taxes relative to wage or consumption taxes, Lord is concerned only with the differences between wage and consumption taxes. Thus his paper is complementary to ours.

2. There has been considerable work, largely by Gary Becker and Nigel Tomes, on the importance of intergenerational links in human capital formation. Although parents cannot bequeath *their* human capital, they typically find it efficient to achieve much, if not all, of their desired transfers to offspring via investment in the *child's* human capital. In this context, estate and gift taxes, in addition to income taxes, can distort human capital investment. Further differences vis à vis the pure life-cycle model considered in this paper arise if capital market imperfections are taken into account. See Becker and Tomes (1986), Davies (1986), and Davies and St-Hilaire (1987).

3. See the original discussion in Becker (1975, 26–37), as well as Hashimoto (1981) and Carmichael (1983) for a more recent treatment.

4. Signaling models have been leant some attraction by the frequent observation that much formal education does not impart job-relevant skills. However, models of investment in person-specific information provide an alternative, and productive, explanation of the earnings payoff to forms of education that do not provide skills (see MacDonald 1980; and Davies and MacDonald 1984). The accumulation of information in these models is in fact a form of human capital investment.

5. In human capital theory an important distinction is made between "gross" or "potential" earnings, which represent the maximum that could be earned, holding leisure constant, and "net" earnings, which correspond to the observed labor income. (The difference between potential and net earnings represents the income forgone for the sake of human capital formation.) Taxes are, of course, levied on net earnings, that is, the portion of full labor income that is currently available for consumption. The treatment therefore corresponds to that given to a "qualified" or "registered" asset in the consumption tax literature (see U.S. Treasury 1977).

6. The diminishing rate of return to investment in human capital here is due solely to diminishing productivity of time and other inputs in human capital production. In an N-period model (Ben-Porath 1967) there will usually also be a decline in the marginal rate of return to a given amount of human capital investment as the individual ages, due to the ever-receding remaining length of the working life.

7. There has recently been considerable interest in the impact of liquidity constraints in intertemporal tax analysis (see Hubbard and Judd 1986; and Browning and Burbidge 1988). It would clearly be very simple to address the implications in figures 6.1 and 6.2. One important implication is that, to the extent that such a borrowing constraint is effective, the distorting effects on human capital investment of interest income taxation discussed below are absent.

8. This is an interesting point since, as outlined in app. A, recent estimates of the value of the human capital stock suggest that it exceeds that of the physical capital stock by a ratio of about three to one.

9. Partial equilibrium welfare calculations can be generated as a by-product of the full dynamic simulations we perform later in the paper. As discussed below, the results of these calculations are not inconsistent with the DR partial equilibrium results.

10. Also, as pointed out by Sherwin Rosen in his comments on this paper, to the extent that human capital increases productivity in nonmarket activities ("leisure"), which produce untaxed income in kind, *any* subsidy to schooling, implicit or otherwise, tends to encourage overinvestment in human capital.

11. A still more general model would incorporate married couples, differentiating between the labor supplied by, and leisure consumed by, the two spouses. There are of course many possible tax effects on the division of labor between husbands and wives. Also, men and women still exhibit marked differences in patterns of human capital investment. It would be interesting to consider the impacts of alternative forms of taxation on these patterns, but that is beyond the scope of this paper.

12. Recently, a variety of alternative explanations for personal wage growth over the life-cycle have emerged. Lazear (1979) has suggested, for example, that positively sloped age-earnings profiles would be observed even if workers' marginal productivity did not vary over the life-cycle in an equilibrium where an incentive mechanism was required to discourage shirking. More recent literature confirms that a rising wage profile may be an important element in such equilibrium mechanisms (see, e.g., Kuhn 1986). To the extent that such factors, rather than human capital investment, explain the shape of the age-earnings profile, interest income taxes might have quite different effects on age-earnings profiles than they do here, with differing consequences for saving.

13. Along a balanced growth path each generation makes the same investment in human capital and provides the same labor supply. Aggregate labour supply, H_t^m, therefore grows at the rate n. Given our specification of (1), such an outcome is only possible with Cobb-Douglas preferences if $g > 0$. Otherwise succeeding cohorts will have differing labor-supply plans. In order to use a more general form of (1), AKS set $g = 0$.

14. Although this specification is widely used in the literature, the implied age profile of consumption departs markedly from what is observed. As is well known, actual age profiles of consumption are hump shaped. The implications for intertemporal tax analysis are discussed in Davies (1988) and Browning and Burbidge (1988).

15. Under Ben-Porath neutrality, an increase in H_t raises the productivity of time in the labor market and in the production of human capital equiproportionally.

16. In fact, (15) is the basic functional form estimated by Heckman (1975), whose results reject the hypothesis that H_t should appear in (14). (In contrast, some other contributions to the empirical literature, e.g., Haley 1976, adopt [14″] as a maintained hypothesis.)

17. In a Summers-type model, g governs the age profile of earnings, which is of course exponential, as well as secular wage growth. Investment in human capital increases the steepness of the age profile of earnings. With any "reasonable" amount of such investment, $g = .02$ would give an extremely steep earnings trajectory, making it impossible to generate sufficient aggregate saving to get the desired steady-state stock of physical capital, given Summers's values for the taste parameters.

18. Our choices of δ and θ are not inconsistent with available empirical evidence (which is, however, limited). Estimates of δ vary widely, from about 0.2% (Heckman 1975), to 1.2% (Mincer 1974), to 3%–4% (Haley 1976). Heckman's (1975) estimate of θ was 0.67.

19. This assumption turns out to produce only a small deviation in the results from

those obtained with Summers's approach. Each individual expects (correctly) that transfers will grow at the rate g in future. If this rate corresponded to the desired growth rate of consumption, paying out the revenues as lump-sum transfers unrelated to age would produce no change in saving (as compared to not paying any transfers). In fact, in the runs reported here the desired growth rate of consumption exceeds g, so that paying out transfers in this way generates some additional saving. The effect on the results is not marked, however.

20. The postponement effect was identified by Summers (1981, 539). With an exogenously growing revenue requirement and year-by-year budget balance, any given cohort will bear a lower present value of lifetime taxes the later it tends to pay its taxes in the life-cycle. Here, when human capital is endogenous the new steady state under the wage tax features somewhat reduced human capital investment. This tilts the age profile of earnings toward the present, resulting in earlier payment of taxes over the life-cycle under a wage tax (but *not* under a consumption tax). This appears to explain the difference here in steady-state welfare gains with exogenous vs. endogenous human capital in the wage tax experiment.

21. That the wage and consumption tax experiments produce slightly better results here in transition when human capital is exogenous may partly reflect the impact of myopic expectations. As shown in tables 6.3 and 6.4, there is a rapid decline in the rate of return on physical capital in the first 10–20 years of transition. Both human capital investment and saving decisions made in the earliest transition years under the expectation of continued high interest rates turn out ex post to have been quite wrong. In particular it turns out *not* to have been a good idea to largely cease all human capital investment, as occurs in the first few transition years with human capital endogenous. If unchanged human capital investment is closer to the perfect foresight policy in these years, one would expect that welfare in transition would be higher with exogenous rather than endogenous human capital, which is what we obtain.

22. The *levels* of the partial equilibrium gains are very sensitive to the parameterization of the utility function. In contrast, the exogenous-endogenous differential in EVs is primarily determined by the shape of the human capital production function. This is because the only difference between the two cases in partial equilibrium analysis is that the distortion in human capital investment is removed by wage or consumption taxes if human capital is endogenous, but not if it is exogenous. The severity of the distortion does not depend on preferences, since the human capital plan here is wealth maximizing.

23. Since we have set the depreciation rate of human capital at 1%, this 0.7% depletion is close to the maximum possible in a single year and reflects a radical short-run change in the allocation of time. There is almost a complete collapse of training activity in the impact year, and it takes several periods before training returns to levels close to those of the base-case steady state. An immediate result of the decline in training time is a substantial increase in labor supply. This is the sole reason for the 8.1% first-period decline in the capital-labor ratio under both wage and consumption tax experiments.

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Comment Sherwin Rosen

This is an excellent paper. It is the most complete analysis available on how human capital considerations affect income and expenditure tax distortions. The principal finding that human capital does not affect welfare calculations very much is compelling and consistent with what is known about this problem from a partial equilibrium perspective.

The most important fact about tax distortions on human capital investment is that most investment costs consist of forgone earnings and are fully "expensed" for tax purposes (Becker 1975). Accelerated depreciation of human capital eliminates most direct tax distortions. The easiest way to see this is in a school-stopping model. A person with labor-market experience x has a gross of tax earning stream of $y(x, S)$ upon completing S years of school, with y increasing S. For an income tax at rate t and out-of-pocket (tuition, books) flow expense $c(S)$, human wealth is

$$W(S) = e^{-rs}\int_0^N (1 - t)y(v, S)e^{-rv}dv - \int_0^S c(z)e^{-rz}dz, \quad (1)$$

because $c(S)$ is not tax deductible. Thus S is chosen to maximize $W(S)$: this occurs where the marginal after-tax internal rate of return equals the after-tax interest rate. Now if $c(S)$ is small then $(1-t)$ multiplies both marginal costs and marginal returns and cancels out. Progressive taxation is necessary to get some effect. If $c(S)$ is not small, then even proportionate taxation discourages investment. It is generally thought that forgone earnings account for three-fourths of total school expenditure. Rising costs of college tuition and related expenses in the past decade may have decreased the proportion recently, but probably not by much. There is also evidence that the return to schooling is discontinuous in degree attainment. This "sheepskin effect" gives an extra return for actually completing a degree. Both factors suggest that proportional income taxation has little direct effect on schooling choices.

The authors concentrate on on-the-job training and do not consider school investments. Taxes could affect human capital investment indirectly by affecting the composition, stability, and division of labor within families and the

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labor-force participation of women. Youth dependency amounts to something like one-fourth to one-third of one's life and a nontrivial fraction of human capital investment takes place in the home in those years. Household production is tax exempt and is encouraged by both income and expenditure taxation, but this never gets counted in the calculations. Of course marital instability, declining fertility, and increasing labor-force participation of women have all affected human capital formation in recent decades, but few of these large social changes are thought to be closely associated with income or expenditure tax policy.

Davies and Whalley's simulations are based on the standard utilitarian calculus without explicit intergenerational linkages in preferences. Their analysis can be simplified by solving the time allocation variable s out of the general model and specifying earnings as a function of skills, learning, and work time instead. Thus write $y = g(H, \dot{H}, L)$, where H is human capital stock and $\dot{H}$ is investment, with $g_1 > 0$, $g_2 < 0$, and $g_3 < 0$. If A is financial assets, r the rate of interest, t the rate of income taxation, and t^* the rate of expenditure taxation, then the flow constraint on the intertemporal problem amounts to

$$\dot{A} = (1-t)[rA + g(H, \dot{H}, L)] - C/(1-t^*), \tag{2}$$

assuming that all human capital investments are fully expensed for tax purposes.

Adding constraint (2) to their preference structure and examining the Euler equations shows the following:

(i) Both t and t^* enter the marginal condition for leisure in the same way and have identical distortions on labor supply.

(ii) The expenditure tax t^* multiplies both sides of the intertemporal consumption decision and cancels out. It is nondistorting on saving. The income tax does not factor out and has a distorting effect on saving and nonhuman investment.

(iii) Both t and t^* drop out of the marginal condition for human capital investment and have no direct effects. There is an indirect effect, because income taxes distort the valuation of future money relative to present money and taxes affect labor supply decisions. Both enter the human capital investment decision.

The main point is that introducing human capital does not add any direct distortions. All of the calculations depend on indirect effects and these turn out to be small. In fact introducing a substitute for nonhuman capital makes things better from the welfare point of view. In the simulations reported in the paper, the labor margin is suppressed and hours are fixed. Allowing hours to adjust would increase the calculated distortion, but the effect would be small for men because their compensated labor-supply elasticity is small. Expanding the model to include women would be more interesting because their wage elasticity of participation is larger, but even so the resulting welfare loss depends on the degree of substitution between market and nonmarket production, and little is known about that.

The simulations are built upon the important unstated assumption that human capital has no value outside of the market sector. Suppose the opposite, that human capital has as much value in nonmarket production as in market production. Then even hours worked in the market do not directly affect the return on human capital. However, since human capital used in household production is not taxed, both income and consumption taxes encourage its utilization there and this stimulates excess investment from the social point of view. In this case there is a *direct* distortion on the human capital margin and eliminating another investment distortion through consumption over income taxation might have much larger welfare effects than are calculated here.

Davies and Whalley point out that their analysis only covers worker-financed investments. However, firm-financed investments are similar because most firm-specific human capital investment costs are wage payments and these are fully expensed in tax accounting of firms: accelerated depreciation of human capital applies to firms as well as individuals, and most of what remains are only indirect effects.

While it probably does not affect the central conclusion, there is a conceptual objection to the form of the investment production function chosen for analysis that is obscured by the way in which the model is presented. The slope $-dy/dH = -g_2$ in the earnings function defined above is the marginal cost of investment. On their assumption that the investment production function only depends on s, direct calculation reveals that the marginal cost of investing is increasing in H. This implies that more able people whose endowments of capital are larger invest less than less able people; and that aggregate investment should fall over time, as labor augmenting technical change increases effective endowments. Neither is true. Specifying marginal cost as decreasing in embodied knowledge is preferable on these grounds. Models with that kind of increasing return do exist (Rosen 1976) and could be worked into the analysis with no greater effort than the form now used. Whatever that may be, the analysis makes no reference to changes over time in the social knowledge available for people to invest in, except insofar as it appears in exogenous technical change. This follows the human capital literature, but who is so sure that tax treatments of human capital do not have anything to do with the invention of new knowledge?

Finally, we have here another all-too-familiar instance where the pure economic case for expenditure taxation is firmly established, but where it is not much used. In this sense income taxation is related to such policies as tariffs and quotas, minimum wages, rent controls and price supports—all cases where economists' overwhelming consensus is hardly reflected in actual public policy. Could it be that political considerations enter the determination of which instruments are used? Income taxes seem to have agency-like virtues of clarifying the amounts actually paid by taxpayers and thereby serve as some limit, however small, to the size of the public sector. Value-added taxes are hard to count and do not have these virtues.

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