

# A Life-Cycle Theory of Human Capital Formation, Pension Saving, and Retirement

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## Abstract

This paper derives a comprehensive theory to simultaneously analyze human capital investment, retirement decisions, and (pension) saving choices. Lifecycle interactions between human capital, retirement and savings are shown to be important in explaining individual behavior in human capital investment, (pension) saving and retirement. Model simulations demonstrate that promoting life-long learning or later retirement will not be effective if strong disincentives caused by high taxes, early retirement schemes and strong incentives for pension savings remain in place. Furthermore, promoting private savings for old-age may inadvertently create implicit taxes on skill formation and indirectly stimulate early retirement, thereby worsening ageing problems.

Key-words: human capital, OJT, life-cycle, saving, pensions, retirement

## 1 Introduction

Too little is known about lifecycle interactions between learning, retirement and saving, both theoretically and empirically. Generally, training, (pension) saving and wage determination are separately analyzed, and no generally accepted theories are available to simultaneously address these issues. The consequence is that human capital policies are considered in isolation from retirement and pension policies. This paper demonstrates that ignoring important life-cycle interactions can be potentially very misleading and could well produce ill-founded policy conclusions.

The paper starts by making a first attempt to *systematically* analyze the interactions between human capital investments in OJT, retirement choices and pension saving. To that end, we develop a Ben-Porath (1967) human capital model of OJT which is firmly grounded in neoclassical human capital theory (see for example Mincer, 1958, 1962, 1974; Schultz, 1963; and Becker, 1964). The model is extended with a discrete, endogenous retirement decision as in Jacobs (2009). We show that retirement and pension saving affect the incentives to invest

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in human capital over the lifecycle. By extending the time-horizon over which investments in skills materialize, a higher retirement age promotes investments in on-the-job training (OJT). Later retirement and OJT-investment are therefore complementary. Generous support for early retirement therefore indirectly discourages investment in OJT.

Individuals also make a lifecycle portfolio choice by investing in both financial and in human capital. Stimulating retirement savings implies that savings in human form are discouraged. The intuition is that the opportunity return at which future labor earnings are discounted increases. Equivalently, arbitrage between financial and human investments ensures that both assets must earn equal returns. Hence, human and financial capital are substitutes over the lifecycle. Simulations of the model with various tax and retirement policies provide important insights into the main mechanisms that are at work. The following highly relevant policy-relevant implications finally appear from this analysis:

- Promoting life-long learning or later retirement will not be effective if strong disincentives caused by high tax burdens, early retirement schemes and strong incentives for pension savings remain in place.
- Promoting private savings for old-age may inadvertently create implicit taxes on skill formation and indirectly stimulate early retirement, thereby worsening labor market problems in ageing societies.

Most Western governments will be confronted with the consequences of demographic ageing in the upcoming decennia. Many countries have started to implement ‘life-long learning’ policies to promote investments in OJT so as to raise labor productivity and to improve employability of especially older workers. Finally, many governments stimulate private pension saving, for example through tax-favored saving schemes, so as to reduce the dependency of pensioners on state pensions and collective occupational pension-schemes. This paper demonstrates that these policies cannot be analyzed in isolation from each other and should take into account the dynamic interactions between OJT-investment, retirement and pension saving.

The remainder of this paper is structured as follows. The next section develops the theoretical model. Section 3 simulates the model for a number of stylized policies. Section 4 concludes.

## **2 A model of training, retirement and saving**

We follow Heckman and Jacobs (2010) and Jacobs (2009) by adding an endogenous retirement decision to the otherwise standard Ben-Porath (1967) model of OJT-investments, see also Heckman (1976) and Weiss (1986). This is the canonical model to think about OJT. Although savings are made to ensure consumption smoothing over the lifecycle, most savings will be made for the retirement period in which individuals have no labor earnings. We abstract here from endogenous (initial) education and labor supply decisions on the intensive margin, i.e. hours of work. A partial equilibrium setup is chosen in which the paths of the rental rates for human capital and the interest rate are exogenously given. This would be the case in small, open economies with perfect capital mobility and perfect substitution between labor types in

labor demand. Capital and labor markets are perfectly competitive and frictionless. The latter assumptions are not innocent and we will return to them in detail later.

We assume that a representative individual is born at time  $t = 0$  and has a life-span  $T$  which is exogenously given. At  $t = 0$  the individual enters the labor market. The individual retires at date  $R < T$ . The time constraint states that total time in the labor market  $R$  and in retirement  $T - R$  should equal the life-span  $T$  of the individual:  $T = R + (T - R)$ .

At each date, the individual derive instantaneous utility  $U(C(t))$  from consumption  $C(t)$ . Individuals derive utility  $X(T - R)$  from the years they are retired  $T - R$ . Retirement is a discrete decision to exit the labor market completely. We therefore assume that the retirement decision is not a zero hours worked ‘corner-solution’ (for more discussion, see Jacobs, 2009).

Life-time utility of the individual is a time-separable function of instantaneous consumption felicities and retirement utility

$$\int_0^T U(C(t)) \exp(-\rho t) dt + X(T - R), \quad (1)$$

with  $U'(C(t)) > 0$ ,  $U''(C(t)) < 0$ ,  $X'(T - R) > 0$  and  $X''(T - R) < 0$ .  $\rho$  is the subjective rate of time preference.

The individual starts his life with  $A(0) \equiv A_0 \equiv 0$  in financial assets, which are normalized to zero for convenience. Borrowing and lending on a perfect capital market is possible at constant real interest rate  $r$ .<sup>1</sup> There is no risk and uncertainty.<sup>2</sup> Upon entering the labor market, the individual may devote part of his time to training on-the-job. The time constraint during the working life implies that the fraction of time working  $1 - I(t)$ , plus the fraction of time invested in training  $I(t)$  should be equal to the total time endowment, which is normalized to one. The individual earns gross labor income  $W(1 - I(t))H(t)$ .  $W$  is the rental rate of human capital, which is time-invariant.  $H(t)$  is the stock of human capital which is gathered through training on-the-job in a manner that will be made precise below.

The flow budget constraints until retirement ( $0 < t \leq R$ ) state that the increase in financial assets should equal total interest income, net labor income minus consumption expenditures

$$\dot{A}(t) = (1 - \tau_A)rA(t) + (1 - \tau_L)W(1 - I(t))H(t) - C(t), \quad 0 < t \leq R. \quad (2)$$

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<sup>1</sup>Both liquidity and borrowing constraints can impede socially desirable investments in human capital. From the microeconomic literature, there is ample empirical evidence that borrowing constraints could be important for consumption choices (see for example Hall and Mishkin, 1982; Hayashi, 1985; Mariger, 1987; Zeldes, 1989; Attanasio, 1995; Browning and Lusardi, 1996; and Blundell, 1988). Empirically, direct evidence of borrowing constraints on investments in training on-the-job is missing, see also Bassanini et al. (2006). A large literature identifying the role of liquidity and borrowing constraints for initial education only finds small effects, see for example Carneiro and Heckman (2003), Cunha et al. (2006). In our model simulations savings are mainly made to save for retirement, see figure 2. Hence, if our model is only roughly plausible, binding borrowing constraints are expected to affect the results for training, but probably not to a very large quantitative extent.

<sup>2</sup>Browning and Lusardi (1996) argue that especially precautionary saving is an empirically important component of household’s financial savings. How risk affects human capital investment is critically determined by the ways in which human capital affects the risk to which individuals are exposed (Jacobs et al., 2008). If human capital investment increases risk in labor earnings, risk-averse individuals will underinvest so as to reduce their exposure to risk. However, if human capital investment reduces the exposure to risk, the opposite holds true, i.e., risk-averse individuals will overinvest (see also Levhari and Weiss, 1974). Empirically, little is known about the risk-properties of human capital, see also Jacobs (2007) and Jacobs et al. (2008), and the references mentioned there.

A dot denotes a time derivative (i.e.,  $\dot{A}(t) = dA(t)/dt$ ),  $\tau_L$  is the labor income tax rate, and  $\tau_A$  is the interest tax (or subsidy when negative).

During retirement ( $R < t \leq T$ ) the individual runs down his accumulated assets for consumption purposes:

$$\dot{A}(t) = (1 - \tau_A)rA(t) + (1 - \tau_P)P - C(t), \quad R < t \leq T, \quad (3)$$

where  $P$  is the time-invariant retirement benefit, and  $\tau_P$  denotes the rate at which retirement benefits are taxed. One should interpret the pension benefit  $P$  as that part of pension benefits that is actuarially completely non-neutral, since individuals only receive retirement benefits conditional upon full retirement. Any actuarially fair pension savings are covered by the voluntary saving decision.<sup>3</sup> The individual has no bequest motive and ends his life with zero wealth:  $A(T) \equiv 0$ .

The individual can increase his human capital by allocating time  $I(t)$  to learning activities, while foregoing labor earnings. Without loss of generality, it's assumed that on-the-job training does not require direct costs (for that case, see Ben-Porath, 1967; Heckman, 1976).<sup>4</sup> The individual starts out with  $H(0) \equiv H_0 > 0$  units of on-the-job human capital when he enters the labor market. On-the-job human capital accumulates according to a Ben-Porath (1967)-type production function

$$\dot{H}(t) = BF(I(t)H(t)) - \delta H(t), \quad 0 < t \leq R, \quad (4)$$

where  $B > 0$ ,  $F'(I(t)H(t)) > 0$ ,  $F''(I(t)H(t)) < 0$ .  $B$  is a general productivity parameter. There is dynamic complementarity in human capital formation on-the-job because the marginal product of training investments increases with the level of human capital  $H(t)$ . Hence, large (small) early investments in human capital make later investments in human capital more (less) productive.  $\delta$  denotes the rate of depreciation of human capital.

Integration of the asset accumulation constraints and imposing the initial and terminal conditions on financial wealth ( $A(0) = A(T) = 0$ ) gives the life-time budget constraint of the individual

$$\int_0^T C(t) \exp(-r^*t) dt = \int_0^R W^*(1 - I(t))H(t) \exp(-r^*t) dt + \int_R^T P^* \exp(-r^*t) dt, \quad (5)$$

where  $r^* \equiv (1 - \tau_A)r$ ,  $W^* \equiv (1 - \tau_L)W$ , and  $P^* \equiv (1 - \tau_P)P$  denote the after-tax values of the interest rate, rental rates, and pensions.

The individual maximizes life-time utility by choosing consumption (saving), on-the-job training, and retirement subject to the household budget constraint, the time constraints, and the accumulation equation for on-the-job human capital. The Hamiltonian for this optimal

<sup>3</sup>Note that in many countries tax systems feature tax-deductibility of pension contributions, taxed pension benefits, and no taxation of pension returns. This is equivalent to setting the tax on (pension) saving to zero ( $\tau_A = 0$ ).

<sup>4</sup>Empirically, forgone earnings are the major cost of investment in human capital. In addition, firms and workers can always make the costs of training effectively deductible by letting the firm pay the direct costs in exchange for lower wages.

control problem can be written as follows

$$\begin{aligned} \max_{\{C(t), R, I(t), H(t)\}} \mathcal{H} \equiv & \int_0^T U(C(t)) \exp(-\rho t) dt + X(T - R) + \mu(t) [BF(I(t), H(t)) - \delta H(t)] \\ & + \lambda_0 \left[ \int_0^R W^*(1 - I(t)) H(t) \exp(-r^* t) dt + \int_R^T P^* \exp(-r^* t) dt - \int_0^T C(t) \exp(-r^* t) dt \right], \end{aligned} \quad (6)$$

where  $\lambda_0$  is the marginal utility of life-time income,  $\mu(t)$  is the co-state variable at time  $t$  associated with the on-the-job human capital accumulation equation, and  $H_0$  is given. In the remainder we assume that all solutions to the maximization problem are interior. Therefore, we ignore the non-negativity constraints on all decision variables. Most of these constraints are trivial, except for one: the non-negativity constraint on working time ( $I(t) \leq 1$ ). This implies that individuals always work some positive amount of time (if not retired) and are never choosing a corner where they invest full-time in OJT.<sup>5</sup>

We assume that the first-order conditions for a maximum are necessary and sufficient<sup>6</sup>

$$\frac{\partial \mathcal{H}}{\partial C(t)} = U'(C(t)) \exp(-\rho t) - \lambda(t) = 0, \quad 0 < t \leq T, \quad (7)$$

$$\frac{\partial \mathcal{H}}{\partial R} = -X'(X - R) + \lambda_R ((1 - \tau_L)W(1 - I_R)H_R - (1 - \tau_P)P) = 0, \quad (8)$$

$$\frac{\partial \mathcal{H}}{\partial I(t)} = \mu(t) BF'(I(t)H(t))H(t) - \lambda(t)(1 - \tau_L)WH(t) = 0, \quad 0 < t \leq R, \quad (9)$$

$$\frac{\partial \mathcal{H}}{\partial H(t)} = \mu(t) [BF'(I(t)H(t))I(t) - \delta] + \lambda(t)(1 - \tau_L)W(1 - I(t)) = -\dot{\mu}(t), \quad 0 < t \leq R, \quad (10)$$

where  $\lambda(t) \equiv \lambda_0 \exp(-r^* t)$  denotes marginal utility of income at date  $t$ . In addition we have to impose a transversality condition on the co-state variable stating that the marginal value of human capital is zero at the date of retirement

$$\mu_R H_R \exp(-(1 - \tau_A)rR) = 0. \quad (11)$$

Using standard routines we obtain the Euler equation for consumption

$$\frac{\dot{C}(t)}{C(t)} = \theta(t) ((1 - \tau_A)r - \rho), \quad 0 \leq t \leq T, \quad (12)$$

where  $\theta(t) \equiv \left(-\frac{U''(C(t))C(t)}{U'(C(t))}\right)^{-1}$  is the intertemporal elasticity of substitution in consumption. If the rate of time preference is lower than the real after-tax return on financial saving, consumption features an upward sloping profile over the lifecycle. A larger intertemporal elasticity of substitution results in a stronger upward sloping consumption profile and a stronger sensitivity of saving with respect to net after-tax returns.

<sup>5</sup>Like Heckman (1976) we think that the analysis of ‘corners’, as pursued for example in Ben-Porath (1967) and Weiss (1986), distracts from the main mechanisms at work. In particular, an initial phase during the lifecycle with mainly training can be seen as a phase with low labor earnings, not necessarily a phase with zero earnings.

<sup>6</sup>Sufficiency is not automatically guaranteed due to the feedback between retirement and human capital accumulation. Only sufficiently strong decreasing returns in human capital formation and sufficiently concave retirement sub-utility ensure an interior solution. We assume that these conditions are met.

Optimal retirement is given by (note that  $I_R = 0$  at the end of the working life, see below)

$$\frac{X'(T - R)}{\lambda_R} = (1 - \tau_R)(1 - \tau_L)WH_R. \quad (13)$$

$\tau_R \equiv \frac{(1 - \tau_P)P}{(1 - \tau_L)WH_R}$  denotes the net replacement rate of net retirement income in terms of net final earnings.  $\tau_R$  is the implicit tax rate on continued work due to non-actuarially fair pension benefits. The marginal willingness to pay for an additional year in retirement should be equal to the marginal costs of an extra year in retirement. The marginal benefit is the marginal rate of substitution between retirement utility and consumption at the date of retirement. The marginal costs are given by the value of the net forgone labor earnings in the last year on the labor market. Note that the implicit tax on retirement  $\tau_R$  is added to the explicit labor tax  $\tau_L$  on retirement. Both give stronger incentives to retire earlier. However, the direct tax is often overlooked in retirement studies, which focus mainly on the implicit tax.  $\lambda_R$  captures wealth effects in the retirement decision. Richer individuals have a lower marginal utility of income and retire earlier – *ceteris paribus*. Note that a higher tax on (pension) saving  $\tau_A$  gives stronger incentives to retire later, since the effective discount rate at which retirement utility is discounted increases, since  $\lambda_R = \lambda_0 \exp(-(1 - \tau_A)rR)$ . A lower interest rate thus effectively ‘enlarges’ the time-horizon over which decisions are made, since the future is less heavily discounted. The individual has stronger incentives to retire later if he has more human capital  $H_R$ , since this raises forgone labor earnings while being retired. Thus, better-skilled workers retire later when the income effect of higher skills are outweighed by the substitution effects of higher skills – *ceteris paribus*. Similarly, if individuals do not train and end their career with low levels of human capital, the incentive to retire will be stronger since the opportunity costs of doing so diminish.

Investment in on-the-job training is governed by

$$(1 - \tau_L)W = m(t)BF'(I(t)H(t)), \quad m(t) \equiv \mu(t)/\lambda(t), \quad 0 \leq t \leq R. \quad (14)$$

This equation states that the marginal costs of an hour devoted to on-the-job human capital investment ( $(1 - \tau_L)W$ ) should be equal to the discounted value of the marginal benefits in terms of higher future wages  $m(t)BF'(I(t)H(t))$ .  $m(t)$  discounts the stream of future wage increases  $F'(I(t)H(t))$  back to time  $t$ .  $m(t)$  is therefore the marginal value of one unit of human capital at time  $t$ . Investment in on-the-job human capital increases if the marginal value of one unit of human capital is large (high  $m(t)$ ) and if the opportunity costs, in terms of forgone labor earnings, are low (low  $(1 - \tau_L)W$ ). Moreover, investments in human capital tend to increase if the individual has a larger stock of human capital (large  $H(t)$ ). This is due to the dynamic complementarity of investments in human capital. Finally, investment in OJT increases if the individual has a higher exogenous productivity of learning  $B$ .  $B$  captures, for example, the level of initial education before entering the labor market. Thus, better educated individuals would invest more in OJT during the lifecycle.

From the first-order condition for  $H(t)$  we find a first-order differential equation for the

marginal value of a unit of human capital.

$$\dot{m}(t) - ((1 - \tau_A)r + \delta)m(t) = -(1 - \tau_L)W, \quad 0 \leq t \leq R. \quad (15)$$

This equation can be solved analytically (after using the transversality condition  $m_R = 0$ ):

$$m(t) = \frac{(1 - \tau_L)W}{((1 - \tau_A)r + \delta)} (1 - \exp[(-(1 - \tau_A)r + \delta)(t - R)]), \quad 0 < t \leq R. \quad (16)$$

The marginal value of a unit of human capital at time  $t$  is increasing with the effective net wage rate at date  $t$ ,  $(1 - \tau_L)W$ , decreasing with the depreciation adjusted real interest rate  $((1 - \tau_A)r + \delta)$ , and decreasing with the remaining time-span over which the returns in human capital are harvested, i.e. a smaller  $[1 - \exp[(-(1 - \tau_A)r + \delta)(t - R)]]$ . Note that the last term is an annuity term capturing the finite time-horizon of the investment in human capital. A higher interest rate (or depreciation rate) effectively shortens the time-horizon of individuals. The marginal value of human capital  $m(t)$  is independent from initial wealth, due to the assumption of perfect capital markets. Hence, individuals with differing wealth endowments would make identical human capital investments (*ceteris paribus*).

The marginal value of human capital declines continuously over the lifecycle:

$$\dot{m}(t) = -(1 - \tau_L)W \exp[(-(1 - \tau_A)r + \delta)(t - R)] < 0, \quad 0 < t \leq R. \quad (17)$$

The reason is that the time-horizon over which the returns to the investments can be reaped diminishes as individuals age. Hence, investment in human capital  $I(t)H(t)$  falls continuously over time, until it becomes zero at the date of retirement  $t = R$ . Intuitively, at the date of retirement investments have no value, since the returns on OJT are zero if individuals do not work anymore.

Substitution of  $m(t)$  into the first-order condition for  $I(t)$  in equation (14) gives an arbitrage condition saying that the net return on the investment in human capital (i.e., after depreciation) must be equal to the net-return on financial saving:

$$BF'(I(t)H(t)) (1 - \exp[(-(1 - \tau_A)r + \delta)(t - R)]) - \delta = (1 - \tau_A)r, \quad 0 \leq t \leq R. \quad (18)$$

Note that the labor tax does  $\tau_L$  not affect the net return to human capital, since all opportunity costs and benefits from investments in human capital receive a completely symmetric tax treatment (Heckman, 1976). Note also that a higher tax on financial saving makes human capital investment more attractive by lowering the effective rate at which future wage increases are discounted, and by increasing the effective time-horizon of the individual.

### 3 Simulations

To gain more insight into the comparative dynamics of the model, we simulate it for a reasonable set of parameters. To that end, we need to put some structure on the utility function and the production function for human capital. We assume that utility is represented by relatively

standard CES sub-utility functions

$$\int_0^T \frac{C(t)^{1-1/\theta}}{1-1/\theta} \exp(-\rho t) dt + \gamma \frac{(T-R)^{1-1/\beta}}{1-1/\beta}, \quad \theta, \gamma, \beta > 0, \quad (19)$$

where  $\theta$ ,  $\gamma$ , and  $\beta$  denote the inter-temporal elasticity of substitution in consumption, a preference parameter for retirement and the retirement elasticity. The human capital production function is Cobb-Douglas

$$F(I(t)H(t)) = (I(t)H(t))^\alpha, \quad \alpha > 0, \quad (20)$$

where  $\alpha$  is the constant elasticity of the human capital production function. The simulations use a discrete-time version of the model, which is derived in the appendix.

The time-span is set at 60 years, hence  $T = 60$ . We assume that individuals start working at age 20 so that individuals die at age 80. We thus ignore the initial education phase. A pure rate of time preference of  $\rho = 0.025$  is chosen, which is fairly standard. The same is true for the real interest rate, which is set at  $r = 0.05$ . After an extensive review of the scarce empirical literature, Trostel (1993) sets the elasticity of the human capital production function at  $\alpha = 0.6$ . We employ the same value in our simulations. Furthermore, we set the depreciation rate of human capital at a relatively low value of  $\delta = 0.02$ . Indeed, most earnings profiles do not tend to level-off much at the end of the lifecycle, hence depreciation of human capital appears to be modest (Heckman et al., 1998).

In the appendix we demonstrate that the uncompensated elasticity of retirement – at constant levels of human capital – is given by  $\frac{(T-R)}{R}\beta\left(1 - \frac{1}{\theta}\right)$ . Consequently, both the intertemporal elasticity of substitution  $\theta$  and the retirement elasticity  $\beta$  jointly pin down the retirement elasticity. The estimates in Gruber and Wise (1999, 2002), OECD (2004), and Duval (2004) imply that the uncompensated elasticity of labor force participation of older workers with respect to the implicit tax on retirement (thus including wealth and income effects) is approximately one third. We employ a more conservative value of 0.2. Moreover, we need to assume an intertemporal elasticity of substitution in consumption  $\theta$  larger than unity so as to find a positive uncompensated retirement elasticity. We have set it at  $\theta = 1.25$  in our simulations. A value of  $\theta = 1$  is often used in real business-cycle models, see e.g. Lucas (1990). Although the empirical estimates vary considerably, a value of  $\theta = 0.5$  is suggested by most empirical microeconomic research, see for example Attanasio and Weber (1995). However, values of  $\theta < 1$  imply backward bending ‘retirement curves’, which are clearly counter-factual. By setting  $\theta = 1.25$  we obtain realistic retirement behavior and avoid too large wealth/income effects in retirement. Finally, a value of  $\beta = 2$  pegs the uncompensated retirement elasticity at 0.2 at a calibrated retirement age of  $R = 40$  (age 60) and a life-span of  $T = 60$ .

The baseline set of policy variables is  $\tau_L = 0.5$ ,  $\tau_A = 0.30$ , and  $\tau_R = 0.3$ . These values match unweighted averages for a sample of 16 continental European and Anglo-Saxon countries (see also Jacobs, 2009). Total marginal tax wedges on labor income (including employer contributions and local taxes) are 51% for a single household without dependents which earns the average production wage (OECD, 2007). The effective marginal tax rate on capital income is harder to obtain given the large differences in tax treatments of various sources of capital



income in different countries (see for example Carey and Rabesona, 2004). For this moment we have set it at 30%. Gruber and Wise (1999), OECD (2004), and Duval (2004) show that the implicit tax on retirement amounts to around 30% for an older worker aged between 55–65, although there are substantial cross-country differences.<sup>7</sup>

The remaining parameters ( $W$ ,  $B$ , and  $\gamma$ ) are calibrated such that the individual retires at age 60 ( $R = 40$ ), he invests 71% of his time at the start of his career in human capital (i.e.,  $I(0) = 0.71$ ) and the individual's gross labor earnings per year are 30.6 (thousand euro) on average during working-life. The calibrated values for the remaining parameters are:  $W = 25.4$ ,  $B = 0.09$ , and  $\gamma = 2.4$ . Tax revenues are absorbed by the government to finance spending on public goods and are not rebated.<sup>8</sup>

The baseline time-paths of consumption, the value of total investment in human capital ( $WI(t)H(t)$ ), total labor earnings ( $W(1 - I(t))H(t)$ ), and total human capital ( $WH(t)$ , scaled with rental rates) are plotted in Figure 1. Investment in human capital is high at the beginning of the working career, and declines monotonically until the retirement age is reached. The reason is that the payback time of investments continuously decreases. Hence, returns on investments fall over time. Indeed, labor earnings drop to zero at the retirement age of 60. The lifecycle profile of labor earnings steadily increases until it peaks at age 53 and then decreases slightly afterwards. This reflects both the investment in OJT before the peak and the depreciation of human capital after the peak. There would be no decline in labor earnings at the end of the lifecycle in the absence of depreciation of human capital. Also, the total value of the time endowment is plotted ( $WH(t)$ ). This is a measure for total labor productivity, since rental rates are constant over time. It peaks at age 46, before the peak in earnings, cf. Ben-Porath (1967) and Heckman (1976). The intuition is that at age 46 individuals are still investing about 10% of their time endowment in OJT. Consequently, total labor productivity peaks earlier in the lifecycle than total earnings do. The individual also has a valuable time endowment after retirement, although it is steadily depreciating. Investment in human capital drops to zero at retirement, since the marginal value of investment in human capital has become zero at that date. Finally, the lifecycle path of consumption is increasing. The reason is that the net interest rate is larger than the pure rate of time-preference. Note that the consumption path is substantially lower than the earnings path, since the latter are denoted in gross terms (i.e., before 50% labor income taxes).

Interesting wealth dynamics emerge from our model, see Figure 2. Like in any lifecycle model, total wealth, defined as the present discounted value of remaining life-time financial and human wealth, declines first, and then rises somewhat until retirement, and then declines to zero at the end of life. In contrast to models with exogenous human capital, financial wealth drops to negative levels at the beginning of the lifecycle while the individual is investing in OJT. After age 33, the individual starts to save, and above age 47 the individual is debt free and financial wealth is accumulated for retirement. The evolution of financial wealth shows

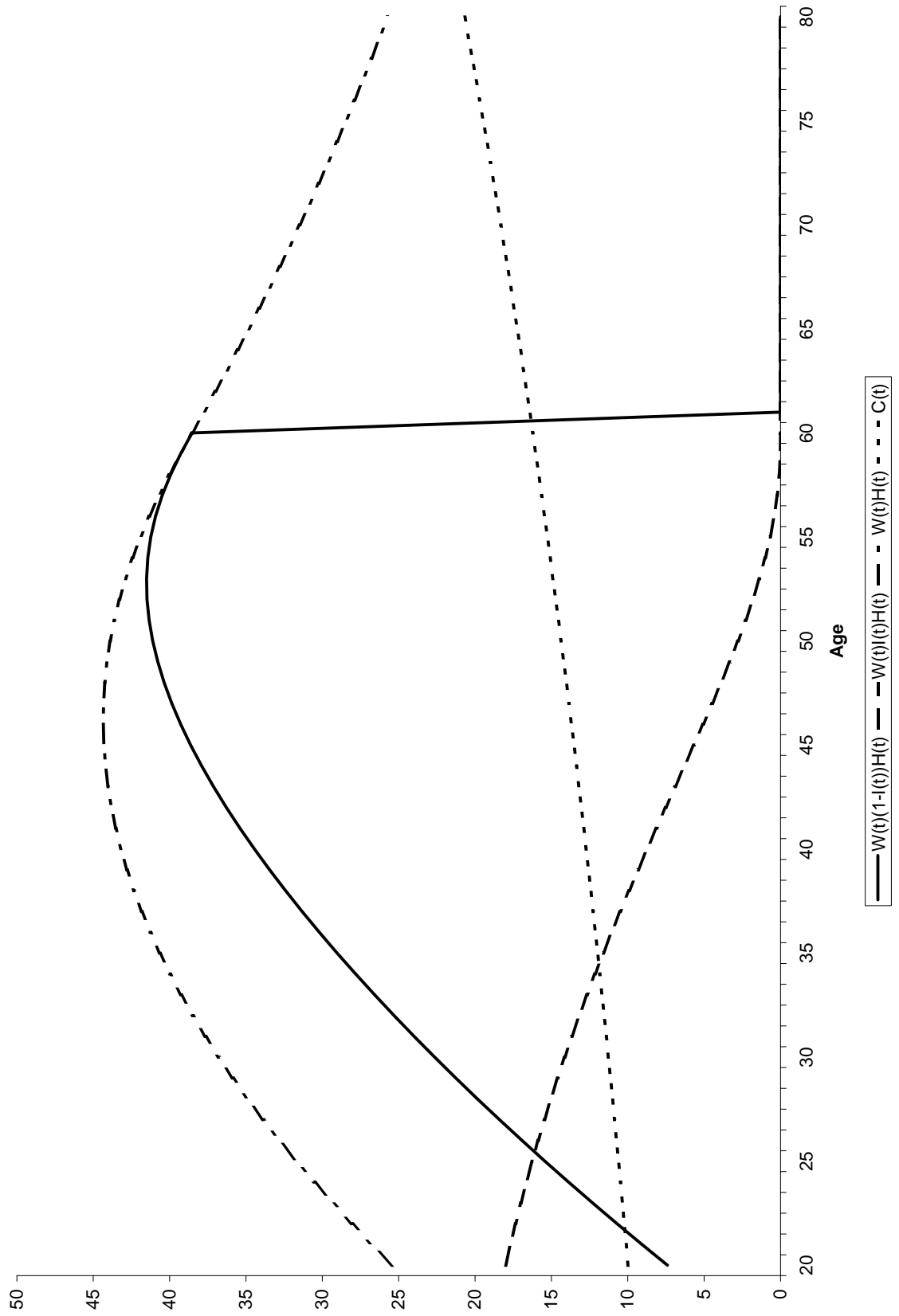
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<sup>7</sup>Gruber and Wise (1999) report the so-called 'tax force' statistic, which corresponds to the sum of marginal tax wedges on retirement while working during ages 55–69. Dividing the 'tax force' by 15 gives a yearly average marginal tax wedge on retirement during working ages 55–69. OECD (2004) computes marginal tax wedges on retirement which are around 20% (40%) on average for 55-59 (60-64) year old workers. Duval (2004, p.33) calculates that average implicit tax rates in OECD countries are equal to 30%.

<sup>8</sup>Implicitly, we assume that public goods enter in a completely separable fashion in the utility function.

Figure 1:

Labor earnings, consumption, OJT-investment and human capital over the life-cycle



that capital markets to smooth consumption over the lifecycle could be important, although borrowing is not that large at the beginning of the lifecycle. Indeed, most of the financial wealth is accumulated after age 45 to finance consumption during the retirement phase. The evolution of human wealth partially mirrors the evolution of financial wealth. Human wealth steadily decreases while working as the remaining life-time earnings diminish. At the moment of retirement, human wealth only consists of the remaining present value of retirement benefits, and would be zero in the absence of them.

Figure 3 plots the simulated patterns of OJT-investment and lifecycle earnings for different values of the labor tax rate and the capital tax rate. Lifecycle investments in OJT are affected by the labor tax rate through its impact on retirement only (recall that all costs of OJT are deductible). Since retirement is distorted by the presence of the implicit tax  $\tau_R$ , a higher explicit tax on retirement  $\tau_L$  reduces OJT-investments to a considerable extent, since the payback period of investment in human capital falls substantially. As a result, lifecycle earnings profiles shift towards the origin. As OJT-investments fall, the peak of earnings will be earlier. Moreover, since less time will be invested in OJT, earnings when young increase slightly. However, at later ages this is more than offset by lower stocks of human capital so that earnings declines. This, in turn, makes earlier retirement more attractive as the opportunity costs of retirement are lower when wages in the last year working are lower. This graph indirectly shows that policies which stimulate earlier retirement, can have important consequences for OJT investments. We return to this below.

A higher capital tax boosts investments in human capital, since saving becomes less attractive compared to investment in OJT. Again, we see earnings-profiles rotate as under the labor tax, but now in the reverse direction. Especially at the beginning of working careers, OJT-investment increases, hence total gross labor earnings fall. Over time, however, this fall in earnings will be compensated by rising levels of human capital, which result in increasing labor earnings at later ages. The peak in the earnings profile shifts to later ages and individuals end their working careers with substantially higher earnings. This graph demonstrates the fundamental interactions between saving policies and OJT-investments. Indeed, human capital investments can be seriously affected if governments want to boost saving by lowering the capital tax (or even give tax-incentives for saving). Consequently, OJT-policies cannot be seen in isolation from pension and saving policies.

Figure 4 plots the investment and earnings profiles for various implicit tax rates on retirement and depreciation rates of human capital. A higher implicit tax on retirement  $\tau_P$ , much like the labor tax, gives stronger incentives to retire early from the labor market. Indeed, investment in human capital falls during all ages. This increases earnings temporarily as workers have higher labor earnings at the beginning of the lifecycle, but their wage growth over the lifecycle will be substantially lower. Since less human capital will be accumulated, workers end up with lower wages at the end of their careers. This makes retirement also more attractive as the opportunity costs of retirement have fallen. Thus, when retirement schemes are actuarially very unfair, and thereby cause large distortions on retirement, this seriously impairs investments in OJT too. As a result, our theoretical model confirms the notion that individuals do not invest in skills because they retire early, and they retire early because they do not invest in skills.

Figure 2:

**Total, human, and financial wealth over the life-cycle**

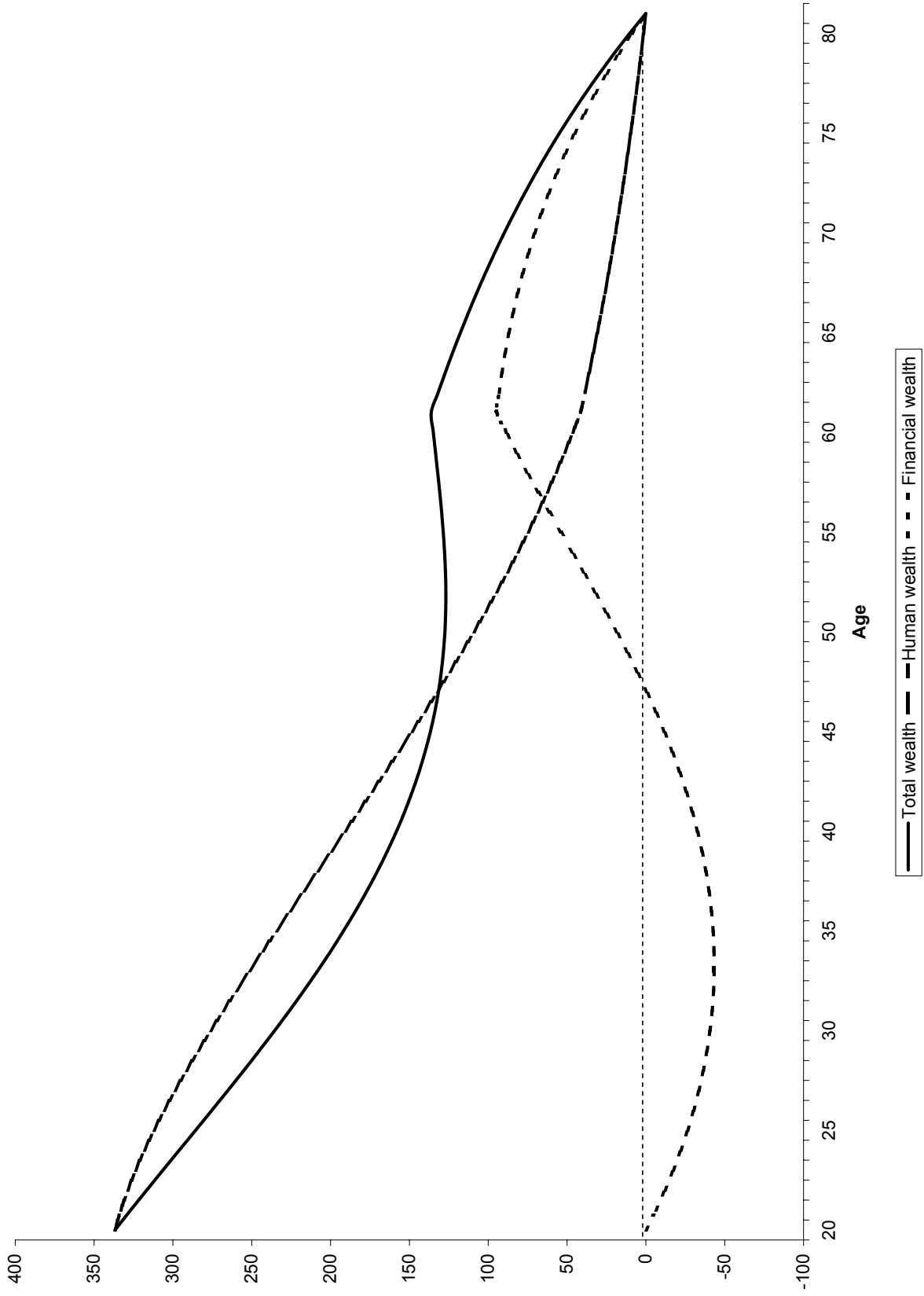


Figure 3:

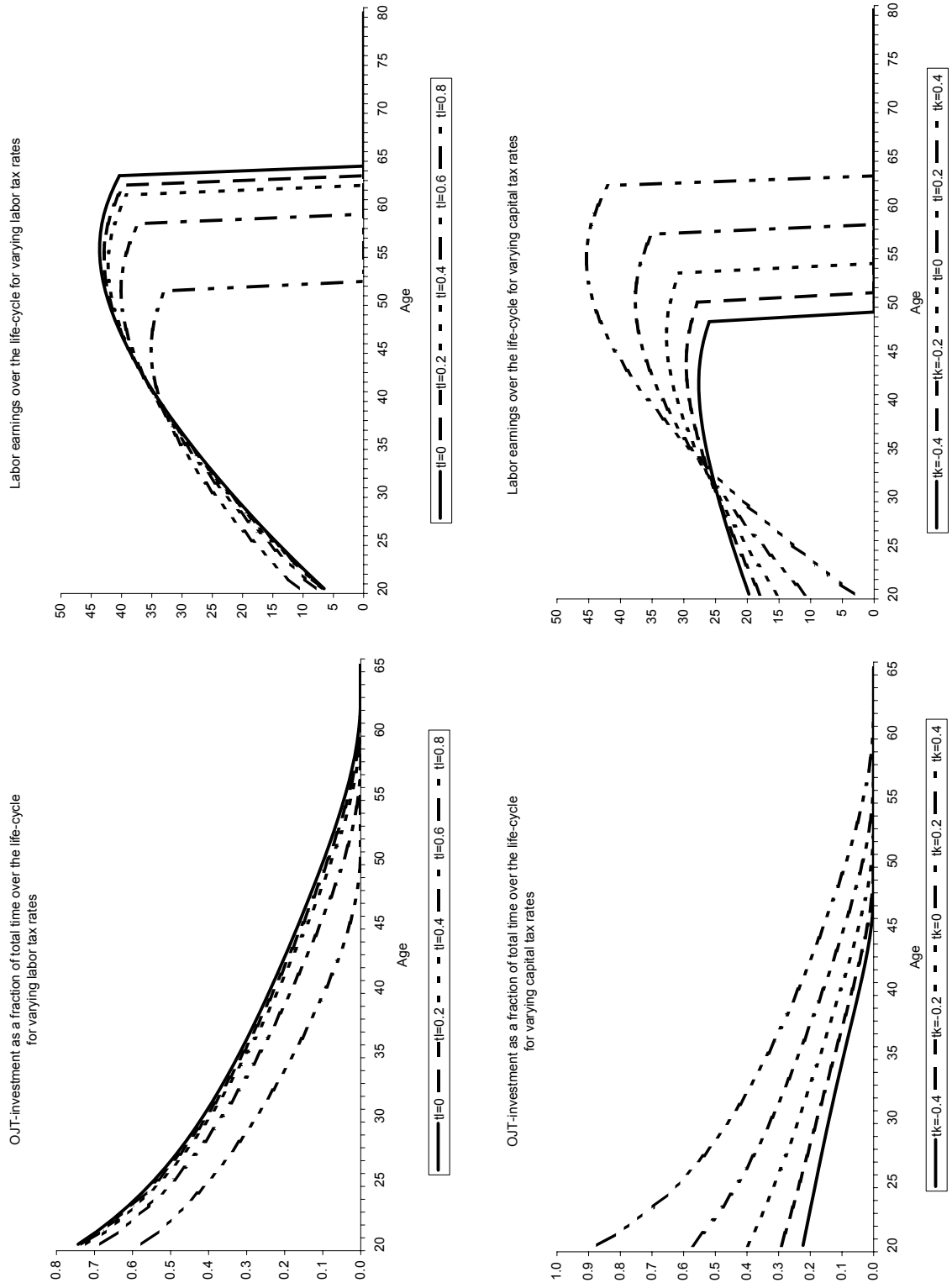
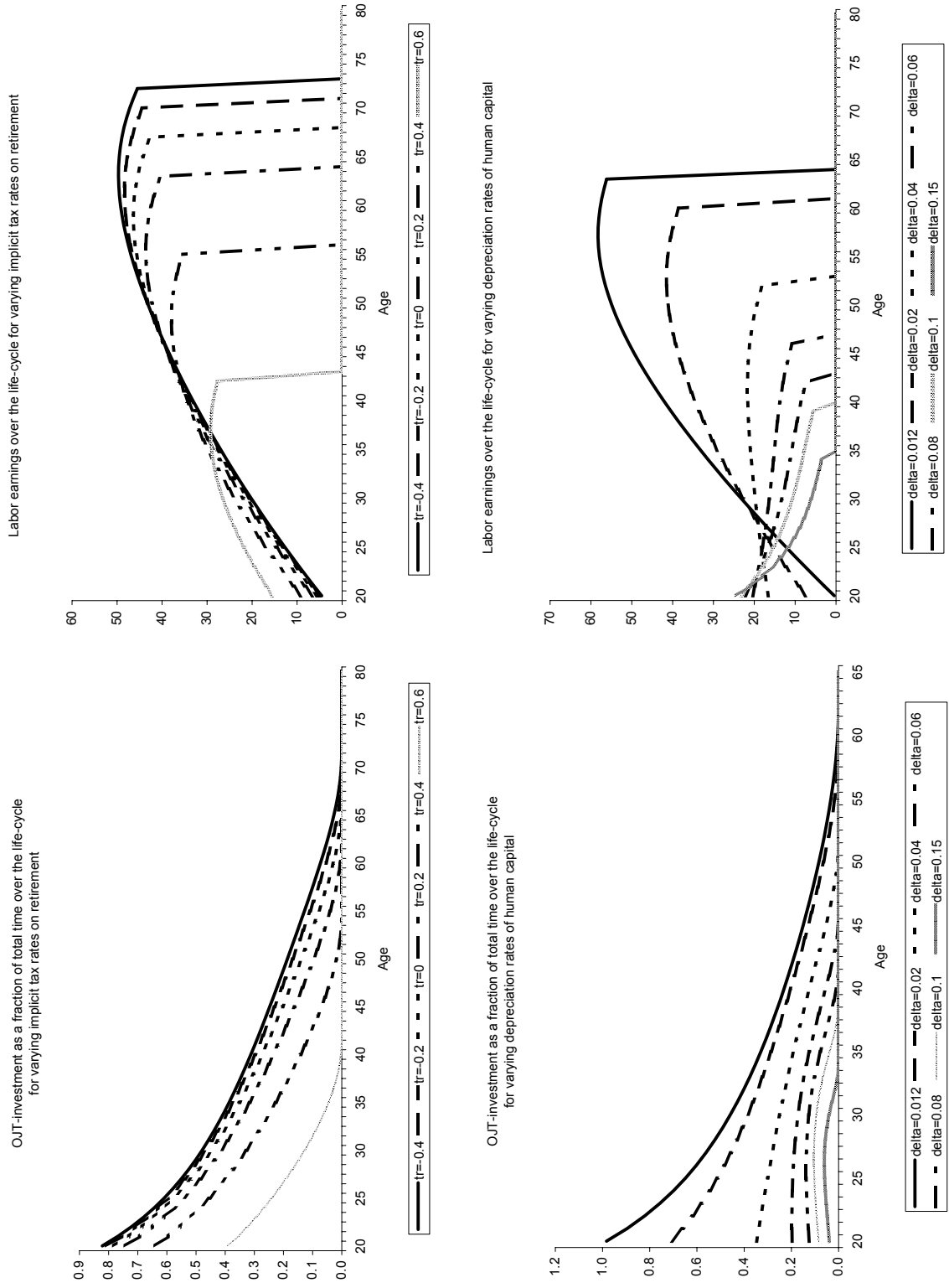


Figure 4:



A larger rate of depreciation of human capital has similar effects as a higher implicit tax on retirement, only the consequences of higher depreciation rates are more severe. Indeed, the higher depreciation rate makes saving in financial capital relatively more attractive at all times, hence investments in human capital decrease throughout the lifecycle. Indeed, at relatively modest depreciation rates (5% and higher), earnings profiles even become downward sloping over the lifecycle. The reason is that the depreciation rate has become larger than the real interest rate, so that human capital decumulation has become optimal.

Although the parameters of the model are not completely unrealistic, we still should be careful in drawing quantitative conclusions. All simulations are driven by the particular assumptions on the intertemporal elasticity of substitution in consumption  $\theta$ , the elasticity of the human capital production function  $\alpha$ , and the retirement elasticity  $\beta$ . Figures 5 and 6 provide some sensitivity analyses on the main elasticities of the model. The consumption and retirement elasticities are indeed important for retirement choices. Slight differences in both parameters give quantitatively large impacts on the retirement decision. This is in main part driven by the severe distortions in retirement choices. Indeed, the total tax wedge on retirement equals  $1 - (1 - \tau_L)(1 - \tau_R) = 0.65$ . Consequently, relatively small changes in elasticities have large impacts on retirement choices. The impacts on retirement choices should therefore be handled with care, given the relatively high value of  $\theta$  we assumed in the base-line simulations so as to avoid backward-bending retirement curves. Not surprisingly, the elasticity of the human capital production function determines to an important extent the behavioral response of OJT-investments over the lifecycle. However, the lifecycle profile of wages is not so much affected. It only flattens out a bit over time as  $\alpha$  increases. Note that we could not increase  $\alpha$  a lot, since the non-negativity constraint on working time would then become binding. Finally, we simulated the model for different productivity levels of human capital  $B$ . We find that a higher productivity in OJT-investments (e.g. due to more initial education) unambiguously raises later OJT-investments. Initial earnings fall because individuals with a larger  $B$  spend a larger fraction of time to human capital investment, but earnings at later stages of the lifecycle increase as a result of more human capital accumulation.

## 4 Empirical content of the model

We developed a parsimonious theoretical model of investment in human capital, saving, and retirement. The model contained a number of empirically testable implications:

- Earnings follow a ‘hump’ shape, and labor productivity peaks before earnings;
- Investment in human capital decreases with age;
- Investment in training increases if productivity of training is larger, e.g. due to larger investment in initial education;
- Retirement ages decrease with the implicit or explicit tax rate on continued work, which in turn reduces OJT;
- (Retirement) savings decrease with a larger tax on savings, which in turn boosts OJT.

Figure 5:

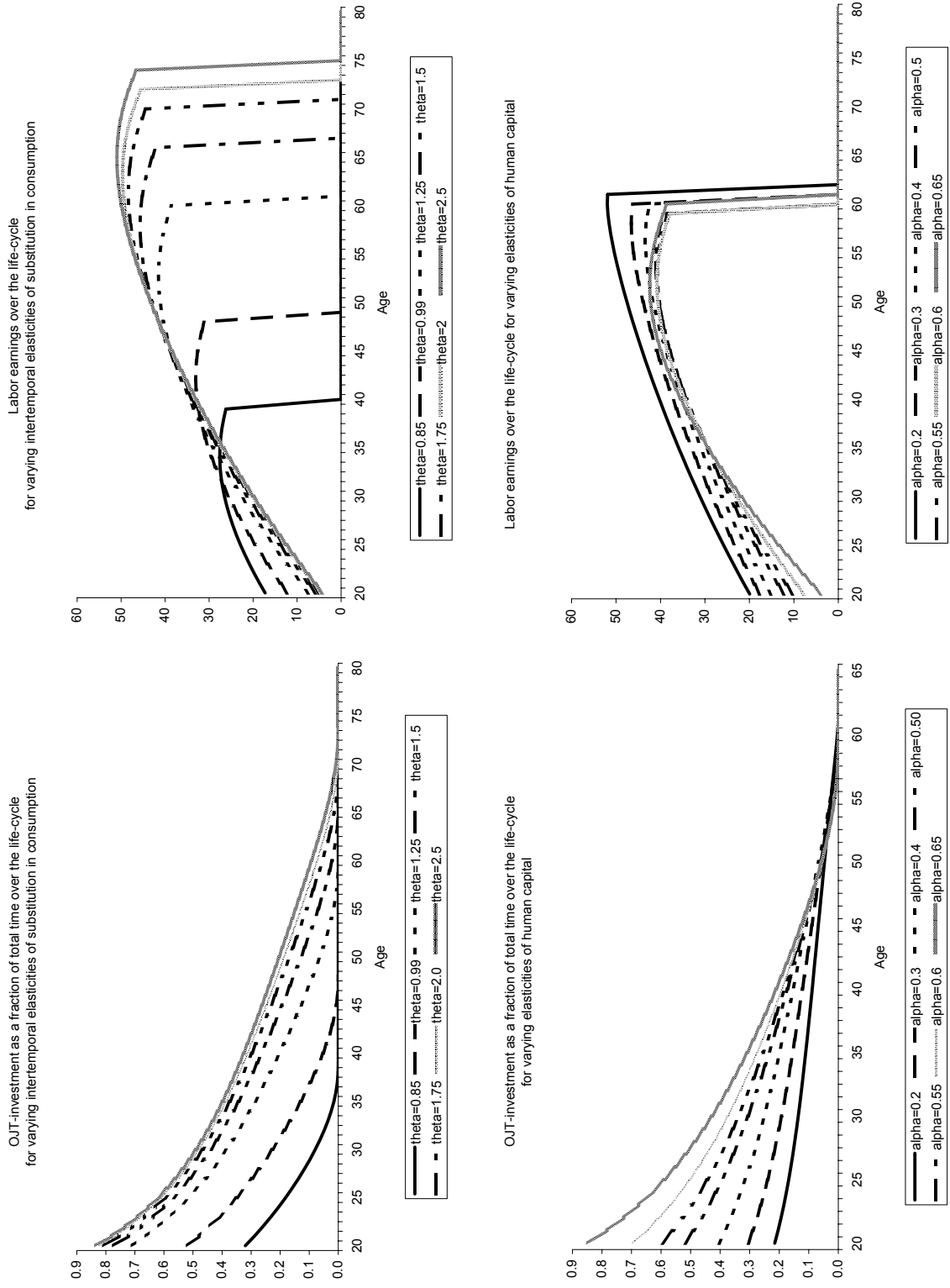
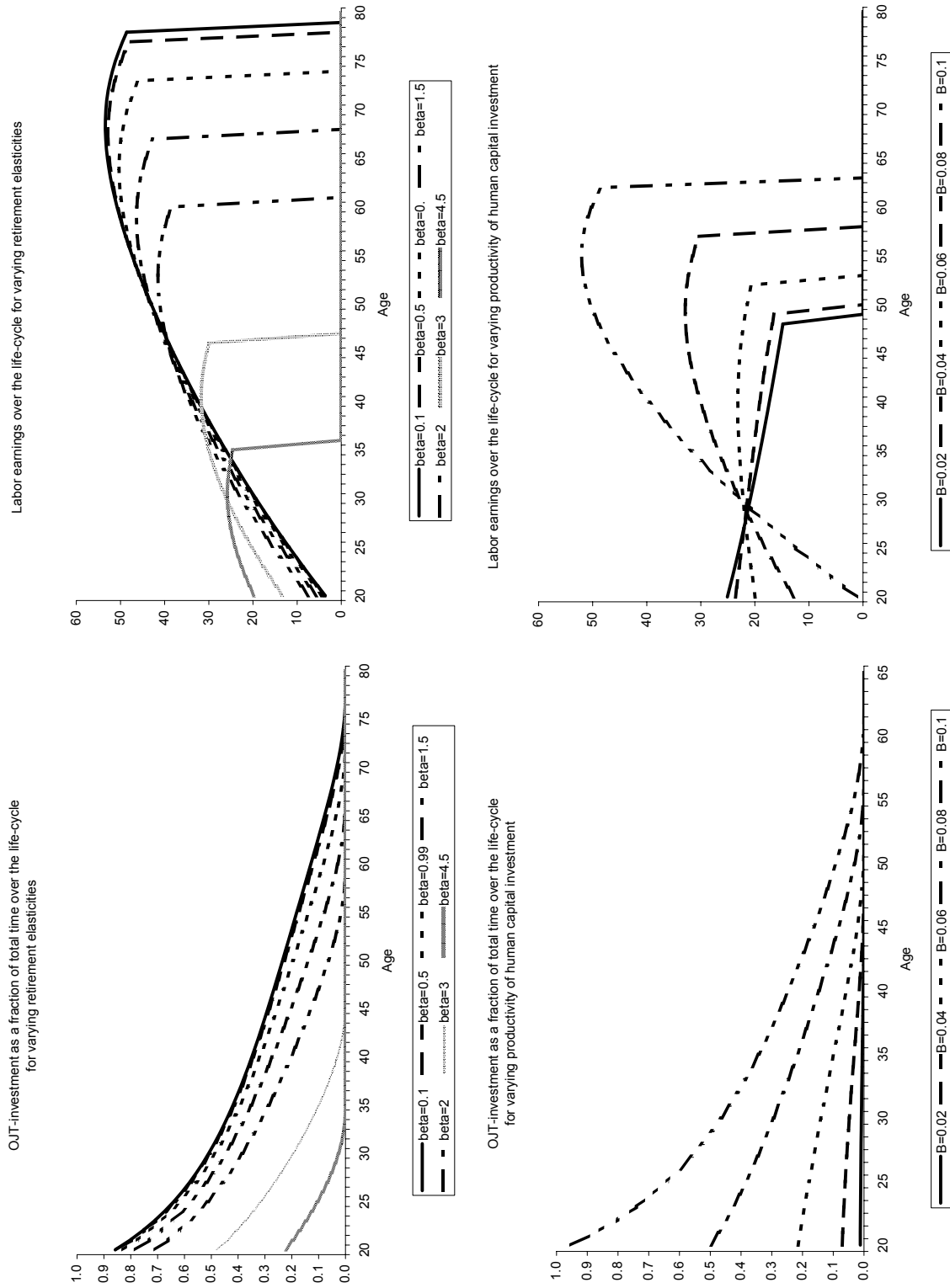




Figure 6:



In the remainder of this section we argue that the empirical evidence is in line with the stylized features of the model.

#### 4.1 Earnings-profiles and OJT

Age-earnings profiles ( $W(1 - I(t))H(t)$ ) are indeed hump-shaped, which follows from the commonly estimated Mincer wage-equation with experience (age) and experience squared (age squared) (see e.g. Card, 1999).

Direct measurements of productivity over the lifecycle ( $WH(t)$ ) are indeed quite suggestive of a hump-shaped pattern of productivity of the lifecycle as well. Note, again, that productivity does not equal labor earnings, because of investments in training  $I(t)$ . Skirbekk (2005) surveys the literature and finds the following stylized facts. Cognitive abilities decline after some stage in adulthood. Older workers compensate withering cognitive skills with sufficient working experience (for example by OJT or learning-by-doing). Based on subjective evaluations of managers, age-productivity profiles do not seem to display systematic patterns. Evaluations by workers suggest that worker's productivity indeed falls with age. Objective evaluations (based on measured outputs) suggests that quantity and quality of output show a hump-shaped pattern with age. Importantly, Skirbekk (2005) also presents empirical evidence that labor productivity measures peak before labor earnings, which is theoretically predicted by our model as well.

However, from the hump-shaped pattern of earnings one cannot conclude that they are *caused* by investments in OJT. Indeed, other theories of wage determination over the lifecycle could be relevant too (deferred payments, learning by doing, wage setting institutions, etc.). Skirbekk (2005) resorts to Lazear's (1976) theory of deferred payments to explain the earnings-profiles. This theory will be discussed later in more detail as well.

Direct estimates of the effect of training activities on wages generally give positive wage returns (Leuven, 2005; Bassanini et al., 2006). Allocating time to training activities is correlated with rising wages over the lifecycle. However, the empirical evidence also seems fragile due to selectivity problems in the estimations (Leuven, 2005; Bassanini et al., 2006). Moreover, some serious measurement issues prevent drawing strong conclusions, see below.

#### 4.2 Time-horizon and complementarity with initial education and OJT

Given the finite horizon ( $T$ ), younger workers are expected to participate more in training. Furthermore, better educated workers (higher  $B$ ) are also expected to invest more in training, since training increases with the productivity of training activities. Both are indeed found to be stylized facts in the data (Leuven, 2005; Bassanini et al., 2006).

#### 4.3 Participation and OJT

Another stylized fact is that male workers have higher participation rates in training than female workers. One obvious explanation is that men work more hours and have higher labor participation. Consequently, their 'utilization rates' of OJT human capital are higher. Given that our model does not allow for an endogenous work/participation decision, we miss this feature. However, Heckman and Jacobs (2010) extend a similar model with endogenous labor

supply and find that workers with less labor supply utilize their human capital less and therefore invest less in OJT. Women could be outside the labor market because they invest more in the human capital of children, which is something that we abstracted from.

#### 4.4 Retirement and OJT

Gruber and Wise (1999) show that labor force attachment of the average worker is rapidly declining with age. Many workers retire long before statutory retirement ages via all kinds of early-retirement schemes. Pension benefits can be generous as well. Pension replacement incomes in Continental European are quite high and about 60-80% of pre-retirement earnings for an average worker (OECD, 2005). Pension systems are PAYG state pensions almost everywhere. Exceptions are the Anglo-Saxon countries, the Netherlands, Sweden and Denmark that also heavily rely on substantial private funding, either through DB/DC occupational pensions or individual saving schemes see also OECD (2005). It is not easy to make international comparisons because the institutional details vary from country to country. Gruber and Wise (1999) summarize the impact of early retirement schemes on the labor market by the implicit marginal tax rates imposed on an additional year of work (our  $\tau_R$ ). Duval (2004) and OECD (2004) demonstrate that early retirement schemes do indeed cause very high marginal tax rates on pre-retirement incomes. Moreover retirement ages and benefit generosity are very negatively related. Gruber and Wise (1999, 2002) present strong evidence that this is a causal relation. In recent years some countries have attempted to reform their pension schemes. The Netherlands, Germany, France, and Italy are examples.

Bassanini et al. (2006) do a simple cross-country panel analysis, which suggests that investments OJT and later retirement are indeed positively correlated. This is consistent with our findings. Moreover, skilled workers typically retire much later than unskilled workers (OECD, 2006). Since education and training are complementary activities, this should come as no surprise either.

#### 4.5 Pensions

Not much is known about the impact of saving or pension policies ( $\tau_A$ ) on the incentives for OJT-investments. As of today, there appears to be no empirical evidence that directly estimates the impact of saving and pension policies on OJT-investment. At least theoretically, saving and investing in human capital are substitutes *for a given level* of overall, i.e., human and financial, saving. Hence, a higher tax rate on financial saving, tends to boost human capital investments. However, also the level of saving can be affected by taxes on savings, depending on off-setting income and substitution effects. Clearly, tax incentives are important for financial saving decisions (see e.g. Bernheim, 2002). In the earlier empirical literature, only small effects of tax incentives on saving were found. On balance, however, most recent empirical evidence clearly points to a dominant substitution effect in saving (Bernheim, 2002).

## 5 Conclusions

We developed a parsimonious theoretical model of investment in human capital, saving, and retirement. The model can explain a host of stylized features of the data. In particular, investment in OJT shifts the wage profiles upwards and earnings follow a ‘hump’ shape. Labor productivity peaks before earnings. Investment in OJT increases if the retirement date increases (lower explicit and implicit taxes on retirement), if the opportunity return on saving decreases (higher capital taxes), and if the depreciation rate is lower. Investment in training increases if productivity of training is larger, e.g. due to larger investment in initial education. (Retirement) savings decrease with a larger tax on savings, which in turn boosts OJT. Policies that boost investment in human capital depress earnings at the beginning of the lifecycle and boost earnings at later ages. The model demonstrates that the policy environment is critical to understand lifecycle patterns in OJT-investment, labor earnings, retirement ages and savings behavior. Indeed, financial saving and human capital investments are substitutes, whereas retirement and human capital investments are complements. Future research should explore in depth the role of imperfectly competitive labor markets, liquidity and borrowing constraints, missing insurance markets to insure human capital related risk, and redistributive issues.

## Appendix

### Model in discrete time

For simulation purposes we write the continuous-time model in discrete time. The utility function is given by

$$\sum_{t=0}^T \frac{U(C_t)}{(1+\rho)^t} + X(T-R), \quad U', X' > 0, \quad U'', X'' < 0. \quad (21)$$

The life-time household budget constraint is:

$$\sum_{t=0}^T \frac{C_t}{(1+r^*)^t} = \sum_{t=0}^R \frac{(1-\tau_L)W(1-I_t)H_t}{(1+r^*)^t} + \sum_{t=R}^T \frac{(1-\tau_P)P}{(1+r^*)^t}. \quad (22)$$

And the human capital accumulation equation is:

$$H_{t+1} - H_t = BF(I_t H_t) - \delta H_t, \quad 0 \leq t \leq R. \quad (23)$$

The Lagrangian for maximizing life-time utility is given by

$$\begin{aligned} \max_{\{C_t, R_t, I_t, H_t\}} \mathcal{L} &\equiv \sum_{t=0}^T \frac{U(C_t)}{(1+\rho)^t} + X(T-R) + \sum_{t=0}^T \mu_{t+1} [(1-\delta)H_t + BF(I_t H_t) - H_{t+1}] \\ &+ \lambda_0 \left[ \sum_{t=0}^R \frac{(1-\tau_L)W(1-I_t)H_t}{(1+r^*)^t} + \sum_{t=R}^T \frac{(1-\tau_P)P}{(1+r^*)^t} - \sum_{t=0}^T \frac{C_t}{(1+r^*)^t} \right], \end{aligned} \quad (24)$$

The first-order conditions are denoted by

$$\frac{\partial \mathcal{L}}{\partial C_t} = \frac{U'(C_t)}{(1+\rho)^t} - \lambda_t = 0, \quad 0 \leq t \leq T, \quad (25)$$

$$\frac{\partial \mathcal{L}}{\partial R} = -X'(T-R) + \lambda_R((1-\tau_L)W(1-I_R)H_R - (1-\tau_P)P) \geq 0, \quad (26)$$

$$\frac{\partial \mathcal{L}}{\partial I_t} = \mu_{t+1}BF'(\cdot)H_t - \lambda_t(1-\tau_L)WH_t = 0, \quad 0 \leq t \leq R, \quad (27)$$

$$\frac{\partial \mathcal{L}}{\partial H_t} = \mu_{t+1}[BF'(\cdot)I_t + 1 - \delta] - \mu_t + \lambda_t(1-\tau_L)W(1-I_t) = 0, \quad 0 \leq t \leq R, \quad (28)$$

where  $\lambda_t \equiv \lambda_0(1+r^*)^{-t}$ . And the transversality condition is

$$\mu_{R+1} = 0. \quad (29)$$

The Euler equation consumption is

$$\frac{U'(C_{t+1})}{U'(C_t)} = \frac{1+\rho}{1+r^*}. \quad (30)$$

In the simulations we employ a CRRA felicity function,  $U(C_t) = \frac{C_t^{1-1/\theta}}{1-1/\theta}$ , so that

$$\frac{C_{t+1}}{C_t} = \left(\frac{1+r^*}{1+\rho}\right)^\theta. \quad (31)$$

The retirement decision is governed by (note  $I_R = 0$ )

$$\frac{X'(T-R)}{\lambda_0(1+r^*)^{-R}} \geq (1-\tau_R)(1-\tau_L)WH_R. \quad (32)$$

If  $U(C_t) = \frac{C_t^{1-1/\theta}}{1-1/\theta}$  and  $X(T-R) = \gamma \frac{(T-R)^{1-1/\beta}}{1-1/\beta}$ , we have

$$\frac{\gamma(T-R)^{-1/\beta}}{C_0^{-1/\theta}(1+r^*)^{-R}} \geq (1-\tau_R)(1-\tau_L)WH_R. \quad (33)$$

Investment in human capital follows from

$$m_{t+1}BF'(\cdot) = (1+r^*)(1-\tau_L)W, \quad (34)$$

where  $m_t \equiv \mu_t/\lambda_t$ , and we used  $\frac{m_{t+1}}{m_t} = \frac{\mu_{t+1}/\lambda_{t+1}}{\mu_t/\lambda_t}$ , and  $\frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1+r^*}$  from  $\lambda_t = \lambda_0(1+r^*)^{-t}$ .

Rewrite the first-order condition for  $H_t$  to find a first-order difference equation in  $m_t$ :

$$\left(\frac{1-\delta}{1+r^*}\right)m_{t+1} - m_t + (1-\tau_L)W = 0. \quad (35)$$

To solve this equation, define  $x \equiv \frac{1-\delta}{1+r^*}$  and  $b \equiv (1-\tau_L)W$  so as to find

$$m_t = xm_{t+1} + b. \quad (36)$$

Repeated substitution yields

$$m_{t+1} = m_0 x^{-t-1} - b \sum_{v=0}^t x^{(v-t-1)}. \quad (37)$$

Using the transversality condition ( $m_{R+1} = 0$ ) gives

$$m_0 = b \sum_{v=0}^R x^v. \quad (38)$$

Hence,

$$m_{t+1} = b \sum_{v=0}^{R-t-1} x^v. \quad (39)$$

Use  $b \equiv (1 - \tau_L)W$  and  $x \equiv \frac{1-\delta}{1+r^*}$  to find

$$m_{t+1} = \frac{(1 - \tau_L)W(1 + r^*)}{r^* + \delta} \left( 1 - \left( \frac{1 + r^*}{1 - \delta} \right)^{t-R} \right). \quad (40)$$

Conditional upon the initial level of consumption  $C_0$  and retirement  $R$ , the Euler equation for consumption pins down the whole time-path of consumption over the lifecycle. Similarly, for given  $R$ , the time-path of the marginal value of human capital  $m_t$  is fully determined. Hence, we know the total path of investment, and the evolution of the human capital stock over the entire lifecycle. We thus end up with two non-linear equations (first-order condition for retirement and the household budget constraint) in two unknowns ( $C_0$  and  $R$ ). We numerically solve this system of equations.

## Uncompensated elasticity of retirement

Linearizing the first-order condition for retirement at constant human capital gives

$$-\frac{1}{\beta} \frac{d(T - R)}{(T - R)} + \frac{1}{\theta} \frac{dC_0}{C_0} = -\frac{d\tau_L}{(1 - \tau_L)}. \quad (41)$$

Rewrite the first-order condition for consumption so as to obtain

$$C_t = \left( \frac{1 + r^*}{1 + \rho} \right)^{t\theta} C_0. \quad (42)$$

Substitute the last result in the household budget constraint – and using the definition for  $\tau_R$  – to find

$$C_0 \sum_{t=0}^T (1 + r^*)^{t(\theta-1)} (1 + \rho)^{-t\theta} = (1 - \tau_L) \left( \sum_{t=0}^R \frac{W_t(1 - I_t)H_t}{(1 + r^*)^t} + \tau_R \sum_{t=R}^T \frac{W_R H_R}{(1 + r^*)^t} \right). \quad (43)$$

At constant levels of investment in human capital  $I_t$  (and therefore  $H_t$ ), we have

$$\frac{dC_0}{C_0} = -\frac{d\tau_L}{1 - \tau_L}. \quad (44)$$

We therefore obtain the following uncompensated elasticity of retirement  $\varepsilon_R \equiv -\frac{dR}{R} \frac{(1-\tau_L)}{d\tau_L}$  with respect to the tax rate at constant investments in human capital

$$\varepsilon_R = \frac{(T - R)}{R} \beta \left(1 - \frac{1}{\theta}\right). \quad (45)$$

As a consequence,  $\theta > 1$  is needed to get a positive uncompensated retirement elasticity. We require a value of  $\beta = 2$  if  $\theta = 1.25$  in order to obtain an uncompensated retirement elasticity of 0.2 if  $R$  is calibrated at  $R = 40$  and the life-span  $T = 60$ .

Note that if human capital responds adversely to a lower retirement age, the interaction with human capital raises the retirement elasticity. This would not affect the qualitative nature of the effects of a tax change, i.e. the condition that  $\theta > 1$  ( $\theta < 1$ ) is still necessary to obtain a positive (negative) uncompensated elasticity of retirement. It would only make the retirement choice more elastic.

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