The Effects of Longevity and Distortions on Education and Retirement.

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Abstract

This article studies the impact of longevity and taxation on life-cycle decisions and long run income. Individuals allocate optimally their total lifetime between education, working and retirement. They also decide at each moment how much to save or consume out of their income, and after entering the labor market how to divide their time between labor and leisure. The model incorporates experience-earnings profiles and return to education function that follows evidence from the labor literature. There are two sectors of production, "goods" and "education services", so that there are costs of education other then foregone wages. In this setup increases in longevity raises the investment in education - time in school - and retirement. The model is calibrated to the U.S. and is able to reproduce observed schooling levels and the increase in retirement, as the evidence shows. Simulations show that a country equal to the U.S. but with 20% smaller longevity will be 25% poorer. In this economy labor taxes has a stronger impact on the per capita income than other forms of taxation, as it decreases labor effort, time at school and retirement age, in addition to the general equilibrium impact over physical capital. Hence, we conclude that life cycle effects are relevant in analyzing the aggregate outcome of taxation.

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1 Introduction

One of the most impressive facts of the twentieth century is the large increase of educational attainment of the adult population. In 1990, the median schooling of a male aged 25 years in the U.S., according to estimations in Gustavus and Nam (1964) based on Census Data, was 6.8 years. By 2000 it had jumped to more than 12 years, according to estimates in Jones (2002).

Even more dramatic is the rise of longevity in the same period. By the beginning of last century life expectancy at birth was, on average, less than 48 years, according to the National Vital Statistics Reports (2002). One hundred years later it was estimated to be 77 years. Although most gains were related to reduction of child mortality, the increase of adult longevity in the same period is very significant. The life expectancy of a man aged 20 years in 1900 was 42.8 years, but in 2000 a man of the same age is expected to die 57.8 years later, a 15 years variation.

These two facts may not be unrelated. Greater longevity allows for extension of the population working life and, consequently, an increase in the present value of the flow of wages of a given investment in education. Higher returns to education in turn induce individuals to stay in school longer, increasing average human capital of the population with a potential effect on long-run income.

At the same time, the number of years individuals expend at retirement increased continuously in the previous century. Lee(2001) calculates that the expected period of retirement increased from 2.6 years for the cohort born in 1880 to 13.1 years to the cohort born in 1930. Moreover, labor force participation for man aged 65 and over went from 58% in 1930 to only 16% by 1985 (Kalemli-Ozcan and Weil (2004)). In principle this fact does not contradicts the link between life expectancy and schooling, as working and retirement lives could have increased with the longevity. However, Gendell and Siegel (1992) estimate that age at final retirement has fallen by 4 to 5 years since 1950, for both man and woman. Median age of retirement for men fell from 66.9 years in 1950-55 to 62.6 in 1985-1990. More years at school and younger retirement age can only mean shorter career length, something at odds with the idea that longevity influences schooling because it increases the period one can enjoy the return to education investment.

In this paper we develop a model that reconcile the above facts. Individuals allocate their total lifetime between education, working and retirement. They also decide at each moment how to divide their time between labor and leisure and how much to save or consume out of their income. The labor/leisure choice is key for the retirement decision. In order to explain, however, why people stop working completely at a certain age and do not spread evenly leisure, the model incorporates experience-earnings profiles that mimics the evidence from the labor literature (e.g., Heckman, Lochner and Todd (2003), among many). At a given moment of a worker life, productivity growth slows down or decreases, so that labor supply falls continuously up to a point when the marginal gain of working is smaller than that of leisure and then individuals leave the labor market for good.

In this model, increases in longevity raises investment in education and retirement life, everything else constant. We are then able to explain in an unified framework these two life-cycle observations. The model is simulated after it was calibrated to U.S. observations. We reproduced qualitatively and quantitatively the main facts. Moreover, if learning technology is faster today than in the past- something that we may infer from estimations across different decades - in addition to rising retirement life we obtain that retirement age falls with longevity. This is so because agents prefer to work more intensively when they are young and more productive, increase savings, and retire earlier. Another result is that, when we use the population growth rates of the beginning and end of the century, we reproduce schooling levels observed at these two points in time.

The theory we propose is also convenient to study development effects of public taxation. We introduce in the economy distortions to human and physical capital investment as well as labor taxation. The many decision dimensions and two sectors of production ("goods" and "education") constitutes a rich general equilibrium environment to explore the transmission mechanisms of public policy. For instance, labor taxation distorts work-leisure decision, but also the education choice - as it impacts its return - and retirement, because it changes the opportunity cost of not working. The last two channels are not usually present in this type of analysis. Consequently, by just focusing in the first dimension, and in its indirect impact on physical capital (also present here), there is a tendency to underestimate the impact of labor taxation. As a matter of fact, we show that in the long-run labor taxation is more detrimental to per capita income levels than capital and human capital taxation, a result that contrasts with Lucas(1990), among many.

We believe that this article extends and improves the previous literature in many respects. First, as said before, we reunite in a single model two strands of the literature that studies separately, in the context of development and growth, the impact of longevity on schooling and retirement . In Soares (2003), Enrlich and Lui (1991) Khakemi-Ozacan, Ryder and Weil(2000) and Boucekkine, de la Croix and Licandro(2002) longer lives become by definition longer career span and retirement is non-existent. That may be a good hypothesis for the seventeenth and eighteenth century Europe, the period examined of Boucekkine, de la Croix and Licandro(2003), but certainly not for the U.S. after 1950. Kabosky(2003) allows working life to vary with longevity, but he treats career spans exogenously and calibrate it to the U.S. observed path[1].

As opposed to some of the studies above, in our framework schooling and human capital have level effects on per capita income, not permanent growth effects. The evidence in Bils and Klenow (2000) and Krueger and Lindhal (2000) does not favor the latter, nor externality due to human capital. Moreover, our model generates rising schooling as a steady state result. Jones (2002) argues that, from the standpoint of a neoclassical growth model, increases in education should generate temporary high growth rates and long-run level effect, but the evidence for the U.S. points toward an economy fluctuating around its balanced growth path. In our model, however, longevity causes schooling to rise, so that the observed increase in life expectancy during the last century explains, partially at least, the observed path of educational attainment in equilibrium.

A second literature that relates to ours investigates the links between longevity and retirement. Khakemi-Ozacan and Weil(2004) shows that exogenous decreases in the probability of death, which allows people to better plan saving for old age, generates longer retirement life. This is a different explanation than ours, which relies on the income-effect due to the longevity-schooling channel and declining productivity, on the individual level, at old age. Their model also incorporates labor-leisure choices, but there is no education decision. As our taxation exercises show, these two dimensions are closely linked. In a sense, our explanation also relates to that in Graebner(1980) that says that technological change leads to retirement because the learning of old people is slower, making then obsolete in periods of faster innovation. In our model there are different learning rates for young and old people, the latter being smaller. However, one needs also longevity effects to explain higher retirement life in the dimension observed in the past. Not to mention, of course, schooling

[1] Also related to our article are Bils and Klenow (2000) and Mateus-Planas (2001) which also use a Mincerian formulation of schooling with a life-cycle decision regarding education. Neither formulation considers a second sector that provides educational services as we do; they have no taxation and do not explore fully the general equilibrium impact of life-cycle features of human capital investment.

expansion.

Finally, we also study the long run impact of human capital, physical capital and labor taxation. In our model, as in Trosten(1993), foregone wages are not the only cost of human capital investment, there are also tuition costs, meant to capture the fact that time is not the only input to human capital investment. Otherwise, tax increases would affect the return but also the opportunity cost of human capital investment, being relatively neutral. So, labor taxes and taxes on tuition have significant impact on schooling decision. As opposed to Stokey and Rebelo (1995) and Hendricks (1999) they do not have growth effect but only level effect. This is similar to Trosten(1993) that, however, ignores life cycle effects - shown in our paper to be relevant - as he uses a dynastic framework. It also contrasts with Lucas(1990), who suggest that life cycle effects are not relevant in analyzing the aggregate effects of taxation. Results in this article show that they are qualitatively and quantitatively important.

The article is organized as follows. In the next section we briefly discuss the hypothesis of exogenous life expectancy and presents the model. Section 3 discusses calibration and measurement issues. Results concerning the link between education and retirement are presented in Section 4 while sensitivity analysis, focusing mostly on distortions are presented in Section 5. Section 6 concludes.

2 The Model and Longevity Behavior

The model assumes finite lifetime with endogenous decision of education, labor effort (leisure), retirement and savings. Human capital depends on the education acquired while in school and on-the-job learning, which is exogenous. Individuals choose how long to go to school so as to maximize the present value of lifetime earnings. The return to human capital investment depends on, among other variables, longevity, taxes and the experience profile. Retirement also depends on the experience profile: if productivity is falling too fast at a point in life, it may be better to stay at home and enjoy leisure. As for the production side of this economy, there are two sectors - the “good” and “educational” sectors - and both use physical capital and effective labor according to homogenous production functions. Government tax/subsidy school tuition, labor and physical capital incomes. School tuition is equivalent to a direct cost of schooling and is not proportional to wages. Tax revenues are lump-sum transferred to individuals.

Although most of the literature assumes, as we do, exogeneity of life expectancy, this is of course a major issue. Preston (1975) shows that economic advances in the last century in developed and less developed countries was not a major factor in the increase of life expectancy. Simple sanitation and medical discoveries, for instance, that can be copied almost at no cost, were more relevant. He constructs a scatter diagram, for different nations, showing that the relationship between life expectancy at birth and national income per capita has shifted upwards during the twentieth century: a country with income per capita in 1960 between \$100 and \$500 had 10-12 additional years of life expectancy than another country with similar income level in 1930. Soares (2003) adds 1990 data to Preston´s figure and also concludes that for constant levels of income, life expectancy has been rising. He shows that a nation with per capita income of \$5000 in 1995 had a life expectancy roughly 10% higher than a country with same per capita income in 1960

Preston(1975) estimates that factors exogenous to a country´s level of economic development accounts for 75-90 per cent of the growth in life expectancy for the world as a whole between the 1930s and the 1960s and that these exogenous factors had a major effect on mortality trends in more developed as well as in less developed countries. France and Austria gained almost 13.7 years of life expectancy in the period, only 0.4 years above Indonesia´s gain and less than 3 years above Philippines improvement. Lee(1980), Kirk (1996) and Preston(1977), among many, confirm, in different contexts, the exogeneity of life expectancy.

2.1 Firms

There are two sectors in this economy, one that produces consumption and investment goods and other that produces educational services, both use effective labor and physical capital as inputs. Let output Y_1 in the *Goods Sector* be a function of physical capital services K_1 and skilled labor H_1 according to:

$$Y_1 = A_1 K_1^{\alpha_1} {H_1}^{1-\alpha_1},$$

where A_1 is the sector total factor productivity. Skilled labor is given by:

$$H_1 = L_1 e^{\phi(T_S)}$$

where L_1 is raw labor. According to the equation above, the productivity of a worker with T_S years of schooling is $e^{\phi(T_S)}$ greater than that of a worker of the same cohort with no education at all. The function $\phi(T_S)$ is assumed to be increasing and to exhibit diminishing returns, and $\phi'(T_S)e^{\phi(T_S)}$ gives the increase in effective labor input from one extra year of schooling. Likewise, output in the educational sector is given by:

$$Y_2 = A_2 K_2^{\alpha_2} (L_2 e^{\phi(T_S)})^{1-\alpha_2},$$

Let p_i be the price of the i-th sector good. Profit maximization of the firm gives

$$R_i = p_i \alpha_i A_i k_i^{\alpha_i - 1} \text{ and } w_i = p_i(1-\alpha_i) A_i k_i^{\alpha_i},$$

where R_i is the rental price of capital, w_i is wage rate (of raw labor without on-the-job experience), and

$$k_i \equiv \frac{K_i}{L_i e^{\phi(T_S)}}, \tag{1}$$

is the i-th sector employment of capital in efficiency units.

In this economy there is free mobility of factors across sectors, so that factors price are the same in both sectors. Considering the good 1 as the numeraire, it follows that:

$$R \equiv R_1 = \alpha_1 A_1 k_1^{\alpha_1 - 1} = p \alpha_2 A_2 k_2^{\alpha_2 - 1} = R_2$$

and

$$w \equiv w_1 = (1-\alpha_1) A_1 k_1^{\alpha_1} = p(1-\alpha_2) A_2 k_2^{\alpha_2} = w_2,$$

where p is the relative price of educational services in units of goods. The factor allocation problem is standard and is presented in the appendix. The production side of this economy is essentially a traditional two sectors, two factors model, and from its solution we obtain the offer function of each sector, given p and $\widetilde{k}$, the per-worker capital stock in efficiency units:

$$y_i(p, \widetilde{k}) = A_i l e^{\phi(T_S)} l_i(p, \widetilde{k}) \left[k_i(p)\right]^{\alpha_i}, \quad i = 1, 2 \tag{2}$$

where y_i is the per capita supply function of sector i, l is the total flow of raw labor services per capita and l_i is the share of labor in sector i.

The two-sector framework is a convenient and realist form of modeling the direct cost of educational services. Moreover, without an education sector of production, taxes on labor and on the direct cost of schooling would be equivalent.

2.2 Household

Individuals live for T years and retire after T_R years. Retirement is not mandatory but is chosen optimally. In the first part of life cycle, ("youth", T_Y), individuals first stay at home for T_C years and then goes to school for T_S years. Once he leaves school, he cannot return. He then join the labor market, working for T_W years. Active life has two sub-periods: T_{W1}, when wages increase with on-the-job learning - which is exogenous in the model -, and T_{W2}, when they decrease (or increase at a slower pace). This last hypothesis follows ample evidence from the labor literature (e.g., Heckman, J., L. Lochner e P. Todd, 2003) of hump shaped (log) earnings-experience profile along the workers life-cycle.

At each instant of time the household decides how much to consume or save and how much work effort to supply. A once for all decision is also made on how much education to buy, which is equivalent in the model to deciding the optimal period of time T_{S} of staying in school. The utility function of an individual is:

$$\int_0^T e^{-\rho a} \left[\beta \ln c\left(a\right) + \left(1-\beta\right) \ln\left(1 - l\left(a\right)\right)\right] \mathrm{d}a, \tag{3}$$

where $c(a)$ and $l\left(a\right)$ are respectively the consumption and the labor effort of an age a individual, while ρ is the discount rate. We already normalized the time endowment to one.

Individuals have four sources of income - wages from labor services, rents from capital, "bequest" and public transfer - which are used to pay for school tuition and consumption goods. Bequest (B), referred as such just for convenience, are in fact financial transfers to children. Each person receives B during their life and transfers B' for each children. In intertemporal format their budget constraint is given by:

$$\begin{aligned} & B + \int_{T_{\mathrm{Y}}}^{T_{\mathrm{Y}}+T_{\mathrm{W}}} e^{-ra}\left(1-\tau_{\mathrm{L}}\right) w(T_s, a, x) l\left(a\right) \mathrm{d}a + \int_0^T e^{-ra}\chi \mathrm{d}a \qquad (4) \\ = \; & e^{-(r-n)T_{\mathrm{B}}} B' + \int_0^T e^{-ra} c(a) \mathrm{d}a + \left(1+\tau_{\mathrm{H}}\right) \int_{T_{\mathrm{C}}}^{T_{\mathrm{Y}}} e^{-ra} \eta p \mathrm{d}a, \end{aligned}$$

where r is the interest rate, $w(T_s, a, x)$ is the wage of age-a worker with T_s years of education and experience x, τ_{L} is a tax (or subsidy) rate on wages and χ are government transfers.

The last expression on the right hand side is the tuition costs, where τ_{H} is a tax (or subsidy) rate on education purchases and η the amount of education services that the student has to buy in order to be in school,[2]. The above expression simply says that the net present value of wages, bequest received and government transfers should be equal to the net present value of consumption, bequest left and tuition costs.

2.2.1 Labor Supply Decision

The function $w(T_s, a, x)$ follows closely the labor literature and will be such that:

$$w(T_s, a, x) = we^{\phi(T_S)}x(a),$$

where $x(a)$ is the "experience function" that gives the increase in productivity while at work.

There is ample evidence that for a given level of education, workers' experience-earnings profiles are such that wages increase initially but later in life decreases with age. Heckman, Lochner and Todd (2003), for instance, using Census data from 1940 to 1990, for white and black males, show that in most cases, and independently of the educational level, mean *log* annual wage and salary income is a parabolic function of experience. The variation of productivity due to on-the-job learning (x) will be modeled as:

$$x(a) = \begin{cases} e^{\gamma(a-T_{\mathrm{Y}})} \text{ if } T_{\mathrm{Y}} \leq a \leq T_{\mathrm{Y}} + T_{\mathrm{W1}} \\ e^{\gamma T_{\mathrm{W1}} - \xi(a-(T_{\mathrm{Y}}+T_{\mathrm{W1}}))} \text{ if } a \geq T_{\mathrm{Y}} + T_{\mathrm{W1}}, \end{cases} \tag{5}$$

According to the above function, from the moment a worker enters the job market (T_Y) to some turning point T_{W1} labor productivity due to experience increases at a constant rate γ. After this it falls at a rate ξ until the worker retires or dies.

Simple calculation give us the first order condition for the labor supply choice at each moment of time:

$$l(a) = 1 - \frac{1-\beta}{\mu} \frac{e^{(r-\rho)a}}{(1-\tau_{\mathrm{L}})\, we^{\phi(T_{\mathrm{S}})}x(a)}, \tag{6}$$

where μ is the Lagrange multiplier associated to restriction (4).

In this economy retirement is endogenous. Given the decrease or slower increase in productivity at old age, there is a moment when the marginal gain of staying longer in the job market and be able to afford more consumption goods becomes smaller then the marginal

[2] We are assuming an indivisibility in the human capital accumulation process. In order to increase his education level, an individual has to buy η units of educational services but not fractions of it.

gain from leaving the job market and using the entire time endowment to leisure. At this point the individual leaves the job market. Retirement occurs when labor supply is zero:

$$\frac{1-\beta}{\mu} = (1-\tau_{\mathrm{L}})\, w e^{\phi(T_{\mathrm{S}})} e^{-(r-\rho)(T_{\mathrm{Y}}+T_{\mathrm{W}})} x\,(T_{\mathrm{Y}}+T_{\mathrm{W}})\,.$$

In the relevant situation when $T_{\mathrm{Y}}+T_{\mathrm{W}} > T_{\mathrm{Y}}+T_{\mathrm{W}1}$ we have, after applying (5) in the expression above, that:

$$e^{-\rho(T_{\mathrm{Y}}+T_{\mathrm{W}})}\frac{1-\beta}{\mu} = e^{-r(T_{\mathrm{Y}}+T_{\mathrm{W}})}\,(1-\tau_{\mathrm{L}})\, w e^{\phi(T_{\mathrm{S}})} e^{\gamma T_{\mathrm{W}\,1}-\xi T_{\mathrm{W}\,2}}. \tag{7}$$

The equation above equates the present value leisure, at retirement time, to the net present value of wages.

An important statistics is the life-cycle average labor supply of an individual, that by definition is:

$$\bar{l} \equiv \frac{1}{T-T_{\mathrm{Y}}}\int_{T_{\mathrm{Y}}}^{T_{\mathrm{Y}}+T_{\mathrm{W}}} l\,(a)\,\mathrm{d}a.$$

After substituting (6) and (7) we obtain:

$$\bar{l} = \frac{T_{\mathrm{W}}}{T-T_{\mathrm{Y}}} - \frac{1}{T-T_{\mathrm{Y}}}\left[\frac{1-e^{-(r+\xi-\rho)T_{\mathrm{W}\,2}}}{r+\xi-\rho} + e^{-(r+\xi-\rho)T_{\mathrm{W}\,2}}\frac{1-e^{-(r-(\rho+\gamma))T_{\mathrm{W}\,1}}}{r-(\rho+\gamma)}\right]. \tag{8}$$

2.2.2 Consumption Decision

In their consumption decision, individuals maximize (3) subject to (4). Solving for consumption, we obtain the individual's consumption profile:

$$c(a) = c(0)e^{(r-\rho)a}. \tag{9}$$

In order to find consumption at each moment of time we need to know the initial consumption. After substituting into the budget constraint (equation 4 above) the expressions (9), (5), and (6) it follows that:

$$\begin{aligned} & c\,(0)\left[\frac{1-e^{-\rho T}}{\rho} - \left(1-e^{-(r-n)T_{\mathrm{B}}}\right)\frac{1-e^{-\rho T_{\mathrm{Y}}}}{\rho}\right] \\ & + e^{-(r-n)T_{\mathrm{B}}}\,(1+\tau_H)\, p\eta e^{-rT_{\mathrm{C}}}\frac{1-e^{-rT_{\mathrm{S}}}}{r} + e^{-\rho T_{\mathrm{Y}}}\frac{1-\beta}{\mu}\frac{1-e^{-\rho T_{\mathrm{W}}}}{\rho} \\ = \;& (1-\tau_{\mathrm{L}})\, w e^{\phi(T_{\mathrm{S}})} e^{-rT_{\mathrm{Y}}}\left[\frac{1-e^{-(r-\gamma)T_{\mathrm{W}\,1}}}{r-\gamma} + e^{-(r-\gamma)T_{\mathrm{W}\,1}}\frac{1-e^{-(r+\xi)T_{\mathrm{W}\,2}}}{r+\xi}\right] + \chi\frac{1-e^{-rT}}{r}, \end{aligned} \tag{10}$$

where we assumed that $B = B'$ and that the endowment is enough to pay for consumption and tuition until age T_{Y}. The right-hand term is the individual's total wealth at the time of birth, given by the market value of labor endowment[3] and government transfers. The household spends his wealth (in the left-hand side) buying goods, education services and leisure, respectively. Note that we have already substituted into (10) the equilibrium condition of an steady state equilibrium. Consumption and education decision are stationary across cohort.

2.2.3 Education Decision

In this economy, the education decision is equivalent to choosing the optimal time to leave school. In the beginning of their lives, individuals pick the optimal quantity of education in order to maximize the present value of wages net of tuition cost, as given in (4):

$$\max_{T_{\mathrm{S}}} \left[\int_{T_{\mathrm{C}}+T_{\mathrm{S}}}^{T_{\mathrm{C}}+T_{\mathrm{S}}+T_{\mathrm{W}}} e^{-ra} \left(1-\tau_{\mathrm{L}}\right) w e^{\phi(T_{\mathrm{S}})} x(a) l\left(a\right) \mathrm{d}a - \left(1+\tau_{\mathrm{H}}\right) \int_{T_{\mathrm{C}}}^{T_{\mathrm{C}}+T_{\mathrm{S}}} e^{-ra} \eta p \mathrm{d}a \right].$$

In making this decision, individuals consider that (given retirement) the longer they stay in school, the shorter their productive life - T_{W} - is, given that life span - T - is exogenous. Moreover, in addition to the foregone wages, there is the direct cost of school tuition. We assume that the *age* in which labor productivity picks, $T_{\mathrm{S}} + T_{\mathrm{W}1}$, is exogenous and independent of the education; any additional year at school reduces the productive life at the first sub-period[4].

In this case, the first order condition for the educational choice follows[5]:

$$\left(\phi'(T_{\mathrm{S}}) - \gamma\right) \left\{ \left(1-\tau_{\mathrm{L}}\right) w e^{\phi(T_{\mathrm{S}})} \left[\frac{1-e^{-(r-\gamma)T_{\mathrm{W}\,1}}}{r-\gamma} + e^{-(r-\gamma)T_{\mathrm{W}\,1}} \frac{1-e^{-(r+\xi)T_{\mathrm{W}\,2}}}{r+\xi} \right] - \right.$$
$$\left. \frac{1-\beta}{\mu} e^{(r-\rho)T_{\mathrm{Y}}} \frac{1-e^{-\rho T_{\mathrm{W}}}}{\rho} \right\} = w e^{\phi(T_{\mathrm{S}})} - \frac{1-\beta}{\mu} e^{(r-\rho)T_{\mathrm{Y}}} + \left(1+\tau_{\mathrm{H}}\right) \eta p. \tag{11}$$

[3]The market value of labor endowment has two components, as seen inside the brackets. The first term corresponds to the period in which experiences increases at a rate γ and the second to the period in which it falls at a rate ζ

[4]This hypothesis seems to us more sensible than assuming that T_{W1} alone is exogenous. Experience-earning profiles in Heckman, Lochner and Todd (2003) of different schooling levels peak approximately at the same age, especially in the case of white males.

[5]Actually, (11) is the first order condition with respect to education after we substituted in, for the sake of simplification, (7) using also the fact that at retirement time, wages (net of leisure) are zero.

The expression above equates the marginal contribution of schooling to lifetime earnings, in the left-hand side, to its marginal cost, in the right-hand side. The latter is the opportunity cost (net of leisure) of not working (i.e., the wages lost) plus the tuition cost at the stopping time. The former is the impact on the present value of time endowment (net of leisure) of staying in school one additional unit of time - which implies higher wages in the future due to more schooling but a loss of experience[6].

Note that dividing both sides of equation (11) by $1 + \tau_{\mathrm{H}}$ one can see (recall from (7) that $(1-\beta)/\mu$ is proportional to $we^{\phi(T_{\mathrm{S}})}$) that tax on tuition, in the context of schooling decision, is equivalent to direct taxation on labor earnings. Note also that if it was not for the tuition term, human capital taxation or taxes on wages would have no impact at all, as a tax term $(1+\tau_{\mathrm{H}})(1-\tau_{\mathrm{L}})$ would divide both sides of the above expression (as all components are proportional to $we^{\phi(T_{\mathrm{S}})}$) and, consequently, be eliminated.

2.3 Demography

At each instant of time a cohort of size me^{nt} is born, where $m \equiv n/\left(1-e^{-nT}\right)$, so that total population is given by

$$\int_{t-T}^{t} me^{ns}\mathrm{d}s = e^{nt}.$$

Within a cohort, all individuals are identical. Let $N(a)$ be the share on the total population of the a-cohort. At time t the a-cohort is the cohort born in $s = t - a$. We have:

$$N(a) = \frac{me^{ns}}{e^{nt}} = me^{-na}. \tag{12}$$

Let $N_{\mathrm{C}}, N_{\mathrm{S}}, N_{\mathrm{W}}$, and N_{R} be, respectively, the population of children, students, workers, and retirees as a share of total population. We have:

$$N_{\mathrm{S}} = \int_{T_{\mathrm{C}}}^{T_{\mathrm{C}}+T_{\mathrm{S}}} me^{-na}\mathrm{d}a = e^{-nT_{\mathrm{C}}}\frac{1-e^{-nT_{\mathrm{S}}}}{1-e^{-nT}}.$$

[6] It may be helpful, in order to get more intuition, to think of a model with no labor choice and no experience gain. In this case equation (11) simplifies to: $we^{\phi(T_S)}\phi'(T_S)\frac{1-e^{-rT_W}}{r} = we^{\phi(T_S)} + (1+\tau_H)\eta q$, which equates the present value of staying in school one additional unit of time (the left-hand side) to the opportunity cost of not working plus the tuition cost at the stopping time (the right-hand side).

Likewise, we get that:

$$N_{\mathrm{C}}=\frac{1-e^{-nT_{\mathrm{C}}}}{1-e^{-nT}},\ N_{\mathrm{W}}=e^{-nT_{\mathrm{Y}}}\frac{1-e^{-nT_{\mathrm{W}}}}{1-e^{-nT}}\text{ and }N_{\mathrm{R}}=e^{-n(T-T_{\mathrm{Y}})}\frac{1-e^{-nT_{\mathrm{R}}}}{1-e^{-nT}}.$$

2.3.1 Total Labor Supply

In order to characterize the supply functions given by (2) we have to determine l, the total flow of raw labor services per capita. As individuals work from age T_{Y} to age $T_{\mathrm{Y}}+T_{\mathrm{W}}$, we have:

$$l=\int_{T_{\mathrm{Y}}}^{T_{\mathrm{Y}}+T_{\mathrm{W}}}N\left(a\right)l\left(a\right)x\left(a\right)\mathrm{d}a.$$

After substituting the experience profile (5), labor supply (6), the expression for $N\left(a\right)$ (12) and (7) ,and solving the integral, we obtain:

$$l=me^{-n(T_{\mathrm{Y}}+T_{W1})}e^{\gamma T_{\mathrm{W}1}}\times \tag{13}$$
$$\left\{\frac{1-e^{-(\gamma-n)T_{\mathrm{W}1}}}{\gamma-n}+e^{-(n+\xi)T_{\mathrm{W}2}}\left[\frac{e^{(n+\xi)T_{\mathrm{W}2}}-1}{n+\xi}-\frac{1-e^{-(r-(\rho+n))T_{\mathrm{W}}}}{r-(\rho+n)}\right]\right\}.$$

2.4 Government Restriction

At a point in time, government revenue is given by the sum of taxation of educational services, on labor services and capital income. The first component is given by:

$$\tau_{\mathrm{H}}\,p\int_{T_{\mathrm{C}}}^{T_{\mathrm{Y}}}N\left(a\right)\eta\mathrm{d}a=\tau_{\mathrm{H}}\,p\,m\,\eta e^{-nT_{\mathrm{C}}}\frac{1-e^{-nT_{\mathrm{S}}}}{n}$$

and the second component by

$$\tau_{\mathrm{L}}\int_{T_{\mathrm{Y}}}^{T_{\mathrm{Y}}+T_{\mathrm{W}}}N\left(a\right)we^{\phi(T_{\mathrm{S}})}x(a)l\left(a\right)\mathrm{d}a,$$

and the third component by $e^{nt}\tau_{\mathrm{K}}Rk$, where $k\equiv K/e^{nt}$ is per capita capital. Consequently, the per capita government transfer is the sum of these 3 terms divided by e^{nt} :

$$\chi=\tau_{\mathrm{H}}p\eta me^{-nT_{\mathrm{C}}}\frac{1-e^{-nT_{\mathrm{S}}}}{ne^{nt}}+\tau_{\mathrm{K}}Rk+\frac{\tau_{\mathrm{L}}}{e^{nt}}\int_{T_{\mathrm{Y}}}^{T_{\mathrm{Y}}+T_{\mathrm{W}}}N\left(a\right)we^{\phi(T_{\mathrm{S}})}x(a)l\left(a\right)\mathrm{d}a, \tag{14}$$

after solving the integral in the last term in the right hand side.

2.5 Equilibrium

Before presenting the equilibrium conditions of this economy, we need to derive an expression for aggregate consumption, which is necessary for the equilibrium of the market for goods. This is done by adding the individual consumption over cohorts:

$$c \equiv \frac{C(t)}{e^{nt}} = \int_0^T N(a)\, c(a) \mathrm{d}a.$$

If we substitute equation (9) into this last equation we obtain

$$c = c(0)\, m \frac{e^{(r-(\rho+n))T} - 1}{r - (\rho + n)} \tag{15}$$

The final expression is trivially obtained by plugging the expression for initial consumption (equation (10)) in the above expression.

We can now describe the steady state equilibrium of this economy, which is given by the following equations:

- The equilibrium in the market for educational services is:

$$y_2(p, \widetilde{k}) = \eta m e^{-nT_{\mathrm{C}}} \frac{1 - e^{-nT_{\mathrm{S}}}}{n}. \tag{16}$$

- The equilibrium in the assets market:

$$r = (1 - \tau_{\mathrm{K}})R - \delta = (1 - \tau_{\mathrm{K}})\alpha_1 A_1 k_1^{\alpha_1 - 1} - \delta, \tag{17}$$

  where τ_{K} is a tax rate on capital income.

- The goods market equilibrium is:

$$y_1(p, \widetilde{k}) = c + (\delta + n)k, \tag{18}$$

  where c is given optimally by equation (15), after the expressions for initial consumption (equation (10)) and for government transfers, (14), is plugged in.

- The equilibrium conditions with respect to the educational choice, which is given by (11) after using equation (7) to eliminate $(1 - \beta)/\mu$.

Note that the equilibrium in the labor and capital markets is implicit in the supply functions $y_1(p, \widetilde{k})$ and $y_2(p, \widetilde{k})$.

3 Quantitative Methodology

3.1 Calibration

The model is calibrated to the U.S. in the recent past, assuming the country is in a steady state equilibrium. Parameters of interest can be separated into two groups. In the first group they are considered as observables while in the second parameters are obtained - measured - using the restrictions imposed by the data on the equilibrium solution of the model.

The function $\phi(T_S)$ is taken from Bils and Klenow (2000):

$$\phi(T_S) = \frac{\theta}{1-\psi} T_S^{1-\psi}. \tag{19}$$

We follow their estimation and use $\psi = 0.58$ and $\theta = 0.32$. Hence, instead of the more usual linear return to education assumed in most of the literature, we posit diminishing returns because this seems to be the case when comparing micro estimates across countries (e.g., Psacharopoulos (1994)).

The capital shares α_1 and α_2 were set equal to 0.4 and 0.05, respectively, and were calculated using U.S. time series data from the National Income and Product Accounts (NIPA). The share of total labor force in the educational sector, l_2, was also obtained from the NIPA and is the average from 1987-1997 of the ratio of Full-Time Equivalent Employees in Educational Services to the Total Full-Time Equivalent Employees and was found to be 0.07. The value of i, set to 0.2, was also obtained in the NIPA for the post 1960 period and so was the value of the capital-output ratio, κ, which will be useful later for the calibration of k and δ. We normalized income per capita, y, to one, without loss of generality.

Life expectancy T was set to 77, which is the value reported in the National Vital Statistics Reports (2002) for 2000. The growth rate of the population is such that $n = \ln(1,0166)$, where 1.66% is the annual population growth rate since 1960, obtained from the U.S. Census. has data on T_S, T and n. The variable T_S corresponds to data of years of schooling attained by the working-age population and was set to 12. The interest rate was set to $r = \ln(1.05)$.

T_{W1}, γ and ξ were obtained from Heckman, J., L. Lochner e P. Todd, (2003)[7]. These authors use non-parametric techniques to estimate experience-earnings profiles using Census data. As we assumed linear growth (and linear decrease, after T_{W1}), in order to find γ we adjusted to their estimated dummies a straight line until the peak T_{W1}. We follow similar

[7]We would like to thank Petra Todd who gave us access to the estimations and data of this article.

procedure to find ξ. This is of course an approximation, but it is necessary to render the model treatable. We also set $T_{\mathrm{B}} = 34$[8]. Finally, there is evidence in McGrattan and Rogerson (1998) that over the life cycle people work on average 18 hours a week. In order to obtain $\bar{l}$, we divided this value by the total number of weekly hours available to work, which is 24 minus 8 (number of hours for sleeping and physical needs) times seven. We found $\bar{l} = 0.161$.

The above variables and parameters, hence, were considered observables. We now explain the solution of the calibration procedure.

Using $y = 1$ and $\kappa = 3$, we obtained trivially the steady state value of per capital , $k = 3$. We used i, κ and n to find - according to the steady state expression $(\delta + n)\,\kappa = i$ - the depreciation rate, which was found to be 0.050. It is also immediate to get $T_Y = T_C + T_S = 18$, and consequently $T_{\mathrm{Y}} + T_{\mathrm{W1}} = 50$, the age at which productivity peaks.

Solving (8) we found $T_{\mathrm{W2}} = 11.560$, and solving (13) we got $l = 0.170$, .the (per capita) total flow of labor services. It then follows from the definition (see appendix) that $\widetilde{k} = 2.03$, .the value of the per-worker capital stock in efficiency units. Also from the appendix, and the hypothesis of full employment of factors, we have that $k_1 = 2.187$ and $k_2 = 0.173$.

Equation (16) solves for the total factor productivity of the educational sector, $A_2 = 2.171$. Plugging this value and those of $\alpha_1$and α_2 in equation (22), it solves for $p/A_1 = 0.943$. The definition of y and its normalization to one imply $A_1 = 0.510$ and $p = 0.221$.

Similar procedure is used to measure the tax rates: from the equilibrium of the asset market, equation (17), it follows $\tau_{\mathrm{K}} = 0.223$. For τ_{H} and τ_{L} we solved jointly the first order condition for the education decision - equation (11) - and the goods market equilibrium - equation (18) - and obtained $\tau_{\mathrm{H}} = -0.03571$ and $\tau_{\mathrm{L}} = 0.14564$. Hence, according to this calibration there is an implicit subsidy to schooling in the U.S.

In order to get a flat labor profile (in the first work period) we assume $\rho = r - \gamma = \ln \frac{1.05}{1.02}$. This is just for convenience, as it facilitates the simulation of the model but does not change results.

Finally, from the first order condition for consumption choice we know that $\frac{\beta}{c(0)} = \mu$ where μ is the lagrange multiplier associated to the budget constraint (4). From the first

[8]We do not know of any estimation of this parameter, and variations around this value did not affect results. This date corresponds to 16 years after entering the job market and a moment in life when most people had children already.

order condition for leisure choice we know that, at retirement,$\frac{1-\beta}{\Delta} = \mu$ where

$$\Delta = (1 - \tau_{\mathrm{L}})\, we^{\phi(T_{\mathrm{S}})} e^{-(r-\rho)(T_{\mathrm{Y}}+T_{\mathrm{W}})} x\,(T_{\mathrm{Y}} + T_{\mathrm{W}})$$

Consequently,

$$\beta = \frac{c\,(0)}{c\,(0) + \Delta} = 0.228.$$

As far as we know, this is the first time the weight of leisure in the utility function in a life-cycle model is calibrated direct from data. This is important because the values for infinity-life agent, usually around one-third, does not take into account retirement, finite career span and time at school.

4 Longevity, Retirement and Education

The first group of model simulations study the impact of longevity on life cycle features - time at school and in the labor market. We kept constant TFP, distortions, population growth rate, γ and ζ. We also assumed that the productivity peak changes with longevity, so that it will be always the case that $T_{\mathrm{Y}} + T_{\mathrm{W1}} = (50/77) * T$. This is somewhat arbitrary, but there is no clear pattern in the data. For robustness check, we also use alternative parameters and hypothesis. The model is then solved, using different values of T, for education, retirement, capital, labor, prices and output.

The figure below displays the relationship between longevity and education.

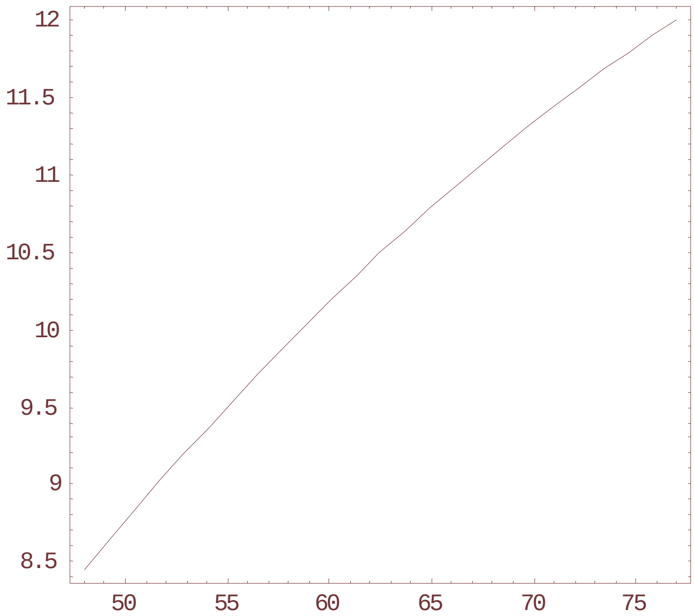


Figure 1: Longevity and Education

The model succeeds in capturing a positive relationship between life expectancy and schooling. We used longevity values in the 48-77 years interval, comprising the variation of life expectancy observed in the last century. Greater longevity allows for extension of the population working life and, consequently, an increase in the present value of the flow of wages of a given investment in education. Higher returns to education in turn induce individuals to stay in school longer. The model simulation found an elasticity of schooling to longevity of 0.74[9].

Note that the model obtains rising educational attainment as a steady state result. Jones (2002) argues that, from the standpoint of a neoclassical growth model, increases in education should generate temporarily high growth rates and long-run level effect, at the same time that the evidence for the U.S. points toward an economy fluctuating around its balanced growth path. However, this is certainly true in a infinity-lived agent model in which the return to schooling by construction does not depend on longevity. In our model, however, increases in the latter raises the return of educational investment so that individuals stay longer in school. Hence, the observed increase in life expectancy during the last century in

[9] Due to the large variation of tariffs and effective rates of protection, we used the arc-elasticity definition to calculate these values.

the US explains, partially at least, the observed path of educational attainment as a steady state result: to each T corresponds a different T_S.

One problem of the simulations is that the model tends to overestimate schooling at lower levels of life expectancy. Hence, in 1910 the median educational attainment of males aged 25 year and over, according to estimates in Gustavus and Nam (1964), was 6.8 years. Life expectancy in this year, according to the National Vital Statistic Report, was 51.45 years. In this case the model finds $T_S = 8.99$. Even if we average with the corresponding figures of education attainment of females, which were largely out of the labor force by this date, we still over-predict schooling by 1.5 years.

The likely cause of the mismatch is that the simulations are done with parameters calibrated from recent data (e.g., 1990 or 2000) or, as in the case of n, using long-run averages. When we modify the calibration, allowing some parameters to better match the corresponding values of a given year, results tend to improve. For instance, in the first decade of the last century average population growth, according to Census data, was 1.96% a year. Using this value instead of that of the benchmark calibration we obtain $T_S = 7.2$, very close to the actual figure. Hence, the combined effect of higher longevity and lower population growth explains schooling so that the model not only reproduces qualitatively the positive relationship between longevity and schooling, but also quantitatively[10]. Kabosky(2003) has also noted that fertility reduction along the twentieth century had a strong effect on the growth of education[11].

The model also predicts that retirement life increases with longevity, reproducing the evidence for the U.S. When life expectancy is 48 years of life, the figure for males in 1900, the model predicts that people would stop working 1.5 years before dying. However, using the numbers for 2000, 77 years, retirement life would last according to the simulations15.4 years and people would stop working at the age of 61.6 years. The significant expansion of retirement life, as we noted in the introduction, is the observed evidence for the twentieth century. Lee(2001) calculates that the expected period of retirement increased from 2.6 years for the cohort born in 1880 to 13.1 years to the cohort born in 1930.

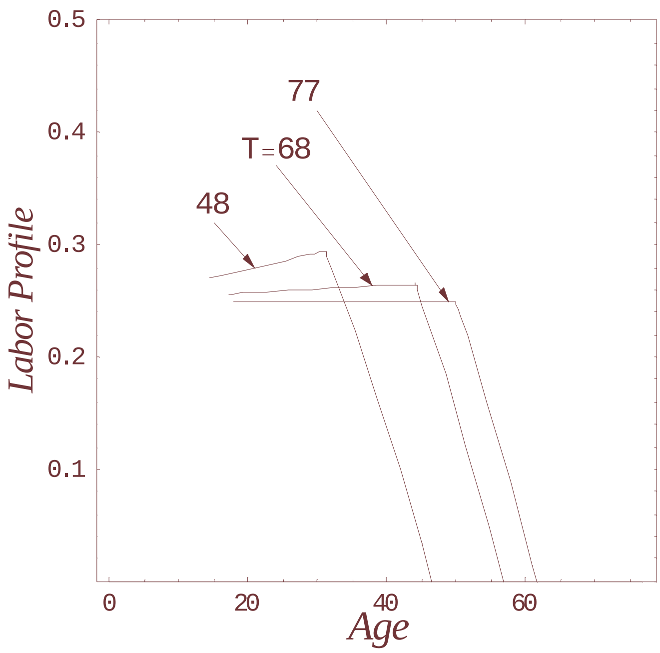
In the model retirement life increases with life expectancy because of an income effect: education raises with longevity and so do wages. As leisure is a normal good, individuals consume more of it. Moreover, given T, people retires because in the second period of their

[10] However, simulated retirement life tend to increase under this alternative parametrization of the model.

[11] Soares (2003) endogeneizes fertility and education in a model in which longevity varies.

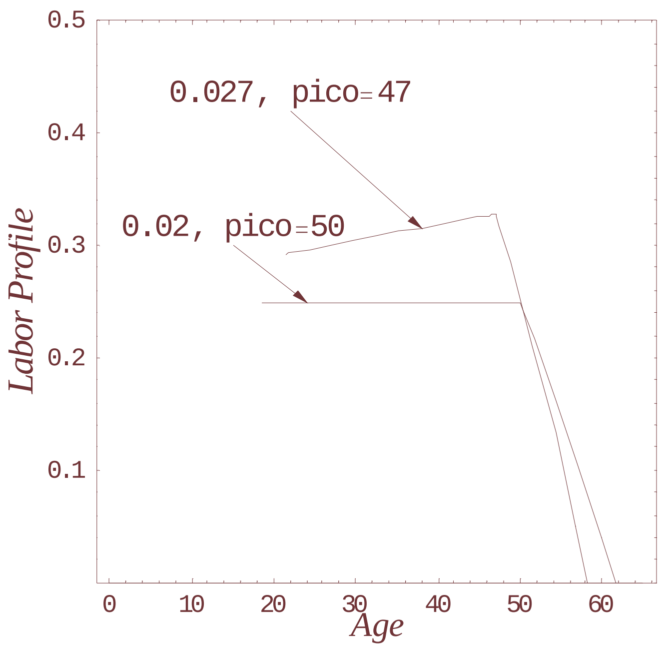
working life, as productivity falls (or increase slower), wages fall and so do the relative cost of leisure, leading people to decrease work effort. At certain point, the marginal gain of staying in the job market is smaller than that of dedicating all the time endowment to leisure. In other words, given that people is more productive when young and mature they rather work harder during this part of their life, save for retirement, and then stop working completely later in life when productivity is falling. This difference in productivity is exactly the reason households do not spread out leisure evenly along their life, as the return to work is lower at old age.

Figure 2 below presents labor profiles as life expectancy goes from 48 to 68 and then to 77. Some facts are worth comment. As longevity increases people enter later in the labor market (as seen in Figure 1). They also work less hours during the period of their life when productivity is increasing, as the graphs shift down continuously. This is due to the income effect caused by higher education and wages and the normality of leisure. Finally, people stay longer in the labor market.



A caveat is that, although we were able to obtain increasing retirement life along the years as in the data, we are not able to reproduce the evidence that retirement age is falling in the recent past. We do not consider this a serious problem as the simulated figures are almost constant for the latest years. For instance, retirement age was estimated to be 61.56 years of age in 2000, 61.40 in 1990, 59.81 in 1980 and 58.29 in 1970.

Nonetheless, the fact is that on average individuals are retiring earlier on life and we do not capture this perfectly. One possible solution is to change across years the learning coefficients γ and ζ. This is not arbitrary because the estimated dummies are not the same across decades. For instance, the estimated productivity profile in 1940 is below that of 1990 for its entire positive portion. In this case γ could be larger in 1990 than in 1940, so that people would work more intensively in the first part of their productive life, increase savings and retire earlier. Figure 3 shows two labor profiles, one obtained from the benchmark calibration ($\gamma = 2.0\%$) and one using gamma equal to 2.7%.



If productivity growth rate (i.e., gamma) in the first period of working life raises, individuals will work more intensively once they enter the labor market - the graph shifts up - and then retire earlier. This is so because the opportunity cost of leisure in the earlier years of working life increased with respect to that of old age.

Note also that individuals enter later in the job market, acquiring more education. This means that, in essence, what matters for schooling is not the *extension* of productivity life, but its *intensity*. In models such as Soares(2003) and Kalemhi-Ozcan and Weil (2000), longer life allows for longer productivity life, increasing the return to human capital investment and so education. A problem here is that, especially in rich capitalist economies, increases in life expectancy were followed by more than proportional increases in retirement, in which case this result does not hold. However, if for some reason productivity growth rate due to experience jumps up, the return to education investment also increases, so people will want to acquire more of it even if longevity does not change. If this jump is high enough, productivity life may well decrease as in Figure 3[12].

5 Distortions, Education and Income

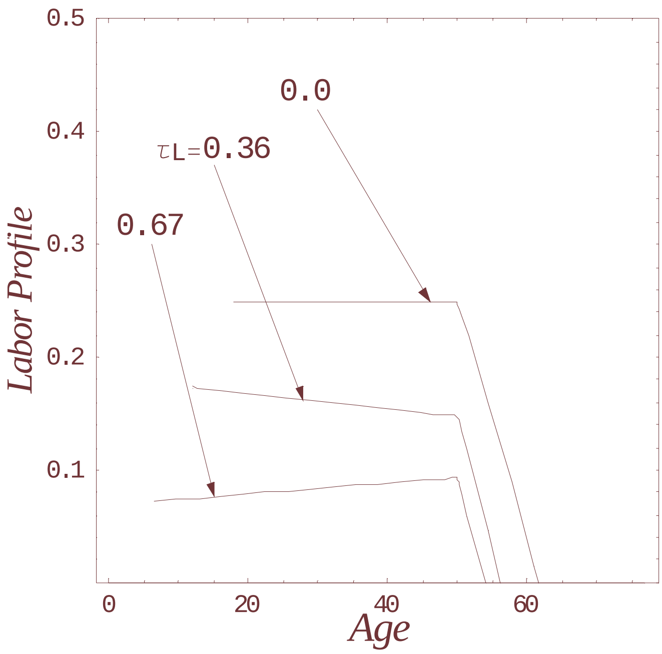
Up to this point we have kept distortions constant while we allow longevity to vary. We have seen that changes in life expectancy have significant impacts on life-cycle decisions such as education and retirement. In this section we study the sensitivity of the model to modifications in the three distortion parameters. Additionally, we are also interested in comparing their relative impact on income.

As the model includes not only life-cycle features but also saving decision and two sectors of production, its general equilibrium structure includes different transmission mechanisms, more so than most models in the field, and is a rich environment to study the relative impact of different forms of taxation. Remember that in this economy the government imposes taxes on labor income, capital income and on the direct cost of education. It is not clear which of these has a stronger impact on education and income. For instance, tax on physical capital returns imposes the usual distortions on saving decisions, investment and capital stock. The latter, affects the marginal productivity of labor - so the labor and education decision - and the production of education services, which uses capital. Tax on labor, on its turn, affects directly the labor and leisure decision. It also affects the education and retirement decision, so working life and the long-run return to physical and human capital.

The picture below presents labor profiles for τ_L equal to 0.0, 0.36 and 0.67. Note that the graphs shift down as τ_L increases, so that, similarly to the standard neoclassical model,

[12]Note, however, that the evidence is not clear that γ increased monotonically in all the previous decades. In any case, what matters is the relative growth rate at different ages, and the evidence is very strong that experience gains at old age are falling much faster in recent years.

higher taxes on labor income leads to less hours worked. There are, however, two additional effects: individuals will enter and leave the labor market earlier. In the first case because more taxes on labor reduces the return to human capital investment, so schooling decreases. In the second case because the relative cost of leisure - and retirement too - decreases. This a significant amplification of the effect of labor taxation on the economy that is not captured in standard neoclassical models. Moreover, as labor supply decreases, physical capital also falls in equilibrium, as its marginal product is now smaller.



Similar pictures apply for the cases of τ_H and τ_K. (see the appendix). In the first case, however, the impact on labor supply is considerably smaller and on retirement almost none. The main effect, as expected, is on the education decision which of course falls with τ_H. The overall impact, however (see Table A.1 in the appendix) is much weaker than that of $\tau_{L,}$ even on education The effect of capital taxation on schooling, income and retirement (see Table A.2 in the appendix), is stronger than that of human capital taxation but is not as large as that of τ_L. We will comment on this surprising result later.

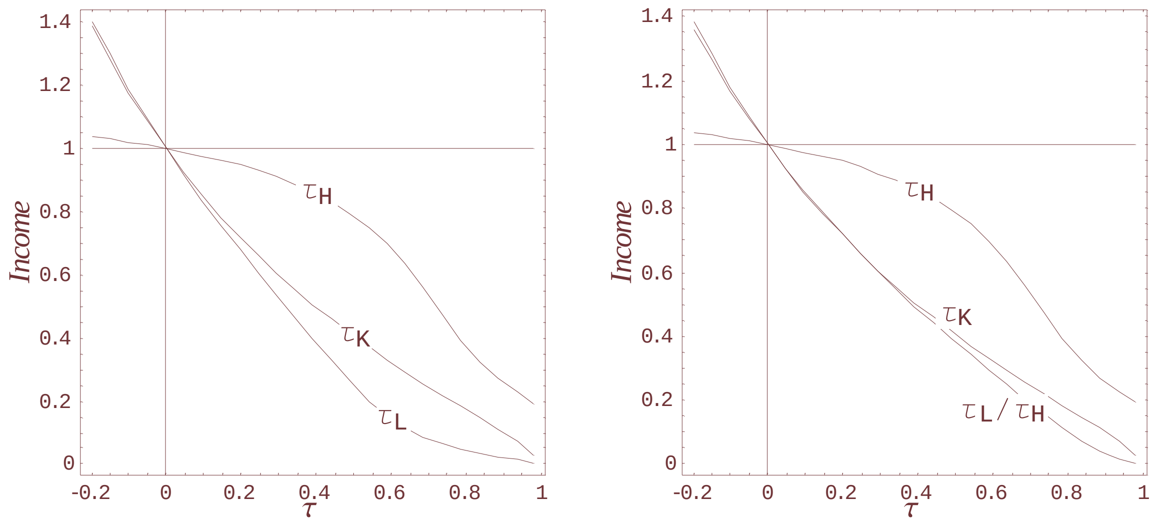
Table 1 below presents the results of an exercise in which τ_L varies and everything else is kept constant at the benchmark values.

Table 1: Long-Run Impact of Labor Taxation

τ_L	T_S	y	T_R
-0.15	13.87	1.29	64.9
0	12	1	61.6
0.15	9.86	0.75	58.89
0.30	7.23	0.53	56.83
0.50	2.59	0.25	55.26
0.65	0.49	0.11	54.22

Income in the benchmark economy - the U.S. in the present - is set equal to one and tax rate to zero just as a normalization. In addition to the direct impact on labor supply seen in Figure 4, τ_L reduces education, retirement age and capital (not shown). Hence, an economy in which tax rate is 0.30 points above the U.S. tax rate, i.e. $\tau_L = 0.30$ will have forty percent less education than the U.S. and people would retire five years younger, even with the same productivity, longevity, τ_K and τ_H. The income per worker would be 47 percent smaller. On the other hand, negative τ_L, a relative subsidy, induces agents to accumulate more education than the US, retire later, work harder and accumulate more physical capital. A subsidy of $\tau_L = -0.15$, would raise per capita income by 29 percent and schooling by almost two years.

Figures 5 and 6 compare the relative impact on income per capita of the different types of taxes.



As shown by Figure 5, the overall simulated effect of τ_L over the long-run income is marginally larger than that of τ_K, for small values of distortion, but relatively larger for values above 0.20. This is somewhat surprising as distortions to the accumulation of physical capital have a direct effect on both sectors and an indirect effect on the returns to educational investment. In most studies in public finance, capital taxation is more detrimental to the economy than labor taxation. Not here. A first reason is that the impact of the later over labor effort is much higher: for τ_L or τ_K equal to 0.36, individuals with 34 years of age would work 28% less hours in the first case, everything else constant. Moreover, in overlapping generation models the modified golden rule is not valid in the steady state, as in the neoclassical model, so that the response of capital stocks to capital taxation is smaller here than in infinity-lived agent models, more so when T_W is not too large.

A third reason is the differentiated impact on schooling. While for high values of τ_L individuals acquire almost no education, this is not true for capital taxation. Even for taxes around 0.30 the difference is already above two years less in schooling for labor taxation. Figure 6 controls this channel, as we subsidy education investment to compensate the distortion caused by $\tau_{L.}$ So the line $\tau_L/\tau_{H.}$shows the impact of a pure labor market distortion. Even in this case the effect of labor taxation on long-run income is larger, especially for taxes above 0.5.

A surprising result is that, although the negative impact of human capital taxation on schooling, as expected, is considerably greater than that of physical capital taxation (see Table A.1 in the appendix) the overall effect on per capita income is not too big. In this model, τ_H influences in the margin the decision of individuals to stay in school but have no significative effect on labor effort and only a mild impact on physical capital accumulation. Moreover, the return to education function used tends to weaken the impact of human capital variation on the remaining variables.

We repeated the above exercises changing instead life expectancy while keeping all other parameters constant. Results are shown in Table 2.

Table 2: Long-Run Impact of Longevity

T	T_S	y	T_R	*Retirement*
77	12	1	61.60	15.40
70	11.3	0.94	57.88	12.12
65	10.7	0.90	55.29	9.71
60	10.1	0.86	52.66	7.34
55	9.5	0.81	50.07	4.93
50	8.7	0.76	47.50	2.50

As one could expect, given the results in the previous session, per capita income decreases with longevity. For instance, when $T = 60$, income per capita estimated is 86% of that of the benchmark model. One possible interpretation is that a country with everything else equal to the U.S. but longevity, would be 14% poorer if its life expectancy was 17 years smaller. As already commented, retirement life increases more than proportionally with longevity, reproducing the evidence: when T is 77 the model predicts that an individual would expend 20% of its life on retirement, but only 5% when T is 50[13].

6 Conclusion

In this paper we have studied a finite life economy in which higher life expectancy explains schooling and retirement increases, and plays an important role in the determination of long-run incomes. This role could only arise because of the hypothesis of finite life and the Mincerian formulation of human capital, which seem to us the most realistic assumptions. When calibrated to the U.S. experience during last century we reproduced education levels, and showed that a 20% difference in longevity, everything else constant, would lead to a 15% gap in per capita income.

The mechanism of the model that allows for retirement are, in addition to the labor-leisure choice, an experience profile that mimics its parabolic shape estimated by studies in

[13]Results concerning productivity differences are as expected. An economy equal in every aspect to the US but with only 50% of its total factor productivity would have only 30% of the income per capita of the latter. The impact is mostly felt through physical capital, as education and retirement almost do not change with A_1.

the labor field. As productivity decreases or slow down at old age, at certain point of life the marginal gain of working is below that of leisure, and people leaves the job market. Longer lives allows people to enjoy proportionally larger retirement. If, on top of that, productivity profile jumps up so that young people learn relatively faster, we obtain that retirement age falls, replicating the evidence.

The sensitivity analysis and tax simulations showed that life-cycle aspects are very important to the study of public policy and the allocative effect of taxation. Once schooling and retirement decisions are incorporated to the analysis, and career span is finite, labor taxation is more detrimental to per capita income than physical capital taxation. The literature on the latter, however, is much more extensive than that on the former, although there are important exceptions, most of them using endogenous growth models. One possible reason is that taxation on human capital in many models is neutral, as it decreases the return to human capital but also the cost of being out of the labor market. However, our results show that if there are any other costs imposed on the acquisition of education which are not proportional to wages (e.g., tuition), the long-run impact of taxation on human capital is relevant. Note, however, that taxation on tuition alone cannot explain the bulk of the impact, as simulations showed that its effect on income is dominated by other forms of distortions.

A Appendix 1: Factors allocation problem

In this economy there is free mobility of factors across sectors, so that factors price are the same in both sectors. Considering the good 1 as the numeraire, it follows that:

$$R \equiv R_1 = \alpha_1 A_1 k_1^{\alpha_1 - 1} = p\alpha_2 A_2 k_2^{\alpha_2 - 1} = R_2$$

and

$$w \equiv w_1 = (1 - \alpha_1) A_1 k_1^{\alpha_1} = p (1 - \alpha_2) A_2 k_2^{\alpha_2} = w_2,$$

where p is the relative price of educational services in units of goods. Dividing the second equation by the first we obtain the wage-rental ratio as a function of the capital-labor ratio in the i-th sector:

$$\omega \equiv \frac{w}{R} = \frac{1 - \alpha_i}{\alpha_i} k_i. \tag{20}$$

In order to express the relative price of final goods as a function of the relative price of production factors we employ the zero profit condition to obtain,. after some simplifications:

$$p = \frac{A_1 k_1^{\alpha_1 - 1}}{A_2 k_2^{\alpha_2 - 1}} \frac{\alpha_1}{\alpha_2}.$$

If we substitute again (20) into this last equation we can express the relative price of factors as a function of the relative price of goods:

$$\omega = \left(\frac{A_2}{A_1} \frac{\alpha_2^{\alpha_2}}{\alpha_1^{\alpha_1}} \frac{(1 - \alpha_2)^{1 - \alpha_2}}{(1 - \alpha_1)^{1 - \alpha_1}} .p \right)^{\frac{1}{\alpha_1 - \alpha_2}}, \tag{21}$$

From (20) and (21) follows the optimum capital-labor ratio as a function of the relative price of the final goods:

$$k_i = \frac{\alpha_i}{1 - \alpha_i} \left(\frac{A_2}{A_1} \frac{\alpha_2^{\alpha_2}}{\alpha_1^{\alpha_1}} \frac{(1 - \alpha_2)^{1 - \alpha_2}}{(1 - \alpha_1)^{1 - \alpha_1}} p \right)^{\frac{1}{\alpha_1 - \alpha_2}}. \tag{22}$$

To wrap up the factor allocation problem we have to find the scale of production of each sector. Let l_i be the share of the labor force in the i-th sector, l the (per capita) total flow of labor services and k the (per capita) endowment of capital. Full employment of labor and capital services implies:

$$\begin{aligned} l_1 k_1 + l_2 k_2 &= \widetilde{k} \\ l_1 + l_2 &= 1, \end{aligned}$$

where $\widetilde{k} \equiv \frac{k}{le^{\phi(T_S)}}$ is the per-worker capital stock in efficiency units. This last two equations solve for l_i as a function of k_i and $\widetilde{k}$.

At a point in time, given $\widetilde{k}$ and p we get the sector offers function as follows:

$$y_i(p, \widetilde{k}) = A_i l e^{\phi(T_S)} l_i(p, \widetilde{k}) \left[k_i(p)\right]^{\alpha_i}, \quad i = 1, 2 \tag{23}$$

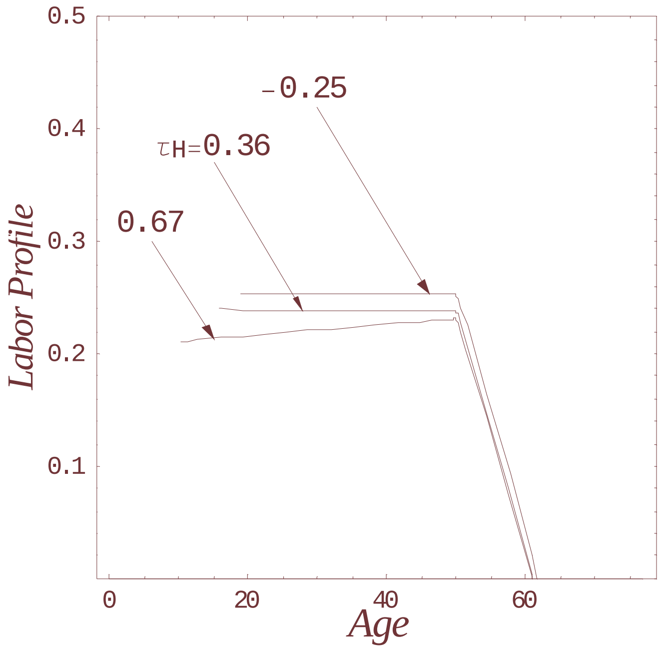
where $k_i(p)$ is given by (22), $y_i \equiv \frac{Y_i}{e^{nt}}$ is the per capita supply functions,e^{nt} is total population and:

$$l_1(p, \widetilde{k}) = \frac{k_2(p) - \widetilde{k}}{k_2(p) - k_1(p)}, \quad \textit{and} \quad l_2(p, \widetilde{k}) = \frac{\widetilde{k} - k_1(p)}{k_2(p) - k_1(p)}$$

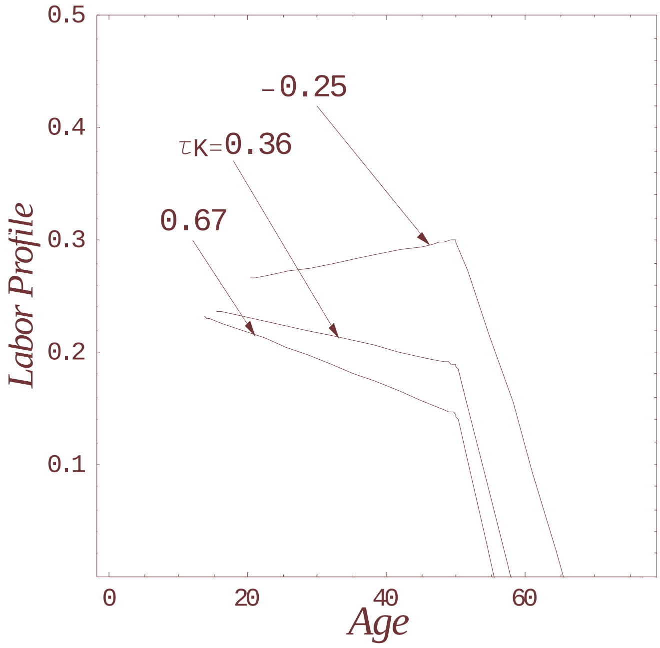
It will be useful for the calibration to solve the model (under the assumption of full employment of factors) for k_1 and k_2:

$$k_1 = \frac{\frac{\alpha_1}{1-\alpha_1}}{\frac{\alpha_1}{1-\alpha_1} l_1 + \frac{\alpha_2}{1-\alpha_2} l_2} \widetilde{k} \text{ and } k_2 = \frac{\frac{\alpha_2}{1-\alpha_2}}{\frac{\alpha_1}{1-\alpha_1} l_1 + \frac{\alpha_2}{1-\alpha_2} l_2} \widetilde{k}$$

B Appendix: Additional Tables and Figures



Direct taxation on human capital accumulation



Tax on capital

Table A1: Long-Run Impact of Human Capital Taxation

τ_H	y	T_s	T_R
-0.15	1.02	12.51	61.73
0	1	12	61.6
0.15	0.96	11.30	61.34
0.30	0.9	10.28	61.09
0.50	0.78	7.99	60.75
0.65	0.61	4.86	60.82

Table A2: Long-Run Impact of Physical Capital Taxation

τ_K	y	T_s	T_R
-0.15	1.27	13.21	63.69
0	1	12	61.6
0.15	0.78	10.88	59.82
0.30	0.60	9.88	58.38
0.50	0.40	8.65	56.78
0.65	0.28	7.80	55.77

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