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"CAN THE COST OF EDUCATION EXPLAIN THE POVERTY OF NATIONS? MEASURING THE IMPACT OF FACTORS TAXATION AND LIFE EXPECTANCY ON INCOME DIFFERENCES"

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Can the costs of education explain the poverty of nations? Measuring the impact of factors taxation and life expectancy on income differences

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Abstract

This paper explores the distortions on the cost of education, associated to government policies, as an additional determinant of cross-country income differences. Human capital follows a Mincerian approach and accumulation of skills is done at school, outside the labor market. There are two sectors, one producing goods and the other providing educational services. The model is calibrated and simulated for 122 economies. We find that human capital taxation has a relevant impact on incomes, which is amplified by its indirect effect on returns to physical capital. For comparable values, distortions to the latter have an overall effect on incomes smaller than human capital taxation. Life expectancy plays an important role in determining long-run output: the expansion of the population working life increases the present value of the flow of wages, which induces further human capital investment and raises incomes. A general conclusion, however, is that there is not a single cause for the poverty of nations. Some are poor because of very low productivity, and others because of excess taxation on factors.
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1 Introduction

This article studies the effects of distortions to factors accumulation, productivity and demography on cross-country income disparity. We posit a continous time overlapping generation model of capital accumulation with exogenous technological change and two sectors, educational and goods. All economies in the world have access to both technologies but they differ in their total factor productivity (TFP). Moreover, human capital in the model follows a Mincerian approach, as individual's skill-level is determined by educational attainment: the skill-level of a worker with T_S years of schooling is $e^{\phi(T_S)}$ greater (where ϕ is an increasing and concave function) than that of a worker of the same cohort with no education at all. Life is finite in the model but average life span differs from country to country.

In this model there are two decisions to be taken by individuals. First, at each instant of time they decide how much to consume or save out of their labor and capital incomes and public transfers. Second, they decide the optimal time to leave school. Following the labor-economics literature, human capital investment is the time spent acquiring formal education plus the tuition cost. As usual, the longer people stay in the school, the higher their stock of human capital is. At each moment, individuals weight the opportunity costs of being in school - the wages forsaken plus tuitions - against its benefit, which is the increase in the present value of wages due to higher human capital. One of the key variables to be considered in this decision is life expectancy, because the present value of the flow of wages, everything else being the same, increases with longevity. Government taxes tuition and the return to physical capital.

The model is calibrated in two steps. In the first, we follow standard procedures and adjust the model to the US, estimating in the process productivity and the distortions to physical and human capital accumulation, among other variables. In the second step, a cross-section data set on schooling, investment ratio, life expectancy and labor force participation is employed, together with the technology and welfare parameters estimated previously for the US, to obtain the TFP, distortions and tuition costs for the remaining economies.

A first finding of the paper is the relative importance of distortions to human capital accumulation. For comparable values, its effect on long-run income is larger than that of distortions to physical capital accumulation. This is somewhat surprising in a model where education has no impact on the long-run growth rate and, as opposed to Lucas (1988) and Uzawa (1965), it is a bounded variable which cannot be accumulated indefinitely. Education in the model determines skill levels and so it directly impacts labor services and output. It also has an indirect effect on the latter due to its impact on the return to physical capital, and so on investment, a channel that multiplies the total impact of the taxes on education investment. On the other hand, the educational sector uses very little capital - its capital share according to the NIPA is only 6 percent- so that the distortion to physical capital has almost no impact on the sector's return.

An unexpected outcome, and one that has received virtually no attention, is the importance of life expectancy in the determination of long-run output. Everything else being the same, the longer people live in a given country, the higher the long-run income of this economy is. Higher longevity allows for extension of the population working life and, consequently, an increase in the present value of the flow of wages for a given investment in education. Higher returns to education in turn induce individuals to stay in school longer, increasing average human capital and so long-run income. There is also an indirect effect on income prompted by physical capital accumulation, as the boost in human capital affects positively the return of the latter. We show that, everything else being equal, a country with life expectancy of 65 years instead of the 76 years of the benchmark case will have 30% less schooling, 24% less physical capital and income will be 26% smaller in the long run.

A consequence of the above finding is that having more or less education does not imply that distortions or incentives to human capital accumulation are large or small. The key factor in this case is the relationship between years of education and working life span. Life expectancy in Angola is only 45 years and so distortions to investment in education were found to be very small, even with very little schooling. On the other hand, in some rich countries such as France, were life expectancy is very high but schooling well below that of US, those distortions were estimated as being extremely high.

Results are used to assess the relative importance of each factor - distortions to physical and human capital investment, productivity and longevity - in explaining cross-country income differences. A general conclusion is that different countries are poor for different reasons - there is not a single cause for the poverty of nations. Hence, a country such as South Korea in 1985 was only 20% as rich as the US mainly because of low productivity, as estimated TFP in South Korea was only 42% of the latter and well below the sample mean. Argentina imposes high distortions to physical capital accumulation while TFP and incentives to human capital investment are in line or above the leaders. In Portugal distortions to education investment are among the highest in the world. Romania is extremely good at at setting the incentives to physical capital accumulation but productivity and education incentives are, however, very poor. Finally, Tanzania, as many African economies, fares very badly in every possible aspect and it is no wonder it is one of the poorest countries in the world.

To the best of our knowledge there has not been much interest in investigating long-run level effects of distortion to human capital accumulation, especially using the Mincerian formulation of human capital. The macro literature has dedicated more effort in studying the long-run growth impact of human capital taxation, as in Trostel (1993), Stokey and Rebelo (1995), and Hendricks (1999). These papers employ the two-sector endogenous growth framework of Uzawa (1965) and Lucas (1988). However, in the face of recent empirical evidence (Bils and Klenow (2000) and Krueger and Lindhal (2000)) it seems that the growth effects of incentives to human capital accumulation is either very low or nonexistent. Additionally, as documented by Krueger and Lindhal, there is not a compelling set of evidence favoring the existence of externality associated to human capital accumulation. Our environment seems to be a conservative one for assessing the long-run importance of education and most likely we are underestimating the importance of education.

Bils and Klenow (2000) and Mateus-Planas (2001) employ a Mincerian formulation of schooling with a life-cycle decision regarding education. The former authors consider a version of the endogenous growth model to study econometrically the causality between education and growth. Mateus-Planas study a vintage model of capital accumulation in order to asses the impact of distortion to capital accumulation on long-run income. Neither formulation consider a second sector that provides educational services as we do.

Mankiw (1995) and Parent and Prescott (1995) investigate the impact of distortions on long-run income for a version of the neoclassical model with three factors of production: raw labor, physical capital, and human capital (or organizational capital). In contrast to our model, they consider human capital and physical capital symmetrically, as stocks of goods that can be accumulated without limit. Another formulation of the neoclassical model of capital accumulation and exogenous technological change is Parent and Prescott (2000, chapter 4). Their set up however does not incorporate the life cycle features of educational choice, making their calibration procedure more difficult.

This paper is organized in four sections in addition to this introduction. In the next section, the model is presented and in Section 3 we discuss the calibration procedures. Section 4 presents the main results and Section 5 concludes.

2 The Model

2.1 Household

Suppose a household that is born at time s and faces a life span of T years. Her life has three different periods: youth, T_Y, adulthood, T_W, when she is working, and old age, T_R, when she retires. Youth has two sub-periods: childhood, T_C, when she stays at home, and T_S, when she is at school. Evidently,

$$T = T_Y + T_W + T_R, \text{ and } T_Y = T_C + T_S.$$

At each instant of time this person decides how much to consume or save out of her labor and capital incomes and public transfers. She also decides how much education she wants to buy, which is equivalent in the model to deciding the optimal period of time T_S of being in school. The utility function of an individual born at time s is:

$$\int_s^{s+T} e^{-\rho(t-s)} \frac{c(s,t)^{1-\frac{1}{\sigma}} - 1}{1 - \frac{1}{\sigma}} \mathrm{d}t, \tag{1}$$

where $c(s,t)$ is the consumption in t of an individual born in s, while ρ and σ are respectively the discount rate and the intertemporal elasticity of consumption.

The individual maximizes (1) subject to her intertemporal budget constraint:

$$\begin{aligned} &\int_{s+T_Y}^{s+T_Y+T_W} e^{-r(t-s)} \mathrm{w}(s, T_S, t)\mathrm{d}t + \int_s^{s+T} e^{-r(t-s)} \chi(s,t)\mathrm{d}t \\ = &\int_s^{s+T} e^{-r(t-s)} c(s,t)\mathrm{d}t + (1+\tau_H) \int_{s+T_C}^{s+T_Y} e^{-r(t-s)} \eta q(t)\mathrm{d}t, \end{aligned} \tag{2}$$

where r is the interest rate (assumed constant along a balanced growth path), $\mathrm{w}(s, T_S, t)$ is the wage in time t of a worker born in s with T_S years of formal education, τ_H is a tax (or subsidy) rate on education purchases, η the amount of education services that the student has to buy in order to be in school,[1] $q(t)$ is the price of one unit of educational services in

[1]We are assuming an indivisibility in the human capital accumulation process. In order to increase her education level, the individual has to buy η unites of educational services. In other words, to be at school means: not working and staying daily some hours at school, which corresponds to buying η unites of educational services.

units of consumption goods, and $\chi(s,t)$ is the government transfer in t toward a cohort-s individual. The above expression simply says that the present value of wages and government transfers should be equal to the present value of consumption and tuition cost.

Education decision

We propose a Mincerian approach to model the impact of schooling on labor productivity. There is only one type of labor in the economy with skill-level determined by educational attainment. It is assumed that 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, following the evidence from country studies based on micro evidence (e.g., Psacharopoulos(1994)).[2]

Agents choose the optimal quantity of education in order to maximize the present value of income:

$$\max_{T_S}\left\{\int_{s+T_Y}^{s+T_Y+T_W} e^{-r(t-s)}\mathrm{w}(s,T_S,t)\mathrm{d}t-(1+\tau_H)\int_{s+T_C}^{s+T_Y} e^{-r(t-s)}\eta q(t)\mathrm{d}t\right\}. \tag{3}$$

Remember that agents born in s stay in school from $s+T_C$ to $s+T_Y$ so that the expression on the right gives the present value of total tuition costs. Moreover, these agents work from the moment they leave school, $s+T_Y$, until retirement, $s+T_Y+T_W$. Consequently the expression to the left gives the present value of labor income. In addition, given that $T_Y=T_C+T_S$ and that T_C is exogenous, choosing T_S is equivalent to choosing T_Y.

In taking this decision, the individual considers that the longer she stays in school, the shorter is her productive life, T_W, as we assume that "old age," T_R, is exogenous. The expression above can be simplified first by letting $\mathrm{w}(s,T_S,t)=\omega(t)e^{\phi(T_S)}$, where $\omega(t)$ are the wages for raw labor. Moreover, as we are interested in studying the model's solution at a balanced growth path in which income, transfers, and tuition grow at the same constant rate g, we will assume that $\omega(t)=\omega e^{gt}$ and $q(t)=qe^{gt}$. Finally, recalling that

$$T_Y+T_W=T-T_R$$

[2] In addition we assume that $\phi(0)=0$.

we can rewrite (3) as

$$\max_{T_S}\left\{\omega e^{\phi(T_S)}\frac{e^{-(r-g)T_Y}-e^{-(r-g)(T-T_R)}}{r-g}-(1+\tau_H)\eta q\frac{e^{-(r-g)T_C}-e^{-(r-g)T_Y}}{r-g}\right\}.$$

The first order condition of this problem after some simple manipulation, at a balanced growth path, is

$$\omega e^{\phi(T_S)}\phi'(T_S)\frac{1-e^{-(r-g)T_W}}{r-g}=\omega e^{\phi(T_S)}+(1+\tau_H)\eta q. \tag{4}$$

The expression above 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).

Consumption decision

Solving the FOC for consumption, we obtain the individual's consumption profile:

$$c(s,t)=c(s,s)e^{\sigma(r-\rho)(t-s)} \tag{5}$$

In order to establish the initial consumption, we substitute (5) into (2) and obtain:

$$c(s,s)\frac{1-e^{-((1-\sigma)r+\sigma\rho)T}}{(1-\sigma)r+\sigma\rho}= \tag{6}$$
$$\int_{s+T_Y}^{s+T_Y+T_W}e^{-r(t-s)}\mathrm{w}(s,T_S,t)\mathrm{d}t-(1+\tau_H)\int_{s+T_C}^{s+T_Y}e^{-r(t-s)}\eta q(t)\mathrm{d}t+\int_{s}^{s+T}e^{-r(t-s)}\chi(s,t)\mathrm{d}t.$$

The right-hand term is the individual's total wealth at the time of birth (i.e., labor income less tuition plus government transfers). It follows from (6) that the marginal propensity of consumption out of initial wealth is

$$v_{ci}=\frac{(1-\sigma)r+\sigma\rho}{1-e^{-((1-\sigma)r+\sigma\rho)T}}.$$

Using $\mathrm{w}(s,T_S,t)=\omega(t)e^{\phi(T_S)}$ we obtain from (6):

$$\begin{aligned}\frac{c(s,s)}{v_{ci}} &= \frac{e^{gs}}{r-g}\left\{\omega e^{\phi(T_S)}e^{-(r-g)T_Y}\left(1-e^{-(r-g)T_W}\right)\right. \\ &\quad \left.-(1+\tau_H)e^{-(r-g)T_C}\left(1-e^{-(r-g)T_S}\right)\eta q+\chi\left(1-e^{-(r-g)T}\right)\right\},\end{aligned} \tag{7}$$

where, once again, it was assumed that $\omega(t)=\omega e^{gt}$, $q(t)=qe^{gt}$, and $\chi(s,t)=\chi e^{gt}$.

2.2 Demography

At each instant a cohort of size $\frac{1}{T}$ is born. Consequently, the total population is equal to 1. Let us call N_C, N_S, N_W, and N_R respectively the population of children, students, workers, and retirees. We have

$$N_C=\frac{T_C}{T},\ N_R=\frac{T_R}{T}$$

and the student population and tlabor force are given respectively by:

$$N_S=\frac{T_S}{T},\ N_W=\frac{T_W}{T}. \tag{8}$$

Note that we obtain $N=N_C+N_S+N_W+N_R=1$.

2.3 Firms

There are two sectors in this economy. In the first one, the *goods sector,* consumption and investment goods are produced. The other sector is the *educational sector.*

Goods Sector

In this sector, technology is given by:

$$Y_1=A_1K_1^{\alpha}(\lambda_1L_1e^{\phi(T_S)})^{1-\alpha}=A_1\lambda_1L_1e^{\phi(T_S)}k_1^{\alpha},$$

where Y_1 is the sector output, $\lambda_1=e^{gt}$ is the (exogenous) technological progress and K_1 and L_1 are the flow of capital and labor services used in the sector, respectively. Profit maximization of the firm gives

$$r_1 = \alpha A_1 k_1^{\alpha-1} \text{ and } \mathrm{w}_1 = e^{\phi(Ts)}\lambda_1(1-\alpha)A_1 k_1^{\alpha},$$

where r_1 is the rental price of capital and w_1 is the wage rate, both in the first sector, and

$$k_1 \equiv \frac{K_1}{\lambda_1 L_1 e^{\phi(Ts)}}, \tag{9}$$

is the stock of capital in efficiency units.

Educational Sector

It will be assumed that the production of educational services is labor intensive, as compared to the good sector. In order to obtain a balanced growth path in which tuition increases at a rate equal to technological change, it is necessary to make the additional assumption that schools employ only labor and that there is no technological progress in the sector.[3] Formally,

$$Y_2 = A_2 L_2 e^{\phi(Ts)}.$$

Profit maximization of schools gives us:

$$\mathrm{w}_2 = e^{\phi(Ts)} A_2.$$

2.4 Production Equilibrium

Let $y_1 = Y_1/N$ be the per capita output of the first sector where $N = 1$ is the total population. We then have:

$$y_1 = A_1 l_1 N_W e^{gt+\phi(Ts)} k_1^{\alpha},$$

[3]Note that according to the publication "Survey of Current Business" published by the U.S. Department of Commerce, Bureau of Economic Analysis, the capital share of income of the educational services sector (SIC code 87) is only 6% (average for 1987-1997).

where l_1 is the fraction of the total labor force employed in sector one. Likewise, per capita output in the educational sector is:

$$y_2 = \frac{Y_2}{N} = A_2 l_2 N_W e^{\phi(T_S)}$$

The equilibrium of the production side of this economy implies the following conditions. First, there is no labor unemployment, which implies that

$$l_1 + l_2 = 1.$$

Second, free labor mobility across sectors implies equality of wages in sectors one and two, both in units of good one:

$$\mathrm{w}_1 = e^{gt+\phi(T_S)}(1-\alpha)A_1 k_1^{\alpha} = q e^{gt+\phi(T_S)} A_2 = q(t)\mathrm{w}_2.$$

Under a balanced growth path this last equation simplifies to

$$\omega \equiv \frac{\omega(t)}{e^{gt}} = (1-\alpha)A_1 k_1^{\alpha} = qA_2.$$

Third, equilibrium in the assets market implies that

$$r = (1-\tau_K)\alpha A_1 k_1^{\alpha-1} - \delta,$$

where τ_k is a tax rate on capital income. Manipulation of the above equation gives us:

$$k_1 = \left(\frac{1}{\alpha A_1}\frac{r+\delta}{1-\tau_K}\right)^{\frac{1}{\alpha-1}}.$$

Finally, there is no unemployment of capital, that is, $K_1 = K$.

2.5 Aggregate Consumption

To derive the aggregate consumption we need to add the individual consumption over cohorts. It follows:

$$C(t) = \frac{1}{T}\int_{t-T}^{t} c(s,t)\mathrm{d}s. \tag{14}$$

Equation (5) provides the consumption profile for an individual. Guessing that the initial consumption, due to technological change, increases at a rate g, so that $c(s,s) = xe^{gs}$ obtain

$$\begin{aligned} C(t) &= x\frac{1}{T}\int_{t-T}^{t} e^{gs}e^{\sigma(r-\rho)(t-s)}\mathrm{d}s \\ &= \frac{xe^{gt}}{T}\frac{1-e^{-(g-\sigma r+\sigma\rho)T}}{g-\sigma r+\sigma\rho}. \end{aligned} \tag{15}$$

From (7) and (15) it follows that:

$$\begin{aligned} c \equiv \frac{C(t)}{e^{gt}} &= \frac{v_{ci}}{T}\frac{1-e^{-(g-\sigma r+\sigma\rho)T}}{g-\sigma r+\sigma\rho}\frac{1}{r-g}\left\{\omega e^{\phi(T_S)}e^{-(r-g)T_Y}\left(1-e^{-(r-g)T_W}\right)\right. \\ &\left. -(1+\tau_H)\eta q e^{-(r-g)T_C}\left(1-e^{-(r-g)T_S}\right)+\chi\left(1-e^{-(r-g)T}\right)\right\}. \end{aligned} \tag{16}$$

The aggregate consumption is the product of two terms: the permanent income of a representative household,

$$\begin{aligned} &\frac{1}{T\,(r-g)}\left\{\omega e^{\phi(T_S)}e^{-(r-g)T_Y}\left(1-e^{-(r-g)T_W}\right)-\right. \\ &\left.(1+\tau_H)\eta q e^{-(r-g)T_C}\left(1-e^{-(r-g)T_S}\right)+\chi\left(1-e^{-(r-g)T}\right)\right\}, \end{aligned}$$

which is the sum of the present value of wages and transfers minus tuition fees, and the marginal propensity to consume (ν_c from now on)[4]

$$\frac{1-e^{-(g-\sigma r+\sigma\rho)T}}{g-\sigma r+\sigma\rho}\frac{(1-\sigma)r+\sigma\rho}{1-e^{-((1-\sigma)r+\sigma\rho)T}}.$$

2.6 Government Restriction

Government revenue is given by the sum of taxation of educational services and capital income:

$$\tau_H\eta q(t)N_S+\tau_K\frac{r+\delta}{1-\tau_K}K(t)=e^{gt}\left(\tau_H\eta qN_S+\tau_K\frac{r+\delta}{1-\tau_K}k\right)=e^{gt}\chi, \tag{17}$$

where $(r+\delta)/(1-\tau_K)$ is the rental price of capital and follows from (12) and $k\equiv K/e^{gt}$.

2.7 Long-Run General Equilibrium

Three equations describe the long-run equilibrium of this economy. First, the goods market equilibrium,

$$c=A_1l_1N_We^{\phi(T_S)}k_1^{\alpha}-(\delta+g)k, \tag{18}$$

where c is given by equation (16) after the expression for government transfers (equation 17) is plugged in; second, the equilibrium in the market of educational services,

$$\frac{A_2}{\eta}l_2N_We^{\phi(T_S)}=N_S; \tag{19}$$

and third, the first order condition with respect to T_S,

$$\omega e^{\phi(T_S)}\left\{\phi'(T_S)\frac{1-e^{-(r-g)T_W}}{r-g}-1\right\}-(1+\tau_H)\eta q=0.$$

[4]Note that if we have golden rule consumption, that is, if $r=g$, we get $\nu_c=1$ and

$$\omega e^{\phi(T_S)}\frac{T_W}{T}+\chi-(1+\tau_H)\eta q\frac{T_S}{T}$$

for permanent income.

An important result that will be useful later is obtained if we substitute $\omega = A_2 q$ into this last equation:[5]

$$\frac{A_2}{\eta} e^{\phi(T_S)} \left\{ \phi'(T_S) \frac{1 - e^{-(r-g)T_W}}{r - g} - 1 \right\} = 1 + \tau_H.$$

The unique link between the distortion to capital accumulation or the productivity of the goods sector and the educational choice is through the interest rate, net of distortion, r. If the economy is open, such that r is given internationally, or if the economy is close but the long-run solution for r is not very sensitive to the distortion to capital accumulation neither to the productivity of the goods sector, the education choice, in general equilibrium, depends mainly on τ_H. The same does not happen with the capital decision: changes in τ_H have a considerable impact on k through their effect on $e^{\phi(T_S)}$.

3 Quantitative Methodology

The calibration of the model is carried out in two steps. First, the model is calibrated to the US. In the second step we assume that the economies in our data set share with the US the same values of preferences and technological parameters. Then, employing some observable variables for each economy, we get the implied (or measured) values for the incentive parameters, τ_K and τ_H, and for productivity, A_1. We use the calibrated model in other to asses the sensitivity of the endogenous variables to changes in parameter values.

3.1 Calibration

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

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

According to their calibration, we have $\psi = 0.58$ and $\theta = 0.32$. Hence, as said before, instead of the more usual linear return to education assumed in most of the literature, we

[5] Equations (18), (19), and (20) can be solved for l_1, T_S, and k. Using equations (8), (9), (10), (11), (13), and the definition of k, we can then solve for l_2, N_S, k_1, q, r as a function of l_1, T_S, and k.

posit diminishing returns because this seems to be the case when comparing micro estimates across countries.[6]

We will also consider the following parameters as observable:

$$l_2, T_C, T_S, T_W, T, g, \alpha, r, \delta, \sigma.$$

The share of labor in the educational sector, l_2, was 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 1.6%. For T we used the life expectancy in 1985, obtained, for all countries in World Bank (1990). T_W was found using equation (8). In this case N_W was constructed using labor force and population data from World Bank(1990).

The capital share in the goods sector was set to be equal to one-third which is the number found in the NIPA. The interest rate was set equal to 4.5%, depreciation at 6.6%,[7] the exogenous growth rate g equal to 1.36% a year[8] and the investment-output ratio to 0.22, the average value for the variable in the Summers and Heston database from 1960-1985. T_S for all economies corresponds to data on years of schooling attainment in the working-age population from the Barro and Lee(1996) database.

There are six parameters left to be found:

$$A_1, \frac{A_2}{\eta}, \eta q, \tau_K, \tau_H \text{ and } \rho,$$

which will be estimated solving equations (11), (18)-(20), the model's value for output

$$y = N_W e^{\phi(T_S)}(A_1 l_1 k_1^\alpha + q\eta \frac{A_2}{\eta} l_2), \tag{22}$$

and the investment-output ratio

$$\frac{i}{y} = \frac{(\delta + g)k}{N_W e^{\phi(T_S)}(A_1 l_1 k_1^\alpha + q\eta \frac{A_2}{\eta} l_2)}, \tag{23}$$

[6]In addition, the value 0.58 for ψ provides 'enough' concavity of $\phi(T_S)$. See discussion in Appendix B.

[7]This is a long-run average for the investment/capital ratio, as given by NIPA, both evaluated at market prices.

[8]We estimated a trend line for the variable RGDPW of Summers and Heston from 1960-1992.

considering y and i/y as observable. Both were obtained using updated Summers and Heston (1991) Penn World Table Mark 5.6 data. Finally, we assume logarithmic preferences, such that σ is set equal to 1.

3.2 Cross-Country Incentive and Productivity Measurement

In order to get the implied values of τ_K, τ_H, A_1 for the remaining economies in our data set, we assumed that the economies share with the US the same preference, technology and return to education parameters. Hence, the values for the following exogenous parameters:

$$\{\theta, \psi, \rho, \sigma, \alpha, \delta\},$$

are those calibrated for the US. Moreover, g, r and A_2 are also equal across economies.[9].

Finally, with the help of cross-section data from the same sources for T, y, and $\frac{i}{y}$, we solve (13), (18), (19), (20), (22), and (23), for $\{A_1, \eta q, \tau_K, \tau_H, l_2, k\}$.

We are left with the calibration of the time spent in the job market, T_W, which, given the assumption of exogenous retirement life, is equivalent to the calibration of T_R. We use population and labor force data from the World Development Report (World Bank 1990) to calibrate T_R such that the model's value for

$$\frac{N_W}{N} = \frac{T_W}{T}$$

reproduces the data.[10] In other words, in this model the ratio of working time to life span is equal to the ratio of labor force to total population. We use data on N_W/N and T to obtain T_W and T_R.

In this sub-section, in other to identify τ_K we made the assumption that the the interest rate, free of distortion and risk, is the same across economies. Consequently, we are assuming capital mobility. Given that we do not have data for the difference between internal output

[9] Instead of the hypothesis that the productivity of the educational sector is the same, we could alternatively impose that the ratio of A_1 to A_2 is constant across countries. But this would imply, even after controlling for human capital, educational sectors four or five time less efficient than others, which appears to be exaggerated.

[10] We are assuming that the daily shift does not vary among economies.

and domestic income, we are implicitly assuming, wh employing (18) that the net external debt is zero.[11]

3.3 Simulation of the Model

We will later perform an experiment to evaluate the sensitivity of the endogenous variables to modifications in the parameter values. In particular we are interested in evaluating the relative impact on long-run per capita income of changes in

$$\{A_1, \tau_H, \tau_K, T\}\,, \tag{24}$$

keeping fixed all other parameters (in particular, when we change T we hold $\frac{T_R}{T}$ constant).

In this exercise we will assume that the economy is open, that is, we consider $r = \log(1.045)$ as given for every combination of (24). We then solve (20) to get T_S, and,consecutively: (19) for l_2, (13) for k, (11) for q, and (22) for per capita income. Finally, the difference between internal output and domestic income is given by the solution of (18), which is not necessarily zero now. The fact that in the open economy solution of the model equation (18) is a residual equation used to get the implied service account means that, for a given value of r, the solution does not change with the preference parameters ρ and σ.

4 Results

4.1 Measurement of productivity and distortions to factor accu- .ulation

We are interested in understanding how differences in productivity and incentives to factors accumulation affect long-run income disparity across countries. In our model, everything else being the same, large τ_K and/or τ_H and small A_1 imply smaller per capita income.

[11] Another possibility is to consider that the economies are closed (which implies zero net external debt by definition). Under this interpretation we can consider that r is the same among the economies if the long-run supply of capital is perfectly elastic (what is true for an infinite horizon economy). Although theoretically overlapping generation models do not deliver a modified golden rule of capital accumulation, numerically, for realistic values for T, the long-run supply of capital has almost infinite elasticity at the level of return equal to $r + \delta$.

As in the long run all countries grow at the same rate g, these differences are permanent. According to our theory, a given country could be poorer than the leading economies for different reasons or for a combination of reasons. It may be the case, for instance, that a well-educated country such as Argentina is relatively productive but imposes extremely high distortions to physical capital investment. Or it could be the case that a country such as Korea is very good at setting incentives to the accumulation of human and physical capital, but at the same time is relatively inefficient in combining them in production.

The estimation of τ_K, τ_H, and A_1 in the 122 countries in our sample found wide variations of these variables. Taking the US as the benchmark economy, so that we set $\{q_{\text{US}}, A_{1\text{US}}\} = \{1, 1\}$ and $\{\tau_{H\text{US}}, \tau_{K\text{US}}\} = \{0, 0\}$[12], τ_H in Mozambique, for instance, was found to be 0.76 and τ_K in Madagascar 0.93, while being -0.23 in Argentina and -0.66 in Singapure (hence, a relative subsidy in both countries), respectively. More interesting, the estimated correlations among τ_K, τ_H, A_1 are close to zero or very small: it is -0.03, between τ_K and τ_H; -0.13, between τ_K and A_1; and -0.26, between τ_H and A_1. The zero correlation between τ_K and τ_H, for instance, implies that an economy with good incentives to capital accumulation, and hence with high investment ratio, may also have very low observed schooling levels.

Fifteen countries were estimated as being more productive than the US, but nine of them were countries rich in natural resources (e.g., Saudi Arabia and Mexico). The other six are European countries such as Sweden and Netherlands. On the other hand, there are countries such as China (the least productive in our sample), Tanzania and Togo were Total Factor Productivity (TFP) is one quarter or less US productivity. Moreover, in most African nations and all the ex-communist countries, the estimated productivity is very low. Ignoring oil rich countries, the TFP ratio of the most productive to the least productive country is 5.3. This result means that if you give a typical worker in Tanzania, for instance, the same education and capital than those of a typical American worker, he would still produce one-fourth to one-fifth as much.

Table 1 below presents the estimated levels of τ_K, τ_H and A_1, relative to the US for a sub-group of countries.[13] Life expectancy and relative income are also presented.

[12] For completeness we report the parameter values calibrated for the US. We got $\{q_{\text{US}}, \tau_{H,\text{US}}, \tau_{K,\text{US}}, A_{1,\text{US}}, \frac{A_{2,\text{US}}}{\eta}, \rho\} = \{0.07, 12.9, 0.10, 0.27, 2.3, 0.00\}$.

[13] In the appendix results for the full sample were presented.

Table 1: Productivity, Distortions, Life Expectancy and Relative Income

	A_1	τ_H	τ_K	T	y
Angola	0.58	-0.06	0.82	45	0.06
Argentina	0.98	-0.23	0.20	71	0.39
Australia	0.92	-0.07	-0.33	76	0.81
Barbados	0.87	0.08	0.41	75	0.39
Belgium	1.01	-0.15	-0.08	75	0.69
Brazil	0.81	0.03	0.06	66	0.23
India	0.39	-0.05	0.34	58	0.06
Korea Rep.	0.42	-0.02	-0.24	70	0.20
Mauritania	0.30	-0.03	0.23	46	0.06
Mozambique	0.91	0.78	0.91	48	0.08
Romania	0.29	0.33	-0.42	70	0.10
Tanzania	0.24	0.27	0.46	53	0.03
USA	1.00	0.00	0.00	76	1
sample mean	0.69	0.01	0.19	63	0.26

India, Mauritania and Mozambique have almost the same relative income per capita and are all very poor. However, the reasons vary. Mozambique is very rich in natural resources and hence its estimated productivity is very large. Its incentives to factor accumulation, however, are extremely poor and among the worst in the sample. The estimated productivity in India and Mauritania, on the other hand, is well below the sample mean but τ_H in both cases was found to be below the sample mean. In both cases distortions to physical capital investment are high. Romania, on the other hand, is very good at setting the incentives to physical capital accumulation and its estimated τ_K is the sixth smallest in the sample (after, U.S.S.R., Singapore, Japan, Finland and Norway). Productivity and education incentives, however, are very poor, which explains Romania's low relative output. Finally, Tanzania fares very badly in every possible aspect and it is no wonder it is one of the poorest countries in the world.

South Korea's strength is capital accumulation and education, but it has below-average productivity for world standards. The same is true for Taiwan and to a lesser extent Japan (where estimated A_1 is above average but only 73% of that of the US). These findings are consistent with Young's (1995) result that the good growth performance of some Asian countries in the recent past was mostly due to factor accumulation, not to productivity.

Australia and Belgian are relatively rich countries. In the case of the former, τ_K and τ_H are both smaller than in the US but productivity is lower. In the latter, however, all three factors are better than in the US but income is 30% smaller. The reason for this apparent puzzle is labor-force participation: while in the USA 49% of the working-age population indeed work, in Belgium this number is only 40%. Hence, part of the difference in income per capita between the two countries is due simply to a larger proportion of workers in the population in the US, which in the model simulation is an exogenous parameter that varies across countries. The same is true for the cases of Sweden, Switzerland and the Netherlands.

Argentina and Barbados have the same relative income per capita, but the former has better incentives and higher productivity than the latter, so one would expect Argentina to be richer than Barbados. However, schooling in Barbados is higher than in Argentina and its larger τ_H is due mainly to differences in life expectancy. The next section studies this fact.

4.2 The Impact of Life Expectancy

One unexpected outcome of the simulation of the model is that in a group of poor or relatively poor countries with little education, the estimated values of τ_H were not very high. Indeed, for some countries such as Angola, Burkina Faso, Ghana and Ivory Coast, the estimated value of this variable was below average and even below those of many rich economies. However, schooling in all four cases is never above 3.5 years.

The apparent contradiction between little observed education and good estimated incentives is explained mostly by longevity. In a country in which agents do not expect to live long, the optimal decision is to stay in school for very few years. Remember that in this model, while in school, agents are out of the labor market. Hence, the shorter the number of years that an agent expects to benefit from investing in education, the sooner is the optimal time to leave school. In the case of Angola, for instance, schooling is only 2.4 years but life expectancy is also very short, 45 years, so that the estimated τ_H is very small. With such a short life, 2.4 years of education is not a bad record.

On the other hand, rich countries with high life expectancy but with relatively less education than the leaders have large estimated τ_H. In France, for instance, the estimated value of this variable was 0.17, way above the sample average. Life expectancy in this country in 1985 was the same as in the US, and income per capita 75% as much. Educational attainment of the French working age population in 1985, however, was only 55% of that of the American working age population (but 35% above the average level in our sample), an indication that distortions to human capital investment in France are comparatively large. Hence, the best performers in this case are not necessarily the ones with the highest schooling levels, but those with relatively high schooling with respect to life expectancy.

Once we control for longevity, this result no longer holds. If we keep education level constant in Angola, but give the US life expectancy to its population (holding T_R/T constant), its estimated τ_H would jump to 0.58. In Brazil it would go from 0.034 (marginally above average) to 0.19. Hence, the correlation between τ_H and education is very small given observable life expectancy, -0.06. However, this correlation is considerably higher in absolute value, -0.54, when we set each economy to US life expectancy. This result indicates that policies that impact longevity may have a considerable effect on output, as they raise the incentives to the acquisition of education.

In order to better understand the relationship between long-run income and longevity, in Table 2 below we present the result of the models simulation holding all parameters constant at the values estimated and calibrated for the US, at the same time that we vary life expectancy numbers:[14]

Table 2: Long-Run Impact of Life Expectancy

T	T_S	K	
45	3.15	0.43	0.40
50	4.21	0.50	0.47
60	6.81	0.66	0.64
65	8.29	0.76	0.74
70	9.85	0.87	0.86
76	11.79	1	1
80	13.01	1.09	1.10

[14]In this exercise we adjusted the retirement time in order to keep $\frac{T_R}{T}$ constant. See subsection 3.3 for the methodology.

As life expectancy decreases, the number of years of education decreases monotonically. If instead of 76 years, people would live on average only 65 years (in line with Brazil, Thailand and Tunisia, for instance) in the US, the equilibrium amount of education would decrease from 11.8 years to 8.29. With life expectancy as low as in Angola, schooling would drop to only 3.15 years in the US. This fall in education has a direct effect in output per worker, through the $e^{\phi(T_S)}$ component of the production functions of both sectors. However, it also has a considerable impact on physical capital. In the case of $T = 45$, optimal k would be only 43% of the benchmark case. The explanation is straightforward: the decrease in education reduces the return to physical capital, consequently decreasing investment and the long-run stock of this factor.

The total effect on output per worker is considerable: the model predicts that a country equal to the US in everything but with six fewer years of longevity in the long run would be 14% poorer. In fact, we estimated that the output elasticity to life expectancy is quite high, around 1.7. The elasticity of schooling with respect to the same variable is even higher, 2.5. In other words, the model predicts that a country currently with $T = 60$ and $T_S = 5$, that increased for some reason its life expectancy to 66 years, would end up with 6.25 years of education and 17% higher output per worker.

4.3 The impact of A, τ_H and τ_K

In this section we repeat the exercise of Table II for variations, one by one, of productivity and distortions to factor accumulation. We start with A_1. An economy equal in every aspect to the US but with only 50% of its productivity would have only 30% of the income per capita of the latter. If the country TFP was just 20% of that of the US, the smallest estimation in our sample, this economy's income per capita would be 9% of the American income. Hence, in this model productivity can explain a large part of the income disparity across countries. In fact, the elasticity of output per capita with respect to A_1 is 1.5. This result is exactly what the standard neoclassical model of capital accumulation - infinite horizon and exogenous technological change - delivers.[15]

The next step is to study the sensitivity of the model to modifications in the two distortion

[15] Assuming a C.-D. production function, we can write the modified golden rule as:

$$(1-\tau_K)A_1 e^{\phi(T_S)}\alpha k^{\alpha-1} = \rho + \delta + \sigma^{-1}g.$$

parameters. Additionally, we are interested in comparing their relative impact on long-run income. On the one hand, capital is an unbounded variable, but subject to decreasing returns; on the other hand, due to a finite life-span, human capital is bounded, but that counteracts the concavity of the production function. Finally, to some extent, the distortion to human-capital accumulation is tax-neutral (wage taxation also reduces the opportunity cost of being in school and not in the labor market). Consequently, it is not clear which distortion is more harmful to long-run income. In order to asses this we have to make them comparable. We define

$$\tau_H^{\mathrm{E}} \equiv \frac{\tau_H}{1+\tau_H},$$

where τ_H^{E} stands for 'equivalent.' It is the flow-equivalent taxation on labor.[16]

Table 3 below presents the results of an exercise in which τ_H^{E} varies and everything else is kept constant at the benchmark values:

Table 3: Long-Run Impact of Human Capital Taxation

τ_H^{E}	T_S	K	y
-0.3	14,57	1,12	1,22
-0,15	13,49	1,07	1,12
0	11,79	1	1
0,15	9,42	0,88	0,82
0,30	6,02	0,69	0,59
0,50	2,00	0,41	0,32
0,65	0,70	0,29	0,22

Consequently,

$$y = A_1^{\frac{1}{1-\alpha}} \left[\frac{(1-\tau_K)e^{\phi(T_S)}\alpha}{\rho+\delta+\sigma^{-1}g} \right]^{\frac{\alpha}{1-\alpha}}$$

If $\alpha = \frac{1}{3}$ we get that $y \sim A_1^{\frac{3}{2}}$. Our model delivers the same result as the infinite horizon model because: first, we are assuming an open economy (cross country equalization of the interest rate net of risk and distortion), and second, because the share of educational services in total output is very low.

[16] If instead of considering a taxation on tuition cost we had considered a taxation on wages, τ_H^{E} would be the tax rate that would reproduce the same economic incentive to human capital accumulation. See appendix A for a further elaboration on distortion to human capital accumulation.

As already said, distortions were normalized to zero in the US. In addition to the direct impact on education, τ_H^{E} also affects physical capital accumulation through the negative impact on its return. Hence, an economy with $\tau_H^{\mathrm{E}} = 0.30$ will have only half the education and 70% of the physical capital of the US, even with the same productivity, τ_K and longevity. Its income per worker will be 40% smaller. There are 20 countries with estimated τ_H^{E} around or larger than 0.30. With distortions such as that estimated for Rwanda ($\tau_H^{\mathrm{E}} \approx 0.70$) there is practically no incentive to education investments: agents would accumulate less than one year of education and consequently income per capita would be less than a quarter of the US income. On the other hand, negative τ_H^{E}, "subsidy," induces agents to accumulate more education than the US, but the final effect on income is proportionally smaller: an economy with $\tau_H^{\mathrm{E}} = -0.30$, everything else the same, would be only 20% richer.

The qualitative impact of τ_K on long-run output is similar to τ_H, as the higher its value, the smaller the income per capita is. There are, however, important differences. In our model, there is no physical capital in the production function of the educational sector. Hence, T_S does not change with $\tau_{K,}$ since the first order condition with respect to educational choice is not affected by it. For comparable values, the impact of distortions to investment in education on income per capita and per worker is larger than that of distortions to physical capital accumulation, as is clear from Figure 1.

While with $\tau_K = 0.25$ income per capita would be 86.6% of the US, with $\tau_H^{\mathrm{E}} = 0.25$ it would be only 75.7%. For all positive values of these parameters, the corresponding values of per capita income are smaller for changes in τ_H^{E}. As said before, τ_H^{E} directly affects education and so labor services, an input in both sectors of the economy. However, it also affects the return to physical capital and hence the investment decision and the long-run stock of this factor. Is it possible that this is due only to the absence of capital in the production function of the educational sector? In the NIPA this sector represents only 0.75% of the American GDP and its capital share is just 6%. Even if the capital share was not assumed to be zero the final impact of τ_K on total output would not change considerably: 6% of 0.75% is a very small number.

4.4 Counter-factual exercises

We next perform some counter-factual exercises on long-run growth. In these simulations for different economies we set in steps the exogenous parameters A_1, τ_H^{E} and τ_K and also

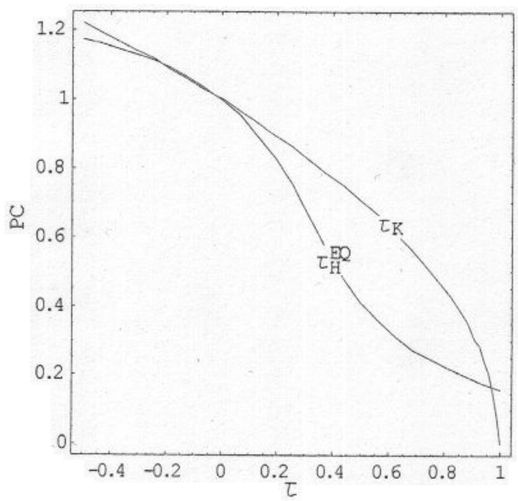

Figure 1: Distortions and long-run income.

life expectancy and labor force participation at the US norm. We first work with a small sub-sample of countries, and we expect that by doing so we will obtain a better grasp of the nature of income inequality across economies. We then present some general results.

We start with South Korea. In 1985 this country's output per worker was 22% of that of the US. However, estimated productivity in the former was only 42% of the latter. By simply substituting in the model the estimated productivity of Korea for that of the US, output per worker would jump to 79.2% of the US figure. Hence, Korea's problem is purely one of productivity.

It has been shown in previously that schooling in France is considerably smaller than in the US, but that life expectancy is equal and output per worker not too distant (73% of the US level). Hence, the estimated τ_H^{E} was relatively high (0.17), while its performance in terms of A_1, and τ_K was good. If France was given the same τ_H^{E} as that of the US, the model predicts that its output per worker would be 92% of the American, instead of 74%. In a model with exogenous human capital accumulation, this fact would not be noted, as education level in this country is relatively large by world standards. On the other hand, estimated incentives to investment in physical capital are better there than in the US (τ_K in France is -0.19) so that if they were substituted for the latter, output would fall to only

66% of the US level.

In Brazil labor force participation and life expectancy are considerably smaller than in the US (0.37 and 66 years, respectively, while the figures for the US are 0.49 and 76 years). Just by correcting these two factors, the model predicts that output per worker would jump to 69% of US output. Additionally, by correcting productivity it would reach 95% of the latter. The correction of τ_H^{E} would not change the country output by much, as the observed under-accumulation of education has more to do with life expectancy, productivity and labor force participation.

Mauritania is an extremely poor African country, with income per worker and estimated productivity at only 5% and 30%, respectively, of the US levels. Moreover, life expectancy is only 46 years. If productivity is equated to the US, income per worker increases almost seven times, to 34.2% of the American level. If on top of this we also equate life expectancy, Mauritania's income per capita would be 80% of that of the USA and schooling would go from 3 to 10 years. The effects of distortions to factors accumulation is therefore small in this country.

Finally, Barbados's per worker income is 42% of that of the US. Productivity and τ_H^{E} are (relatively) in line with the US, 0.86 and 0.07, respectively. However, distortions to capital accumulation, τ_K, are very high (0.41) and labor force participation relatively smaller. If τ_K was zero in this country, the model predicts that income per worker would reach 0.55 of that of the US in the long run, but τ_H^{E} equal to zero would change income to only 46% of that of the US. The impact of changes in productivity is between the last two: Barbados with US productivity would have 52% of the income per worker of the latter. The simultaneous correction of A_1, τ_H^{E} and τ_K would take Barbados's income to only 75% of the US income. The remaining difference is mostly due to labor force participation.

In a second group of simulations we changed for all economies, one at a time, τ_K, τ_H^{E}, A_1 and life expectancy to the values estimated for the US. In each exercise we held labor force participation (and the ratio T_R/T) constant. We observed the largest gains on per worker income when substituting in all economies American productivity. In this case, median y goes from 21.7 percent to 39.7 percent of the US per worker income. In contrast, the average changes in the case of the simulations with the American τ_K, and τ_H^{E} are minimal, as median y increased to 24.9 percent in the first case and remained constant in the second. Moreover, the highest fall in dispersion (as measured by the variance-median ratio) is also obtained when the American A_1 is given to all economies: it decreases from 0.31 to only 0.15. Hence, policies aimed at increasing productivity apparently have the potential to deliver the highest average payoffs.[17]

The big picture here is the following. Countries are poor for different reasons, so that development policies have to take into account the specific causes for the relative disadvantage of each economy. On average, however, the largest gains will come from policies that improve total factor productivity.

5 Conclusion

In this paper we have studied a finite life economy where distortions to factor accumulation and productivity differences explain cross-country income disparities. Human capital was modeled following the tradition of the labor field (e.g., Mincer (1974)) recently incorporated into the growth literature as well, e.g., Bils and Klenow (2000). In this formulation, the skill level of workers is an increasing function of schooling and the accumulation of skills is mostly done at school, outside the labor market.

This framework contrasts with the usual Uzawa-Lucas formulation where there is no bound for the accumulation of human capital, which is continuously acquired during the worker's infinite life. Moreover, in the usual Uzawa-Lucas models there are no other costs of investing in human capital, such as tuition, than the forgone wages.

In our model longevity 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. In this sense we found a channel from health policy to growth that has not been explored by the literature. Basic and cheap measures such as sanitation and preventive care are well known to have a huge impact on the welfare of populations. However, by increasing average life expectancy they indirectly effect the return to educational investment, as the present value of the flow of wages potentially rises. This in turn will induce further accumulation of human capital,

[17]Results did not change much when we repeated the simulations substituting first the estimated parameters of each economy with the sample mean and in a third set of simulations with the 12th-best estimated value of each parameter (it divides the 10th from the 9th decile and we did so to avoid outliers). Although values vary considerably, it is still the case that changes in productivity dominate modifications in any other policy parameters (and life expectancy) in both groups of simulations. In the last set of exercicies, the median more than doubled and dispersion was halved when the 12th-highest estimated productivity (that from Sweeden) was given to all economies.

higher labor productivity and long-run income. Hence, the fight against common Third World epidemics such as malaria, and more recently AIDS, not only has a direct benefit in terms of lives saved but also an impact on the long-run prospects of these economies that may well surpass the static loss of product due to deaths and diseases.

The exploration of the general equilibrium effects of distortions to human capital accumulation showed that they have a multiplicative impact through their effect on savings and physical capital. As investment in education falls because of taxation (or due to any other distortion), and with it the long-run stock of human capital, the return to physical capital also decreases, inducing individuals to reduce their investment. Our simulations showed that for reasonable values of parameters, human capital taxation may be more detrimental to long-run income than taxation to physical capital. 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.

There are, however, other motives for a country to be relatively poor. The simulations show that productivity differences are an important source of output disparity across economies. Some poor countries were found to be one-fourth to one-fifth as productive as the leaders, and in this sense theories of TFP differences such as Parente and Prescott (2001) are in fact essential to understanding poverty. However, there are economies in which TFP and even incentives to educational investment are very close to the leaders but distortions to physical capital are very high. One such country is Uruguay, where τ_k was found to be almost twice as big as the sample mean and well above the leading economies. A similar case can be made to Argentina and Jordan. In this sense a better comprehension of the reasons why certain countries impose barriers to physical capital accumulation, while others subsided it, may be so important than the study of TFP differences and taxation of human capital.

In summary, countries are poorer than the leaders for different reasons and to search for a single-factor explanation for the difference in output per worker across nations seems like a futile exercise. If it is true that on average the largest gains are on TFP policies, some countries are poor because the distortions to capital accumulation are too high and others because the cost of acquiring an education is large. In others, such as China, South Korea and Taiwan, low productivity is the main (and almost the single) problem. Hence, uniform policy recommendation applied to all nations is likely to be either wrong or ineffective. For instance, in countries where life expectancy is too low, health and sanitation measures are probably the most effective growth policy.

A Appendix: A Note on the Return on Education

In this paper, education modeling descends from the human capital literature of Schultz, Becker and Mincer. A very important concept in this tradition is the Social Marginal Internal Rate of Return (SMIRR) of T_S years of education, which is defined as the discount rate R such that the present value (PV) of wages minus the PV of tuition is equal to the PV of wages minus the PV of tuition when the individual stays $T_S + \Delta t$ years in school (Willis, 1986. p. 531). Formally,

$$
\begin{aligned}
& \omega e^{-(r-g)T_S} e^{\phi(T_S)} \frac{1 - e^{-(R-g)T_W}}{R-g} - \eta q \frac{1 - e^{-(R-g)T_S}}{R-g} \\
= \; & \omega e^{-(r-g)(T_S+\Delta t)} e^{\phi(T_S+\Delta t)} \frac{1 - e^{-(R-g)(T_W-\Delta t)}}{R-g} - \eta q \frac{1 - e^{-(R-g)(T_S+\Delta t)}}{R-g}.
\end{aligned}
$$

After taking a Taylor expansion up to the first-order term and taking the limit for $\Delta t \to 0$ in this last expression we get (4) for $R = r$ if τ_H is zero. In other words, if there is no distortion to the acquisition of education, at the market equilibrium the SMIRR is equal to the market interest rate.[18]

With the help of the concept of SMIRR we can calculate the difference between the private rate of return and the social rate of return. The SMIRR of T_S years of education for

[18]According to Mincer: "Investments in people are time consuming. Each additional period of schooling or job training postpones the time of the individual's receipt of earnings and reduces the span of working life, if he retires at a fixed age. The deferral of earnings and the possible reduction of earning life are costly. These time costs plus direct money outlays make up the total cost of investment. Because of these costs investment is not undertaken unless it raises the level of the deferred income stream. Hence, at the time it is undertaken, the present value of real earnings streams with and without investment are equal only at a positive discount rate. This rate is the internal rate of return on the investment." (1974, pg.7).

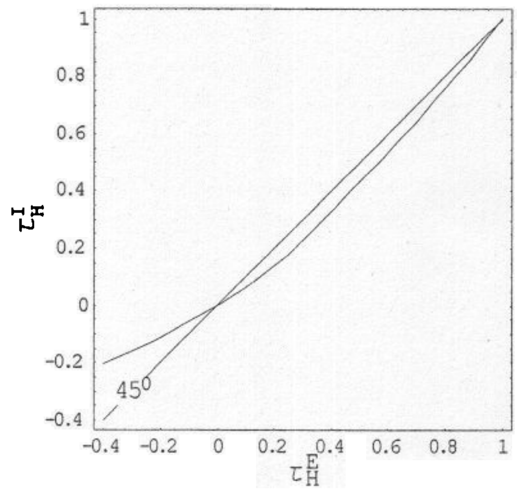

Figure 2: Relationship between τ^{E}_H and τ^{I}_H

a given economy is the value of R that solves

$$\omega e^{\phi(T_S)}\phi'(T_S)\frac{1-e^{-(R-g)T_W}}{R-g} = \omega e^{\phi(T_S)} + \eta q.$$

The private rate is the market interest rate. Consequently, the distortion to the human capital accumulation decision is

$$\tau^{\mathrm{I}}_H = \frac{R-r}{R},$$

or, rearranging terms, it is the implicit tax rate that solves

$$r = (1-\tau^{\mathrm{I}}_H)R,$$

where τ^{I}_H stands for 'internal.' Figure 2 presents the relationship between τ^{E}_H and τ^{I}_H and Figure 3 presents the behavior of the two endogenous variables, SMIRR and education.

Both exercises used the benchmark configuration (i.e., the US parameters) and took τ^{E}_H as the exogenous variable. From Figure 2 we can see that the distortion concept used in the paper is very close to the distortion constructed using the SMIRR notion employed by the

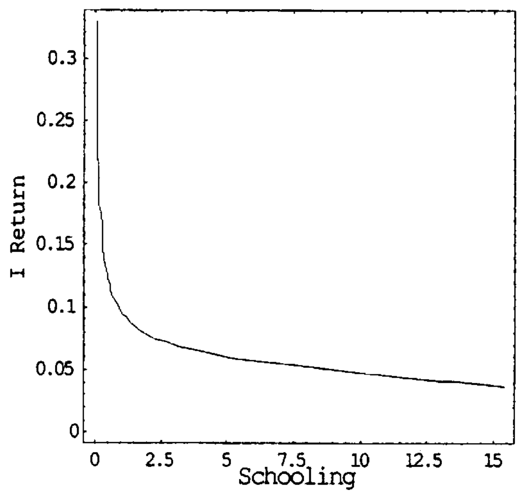

Figure 3: Social Marginal Internal Rate of Return and Schooling

labor literature. Although Figure 3 represents a general equilibrium outcome, due to the fact that physical capital does not affect the optimum educational decision, it can be considered a partial equilibrium relationship. From this point of view, Figure 3 is a clear representation of the capital view of education: we obtained a decreasing and strongly convex behavior of the marginal productivity of education as a function of years of education. We can say that T_S fulfills the role of a capital stock.

B Appendix: Existence and Uniqueness

In this paper we solved three different systems of equations: (1) the calibration of the model for the benchmark economy; (2) the measurement of distortions across countries; (3) the solution of the open-economy version of the model. In this appendix we discuss uniqueness for the calibration and distortion measurement procedures. Existence and uniqueness of the open economy version solution of the model follows directly from the equations if (20) is well behaved. We start by studying this equation.

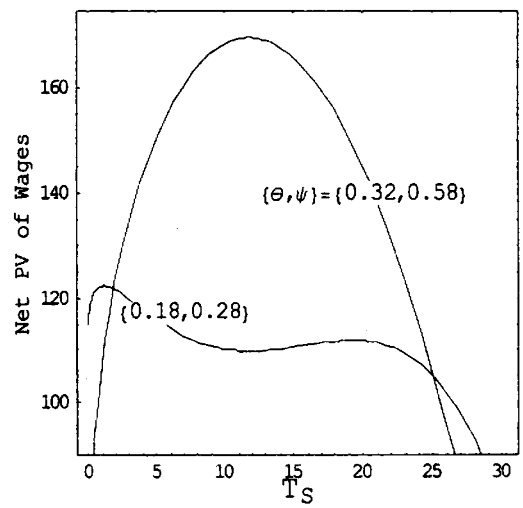

Figure 4: Net present value of wages as a function of T_S for two sets of values of $\{\theta, \psi\}$

B.1 Uniqueness of the educational choice

In other to calibrate the $\phi(T_S)$ function we employed the specification for $\{\theta, \psi\}$ in Bils and Klenow (1999). Actually, in their work there are three possible sets of parameters, and although they produce the same average return of education on wages, they differ in concavity. We employed the most concave specification. One of the reasons is that it seems to be consistent with cross-section studies of return to education. The second reason is uniqueness. The first order condition with respect to the education choice, equation (20), is:

$$\frac{A_2}{\eta} e^{\phi(T_S)} \left\{ \phi'(T_S) \frac{1 - e^{-(r-g)T_W}}{r - g} - 1 \right\} = 1 + \tau_H.$$

Although $\phi(T_S)$ is concave $e^{\phi(T_S)}$ is convex. If there is no tuition cost (as is the case in Bils and Klenow(1999)), the term $e^{\phi(T_S)}$ cancels out and we get local second order condition for the solution of the first order condition.[19] This is not the case in our formulation. In particular, if we consider a less concave specification for $\phi(T_S)$, the observation of T_S for the US would be a minimum of the calibrated net present value function, as Figure 4 illustrates.

[19] We thank Marcos Lisboa for this observation.

Evidently, in the distortion measurement and simulation exercises we checked if the solution for (20) is the global maximum of the net-present-value of wages function (which has a compact domain)

B.2 Uniqueness of the calibration procedure

The solution is as follows: (19) gives $\frac{A_2}{\eta}$; (11) and (22) give ηq; (23) gives k; and (13) (after recalling (9)) gives A_1; (20) gives τ_H; (13) and (23) give τ_K; and (18) gives ρ. It is not possible to solve explicitly (18) for ρ. In order to get uniqueness we have to show that (18) is monotonic in ρ. That is, we have to show that

$$\nu_c = f(s) \equiv \frac{1-e^{-sT}}{s} \frac{s+r-g}{1-e^{-(s+r-g)T}},$$

where $s \equiv g - \sigma(r-\rho)$. Calculating, we obtain

$$s\frac{f'(s)}{f(s)} = sT\left[g\left(sT\right) - g\left((s+r-g)T\right)\right],$$

in which

$$g(a) \equiv \frac{e^{-a}(1+a)-1}{a(1-e^{-a})} \text{ and } g'(a) > 0.$$

Given that $r - g > 0$ we have that

$$f'(s) < 0,$$

which guarantees uniqueness.

B.3 Incentive Measurement

The solution is as follows. It is possible to express $\{\tau_K, \tau_H, l_2, k, \eta q\}$ as a function of A_1: (23) gives k, (19) gives l_2, (20) gives τ_H, and (13) gives τ_K, (11) and (22) give ηq. Then, we substitute for τ_K into (18), and recalling (9), we solve explicitly for A_1.

Table A1: Productivity, Human Capital Distortion, Physical Capital Distortion, Relative Income and Life Expectancy.

	A_1	τ_H	τ_K	T	y
Algeria	0.83	-0.24	-0.15	64	0.15
Angola	0.58	-0.06	0.82	45	0.06
Benin	0.81	0.59	0.65	51	0.08
Botswana	0.48	-0.03	-0.07	67	0.11
Burkina Faso	0.26	-0.27	0.59	47	0.03
Burundi	0.29	0.14	0.73	49	0.03
Cameroon	0.54	0.04	0.54	56	0.07
Cape Verde	0.25	-0.04	-0.16	65	0.04
Central Afric. Rep.	0.66	0.01	0.74	50	0.05
Chad	0.60	-0.44	0.90	46	0.04
Comoros	0.22	0.02	0.28	56	0.04
Congo	0.61	0.14	0.54	53	0.13
Egypt	0.78	-0.42	0.77	63	0.10
Gabon	0.76	0.06	-0.15	53	0.27
Gambia	0.62	0.56	0.74	44	0.06
Ghana	0.54	-0.15	0.76	54	0.06
Guinea	0.33	-0.08	0.72	43	0.04
Guinea Bissau	0.35	0.73	0.24	40	0.04
Ivory Coast	0.63	-0.19	0.44	53	0.12
Kenya	0.34	0.12	0.27	59	0.06
Lesotho	0.29	0.15	0.43	56	0.05
Madagascar	0.80	-0.35	0.93	50	0.06
Malawi	0.29	-0.26	0.47	47	0.03
Mali	0.64	0.04	0.70	47	0.04
Mauritania	0.30	-0.03	0.23	46	0.06
Mauritius	0.77	0.32	0.52	67	0.25
Morocco	0.57	-0.28	0.53	61	0.11
Mozambique	0.91	0.78	0.91	48	0.08
Namibia	0.74	-0.32	-0.27	57	0.21
Niger	0.48	0.74	0.60	45	0.04
Nigeria	0.44	0.14	0.34	51	0.07
Reunion	0.60	-0.08	0.02	71	0.15
Rwanda	0.60	0.72	0.80	49	0.05
Senegal	0.66	-0.15	0.76	48	0.07
Seychelles	0.61	0.45	0.09	70	0.16
Sierra Leone	0.92	0.14	0.93	42	0.07
Somalia	0.35	0.18	0.57	47	0.05
South Africa	0.77	-0.33	0.11	61	0.22
Swaziland	0.62	0.00	0.40	57	0.15
Tanzania	0.24	0.27	0.46	53	0.03
Togo	0.26	0.30	0.18	53	0.04
Tunisia	0.78	0.02	0.29	66	0.14
Uganda	0.52	0.24	0.89	48	0.04

Table A1: Productivity, Human Capital Distortion, Physical Capital Distortion, Relative Income and Life Expectancy. (Cont.)

	A_1	τ_H	τ_K	T	y
Zaire	0.44	0.04	0.77	52	0.04
Zambia	0.40	-0.82	0.05	33	0.08
Zimbabwe	0.50	0.04	0.27	63	0.08
Barbados	0.87	0.08	0.41	75	0.39
Canada	0.96	0.05	-0.12	77	0.87
Costa Rica	0.78	-0.14	0.22	75	0.22
Dominican Rep.	0.72	-0.46	0.20	66	0.13
El Salvador	0.81	-0.19	0.62	62	0.13
Guatemala	1.01	-0.16	0.56	62	0.15
Haiti	0.54	0.38	0.71	55	0.06
Honduras	0.47	0.05	0.34	64	0.09
Jamaica	0.51	0.38	0.07	73	0.17
Mexico	1.01	-0.04	0.20	69	0.33
Nicaragua	0.89	-0.45	0.45	64	0.14
Panama	0.62	-0.26	-0.02	72	0.20
Trinidad & Tobago	1.42	-0.20	0.40	71	0.59
USA	1.00	0.00	0.00	76	1.00
Argentina	0.98	-0.23	0.20	71	0.39
Bolivia	0.62	-0.53	0.22	53	0.12
Brazil	0.81	0.03	0.06	65	0.23
Chile	0.69	-0.17	0.14	72	0.24
Colombia	0.77	-0.25	0.26	68	0.18
Ecuador	0.54	-0.21	-0.08	66	0.17
Guyana	0.52	-0.34	-0.02	63	0.13
Paraguay	0.53	-0.01	0.30	67	0.13
Peru	0.64	-0.32	0.19	62	0.19
Suriname	1.24	-0.08	0.22	67	0.25
Uruguay	0.91	-0.27	0.34	72	0.29
Venezuela	1.11	-0.22	0.08	70	0.41
Bangladesh	0.89	-0.19	0.84	51	0.07
China	0.20	0.46	0.00	70	0.06
Hong Kong	0.82	0.23	0.10	77	0.50
India	0.39	-0.05	0.34	58	0.06
Indonesia	0.34	0.00	0.10	61	0.07
Iran	1.20	-0.34	0.23	63	0.26
Israel	0.77	-0.15	-0.17	76	0.49
Japan	0.74	0.22	-0.65	78	0.64
Jordan	0.90	-0.47	0.24	66	0.18
Korea Rep.	0.42	-0.02	-0.24	70	0.20
Malaysia	0.56	0.05	-0.16	70	0.21

Table A1: Productivity, Human Capital Distortion, Physical Capital Distortion, Relative Income and Life Expectancy. (Cont.)

	A_1	τ_H	τ_K	T	y
Myanmar	0.29	0.35	0.58	60	0.03
Oman	1.12	-0.45	0.13	64	0.33
Pakistan	0.66	-0.17	0.55	55	0.07
Philippines	0.42	-0.27	0.24	64	0.11
Saudi Arabia	1.81	-0.42	0.52	64	0.52
Singapore	0.97	-0.10	-0.67	74	0.41
Sri Lanka	0.48	-0.02	0.52	71	0.10
Syria	1.11	-0.46	0.27	65	0.23
Taiwan	0.49	0.21	-0.14	70	0.26
Thailand	0.47	-0.04	0.17	65	0.13
Austria	0.93	0.24	-0.22	75	0.64
Belgium	1.01	-0.15	-0.08	75	0.69
Cyprus	0.61	0.11	-0.24	76	0.32
Czechos.	0.44	0.21	-0.35	71	0.23
Denmark	0.74	0.29	-0.19	75	0.76
Finland	0.65	0.33	-0.59	75	0.67
France	1.08	0.17	-0.28	76	0.74
West Germany	0.88	0.20	-0.26	75	0.75
Greece	0.73	0.01	-0.18	77	0.35
Iceland	0.87	0.20	-0.34	78	0.67
Ireland	0.63	0.16	-0.23	74	0.41
Italy	1.08	0.04	-0.24	77	0.62
Luxembourg	1.03	-0.12	-0.26	75	0.79
Malta	0.67	-0.21	-0.07	73	0.26
Netherlands	1.06	-0.09	-0.12	77	0.72
Norway	0.74	0.10	-0.47	77	0.71
Portugal	0.74	0.43	-0.08	74	0.30
Romania	0.29	0.33	-0.42	70	0.10
Spain	1.00	0.03	-0.19	77	0.47
Sweden	1.05	-0.02	-0.06	77	0.82
Switzerland	1.09	-0.03	-0.34	77	0.92
Turkey	0.65	0.13	-0.05	64	0.19
UK	0.97	0.10	0.16	75	0.66
USSR	0.59	0.19	-0.79	70	0.37
Yugoslavia	0.57	0.05	-0.42	72	0.31
Australia	0.92	-0.07	-0.33	76	0.81
Fiji	0.68	-0.33	0.17	71	0.21
New Zealand	0.61	0.37	-0.12	75	0.71
Papua New Guinea	0.60	0.62	0.22	65	0.12
Mean	0.688	0.005	0.193	63.48	0.257
Median	0.650	0.002	0.202	65.00	0.155

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