JEL: D9, I2, O1
Keywords: growth, human capital, education, time discounting, poverty

Time Discounting, Education, and Growth: Evidence and a Simple Model

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Abstract
In the paper we propose a new channel through which education may promote economic growth: education makes people more patient, and more patient people are more likely to save, invest, or send children to school. The paper first summarizes the results of field studies which we conducted in two very different poor countries: Uganda and India. In both countries the findings are consistent with the causal effect of education on the subjective discount rate. In the second part of the paper, we build a simple two-period human-capital-driven growth model where the subjective discount rate depends on the level of human capital. This new assumption gives rise to the possibility of multiple development regimes and the model illustrates a wider role of education in tackling possible development traps.

1. Introduction

In recent decades, much of the attention of economists has been directed at understanding the determinants of economic growth. The results of many cross-country empirical studies underline the role of education, and it has been shown that the growth rate of GDP per capita and the education level are highly correlated across countries (Benhabib and Spiegel, 1994; Barro and Sala-i-Martin, 2004). However, the correlation between education and growth appears to be too high to be fully reconciled with micro-level estimates of the effects of education on individual productivity (Bils and Klenow, 2000; Banerjee and Duflo, 2005). Bils and Klenow (2000) calibrated a simple neoclassical growth model where the impact of education on individual productivity was consistent with the average coefficients of Mincerian private returns to education that are commonly estimated in the labor literature. According to their results, the impact of education on productivity explains less than one-third of the high correlation between education and growth in the aggregate cross-country relationship.[1] Similarly, World Bank (2006) acknowledges that *"the education impact on economic growth is well-established; precisely how this happens is less well-understood"*.

* We would like to thank O. Bandiera, R. Filer, I. Gang, W. Greene, J. Hlaváček, O. Knot, M. Mejstřík, J. Morduch, D. Munich, A. Ortmann, D. Ray, A. Schotter, M. Skořepa, P. Streblov, anonymous referees, and participants at various conferences and seminars for valuable comments and discussions about the empirical part of the paper. We thank BPKS, UCDT, and Caritas Prague for collaboration on the field work and J. Kabatová, D. Mascarenhas, S. Crasta, and L. Perreira for excellent research assistance. We appreciate the comments of T. Cahlík on the model. We gratefully acknowledge financial support from the IES Research Institutional Framework 2005–2010 (MSMT 0021620841), the CERGE-EI Foundation under a program of the Global Development Network, the Fulbright Foundation, and the Charles University Mobility Fund. All errors are the authors' own.

[1] The explanation of Bils and Klenow (2000) relies on the reverse causality, i.e., that a high expected growth rate is reflected in higher returns to education and thus leads to increased demand for education.

In addition to the role of human capital as a factor in the aggregate production function, there might be other effects that contribute to economic growth. For example, education may stimulate growth by inducing a lower fertility rate (Barro, 2001). Psacharopoulos (1994) summarizes other, less measurable channels such as the effect of education on transaction costs, quality of democracy or health.

This paper focuses on an additional pathway between education and growth: education may lower the individual subjective discount rate. Time discounting may be a fundamental factor for explaining a number of puzzling phenomena behind dismal economic performance, particularly in countries with less developed economic institutions. If people are impatient, they may be reluctant to form savings or invest in profitable opportunities. They may also be less inclined to educate themselves and their children, since education may be understood as a long-term investment in future income.

The paper first discusses our recent empirical studies from two completely different developing country environments – Uganda and India. We show that the results are consistent with the proposition that education lowers the discount rate. We then build a human capital growth model with endogenous time discounting which illustrates the wider role of education in the process of development. The economic dynamics, the possibility of multiple development regimes, and the policy implications are discussed.

2. Education and Time Discounting: Empirical Evidence

2.1 Literature Review

Many psychological studies from developed countries (e.g. Metcalfe and Mischel, 1999) argue that humans are born impatient, as patience can be regarded as a component of a broader set of non-cognitive skills. The abilities to imagine future, to structure problems, and to plan scenarios help people to become more future-oriented (Becker and Mulligan, 1997). Learning to be future-oriented and to choose actions whose reward is postponed in time is essential part of our upbringing and educational process. Without such learning, people would live solely in the present and would forego the pleasures that future events can bring.

In a major study that elicits the discount rate for a representative sample in a developed country, Harrison, Lau, and Williams (2002) showed on a sample of Danish households that highly educated adults have subjective discount rates as low as two-thirds of those less educated. In the least developed countries, the difference is likely to be even more profound, as there may be additional pathways through which education makes people more patient. The evidence confirms that education enhances life expectancy through putting a higher emphasis on prevention and healthier lifestyle (Mirowski and Ross, 1998). Social norms embedded in traditional cultures may also direct individuals to focus on present gratification and rely on a "higher will" with respect to the future (Harrison and Huntington, 2000). Education typically reduces the role of traditional beliefs in an individual's decision-making.

The emerging evidence from field experiments in developing countries also shows a negative correlation between the subjective discount rate as a measure of patience and education. Kirby et al. (2002) studied the discount rate in remote villages in the Bolivian rain forest. They found a high average discount rate and that a big proportion of its variance can be explained by years of schooling, parental education, and measures of qualitative education achievement in terms of mathematics and language proficiency. In Vietnam, Anderson et al. (2005) measured the stability of subjective discount rates when the delay varies. They also refer to the importance of education, although they do not specifically measure it. On the other hand, Pender (1996) in Indian villages finds a correlation between the discount rate and recent income and credit constraints, but not with education.

In addition to the empirical evidence summarized above, our proposition about the relationship between the discount rate and education builds on the results of two surveys we conducted in Uganda and India in 2005 and 2007, respectively. The next two subsections describe the methodology, the sample, and the results of these surveys.

2.2 Evidence from Uganda

The study from Uganda (Bauer and Chytilová, forthcoming) is based on data from a questionnaire survey that was conducted in November 2005 in ten village areas in the southern part of the country. The data were collected in cooperation with UCDT, a Czech-Ugandan NGO. We used a combination of the random walk method and quota sampling in our sampling procedure. The target population was restricted to literate individuals above 15 years. The questionnaires were bilingual – in English and Luganda – to allow us to approach less educated people who speak only Luganda.[2] Our sample size is 856 respondents.

The area is primarily rural with an economy based on small-scale subsistence farming and local market trade. People usually grow maize, vegetables, plantain bananas, cassava, vanilla, and coffee. The vast majority of households in this region are very poor by any standards, with an average per capita income of less than 300 USD a year and a life expectancy at birth of only 46 years, largely due to the effects of malaria and HIV/AIDS.

We used the so-called choice task method with hypothetical questions to elicit the discount rate. Individuals were asked to express their preference between receiving a smaller reward immediately and receiving a larger reward with some delay. Starting with the question, "Would you prefer to receive 200,000 USh today or 250,000 USh in one year?"[3] we posed five questions, each time increasing the amount offered in the future. As we increased the future amount, we expected more individuals to select the future option. The point at which a respondent switched from the current amount to the future amount provides the range for her discount rate, and the midpoint of the range is our best estimate of the person's discount rate. We also collected information on individual characteristics, specifically regarding education level, age, marital status, clan linkage, and profession. The level of education was measured by the number of school classes completed by the respondent.

We identified a close association between education and the discount rate, which suggests that more educated people make more future-oriented choices. The higher is the level of education completed, the lower is the discount rate. This re-

[2] The official language in Uganda is English. The different local languages reflect the tribal divisions within Uganda. Luganda is the language of the Baganda people – the largest tribe in Uganda.

[3] In November 2005, the exchange rate was 1,830 USh to the U.S. dollar.

Table 1 Education and the Discount Rate (Uganda) – OLS

Dependent variable	Discount rate		
	(1) all	(2) male	(3) female
Education (years)	-0.170	-0.168	-0.171
	(0.048)***	(0.066)**	(0.035)***
Observable characteristics	yes	yes	yes
Observations	856	465	391
R-squared	0.06	0.06	0.11

Notes: Standard errors corrected for clustering at village level.
** significant at 5%, *** significant at 1%.

sult also holds if we control for cohort effects and all other observable characteristics (*Table 1*). This correlation, however, does not help us determine the direction of the causal relationship between these two factors. It is also possible that people with a lower – perhaps innate – discount rate are more willing to invest in schooling, which has delayed payoffs, and study longer. Alternatively, there could be an omitted variable, such as intelligence, which would account for both the discount rate and the differences in education level.

To our knowledge, as yet there has been no empirical study of the discount rate that has tested the causal direction in the observed correlation between education and the discount rate. In order to do so, we exploit two independent exogenous sources of variation in schooling: across villages and over time. The first instrumental variable is based on differential access to secondary schools in different villages. The second type is based on the number of individual school-age years that overlap with the rule of Idi Amin (1971–1979) – a period of overall instability characterized by a drastic decline in the quality of education. For reasons described elsewhere (Bauer and Chytilová, forthcoming) both identification strategies are more suitable for men than for women. For men, both instrumental variables strongly predict individual education in the expected direction and the 2SLS estimates demonstrate a significant effect of education on men's discount rate (*Table 2*). The two types of instrumental variables deliver estimates of similar magnitude. The results are robust to the inclusion of a set of dummies for cohort effects and individual characteristics such as profession and family status.[4]

2.3 Evidence from India

The study from India (Bauer and Chytilova, 2008, 2009) is based on data from a series of lab experiments in the field and a questionnaire survey organized in June 2007 in cooperation with the Indian NGO, BPKS, in 18 villages in the south--western Indian state of Karnataka. In each village, 35 people older than 15 years were selected using the random walk method. This study was organized in such a way that illiterate respondents could also participate; their proportion in the sample is almost 40 %. Our sample size is 540 respondents. Although the selection strategy was not intended to generate a sample representative of the entire rural Karnataka popula-

[4] The discount rate elicited is, of course, a noisy measure of patience. It is therefore not surprising that the proportion of unexplained variance in the OLS regressions is quite high, similarly as in other studies related to this topic. In any case, a low *R*-squared is not an indicator of model misspecification.

Table 2 The Effect of Education on the Discount Rate for Men (Uganda) – 2SLS

	IV: Number of secondary schools		IV: Number of school-age years during Amin era (1971–1979)	
	(1)	(2)	(3)	(4)
Education (years)	-0.600	-0.948	-0.636	-1.020
	(0.234)**	(0.320)***	(0.288)**	(0.443)**
Number of SS	4.949	3.125		
	(0.728)***	(0.759)***		
At PS age during war (years)			-0.301	-0.171
			(0.111)**	(0.056)**
Cohort effects	yes	yes	yes	yes
Observable characteristics	no	yes	no	yes
Underidentification test (*p*-value)	0.070	0.069	0.053	0.026
Weak identification test (*F* stat.)	46.273	16.933	7.365	9.311

Notes: * significant at 10 %, ** significant at 5 %, *** significant at 1 %. Standard errors corrected for clustering at village level. The lower panel reports results from the first-stage regression, where the dependent variable is years of schooling. The upper panel shows the results for the second stage, where the dependent variable is the discount rate. In columns 1 and 2, the instrumental variable is the number of secondary schools per thousand inhabitants in the particular village area when an individual was at the age of 15 years. In columns 3 and 4, the instrumental variable is the number of school-age years that overlap with the era of Idi Amin (1971–1979). The underidentification test statistic is the Kleibergen-Paap rk LM statistic. The weak identification test statistic is the Kleibergen-Paap rk Wald F statistic.

tion, it captures most of its variety, and the averages for the socio-economic characteristics measured are not statistically different from the averages for the whole of Karnataka.

To elicit the discount rate we again used the choice task method, this time with real incentives build into the experiment. The respondents were asked to choose between receiving a smaller monetary amount earlier in time or a larger amount with a three-month delay – for example: "Would you prefer 250 Rs. tomorrow or 300 Rs. three months later?" [5] We posed five such questions to each individual, each question increasing the future amount while keeping the earlier amount constant. The same series of binary choices were made in a further time frame: "Would you prefer 250 Rs. in one year's time or 300 Rs. in one year and three months?" The time frame was shifted by exactly one year to avoid the possibility of confounding factors due to the seasonality of agricultural incomes or the regularity of local celebrations. At the end of each experimental session, 20 percent of the respondents, selected randomly, were paid according to one of their choices. The future payments were guaranteed by cash certificates signed by the chief of the NGO, a local leader, and a social worker familiar to the community.

In line with the previous findings of others and our findings from Uganda, the results suggest a negative correlation between these two variables. *Table 3* provides the results of OLS regressions, which show that more educated men are significantly more patient.[6] For women, we also find a negative correlation with respect to education, although it is not statistically significant. This finding may be due to low-

[5] In July 2007, the exchange rate was 1 USD = 40.2 Indian Rupees. In the area of our study, 250 Rs. is approximately a week's wage.

Table 3 Education and the Discount Rate (India) – OLS

Dependent variable	Current discount rate			Future discount rate		
	all	male	female	all	male	female
Education	-0.013	-0.018	-0.007	-0.015	-0.022	-0.007
	(0.003)***	(0.004)***	(0.005)	(0.003)***	(0.003)***	(0.005)
Observable characteristics	yes	yes	yes	yes	yes	yes
Observations	538	272	266	538	272	266
R-squared	0.09	0.15	0.03	0.11	0.17	0.04

Note: *** significant at 1 %. Standard errors corrected for clustering at village level. For columns 1, 2, and 3, the dependent variable is the "current discount rate" calculated from the binary choices between the amount the next day and the amount after three months. For columns 4, 5, and 6, the dependent variable is the "future discount rate" calculated from the binary choices between the amount after one year and the amount after one year and three months.

er variance in women's education, as 45.1 % of the women in our sample are illiterate, compared to 34.2 % of men. The results hold for both measures of discount rates that were elicited. For the Indian dataset, we did not have suitable data to construct a valid instrumental variable and therefore we cannot run 2SLS regression to test the causal effect.

3. Model

3.1 New Feature of the Model: An Endogenous Discount Rate

This paper aims to integrate these empirical findings into a human-capital-driven, overlapping-generations growth model. We understand human capital to mean skills and abilities that increase the productivity of an individual. These skills and abilities can be inherited from parents and transmitted from parents to children during the process of upbringing and education. We will abandon the usual assumption of growth models about a constant, exogenously given, subjective discount rate. A key component of our model is the assumption that the subjective discount rate is high for low levels of human capital and decreases with own and parental education. Our model theoretically illustrates how this relationship may generate a stable low-human-capital equilibrium (poverty trap), where people have a strong preference for current consumption and do not save and invest, and hence the economy remains poor. As is common in the related literature (e.g. in the survey article of Azariadis and Stachurski, 2004, on poverty traps), we define a poverty trap as being a self-reinforcing mechanism which causes poverty to persist. It is a result of individually optimal choices, but at the same time it depends on the initial conditions of the endogenous variables, which can shape the long-run outcomes and prevent sustained growth.

There are a number of poverty trap models based on a varying propensity to save (for a survey, see Azariadis and Stachurski, 2004). It has typically been assumed that poor people cannot save due to their low income. Recently, this argument has

[6] *Table 1* and *Table 3* both show a significant negative association between education and the discount rate. However, note that the magnitude of the particular coefficients is not directly comparable. In the Ugandan study, the dependent variable is the one-year discount rate, whereas in the Indian study it is the three-month discount rate. The set of observable characteristics that we control for differs slightly as well.

been further elaborated in models which introduce endogeneization of life expectancy by allowing the probability of survival to depend on the level of development of the economy itself (Haaparta and Puhakka, 2004; Chakraborty and Das, 2005). It is argued that individuals (or governments) in poor countries cannot afford to invest in their patience by investing in health, and a shorter lifespan consequently distorts savings. The complementarity between the level of development and health may produce multiple equilibria.

We believe the following model differs from the existing ones in the sense that a high discount rate does not necessarily have to be related to an income constraint. Although we are still far from a full understanding of patience formation in poor countries, from the available evidence it seems that being future-oriented can be learned at school and transmitted from parents. We construct a model where the discount rate is treated as a characteristic rooted in individual human capital, which encompasses the level of education and parental influence.[7]

3.2 Human Capital and Growth: Standard Model

We begin with a simple human-capital-driven model with overlapping generations. The agents are homogenous and the model abstracts from the potential role of human capital spillover effects at the country level. The individuals live for two periods. We distinguish two types of individuals: "young" and "old". In our model, parents exhibit the standard type of perfect altruism as in mainstream dynastic models. Parents evaluate their children's life prospects from the standpoint of their own preferences and induce them to make the schooling choices they regard as desirable.

An individual is young in period 1 and old in period 2. She maximizes her expected lifetime utility over consumption in the two periods. We assume that individuals have the following utility function:

$$U\left(C_1, C_2, \rho\right) = \ln C_1 + \frac{1}{1+\rho} \ln C_2 \tag{1}$$

where C_1 denotes consumption when the individual is young, C_2 is consumption during old age, and ρ is the subjective discount rate. The utility function is increasing and concave in consumption and Inada conditions hold.

The young generation invests in education and produces and consumes the output. The old generation acts only as a producer and consumer. An agent combines her initial human capital with labor to produce output y_t:

$$y_t = A h_t^{t-1} l_t$$

where $A > 0$ is a productivity parameter. In the first period of life, agents divide their time between schooling and labor supply. The total time available to an agent is normalized to one and is spent only on working and schooling. The time spent on

[7] In line with the usual literature on economic growth we *do* assume that less educated individuals are able to maximize utility over time; only the weight they assign to future utility varies. Admittedly, some of the psychological arguments for why education makes an individual more future-oriented are also compatible with the notion of bounded rationality of less educated people. An analysis of bounded rationality could be an interesting extension of this issue. We thank T. Cahlík for this point.

education s_1 is therefore $1-l_1$, where l_1 is the time spent working. We can rewrite the first-period production function as follows:

$$y_1 = Ah_1^0(1-s_1)$$

where s_1 is the endogenous level of schooling, chosen so that individual utility is maximized, and h_1^0 is the initial level of human capital. The subscript 1 indicates the level of human capital in the period when an individual is young, while the superscript 0 indicates that the level of human capital was determined one period earlier. In general, we assume that human capital can be either transmitted from parents through innate abilities and upbringing, or accumulated through education. In the first period, the level of human capital h_1^0 is derived only from parental human capital, because schooling is not completed. In the second period, the inherited human capital is combined with the accumulated human capital gained by attending school.

Given this, an agent produces her human capital for the second period, h_2^1, in accordance with

$$h_2^1 = Bh_1^0 s_1 \tag{2}$$

where $B \geq 0$ is the productivity parameter in human capital accumulation. For h_2^1, the subscript 2 indicates the level of human capital in the period when an individual is old, while the superscript 1 indicates that the level of human capital was determined by the level of human capital and choices made in the period when an individual was young.

Income in the second period is of the same form as in the first period. The agent no longer invests in education through schooling. She spends all time working and utilizes the new human capital level.

$$y_2 = Ah_2^1 \tag{3}$$

By combining (3) with human capital formation (2) we get

$$y_2 = ABh_1^0 s_1$$

In each period, each agent consumes what she produces. There are no savings and bequests in the form of physical capital.

$$y_t = C_t$$

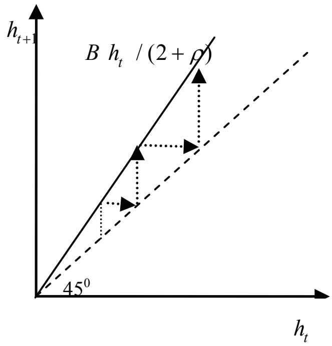
Individual utility (1) is maximized subject to the constraints $C_1 \leq Ah_t^0(1-s_1)$ and $C_2 \leq ABh_1^0 s_1$.

The maximization problem $MaxU\left(C_1, C_2\right)$ can be rewritten as follows

$$\underset{s\geq 0}{MAX}\left\{\ln\left[Ah_1^0(1-s_1)\right]+\frac{1}{1+\rho}\ln\left(AB\ h_1^0 s_1\right)\right\} \tag{4}$$

Individuals compare the opportunity costs of education with the discounted future benefits of education in the form of higher income. By differentiating (4) with

Figure 1 Human Capital and Growth



respect to the level of schooling we get the optimal decision rule for schooling, which depends on the subjective discount rate

$$s_1^* = \frac{1}{2+\rho} \tag{5}$$

The higher is the discount rate, the less are individuals inclined to study. A lower ρ has a positive effect on human capital accumulation by increasing the amount of time devoted to education. This can be easily verified by combining (2) and (5) to obtain the general formula

$$h_{t+1}^{t} = B\frac{1}{2+\rho}h_t^{t-1}$$

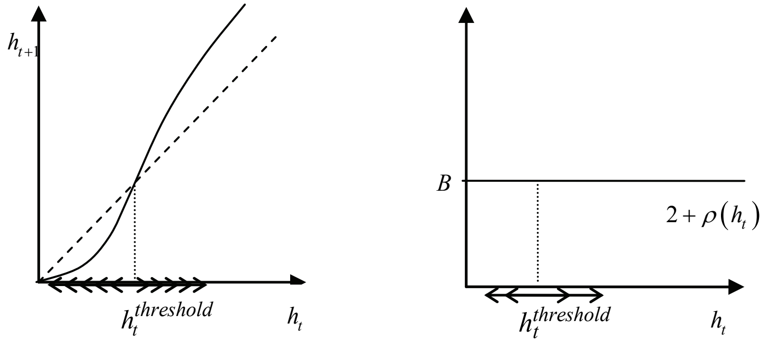
This expression is crucial for generating growth and it is the major building block of the remainder of our analysis, as it describes the equilibrium path of development. In the simplest version of this model, the productivity parameter of human capital accumulation B and the subjective discount rate ρ determine if an economy develops perpetually along a constant positive growth path ($B > 2+\rho$) or if it stagnates ($B < 2+\rho$).

Figure 1 illustrates the former situation. An increase in the efficiency of schooling or a decrease in the subjective discount rate makes the condition for long-run growth more likely to be satisfied. The reason is straightforward. The discounted future benefits of education outweigh the earnings forgone during schooling, which motivates parents of young individuals to invest a higher proportion of time in education and accumulating human capital.

3.3 Human Capital and Time Discounting

The implications of the model become more interesting when we link the subjective discount rate and the level of human capital. It is this feature that distinguishes this model from the existing ones. The effects of education on promoting planning abilities and disease prevention and the cultural influences mentioned earlier suggest a negative relationship between the level of human capital and the subjective discount rate. We will therefore assume that $\rho'(h) < 0$.[8] We further assume that the strength of this effect is diminishing, so that $\rho''(h) < 0$.

Figure 2 Human Capital and Time Discounting



Again, the schooling choices are made in the first period under the influence of perfectly altruistic parents. The subjective discount rate, which depends on parental human capital, enters the utility function of the young individual:

$$U\left(C_1, C_2, \rho_t\right) = \ln C_1 + \frac{1}{1+\rho\left(h_1^0\right)} \ln C_2$$

Using the same procedure as above, we find the optimal decision rule for schooling to be $s_1^* = \frac{1}{2+\rho\left(h_1^0\right)}$. The lower is the human capital in the family, the less patient is the young individual and the lower is the optimal level of schooling perceived by the individual and her parents. The transition function of human capital then looks as follows:

$$h_{t+1}^{t} = B \frac{1}{2+\rho(h_t^{t-1})} h_t^{t-1} \tag{6}$$

The role of human capital is now enlarged for its effect on the discount rate. *Figure 2* shows the dynamics of the economy. This non-convexity gives rise to an S-shaped transition curve and hence the possibility of multiple equilibrium development paths, and a poverty trap emerges.

A low-income equilibrium appears if the efficiency of the education system is too low compared to the individual discount rate, specifically if $2+\rho(h_t^{t-1}) > B$. In such a situation, the opportunity costs of education are higher than the discounted future benefits of education in the form of higher income, and there is negative human capital accumulation. In an environment of low human capital, people discount future income heavily and accumulate an insufficient level of human capital. However, when the threshold level of human capital is overcome, autonomous growth gets generated.

[8] Admittedly, we could have included two parameters, one for the subjective discount rate and one for the probability of survival – in our model it would be the probability that an agent survives to the second period. These two sources determining the weight assigned to future pleasures are practically difficult to distinguish. As both are dependent on human capital, we find it convenient to simplify the analysis by including only one variable encompassing both. The major results remain unchanged.

An endogenous subjective discount rate poses difficulties for welfare analysis. As a consequence of varying time discounting, the form of the utility function changes for different levels of human capital. In such a case, it is not possible to compare an individual's well-being in alternative situations.

3.4 Human Capital, Time Discounting and Population Growth

The likelihood of a low-income equilibrium in the model may be further reinforced by considering factors that influence the efficiency of schooling *B*, which we have so far treated as a constant. A variety of evidence (e.g. Greenwald, Hedges, and Laine, 1996) suggests that schools with more resources per student deliver more efficient outcomes to the studying individuals. We approximate the functional form as $B_t = B\left(T, n_t\right)$, where *T* represents public resources invested in the education system, which are not paid by individuals, and n_t is population growth. Per capita public expenditure on education determines class size, training of teachers, and availability of books and other school equipment, or may reduce the financial exposure of individuals by eliminating school fees. In poor countries, public education expenditures are usually under constant pressure from rapid population growth. For example, the pupil-teacher ratio in primary schools in sub-Saharan Africa is three times higher than in high-income countries (Glewwe and Kremer, 2005). Hence, it is plausible to assume a positive relationship between the level of expenditure on education and the efficiency of education, such that $\frac{\partial B\left(T, n_t\right)}{\partial T} \geq 0$, and a negative relationship with respect to population growth: $\frac{\partial B\left(T, n_t\right)}{\partial n_t} \leq 0$.

In addition, empirical studies based on the World Fertility Surveys and the Demographic and Health Surveys establish a strong negative correlation between education and fertility in the developing countries (e.g. Martin, 1995). This correlation is of even greater magnitude than the correlation with per capita income. Recent micro--level studies have found a significant causal impact of education on lowering fertility (Breierova and Duflo, 2002; Bauer and Chytilová, 2007). The relationship has also been illustrated theoretically in a model of human capital and endogenous fertility by Becker, Murphy, and Tamura (1990).

In line with this literature, we assume that population growth in period *t* depends negatively on parental human capital and is given by a non-increasing concave function: $n_t = n\,(h_t^{t-1})$, $n'(h) < 0$, and $n''(h) < 0$.

The transition path (6) emerges now as:

$$h_{t+1}^{t} = B\left(T, n\left(h_t^{t-1}\right)\right)\frac{1}{2+\rho\left(h_t^{t-1}\right)}h_t^{t-1} \tag{7}$$

Again, the resulting transition function is compatible with the possibility of multiple equilibrium development paths. There are now two non-convexities with respect to human capital built into the model. First, for low levels of initial human capital, people discount the future heavily. Secondly, the efficiency of schooling is low due to rapid population growth, which is also rooted in low levels of human capital. These two effects jointly undermine the motivation of the young generation to attend school. For countries with an uneducated population, the dynamic behavior of society does not generate a sufficient level of human capital for growth, because the optimal level of schooling is too low (see the Appendix for the algebraic derivation). The two charts in *Figure 3* illustrate the dynamics graphically. On the left-hand side, the transition curve (7) is depicted. The chart on the right-hand side goes further behind the slope of the transition curve by showing how ρ_t and B_t are associated with human capital.

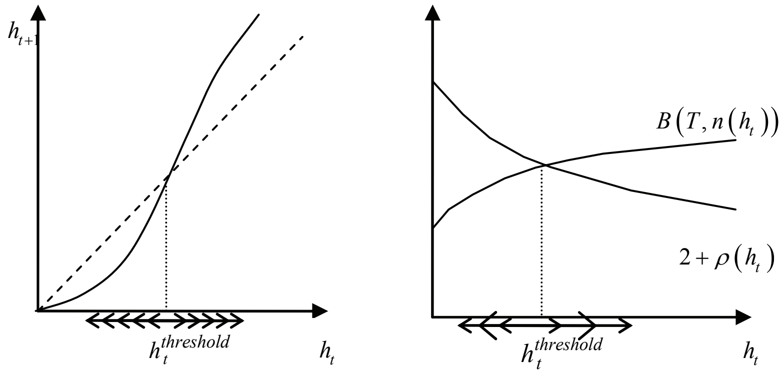
If $B\left(T,n\left(h_t^{t-1}\right)\right)-\rho\left(h_t^{t-1}\right)<2$, the economy is placed on a low development path, as $h_{t+1}^{t}<h_t^{t-1}$. People discount future pleasures heavily and have high numbers of children, the efficiency of schooling is low, and as a consequence people decide on a low level of education. If $B\left(T,n\left(h_t^{t-1}\right)\right)-\rho\left(h_t^{t-1}\right)>2$, the economy is on a positive development path. People are future-oriented, fertility is low, the efficiency of schooling is high, and people invest in their human capital.

The outcome of the economy may then depend on the initial conditions in terms of human capital. An economy with human capital below $h_t^{threshold}$ converges to the low equilibrium, whereas an economy with an initial human capital stock above $h_t^{threshold}$ grows perpetually.[9] The threshold level of human capital is an unstable equilibrium. In this situation, $B\left(T,n\left(h_t^{threshold}\right)\right)-\rho\left(h_t^{threshold}\right)=2$.

Our model shows that in an environment of low human capital, a high level of time discounting, and low efficiency of schooling, economic agents make choices such that poverty may become persistent. The model implies a particularly important role of public action in education systems in the least developed countries. The threshold level of human capital can be reached by introducing mandatory school attendance. In poor countries, where parents may not have enough resources to send their children to school, alternative actions may stimulate children's school attendance. Higher public expenditure focused on increasing quality or reducing the direct costs of education (*T*) increases the efficiency of schooling as perceived by individuals (*B*). This can be achieved, for example, by spending more on training teachers, buying more books and other school equipment, or eliminating school fees. The higher "returns" from attending school are then more likely to outweigh the high subjective discount rate in individual schooling choices. A higher *T* can be illustrated as an upward shift of the $B\left(T,n\left(h_t\right)\right)$ curve (the right-hand side of *Figure 3*) or as an anti-clockwise rotation of the transition curve (the left-hand side of *Figure 3*). As a result, the threshold level of human capital decreases and autonomous growth is more likely to appear.

[9] If we assumed decreasing returns to scale of human capital above a certain level of human capital, the economy would converge to a high steady state and would not grow perpetually. However, for the sake of simplicity we keep constant returns to scale over the whole interval.

Figure 3 Human Capital, Time Discounting, and Population Growth



4. Conclusions

There is no doubt that the subjective discount rate is an important factor in determining the life-cycle behavior of individuals. A high level of time discounting may help to explain widely observed phenomena in the poorest countries, such as low savings, school attendance or investment rates. At the same time, it is usual to presume that the discount rate is wholly exogenous and independent of personal characteristics and economic conditions.

This paper complements recent micro-level evidence from field studies in the least developed countries demonstrating a close negative relationship between education and the individual discount rate. We describe in greater detail the evidence from our two recent studies in Uganda and India. Both environments are characterized by a high prevalence of poverty, though they are different across many other dimensions. Interestingly, we find the results from both studies to be consistent with the causal effect of education on the subjective discount rate.

In accordance with this evidence, the paper integrates an additional assumption about the negative impact of human capital on the individual subjective discount rate into a simple human-capital-driven growth model. In this model, an individual optimizes consumption over two periods by dividing her time between schooling and work in the first period. The endogenous level of schooling represents individual savings between the two periods. It is demonstrated that in a low-human-capital environment the individual discount rate may be too high compared to the efficiency of schooling. Consequently, the individual optimal schooling choices may result in negative or low dynamics of human capital accumulation, and a low human capital equilibrium may emerge. The theoretical predictions are further reinforced when we model school efficiency in the context of population pressure, which largely stems from low education levels, as demonstrated by a large body of empirical evidence.

The analysis points to education investment as a prerequisite for sustained economic growth, as its wider impacts are particularly important in countries with less developed economic institutions. The relationship between education, time discounting, and fertility is consistent with slower growth in poor countries than predicted by standard theory and may even result in a development trap, where the initial conditions in terms of human capital matter and threshold effects appear.

As noted earlier, it has been widely observed in cross-country analyses that standard estimates of the contribution of additional schooling to economic growth, based on productivity differences associated with differences in the level of schooling, cover only a small portion of the total correlation between education and subsequent growth. The paper may help to reconcile this important puzzle by analyzing an additional channel through which education promotes economic growth – by shaping individual time discounting.

APPENDIX

The first derivation of the transition function[10] (7) underlines the broader role of human capital in this model and shows three channels through which human capital influences growth dynamics, especially in less developed countries:

$$\frac{\partial h_{t+1}}{\partial h_t} = B_t \frac{1}{2+\rho_t} + B_t h_t^{t-1} \frac{(-1)}{(2+\rho_t)^2} \rho_t' + \frac{\partial B_t}{\partial h_t} \frac{1}{2+\rho_t} h_t$$

The first item on the right-hand side is the standard result. It shows how optimal schooling time translates into new human capital. The second item represents the effect through a decreased discount rate. The third item represents the impact through decreased population growth and hence increased education efficiency. All three items are positive, ensuring a positive slope of the transition function.

The second derivation of (7) after rearranging looks as follows:

$$\begin{aligned}\frac{\partial^2 h_{t+1}}{\partial^2 h_t} &= 2\frac{\partial B_t}{\partial h_t}\frac{1}{2+\rho_t} + 2B_t \frac{(-1)}{(2+\rho_t)^2}\rho_t' + 2\frac{\partial B_t}{\partial h_t} h_t \frac{(-1)}{(2+\rho_t)^2}\rho_t' + \\ &+ B_t h_t \frac{2}{(2+\rho_t)^3}(\rho_t')^2 + B_t h_t \frac{(-1)}{(2+\rho_t)^2}\rho_t'' + \frac{\partial^2 B_t}{\partial^2 h_t}\frac{1}{2+\rho_t} h_t\end{aligned} \qquad (8)$$

The necessary condition for the existence of a low-human-capital equilibrium is a convex transition function for low levels of human capital, or equivalently $\frac{\partial^2 h_{t+1}}{\partial^2 h_t} \geq 0$. Equation (8) confirms that the transition function is very likely to be convex in our model. The first four items on the right-hand side are positive, whereas the last two items are negative, and the relative magnitudes differ with the level of human capital. However, to ensure a convex transition function, we would need to make additional assumptions about the specific functional forms of $B(.)$, $\rho(.)$, and $n(.)$.

[10] For simplicity the superscripts are omitted in the derivations.

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