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A Model of Human Capital, Time Discounting and Economic Growth

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Abstract:
Endogenous time discounting is introduced in a two-period human-capital-driven growth model: subjective discount rate depends upon the level of human capital. This assumption accords strongly with the micro-level evidence. In the model an individual optimizes consumption over two periods. Low human capital societies do not grow fast since high discount rate discourages schooling as the major form of savings. This implication is further reinforced by modeling the efficiency of schooling in the context of population pressure which is also driven by low human capital. The model may produce multiple development regimes and it illustrates wider role of education in tackling possible development traps.

Keywords: growth, human capital, education, time discounting, discount rate, poverty.

JEL: D9, I2, O1.

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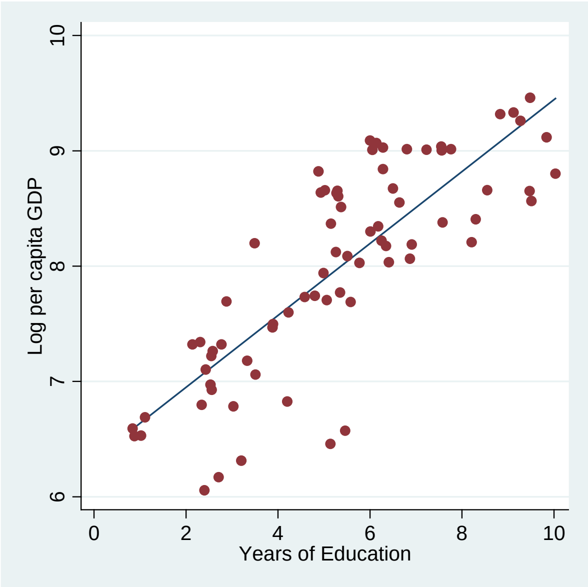
1 Introduction

In recent decades much of the attention of economists has been directed to 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 growth rate of GDP per capita and education level are highly correlated across countries (Benhabib and Spiegel 1994; Barro and Sala-i-Martin 2004). In Chart 1 this relationship is shown for the low- and middle-income countries.

Chart 1: Education and per capita GDP (2000)



Source: World Development Indicators (2006); and Barro and Lee (2000)
These data are for 76 low- and middle-income countries as defined in WDI for which these data are available.

However, the correlation between education and growth appears to be too high to be fully reconciled with the 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 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 high correlation between education and growth in the aggregate cross-country relationship. [1] Similarly, World Bank (2006) acknowledges that "education impact on economic growth is well-established; precisely how this happens is less well-understood."

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

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

(1994) summarizes also other less measurable channels like the effect of education on transaction costs, a quality of democracy or health. This paper focuses on additional pathway between education and growth. The model complements the empirically observed relationship between schooling and individual time discounting (Harrison, Lau and Williams 2002; Kirby et al. 2002; Bauer and Chytilová 2007a, 2008), underlines the role of human capital in economic growth and gives rise to the possibility of multiple development regimes.

Time discounting may be a fundamental factor for explaining 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.

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 by the present and would omit the pleasures that future events can bring.

In the major study that elicits 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 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 gratifications and rely on “higher will” with respect to the future (Harrison and Huntington 2000). Education typically reduces the role of traditional believes in individual’s decision-making.

The emerging evidence from field experiments in developing countries also shows negative correlation between subjective discount rate as a measure of patience and education. Kirby et al. (2002) studied discount rate in remote villages in Bolivian rain forest. They found high average discount rate and that big proportion of its variance can be explained by the years of schooling, parental education and measures of qualitative education achievements in terms of mathematics and languages 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. Bauer and Chytilova elicited subjective discount rate in Ugandan (2007a) and Indian villages (2008) and found negative correlation with the level of completed education.[2] In the Ugandan survey, they addressed the issue of possible mutual causality between education and discount rate. They use school frequency across villages and the number of school age years that overlap with the dictator Idi Amin’ rule as instruments and find significant impact of education on discount rate for men.

[2] On the other hand Pender (1996) in Indian villages finds correlation with recent income and credit constraints, but not with education.

This paper aims to integrate these empirical findings into a human-capital-driven, overlapping-generations growth model. We will abandon the usual assumption of the growth models about constant exogenously given subjective discount rate. A key component of our model is the assumption that subjective discount rate is high for low levels of human capital (education) and decreases with own and parental education. Our model theoretically illustrates how this relationship may generate stable low-human capital equilibrium, where people have strong preference for current consumption, do not save and invest and hence the economy remains poor.

There are a number of poverty trap models based on varying propensity to save (for survey see Azariadis and Stachurski 2004). It has typically been assumed that poor people cannot save due to their low income. Recently this argument was 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 investing in their patience by investing in health; and 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 high discount rate does not necessarily have to be related to an income constraint. Although we are still far from 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.[3]

The paper is organized as follows. We begin by constructing a simple human capital growth model and later enrich the analysis with additional assumptions about wider effects of education. The economic dynamics, possibility of multiple development regimes and policy implications are then discussed. The final section concludes.

2 Model

2.1 Human capital and growth: standard model

We begin with simple human-capital-driven model with overlapping-generations. The individuals live for two periods and we distinguish two types of individuals: „young“ and „old“. In our model, parents exhibit a 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 schooling choices they regard as desirable.

An individual is born at period t and maximizes her expected lifetime utility over consumption in two periods. We assume the individuals have the following utility function:

[3] In compliance 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 on why education makes an individual more future-oriented are compatible also with the notion of bounded rationality of less educated people. Analysis of bounded rationality could be an interesting extension of this issue. We thank T. Cahlík for this point.

$$U(C_t, C_{t+1}, \rho) = \ln C_t + \frac{1}{1+\rho} \ln C_{t+1} \tag{1}$$

where C_t denotes consumption when individual is young, C_{t+1} is consumption during old age, and ρ is a subjective discount rate. The utility function is increasing and concave in consumption and Inada conditions hold.

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

$$y_t = Ah_t^{t-1} l_t \tag{2}$$

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 agent is normalized to one and is spent only on working and schooling. Time spent on education s_t is therefore $1 - l_t$, where l_t is time spent on working. We can rewrite the first-period production function as follows:

$$y_t = Ah_t^{t-1}(1 - s_t) \tag{3}$$

where s_t is endogenous level of schooling chosen so that the individual utility is maximized, and h_t^{t-1} is initial level of human capital in period t determined by choices in period t-1. In general, we assume that human capital can either be transmitted from parents through innate abilities and upbringing, or accumulated through education. In the first period the level of human capital h_t^{t-1} 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_{t+1}^t, in accordance with

$$h_{t+1}^t = Bh_t^{t-1} s_t \tag{4}$$

where $B \geq 0$ is the productivity parameter in human capital accumulation.

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

$$y_{t'+1} = Ah_{t+1}^t \tag{5}$$

When combining (5) with human capital formation (4) we get

$$y_{t'+1} = ABh_t^{t-1} s_t . \tag{6}$$

In period one and period two agents consume all that is produced. There are no savings and bequests in the form of physical capital.

$$y_t = C_t \quad y_{t+1} = C_{t+1} \tag{7}$$

The individual utility (1) is maximized subject to the constraints $c_t \le Ah_t^{t-1}(1-s_t)$ and $c_{t'+1} \le ABh_t^{t-1}s$.

The maximization problem $MaxU(C_t, C_{t+1})$ can be rewritten as follows

$$\underset{s\ge 0}{MAX}\left\{\ln\left[Ah_t^{t-1}(1-s_t)\right]+\frac{1}{1+\rho}\ln\left(AB_t h_t^{t-1}s_t\right)\right\} \tag{8}$$

By differentiating (8) with respect to the level of schooling we get the optimal decision rule for schooling, which depends on the subjective discount rate

$$s_t^* = \frac{1}{2+\rho}. \tag{9}$$

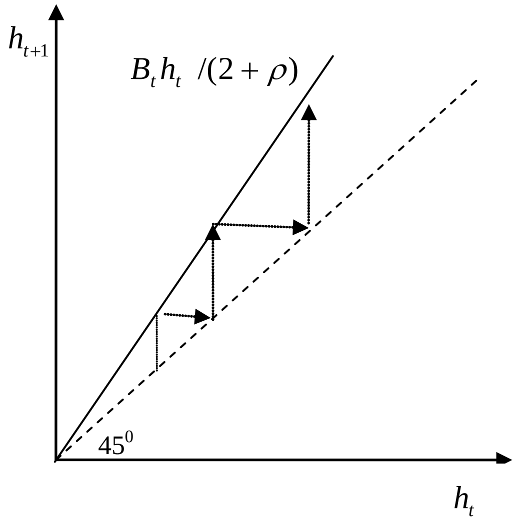
The higher is the discount rate the less are the individuals inclined to study. Lower ρ has a positive effect on human capital accumulation by increasing the amount of time devoted to education. This can be easily verified by combining (4) and (9) to obtain

$$h_{t+1}^t = B\frac{1}{2+\rho}h_t^{t-1} \tag{10}$$

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 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 decrease in the subjective discount rate makes the condition for long-run growth more likely to be satisfied. The reason behind is straightforward, lower discount rate and higher efficiency of schooling motivates parents of young individuals to invest higher proportion of time into education and accumulate human capital.

Figure 1: Human capital and growth



2.2 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, health prevention and cultural influences mentioned earlier suggest negative relationship between the level of human capital and subjective discount rate. We will therefore assume that $\rho'(h) < 0$.[4] We further assume that the strength of this effect is diminishing so that $\rho''(h) < 0$.

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

$$U(C_t, C_{t+1}, \rho_t) = \ln C_t + \frac{1}{1+\rho\left(h_t^{t-1}\right)} \ln C_{t+1} \qquad (11)$$

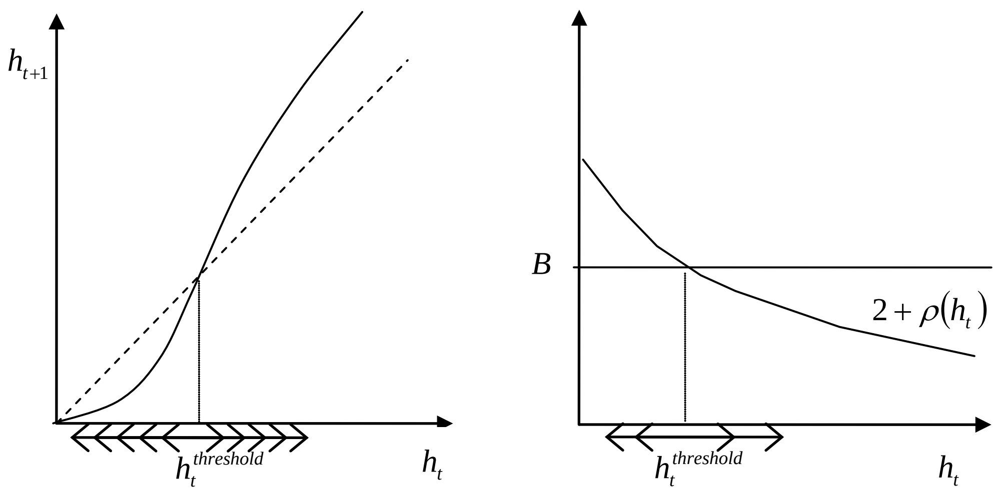
Using the same procedure as above we find the optimal decision rule for schooling being $s_t^* = \dfrac{1}{2+\rho\left(h_t^{t-1}\right)}$. The lower the human capital in the family, the less patient is the young individual and the lower is the optimal level of schooling perceived by the individual and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

$$h_{t+1}^t = B \frac{1}{2+\rho(h_t^{t-1})} h_t^{t-1} \qquad (12)$$

[4] Admitedly, we could have included two parameters, one for subjective discount rate and one for 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 the 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.

The role of human capital is now enlarged for its effect on discount rate and Figure 2 shows the dynamics of the economy. This non-convexity gives rise to the S-shaped transition curve and hence the possibility of multiple development regimes and a poverty trap emerges. As in the surveying article of Azariadis and Stachurski (2004) on poverty traps we define a poverty trap as 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 initial conditions of the endogenous variables which can shape long run outcomes and prevent sustained growth.

Figure 2: Human capital and time discounting



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

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

2.3 Human capital, time discounting and population growth

The likelihood of 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 $B_t = B(T, n_t)$, where T represents public resources invested into the education system which are not paid by individuals and n_t is population growth. Per capita public expenditures on education determine the class size, training of the teachers, availability of books and other school equipment or may reduce the financial exposure from the side 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 on 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 expenditures into education and the efficiency of education such that $\frac{\partial B(T, n_t)}{\partial T} \geq 0$ and negative relationship with respect to population growth $\frac{\partial B(T, n_t)}{\partial n_t} \leq 0$.

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

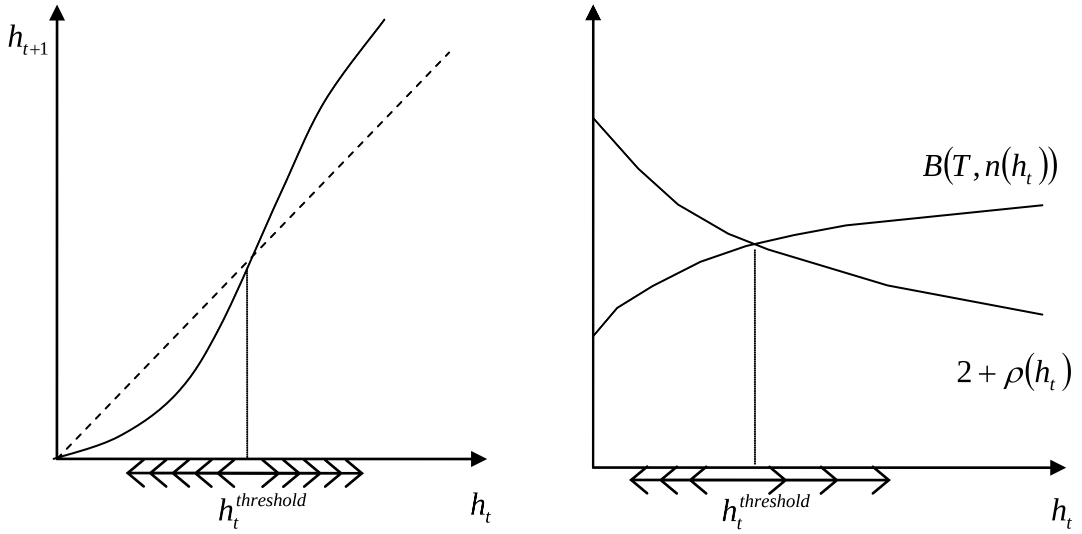
In compliance with this literature we assume that population growth at period *t* depends negatively on parental human capital and is given by a non-increasing concave function: $n_t = n(h_t^{t-1})$, $n'(h) < 0$ and $n''(h) < 0$.

The transition path (12) emerges now as:

$$h_{t+1}^{t} = B\left(T, n\left(h_t^{t-1}\right)\right) \frac{1}{2 + \rho\left(h_t^{t-1}\right)} h_t^{t-1} \tag{13}$$

Again the resulting transition function is compatible with the possibility of multiple development regimes. 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 future heavily. Secondly, the efficiency of schooling is low due to the rapid population growth which is also rooted in the low levels of human capital. These two effects jointly undermine the motivation of the young generation to attend school. For countries with uneducated population the dynamic behavior of the society does not generate sufficient level of human capital for growth, because the optimal level of schooling is too low (see Appendix A for algebraic derivation). The two charts below illustrate the dynamics graphically. On the left hand side the transition curve (13) is depicted. The chart on 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.

Figure 3: Human capital, time discounting and population growth



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

The outcome of the economy may then depend on initial conditions in terms of human capital. An economy with the human capital below $h_t^{threshold}$ converges to the low equilibrium, whereas the economy with the initial human capital stock above $h_t^{threshold}$ grows perpetually.[5] The threshold level of human capital is an unstable equilibrium. In this situation $B(T, n(h_t^{threshold})) - \rho(h_t^{threshold}) = 2$.

Our model shows that in the environment of low human capital, a high level of time discounting and a low efficiency of schooling, economic agents make choices such that poverty may become persistent. The model implies particularly important role of public action into the education systems in least developed countries. Higher public expenditures focused on increasing quality or reducing direct costs of education (*T*) increase the efficiency of schooling as perceived by individuals (*B*). Higher „returns“ from attending school are then more likely to overweight the high subjective discount rate in individual schooling choices. Higher *T* can be illustrated as a shift of $B(T, n(h_t))$ curve upwards (right hand side of Figure 3) or as anti-clockwise rotation of the transition curve (left hand side of Figure 3). As a result the threshold level of human capital decreases and autonomous growth is more likely to appear.

[5] Once we assume decreasing returns to scale of human capital taking place above certain level of human capital, the economy would converge to high steady state and would not grow perpetually. However, for the sake of simplicity we keep constant returns to scale on the whole interval.

3 Conclusions

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 the usual practice to assume that the discount rate is wholly exogenous and independent on personal characteristics and economic conditions. The paper complements recent micro-level evidence from field studies in the least developed countries that demonstrate close negative relationship between education and individual time discounting. In accordance with this evidence the paper integrates an additional assumption about negative impact of human capital on individual subjective discount rate into a 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 the 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 a negative or low dynamics of human capital accumulation and a low human capital equilibrium may emerge. The theoretical predictions are further reinforced once we model the school efficiency in the context of population pressure that largely stems from low education levels as demonstrated by large body of empirical evidence.

The analysis points to education investments as 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 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 smaller portion of the total correlation between education and subsequent growth. The paper may help to reconcile this important puzzle by analyzing additional channel through which education promotes economic growth - by shaping individual time discounting.

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Appendix

The first derivation of transition function[6] (13) 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:

$$\frac{\partial h_{t'+1}}{\partial h_t} = B_t \frac{1}{2+\rho_t} + B_t h_t^{t-1} \frac{(-1)}{(2+\rho_t)^2} \rho_t^{'} + \frac{\partial B_t}{\partial h_t} \frac{1}{2+\rho_t} h_t \qquad (14)$$

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

The second derivation of (13) after rearranging looks as follows:

$$\frac{\partial^2 h_{t+1}}{\partial^2 h_t} = 2\frac{\partial B_t}{\partial h_t}\frac{1}{2+\rho_t} + 2B_t \frac{(-1)}{(2+\rho_t)^2}\rho_t^{'} + 2\frac{\partial B_t}{\partial h_t} h_t \frac{(-1)}{(2+\rho_t)^2}\rho_t^{'} + B_t h_t \frac{2}{(2+\rho_t)^3}(\rho_t{}')^2$$
$$+ B_t h_t \frac{(-1)}{(2+\rho_t)^2}\rho_t^{''} + \frac{\partial^2 B_t}{\partial^2 h_t}\frac{1}{2+\rho_t} h_t \qquad (15)$$

The necessary condition for the existence of low-human-capital equilibrium is the convex shape of the transition function for low levels of human capital, or equivalently $\frac{\partial^2 h_{t+1}}{\partial^2 h_t} \geq 0$. The equation (15) confirms that convex shape of the transition function is very likely 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 the convex shape of the transition function we would need to make additional assumptions about specific functional forms of $B(.)$, $\rho(.)$ and $n(.)$.

[6] For simplicity the upperscripts are omitted in the derivations.

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