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Introduction

Per capita incomes vary enormously between countries. While GNP per capita in the high-income economies was almost $25,000 in 1995, low-income economies had a per capita GNP of $430 on average (World Bank 1997). Why such large differences between incomes persist in an increasingly connected world where technology has made it possible to interchange not only goods but also knowledge and ideas relatively cheaply is certainly a topic worth examining more closely as it affects millions of people.

Understanding what determines these differences in living standards has prompted an abundance of research for obvious reasons: knowing why one country develops economically while another does not has important policy implications. Governments could actively pursue policies that increase the growth of their respective countries and thus increase living standards of their citizens.

Development economics does just that: it attempts to discern why some countries have developed rapidly while others appear to be stuck at low levels of development, thus determining what kinds of policies governments could implement to aid the progress of development. The discipline is related to the area of economic growth but it asserts that less developed countries differ from developed nations and that a different set of tools is therefore necessary (Meier and Rauch 2000).

Nonetheless, economic growth theory and development economics certainly overlap. In particular, growth theory presents a useful basis for thinking about how the overall growth path of a nation may be shaped while development economics provides a variety of variables that may be significant in determining the development of countries.

Both development economics and economic growth theory place emphasis on technological progress as an explanation for continually increasing livings standards. In the neoclassical growth model, technological progress enters as an exogenous variable which is important in determining the long-run growth rate of per capita income. Endogenous growth models attempt to incorporate technological progress into the model itself through the accumulation of human capital and knowledge creation which allow for continual growth. Development economics recognizes the importance of technological progress through, for example, openness to trade which allows a less developed country to adopt foreign technology, and education which builds human capital and thus may aid economic development.

Human capital in general, and education in particular, have received much attention recently, and generally empirical research is supportive of the theory that higher levels of education appear to be positively correlated to economic. Given the apparent importance on economic growth, and the policy implications this entails, I will examine the relationship between specific levels of education, that is primary, secondary and tertiary education, on economic growth.

Organization

In the first section, I will first very briefly review the Harrod-Domar growth model in order to pave the way for the more influential neoclassical model formulated by Robert Solow (1956). The contrast between the two is intended to show the robustness of the Solow model, and thus provide an explanation why the neoclassical model is still used today while the Harrod-Domar model is not.

As mentioned earlier, the shortcoming of the Solow model is its exogenous treatment of technical progress. Despite this understandably unsatisfactory detail, the available data nevertheless support the neoclassical growth theory rather well. In addition, the model allows for a very clean way of incorporating of human capital and shows very clearly how it may affect the growth path of an economy. For these reasons, I will illustrate how human capital may influence economic growth using the neoclassical model.

The endogenous growth theory attempts to correct the problem of exogenous technical progress, and I will give a short overview of this model as well. It should be noted that the endogenous growth model does not reject the neoclassical growth theory but simply attempts to explain technical progress within the model, generally in the form of human capital.

The next section turns to the data. I will present the general framework often used in empirical research which is heavily influenced by the premise of convergence predicted by the neoclassical growth model. The specification of the regression model follows closely that of Barro (1996).

A variety of choice and environmental measures are included which are generally believed to affect economic growth. I will briefly review these variables and compare the regression results to those of similar studies.

The primary difference between Barro's model and the one I am using is that that schooling measures are separated by level of education, i.e. primary, secondary, and higher schooling whose distinct effects are the focus of this paper. I find that secondary schooling in particular has a large positive effect on growth. Higher schooling also enters the model significantly but with a negative estimated coefficient. There is some support for the supposition that the effect of higher schooling may be by increasing the rate of conditional convergence.

Primary, secondary, and higher levels of schooling are also separated by gender as there is some evidence by Barro (1996) that female schooling has no significant effect on economic growth. Contrary to his results, I find that female schooling is a significant factor for predicting growth although the results are varied and somewhat difficult to interpret. Nevertheless, female schooling enters significantly in a variety of specifications and thus should not be ignored.

The final section consists of a brief summary and conclusion.

1. Economic Growth Theory

Following the depression of the 1930s, confidence in capitalism was shaken. While the economy picked up rapidly in the 1940s, economic growth theory published in the same decade did not do much to be reassuring. The prevalent theory of the time, formulated simultaneously by Harrod and Domar, basically predicted the doom of capitalism.

The Harrod-Domar model assumes a production function that requires fixed amounts of labor and capital and is given by

$$F(L,K) = \min[\beta L, \sigma K].$$

The economy's productive capacity is $\sigma \exists K$, which must be equal to aggregate demand in order to fully employ the current capital stock. Therefore, given a constant savings rate s, investment must be

$$I = s \exists \sigma \exists K.$$

Next period's productive capacity will then be equal to $(1+s \exists \sigma) \exists K$ which determines the amount of investment needed in the next period. This pattern will continue as each period's capital stock will again increase and thus the economy's productive capacity. Consequently, it is not enough that "savings of yesterday be invested today … . Investment of today must always exceed savings of yesterday. … The economy must continuously expand" (Domar 1947).

The labor force is assumed to grow at a constant proportional rate of n, and its productivity is given by $\beta \exists L$. It follows that in order to maintain full employment, the labor force must grow at the same rate as the productive capacity of the capital stock.

This model has the unfortunate characteristic of predicting eternally growing unemployment of either labor or capital unless the productive capacity of the economy happens to grow at the exact same rate as the labor force. Even under these most favorable—and very unlikely—circumstances, however, the equilibrium is unstable. Any change in the capital stock, savings rate, or labor force leads to growing unemployment of labor or capital.

As unhappy as the implications of the Harrod-Domar model were, reality fortunately did not did not reflect the predictions of the model. Rather, economies tended to exhibited continued positive growth overall with little tendency to turn into eternal disaster if one of the parameters changed. While theory cannot reflect reality perfectly, the results of the theoretical model in this case were completely different from reality.

As Solow (1956) expressed, "All theory depends on assumptions which are not quite true. That is what makes it theory. The art of successful theorizing is to make the inevitable simplifying assumptions in such a way that the final results are not very sensitive." In the Harrod-Domar model, the assumption that proved to be the limiting factor was the idea that production required a fixed amount of capital and labor and did not allow for substitution of inputs. As Solow (1956) points out, "… it is hardly surprising that such a gross rigidity in one part of the system should entail lack of flexibility in another."

Solow relaxed this assumption by replacing the production function used by Harrod and Domar with one that allows for substitution between capital and labor and exhibits constant returns to scale. Allowing for this generally more realistic production function has the amazing result of predicting a stable full employment equilibrium at which the economy grows at a constant proportional rate. Moreover, this model has proved to be very robust, withstanding the scrutiny of economists for half a century and surviving various modifications without losing its initial framework or implications.

In the Solow model, the production function given by

$$Y = F(L,K)$$

allows for substitution of factor inputs and exhibits constant returns to scale with diminishing returns to capital. Given a constant savings rate s and depreciation rate δ, the change in the capital stock is

$$K' = sY - \delta K,$$

so net investment is equal to the change in the capital stock. The labor force is assumed to grow at a constant rate n, and can be expressed by

$$L = L(0)\exists e^{nt}.$$

Output per worker can be expressed as a function of capital per worker due to the constant returns to scale property of the production function:

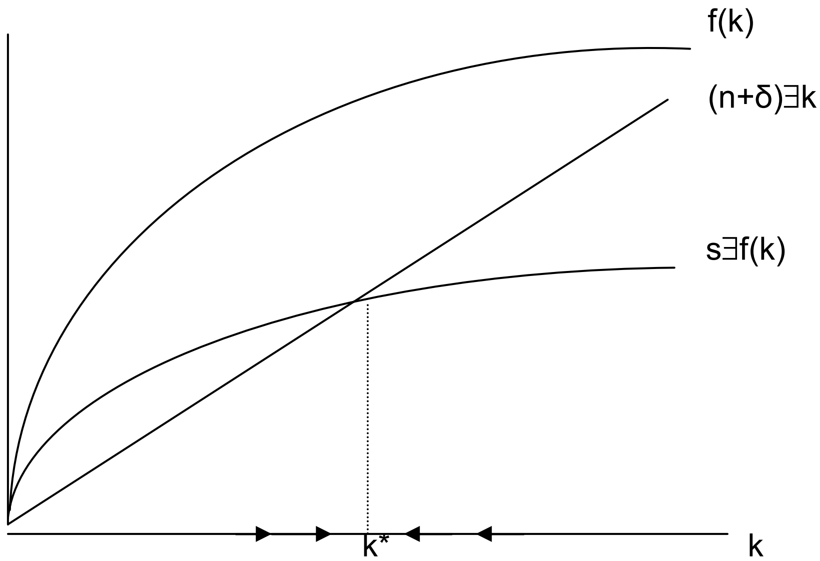
(1) $$y = f(k).$$

The change in the capital stock per worker can (with some manipulation) be shown to be

(2) $$k' = sf(k) - (n+\delta)k.$$

This rather simple-looking equation is incredibly versatile and can be used to determine the current and steady state growth rate of an economy in addition to the growth paths of the total capital stock, labor force, and output. Equally importantly, it provides an excellent basis for thinking about how economies may be affected by changes in the parameters, and how policies may affect the long-run, and thus current, growth path of a nation.

This may best be seen by a graphical representation of equations (1) and (2).



The graph illustrates nicely that an economy will always approach its steady state value of per capita capital, and that this steady state will be stable. For example, if

$$sf(k) > (n+\delta)k$$

so that the economy finds itself with less capital per person than its steady state level, net investment exceeds the amount of capital needed for replacement due to depreciation and to compensate for a growing labor force. Thus, the capital stock per person will increase until s∃f(k) is just equal to (n+δ)∃k. At this point, per capita capital will neither increase nor decrease and the economy is thus at a steady state. The process is similar if capital per person exceeds its steady state value: k will decrease until it reaches k*.

The steady state value of capital per person k* thus represents a stable equilibrium which the economy will always approach. At this point, s∃f(k) = (n+δ)∃k or, alternatively, k’ = 0. Thus, there is no change in per capita capital. This does not imply, however, that there is no growth. While capital and output per capita remain constant, total capital and output in the steady state grow at the constant proportional rate of $(n+\delta)$.

Up until now I have completely ignored technical progress, and the consequence becomes apparent at this point: while total output, or income, grows at rate $(n+\delta)$ at the steady state, output per person and thus living standards remain the same. The rate of growth is just enough to compensate for depreciating capital and an increasing labor force. However, increasing living standards are obviously characteristic especially of more advanced economies, and thus another parameter, technological progress, is needed to account for this.

I have discussed the Solow model in some detail because once the basic framework is in place, the model can then be easily extended.

To incorporate technological progress, let the production function take the form

$$Y = F(AL,K)$$

where A represents technological progress which is assumed to grow at a constant rate g so that

$$A = A(0)e^{gt}.$$

In order to see the dynamics of the model, the capital-technology ratio can be defined as

$$k = K/AL$$

and the output-technology ratio is thus given by

$$y = f(k).$$

Just as in the basic Solow model without technical progress, the change in the capital stock per effective worker can now be represented by

$$\dot{k} = sf(k) - (n+g+\delta)k.$$

The model once again predicts that the economy will approach a stable steady state equilibrium level of *k.* At this point, just enough capital is accumulated to account for an increasing labor force, depreciation of capital, and technological progress. There is one important difference between this model and the basic Solow model without technical progress however. Capital per person in steady state is now given by

$$k = Ak^*$$

and per capita output is

$$y = Ay^*.$$

It follows that the growth rate of per capita output and capital is given by

$$y'^*/y^* = k'^*/k = A'/A = g$$

Therefore, capital and output per person are no longer constant in the steady state but grow at the constant rate of technological progress g. The model now shows that given technical progress it is possible for living standards to increase continually. It also still predicts that economies will approach a steady state ratio of per capita capital, determined by its production function, savings rate, labor force growth rate, and now also its rate of technological progress.

Even incorporating technical progress in the model is, of course, not entirely realistic. The savings rate, for example, is likely to vary with per capita income, as is the growth rate of the population, and thus the labor force. It is quite possible to extend the model to integrate these variables without losing stability. In addition, the model will continue to predict a steady state. As a matter of fact, the model can be extended rather considerably, and the dynamics will remain the same.

The robustness of the Solow model is part of the reason why it has survived more or less intact for such a long time, and why I have spent so much time reviewing it here. Because of this property and its versatility, it provides an incredibly useful framework for thinking about almost kinds of variables and their effects on economic growth, directly or indirectly.

Human Capital and Economic Growth

Technological progress is clearly incredibly important for a nation. While it is possible for an economy to grow without it, technological progress enables the economy to grow enough not only to keep living standards constant but to grow at a rate that will continually increase the living standards of its citizens.

The basic Solow model takes technical progress as an exogenous variable that is assumed to grow at some constant rate. While it shows the importance of technological progress, it does nothing to shed light on how this progress may be accomplished in the first place or how its rate may be influenced which is obviously of interest to policy makers looking to increase their nations' growth rates and levels of development.

Human capital has been studied quite extensively in this context as it is necessarily closely linked to technological progress. By definition, human capital is " … embodied skills and knowledge, and because advances in technical knowledge drive economic growth, it follows that human capital accumulation and economic growth are intimately related" (Topel 1999).

While it is certainly possible to add human capital to the Solow growth model, and I will show how this is done, several new growth models have been developed that incorporate human capital as an endogenous variable. The basic difference between these two approaches is that endogenous models allow for increasing returns and thus per capita output can possibly increase at a rate that is increasing over time (Romer 1986). The neoclassical model, on the other hand, sticks to its basic premise of diminishing returns and the dynamics of the model therefore remain the same. This difference yields important results concerning the prediction of how nations will develop over time, i.e. whether economies will converge in the long run.

Human capital can be incorporated into Solow model very cleanly with few modifications to the basic model. The primary difference is that labor is replaced by a variable measuring efficiency units. This variable, denoted by the capital letter E, modifies the labor variable and is assumed to grow at a constant rate ρ. It can be represented as

$$E = e^{\rho t}L.$$

Replacing labor in the production function by E, output is now given by

$$Y = F(E,K).$$

The process for examining the dynamics of the model is now similar to the one in the basic Solow model with the exception that output and capital will not be studied on a per capita basis but per efficiency unit. This is simple enough to do and provides very clear results of the influence of this modified labor variable. One additional step will be necessary at the end which converts output and capital per efficiency unit to output and capital per person because this is what is ultimately of interest.

Given the detailed derivation of the basic Solow model earlier, it is not necessary to go through the whole process again, and the consequence of the modification should be fairly obvious: the economy will approach a steady state where output per person will grow at rate ρ. Thus an increase in efficiency which is assumed to occur through greater education raises output and therefore income per worker.

One drawback of representing an increasingly efficient labor force this way is that labor is assumed to be homogenous so that an uneducated worker is in effect worth some fraction of an educated worker which is obviously not entirely true (Meier and Rauch 2000). As before, the neoclassical model also neglects to explain how these efficient workers and knowledge in general are created. The rate at which efficiency units grow is taken as exogenous.

Early endogenous growth theory took a somewhat different approach at explaining long-run sustainable growth. The basic idea was that continuously increasing living standards could be achieved by countering decreasing returns by defining capital broadly to include human capital which may possibly exhibit increasing returns. Without decreasing returns to capital, returns to investment remain the same, and as long as investment is greater than the amount of capital needed to replace depreciated capital, the economy grows forever. While increases in the savings rate in the Solow model can increase the growth rate of an economy temporarily, the long-run growth rate will always be determined by exogenous technological progress. In this model, increases in savings can lead to an indefinitely higher growth rate.

Endogenous growth theory has developed far beyond this model, and there is now an array of models. It would take too much time to review each variation. A simplified and very brief example of the Lucas model may be sufficient here to illustrate the direction of this line of research.

The Lucas model (1988) modifies the production function by adding human capital per person, denoted by h, as follows:

$$Y = F(K,hL).$$

Human capital is assumed to develop according to

$$h' = (1-u)h$$

where each worker spends the fraction of time u on current production, and 1 – u on acquiring new skills. There are no diminishing returns to the stock of human capital. An increase in h will not lead to a smaller increase in human capital once a certain level of h is reached. The growth rate of human capital is given by

$$h'/h = 1 - u$$

which depends only on u, not on the stock of h. Thus there are constant returns to human capital. It follows that devoting a larger fraction of time to acquiring new skills permanently increases the economy's growth rate.

The literature on endogenous growth models is rather large and includes theoretical models that integrate technology spillovers, consumer preferences, optimal allocation of time spent on acquiring human capital, technology diffusion, research and development, and the role of institutions to name a few. For the purposes of this paper, the review of theoretical growth models thus far should be sufficient for two reasons: first, my primary goal is to demonstrate the importance of human capital and thus education on the growth rate of per capita output. The models illustrated in greater or lesser detail here clearly confirm the significance of human capital. Secondly, while some endogenous growth models are much more exhaustive in their explanations of technological progress, the Solow model extended to include accumulation of human capital, variable population growth rates, government policies, and technology diffusion is very useful for examining cross-country data. As Robert Barro (1996) points out,

> Theories of basic technological change are most important for understanding why the world as a whole-and, more specifically, the economies at the technological frontier–can grow in the long run. But these theories have less to do with the determination of relative rates of growth across economies; that is, with the relations studied in cross-country or cross–region statistical analyses. It is surely an irony that one of the lasting contributions of endogenous growth theory is that it stimulated empirical work that demonstrated the explanatory power of the neoclassical growth model.

2. Empirical Findings

Basic Framework

The basic framework for testing theoretical growth models often follows the neoclassical theory by assuming that the growth rate of output per person is a function of initial and steady state per capita output. The Solow model predicts convergence, that is, lower initial per capita output, *y*, relative to steady state per capita output, *y**, will result in a higher growth rate during the transition period. Cross-country regressions support the premise of convergence provided that convergence is conditional.

Unlike absolute convergence, which assumes that *y** is identical across all countries, conditional convergence allows for *y** to differ across countries. These differences may depend on a variety of choice and environmental factors such as political choices including government consumption and investment, rule of law, market distortions, and political freedom, private sector choices such as labor market participation rates, savings rates, and fertility rates as well as environmental variables such as terms of trade (Barro 1996).

A country's growth rate is expected to be higher if its initial level of y is far below its steady state level of *y** and lower if the initial level of y is close to *y**. An increase in *y** through changes in the environmental or choice variables will thus lead to a higher growth rate in the transition period. As per capita output rises, the gap between *y* and *y** closes and growth rates will decrease to the rate determined by technological progress. As Barro (1996) points out, however, these transition periods are rather lengthy so that growth-enhancing policy changes may effect the economy's growth rate for an extended period of time.

An important consequence of the concept of conditional, rather than absolute convergence is that lower initial output in itself does not imply higher growth rates. Countries with low initial per capita output are not necessarily far below their steady state output and should therefore not inevitably be expected to exhibit faster economic growth than richer nations. Differences in steady state per capita output thus explain why initial output in cross-country regressions is usually found to be uncorrelated with economic growth.

Methodology and data

Following the research of Barro (1996) and others, I estimate models of the form

$$\mathrm{D}Y_{i,t} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 X_{i,t} + \beta_3 H_{i,t} + \varepsilon$$

where D*Y* is the growth rate of per capita output, *Y* is the log of initial per capita income, *X* consists of various choice and environmental control variables, and *H* contains human capital measures including schooling variables. The subscripts i and t denote country and time, respectively.

The primary difference between the model I am using and Barro's lies in the choice of schooling measures in *H*. While Barro uses average secondary and higher years of schooling in the male population to examine the overall effect of education on economic growth, the goal of this paper is to explore whether primary, secondary, and higher levels of schooling affect growth differently. Thus the schooling variables I use are average years of primary, secondary, and higher schooling in the total population above age 25.

Data for choice and environmental variables are obtained from the revised Barro-Lee data set (1993) while the data on schooling variables are taken from the updated Barro-Lee data set (2000). The panel contains data on roughly 130 countries. Data on schooling is available quinquennially from 1960 to 1990, while data on choice and environmental variables is presented either as averages over 5-year periods or observed in 5-year intervals over the period 1960 to 1989 or 1990, when available. Estimation is by ordinary least squares with White's standard error correction method.

Findings

Table 1 shows the regression results from the model described above. The dependent variable is the growth rate of real per capita GDP over 5-year periods beginning in 1960-1965 and ending in 1985-1990. The log of real per capita GDP at the beginning of each 5-year period is used to measure the rate of conditional convergence, following the example of Barro (1996) and others. I will refer to real per capita GDP as GDP only from here on.

Choice and environmental variables include the government consumption ratio, investment ratio, terms of trade change, political assassinations per million, the black market premium and the log of the fertility rate. Human capital measures include the log of life expectancy at age 0 and average years of primary, secondary and higher schooling in the total population above age 25. Column (5) and (6) additionally contain the interaction of initial GDP and the schooling variables. Columns (3) through (6) also include regional dummy variables for Africa, Latin America, and East Asia.

Initial GDP

As mentioned above, the neoclassical model predicts conditional convergence, i.e. that countries with lower initial GDP relative to their steady state GDP will exhibit faster growth rates. This implies a negative coefficient on the initial level of GDP. The coefficient can be interpreted at the conditional rate of convergence and its magnitude indicates the rate at which the economy approaches its steady state GDP (Barro 1996). As expected, the estimated coefficient on initial GDP is negative and highly significant, and the results hold in a variety of specifications. As shown in table 1, the magnitude of the coefficient varies between 0.0202 (s.e. 0.0046) and 0.0233 (s.e. 0.0553) which is slightly lower than Barro's result of 0.025. As Barro (1996) notes, the rate of convergence is slow, just slightly above 2% per year which implies it would take a country 30 years to get half-way to its steady state income, but this finding is consistent with convergence rates found for regional data.

Choice and Environmental Variables

I include a variety of choice and environmental variables that are believed to affect economic growth. Investment is predicted to be positively related to growth by the Solow model, and the regressions confirm this prediction. Investment enters the regression as the public and private investment ratio to GDP and the estimated coefficient is positive and highly significant, ranging from 0.1132 (s.e. 0.0222) to 0.1256 (s.e. 0.0226).

Government consumption is measured as the ratio of government consumption to GDP net of defense and education spending. Constructed by Barro and Lee (1993), the variable is designed to measure nonproductive government spending (Barro 1996). The estimated coefficient varies between –0.1005 (s.e. 0.0311) and 0.0856 (s.e. 0.0293). It is consistently highly significant and negatively related to growth.

The change in a country's terms of trade, that is the change in the price of its exports relative to its imports, is considered especially important to less developed economies which presumably specialize in exporting a few primary products. Improvements in a country's terms of trade allow it to purchase more imports for the same amount of exports and thus such changes can have tremendous welfare implications (Debaere and Lee 2001). The estimated coefficient on the change in terms of trade is highly significant and positive: between 0.0709 (s.e. 0.0266) and 0.0996 (s.e. 0.0286). An improvement in terms of trade is therefore appears to be positively related to economic growth.

To control for political instability, a measure of political assassinations, which is measured as averages per million, is included which Easterly and Levine (1997) and Barro (1989) found to be inversely related to economic growth. Barro (1989) interprets this variable as having a negative influence on property rights and consequently on growth. The estimated coefficient on assassinations in table 1 is highly significant and negative as expected, ranging from –0.0476 (s.e. 0.0120) to -0.0467 (s.e. 0.0123).

The black market premium is generally used as an indicator or exchange rate, trade, and price distortions and has been found to be negatively related to economic growth in previous studies (see Easterly and Levine 1997 and Fisher 1993, for example). The black market premium, averaged over 5-year periods, has a significantly positive estimated coefficient between –0.0072 (s.e. 0.0026) and –0.0068 (s.e. 0.0027).

The neoclassical model predicts a negative effect of the fertility rate on economic growth as investment must be used to supply new workers with capital rather than raise each the amount of capital per worker which would increase the economy's steady state GDP and thus lead to higher growth rates during the transition period. Additionally, as Barro (1996) points out, higher fertility rates imply that more resources are used for child-rearing rather than the production of new goods. Empirical findings generally support the negative correlation between the fertility rate and economic growth. Surprisingly, the regressions in table 1 do now show a significant effect of fertility rate on growth.

Human capital

Several human capital measures are included in the regressions shown in table 1 and 2. The log of life expectancy, average years of primary, secondary and higher schooling, and the interaction between initial GDP and schooling measures. In table 2 schooling variables are further separated by gender to examine the effects of male and female schooling on economic growth at various levels.

Life expectancy is often used as a general indicator of health status where higher life expectancy is expected to interact positively with economic growth. The regressions in table 1 and 2 show that life expectancy is significantly positive with an estimated coefficient between 0.0517 (0.0214) and 0.0570 (s.e. 0.0219) except in columns (1) and (2) of table 1 where life expectancy is not significantly different from zero.

Table 1 contains regressions using average years of primary, secondary and higher schooling in the total population to examine the effects of each level of schooling. Education in general is expected to be positively related to economic growth as it builds human capital. In less developed countries, more education is believed to assist countries in better adopting existing technology from developed nations and thus aid their development. It is, however, not clear whether primary, secondary or higher schooling is expected to be more important.

Primary and Secondary Schooling

Table 1 shows all three schooling variables mentioned above in a variety of specifications. Average years of secondary schooling in the total population is significantly positive in every regression except column (4) with the estimated coefficient ranging from 0.0046 (s.e. 0.0028) to 0.0073 (0.0026). The preferred specification in column (3) shows a coefficient on 0.0071 (s.e. 0.0025). Thus, an extra year of secondary schooling is expected to raise the growth rate by a quite substantial 0.71% a year. For Bolivia, for example, over the period from 1965 to 1990 an additional year of secondary schooling would have increased its per capita GDP in 1990 by almost 21% from $1,596 to $1,927.

For developing countries, adaptation and diffusion of existing technology invented in advanced nations is believed to be a key factor in economic growth, and secondary education may be especially important in this process. While existing technology is theoretically available to less developed nations, the technology and income gaps between developing and advanced economies remain and in some cases have increased. Lee (2000) finds that secondary schooling and, to a lesser extent, higher education is highly correlated with the adoption of new technology and concludes that the accessibility of new technology alone is not enough in order to bridge the gap between developing and advanced nations. The availability of secondary education is less developed countries is instrumental in building the human capital necessary to adopt this technology.

Primary schooling is not significantly different from 0 in any of the models in table 1 with an estimated coefficient varying from –0.0003 (s.e. 0.0012) to 0.0011 (s.e. 0.0013). Primary schooling thus does not predict growth directly. However, as it is a prerequisite for secondary education, primary schooling does improve growth indirectly and should therefore be considered quite important.

Higher Education

Surprisingly, higher education consistently enters each regression in table 1 except column (5) with a highly significant negative coefficient ranging from –0.0409 (s.e. 0.0139) to –0.0335 (s.e. 0.0133). The interpretation of this negative coefficient is ambiguous. On one hand, diminishing returns may be to blame, and microeconomic studies support this interpretation but only to a certain extent. Psacharopolous (2002), for example, finds that social returns to education are lowest at the university level which is likely to due to the larger cost of higher education. However, public returns are nevertheless positive which should translate into a positive effect on the macro level as well.

Another explanation is offered by Topel (1999) who asserts that negative coefficients on schooling variables may in fact be consistent with the conditional convergence theory: a country with lower initial levels of schooling may have a greater opportunity to grow. Schooling would then be inversely related to growth and the estimated coefficient negative.

Barro’s (1996) findings support the idea that education increases the rate of conditional convergence. He concludes that the interaction between initial GDP and male secondary and higher schooling raises the rate of convergence by 0.62% to 3.2%. Column (5) of table 1 includes the interaction terms between initial GDP and primary, secondary, and higher schooling. Somewhat surprisingly, none of the schooling measures except secondary schooling nor interactions terms are significantly different from zero.

Column (6) of table 1 replaces average year of higher schooling with the interaction between initial GDP and higher schooling. The interaction term is highly significant and negative with an estimated coefficient of –0.0039 (s.e. 0.0015). The implication is that higher schooling raises the rate of conditional convergence from 2.2% to 2.59%. This increase implies a reduction of approximately 4 years in the amount of time it would take a country to get half-way to its steady state, from 30 years to 26 years. Thus, there may be some evidence that higher education provides a country with a greater opportunity to grow perhaps by aiding in the adaptation of new technologies.

Male and Female Schooling

Barro (1996) finds that female schooling at various levels is not significantly related to economic growth. This result are rather surprising especially since he finds that it is robust to the exclusion of the fertility rate and life expectancy. It is generally believed that at the very least female schooling has a significantly negative effect on fertility rates and positive effect on life expectancy and health in general and thus an overall positive effect on economic growth.

Table 2 shows the results of the regression of table 1, column (3), with average years of primary, secondary, and higher education separated by gender. Choice and environmental variables as well as initial GDP show similar estimated coefficients as before and all remain highly significant with the exception of fertility rate which continues to be insignificant.

Column (1) includes all levels of schooling for males and females with some rather surprising results. Male primary schooling is highly significant and negative with an estimated coefficient of –0.0102 (s.e. 0.0039). The estimated coefficient on male secondary schooling is also very significant but positive: 0.0172 (s.e. 0.0055). Average years of higher schooling for males is insignificant.

Female primary schooling shows a highly significant positive estimated coefficient of 0.0117 (s.e. 0.0040) while female secondary schooling has a significant negative coefficient of –0.0137 (s.e. 0.0064). The estimated coefficient for average years of female higher schooling is highly significant and negative: -0.0428 (s.e. 0.0216).

The schooling measures used in column (2) include only average years of male primary, secondary, and higher schooling. The estimated coefficient on male secondary schooling remains highly significant and positive: 0.0056 (s.e. 0.0021). Primary male schooling is no longer significantly different from zero while higher schooling is significantly negative with an estimated coefficient of –0.0183 (s.e. 0.0105).

Column (3) shows the same regression including only average years of female primary, secondary, and higher schooling. The results are similar to those found in column (2) which only use male levels of schooling. Female primary schooling is positive but no longer significant while female secondary schooling is significantly positive with an estimated coefficient of 0.0064 (s.e. 0.0026). Higher schooling remains significantly negative for females with a much larger estimate coefficient than found for male higher schooling: -0.0453 (s.e. 0.0149). Using a Wald test, the hypothesis that female schooling is jointly insignificantly different from zero is rejected at the 1% level. These findings show that female schooling does appear to be significant in explaining economic growth and thus differ from Barro's (1996) results that female education has no explanatory power in growth regressions.

Combining the estimated coefficients of male and female schooling measures in column (1) results in findings similar to the ones estimated in table 1. The coefficient on primary schooling becomes positive with a magnitude of 0.0015 which is slightly larger than the estimated coefficient on primary education in the total population. The hypothesis that the estimated coefficients are jointly zero is rejected by a Wald test at the 2% level of significance. The positive estimated coefficient also dominates for secondary schooling, making the combined coefficient positive with a magnitude of 0.0035 which is only about half as large as the coefficient on secondary schooling estimated in table 1, however. Higher schooling remains negative with a coefficient of –0.0317 which is very similar to the estimated coefficient found in table 1.

The results of the regressions with schooling measures separated by gender are quite difficult to interpret. It appears that secondary schooling remains an important factor for economic growth despite the negative estimated coefficient on female secondary schooling in column (1). The combined effect of male and female secondary schooling continues to be positive, and when male and female schooling measures are examined separately, secondary schooling is significantly positive in both cases as well.

Primary schooling seems to continue to have a small to insignificant overall effect on growth. The relatively large positive estimated coefficient on primary female schooling may indicate that gains from educating females at the primary level are significant for growth beyond the effect on fertility and life expectancy which are held constant. However, when female schooling is examined separately, primary education becomes insignificant while secondary schooling becomes a significant positive factor in determining the growth rate. Female education does, however, appear to have an effect on economic growth that goes beyond improvements on health measures or population growth.

The findings on higher schooling for both male and female schooling remain similar to those found on higher schooling in the total population: the estimated coefficients are consistently significant and negative. As it seems improbable that higher education has a large negative effect on economic growth in addition to the result found in table 1 of the estimated negative coefficient on the interaction term between initial GDP and higher schooling, the interpretation expressed by Topel (1999) that a negative coefficient on education is consistent with convergence theory may be correct.

3. Conclusion

Building human capital is believed to be a necessary ingredient for successful economic growth in advanced and developing nations alike. Microeconomic studies consistently show large positive returns to education which assign schooling an important role in income growth on the country level as well. Cross country studies often do not reflect microeconomic findings accurately, however, such as the apparent lack of positive correlation between primary schooling and economic growth which is found to be largest in microeconomic research (see, for example, Psacharopolous 2000). Additionally the interpretation of estimated schooling coefficients is sometimes ambiguous. As Topel (1999) points out, a negative coefficient on schooling may well reflect a country's larger opportunity to grow.

Keeping these difficulties in mind, I consistently find that secondary schooling has a relatively large positive effect on economic growth and thus appears to be an important factor in determining a nation's income growth. Secondary education in particular may be most strongly related to the adoption and diffusion of available technology, a factor that is believed to be of great importance for the success of developing countries.

Similar to the results of other cross-country research, I do not find primary education to be significantly related to economic growth. However, while the effect of primary schooling may not be evident here, its importance as a prerequisite for the highly growth-enhancing secondary education should not be overlooked. While higher education is strongly associated with economic growth, the estimated coefficient is consistently negative which is rather surprising. It is possible, however, that this finding indicates a nation's greater opportunity to grow and thus increases the rate of conditional convergence. This interpretation is supported by the highly significant interaction term between initial income and higher schooling.

The regression results which separate male and female schooling are quite difficult to interpret. Overall secondary schooling remains an important factor in explaining growth. While Barro (1996) finds female education to be unrelated to economic growth, these results do not hold here. Female education shows a clear positive association with growth even when fertility rates and life expectancy are held constant. Education of girls is generally believed to be positively related to growth through its effect on fertility rates, life expectancy, and other health measures. The findings here suggest that the impact of female schooling goes beyond these indirect effects. Thus, female education should not be neglected as it apparently has a significant positive influence on economic growth.

Education clearly has an essential effect on income growth. It may be most important to increase the quantity secondary schooling which necessitates that primary schooling must be made available as well. This may be especially important for developing nations where human capital is needed in order to bridge the technology and income gap between advanced and less developed countries.

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Table 1: Regressions for Growth Rate of real per capita GDP

Independent Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Investment ratio	0.1265***	0.1334***	0.1134***	0.1191***	0.1132***	0.1133***
	(0.0226)	(0.0214)	(0.0219)	(0.0217)	(0.0222)	(0.0219)
Log of initial income		-0.0202***	-0.0223***	-0.0233***	-0.0231***	-0.0220***
		(0.0046)	(0.0053)	(0.0053)	(0.0089)	(0.0053)
Government consumption ratio	-0.0856***	-0.1005***	-0.0973***	-0.0914***	-0.0968***	-0.0984***
	(0.0293)	(0.0311)	(0.0325)	(0.0325)	(0.0320)	(0.0325)
Terms of trade change	0.0829***	0.0996***	0.0745***	0.0776***	0.0709***	0.0751***
	(0.0296)	(0.0286)	(0.0262)	(0.0262)	(0.0266)	(0.0261)
Log of life expectancy	-0.0134	0.0245	0.0519**	0.0570***	0.0567*	0.0499**
	(0.0167)	(0.0190)	(0.0220)	(0.0219)	(0.0308)	(0.0220)
Log of fertility rate	0.0044	-0.0064	0.0018	-0.0010	0.0035	0.0013
	(0.0056)	(0.0060)	(0.0063)	(0.0062)	(0.0069)	(0.0063)
Assassinations per million (averages)			-0.0474***	-0.0476***	-0.0467***	-0.0475***
			(0.0121)	(0.0120)	(0.0123)	(0.0121)
Black market premium			-0.0070***	-0.0068**	-0.0072***	-0.0070***
			(0.0027)	(0.0027)	(0.0026)	(0.0027)
Average years of primary schooling	-0.0002	0.0009	0.0011	-0.0003	-0.0089	0.0011
	(0.0014)	(0.0013)	(0.0013)	(0.0012)	(0.0204)	(0.0013)
Average years of secondary schooling	0.0046*	0.0073***	0.0071***	0.0021	0.0533*	0.0071***
	(0.0028)	(0.0026)	(0.0025)	(0.0016)	(0.0319)	(0.0025)
Average years of higher schooling	-0.0409***	-0.0335**	-0.0360***		-0.2095	
	(0.0139)	(0.0133)	(0.0136)		(0.1747)	
Log initial GDP*avg. years of prim. schooling					0.0011	
					(0.0023)	
Log initial GDP *avg. years of sec. schooling					-0.0053	
					(0.0036)	
Log initial GDP *avg. years of higher schooling					0.0201	-0.0039***
					(0.0195)	(0.0015)
Dummy for Africa			-0.0061	-0.0062	-0.0064	-0.0059
			(0.0050)	(0.0050)	(0.0050)	(0.0050)
Dummy for Latin America			-0.0087*	-0.0085	-0.0082	-0.0090**
			(0.0045)	(0.0046)	(0.0052)	(0.0045)
Dummy for East Asia			0.0049	0.0049*	0.0068	0.0045
			(0.0051)	(0.0053)	(0.0054)	(0.0051)
constant	0.0561	0.0667	-0.0321	-0.0397	-0.0471	-0.0259
	(0.0711)	(0.0710)	(0.0830)	(0.0836)	(0.0894)	(0.0829)
F	11.69	13.74	13.34	12.74	11.74	13.37
R^2	0.1731	0.2280	0.3605	0.3491	0.3649	0.3596
Obs	405	405	374	374	374	374

*significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.

Standard errors in parentheses.

Table 2: Regressions for Growth Rate of real per capita GDP

Independent Variable	*(1)*	*(2)*	*(3)*
Investment ratio	0.1136***	0.1188***	0.1085***
	(0.0215)	(0.0217)	(0.0218)
Log of initial income	-0.0238***	-0.0221***	-0.0226***
	(0.0052)	(0.0052)	(0.0053)
Government consumption ratio	-0.0964***	-0.0948***	-0.0935***
	(0.0319)	(0.0329)	(0.0332)
Terms of trade change	0.0751***	0.0756***	0.0759***
	(0.0282)	(0.0279)	(0.0280)
Log of life expectancy	0.0517**	0.0546**	0.0528**
	(0.0214)	(0.0222)	(0.0220)
Log of fertility	0.0060	0.0003	0.0021
	(0.0061)	(0.0065)	(0.0060)
Assassinations per million (averages)	-0.0476***	-0.0471***	-0.0481***
	(0.0119)	(0.0122)	(0.0120)
Black market premium	-0.0070***	-0.0070***	-0.0069**
	(0.0024)	(0.0026)	(0.0027)
Average years of male primary schooling	-0.0102***	-0.0003	
	(0.0039)	(0.0013)	
Average years of male secondary schooling	0.0172***	0.0056***	
	(0.0055)	(0.0021)	
Average years of male higher schooling	0.0111	-0.0183*	
	(0.0156)	(0.0105)	
Average years of female primary schooling	0.0117***		0.0018
	(0.0040)		(0.0013)
Average years of female secondary schooling	-0.0137**		0.0064**
	(0.0064)		(0.0026)
Average years of female higher schooling	-0.0428**		-0.0453***
	(0.0216)		(0.0149)
Dummy for Africa	-0.0040	-0.0063	-0.0060
	(0.0049)	(0.0049)	(0.0050)
Dummy for Latin America	-0.0074*	-0.0083*	-0.0091**
	(0.0044)	(0.0045)	(0.0045)
Dummy for Asia	0.0072	0.0047	0.0059
	(0.0053)	(0.0052)	(0.0050)
constant	-0.0253	-0.0407	-0.0334
	(0.0813)	(0.0824)	(0.0847)
F	12.07	13.07	13.38
R^2	0.3893	0.3564	0.3633
Observations	373	373	373

*significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.

Standard errors in parentheses.

Descriptive Statistics

Variable	Mean	Standard Deviation
Growth rate of real per capita GDP	0.0189	0.0336
Investment ratio	0.1788	0.0962
Log of real per capita GDP	7.6744	1.0295
Consumption ratio	0.1014	0.0725
Terms of Trade change	-0.0009	0.0633
Log of life expectancy	4.0245	0.2177
Log of fertility	1.5252	0.4748
Assassinations per million (averages)	0.0288	0.1238
Black market premium	0.4398	1.1637
Average years of primary schooling	3.1516	2.0542
Average years of secondary schooling	0.9269	0.8716
Average years of higher schooling	0.1519	0.1788
Average years of male primary schooling	3.4587	1.9869
Average years of male secondary schooling	1.0773	0.9306
Average years of male higher schooling	0.1981	0.2154
Average years of female primary schooling	2.8566	2.1719
Average years of female secondary schooling	0.7807	0.8464
Average years of female higher schooling	0.1081	0.1522
Dummy for Africa	0.3273	0.4694
Dummy for Latin America	0.0836	0.2768
Dummy for East Asia	0.0766	0.2661