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ABSTRACT

We use cross-country estimates of physical and human capital accumulation to run the growth accounting regressions implied by an aggregate production function based upon a Cobb-Douglas technology in which human capital enters as a factor of production. Our results indicate that human capital either enters insignificantly in explaining per capita growth rates, or with the incorrect sign.

We next entertain alternative roles for human capital in economic growth. We specify a growth model in which the Solow residual, or the growth rate of total factor productivity, depends on a nation's human capital stock. Tests of the specification implied by this model do indeed indicate a positive role for human capital, as well as a negative role for economic distortions. In addition, we examine the determinants of physical capital accumulation, which plays an important role in determining growth rates. Our results suggest that the presence of human capital increases the investment in physical capital, while political instabilities may deter it.

1. Introduction

The recent growth accounting literature [for example, see Barro (1991)] has concentrated on estimation of aggregate production functions to investigate the determinants of economic growth. Typically, the methodology followed in this literature entails regressing per capita income growth on a set of ancillary variables in an effort to determine the characteristics which are thought to contribute positively or adversely to economic growth. In addition, these studies have attempted to estimate the contribution of factors of production to economic growth once one has properly accounted for differences in country characteristics through introduction of these ancillary variables.

Because of data constraints, the literature has often attempted to proxy the variables relevant to growth accounting by those which are directly observable. For example, although physical capital stocks are necessary to estimate the growth accounting equations, the literature has usually used gross investment rates as a proxy for physical capital accumulation [Barro (1991)].[1] In addition, human capital has been proxied in the literature by enrollment ratios or literacy rates. At best, however, enrollment ratios represent investment levels in human capital. Literacy is a stock variable, but there are important empirical problems associated

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[1] An exception is the work of Mankiw, Romer and Weil (1992). In their study, they are able to generate a specification in terms of investment rates by assuming that all countries are in their steady state.

with the use of literacy as a proxy for human capital.[2]

This paper continues work by Benhabib and Spiegel [BS (1992)] in which estimates of physical and human capital stocks are used in growth accounting equations. We begin with estimation of a standard Cobb-Douglas production function in which labor and human and physical capital enter as factors of production. In the context of this estimation, we also examine the impact of two ancillary variables which indicate the severity of political conflict and distortionary economic policy, as well as the role played by initial levels of per capita income.

One of our main findings concerns the role of human capital in explaining the growth of per capita income. In our first set of results, we find that human capital growth is either insignificant, or has a significant but negative effect in explaining per-capita income growth. This result is robust to a number of alternative specifications, as well as to the possibility of bias which is encountered when regressing per capita income growth on accumulated factors of production.[3]

This findings shed some doubt on the traditional role given to human capital in the development process as a separate factor of production. Nevertheless, human capital accumulation has long been stressed as a pre-requisite for economic growth. In the remainder of the paper, we

[2] These include quality of measurement differences across countries, biases introduced by the skewness of sampling towards urban areas, and the fact developed countries typically have literacy rate which are close to unity.

[3] See section 2 and appendix.

examine alternative specifications that allow human capital to play a role in the development process and in the determination of per capita income growth.

First, it may be that standard growth accounting equations misspecify the role played by human capital. Below, we introduce an alternative model which allows human capital levels to directly affect aggregate factor productivity through two channels: Following Romer (1990), we postulate that human capital may directly influence productivity by determining the capacity of nations to innovate new technologies suited to domestic production. Furthermore, we adapt the Nelson and Phelps (1966) model to allow human capital levels to affect the speed of technological catch-up and diffusion. We assume that the ability of a nation to adopt and implement new technology from abroad is a function of its domestic human capital stock. In our model, at every point in time there exists some country which is the world leader in technology. The speed with which nations "catch-up" to this leader country is then a function of their human capital stocks.

The combination of these two forces, domestic innovation and catch-up, produces some noteworthy results: First, under certain conditions, in particular when the innovation parameter dominates, growth rates may differ across countries for a long time due to differences in levels of human capital stocks. Second, a country which lies below the "leader nation" in technology, but possesses a higher human capital stock, will catch up and overtake the leader in a finite time period. Third, the country with the highest stock of human capital will always eventually emerge as the technological leader nation in finite time and maintain its leadership as long as its human capital advantage is sustained.

We test the specification indicated by this alternative model below. In particular, our model assigns a positive role to the levels of human capital in growth accounting. Our results below confirm that per capita income growth indeed depends positively upon average levels of human capital, although not always measurably at a five percent confidence level. In addition, our results also indicate that distortionary economic policy hinders economic growth, although indices of political instability fail to enter directly in the determination of per capita income growth rates.

Second, although the growth of human capital may not be significant in explaining relative growth rates on its own, the levels of aggregate human capital may act as an engine for attracting factors, such as physical capital, which do contribute measurably to per capita income growth. Lucas (1990) suggested that physical capital fails to flow to poor countries because of their relatively poor endowments of complementary human capital. Below, we investigate this relationship by examining the determinants of cross sectional gross investment rates as a share of the capital stock. In addition, we find that political instability and exchange rate overvaluation have an influence on investment rates, particularly when one omits the highly collinear human capital variable.

Our results indicate that levels of human capital play an important role in attracting physical capital. In addition the ancillary variables, namely political instability and distortionary price policies, are found to measurably inhibit physical capital accumulation, although not always measurably at the five percent confidence level.

The following section introduces the methodology used in the standard growth accounting regressions and provides an overview of the generation of the physical and human capital stock variables. Section 3 then introduces the alternative theoretical model in which human capital plays a role in determining productivity, rather than entering on its own as a factor of production. Section 4 empirically tests this alternative specification, including the robustness of the results to the inclusion of the ancillary variables. Section 5 then investigates empirically the relationship between human capital stocks and physical capital accumulation rates. Section 6 concludes.

2. Growth Accounting with Human Capital as a Factor of Production

2.1 Methodology and Data

The standard growth accounting methodology with human capital specifies an aggregate production function in which per capita income, Y, is dependent upon three input factors: Labor, L, physical capital, K, human capital, H, and a technology factor, A. Assuming a Cobb-Douglas technology, $Y=AK^{\alpha}L^{\beta}H^{\gamma}$, and taking logs, this production function can be approximated in growth terms as:

(1) $\Gamma Y = \Gamma A + \alpha\ \Gamma K + \beta\ \Gamma L + \gamma\ \Gamma H + \epsilon$

where ΓX represents the growth rate of X, $\Gamma X=(X_T-X_0)/X_0$.

A difficulty associated with estimating aggregate production functions such as equation (1) concerns the possibility that because physical and human capital are accumulated factors, they will be correlated with the error term ϵ. This would imply the possibility of biased estimates. In the appendix, we attempt to assess the size of the bias using a bootstrap procedure. The results suggest that a coefficient bias, if one exists, is likely to be positive, so that one would tend to overestimate the dependence of per capita income growth on physical and human capital accumulation.

Estimation of equation (1) in the standard growth accounting framework entails assuming that the growth of A is identical across countries and regressing per capita income growth on rates of factor accumulation in order to estimate the magnitudes of α, β, and γ. In addition, a number of "ancillary variables" are commonly introduced to adjust for productivity differences, such as proxies for political instability and distortionary activity.

In practice, data for physical and human capital stocks are not available for large cross-country samples. However, BS (1992) provide physical capital stock estimates using the flow data from the Summers-Heston [SH (1991)] data set, and estimating initial physical capital stocks by positing that a fixed-point relationship exists in logs between the capital-output ratio of a nation and its capital-labor ratio. The methodology used in the generation of these data sets as well as the generated data used in the regression analysis is reported in appendix of this text.

In addition, human capital stock estimates have been constructed by Kyriacou (1991). Kyriacou estimates human capital stocks by first estimating the relationship between the educational attainment of the labor force from 1974 through 1977, which is available for 42 countries, and past values of human capital investment, such as enrollment in primary, secondary, and tertiary education. His methodology used in the construction of the data used in this study is also described in greater detail in the appendix.

Per capita income and population growth data are acquired from the SH (1991) data set. In addition, we add ancillary variables to incorporate cross-country differences in political stability and the severity of distortionary activity.

As in BS (1992), we use the Gupta (1990) index of political instability. Gupta uses discriminant analysis to measure the influence of ten explanatory variables on incidents of political violence. The variables considered by Gupta include the number of political demonstrations, the number of riots, the number of strikes, the number of deaths from political violence, the number of assassinations, the number of armed attack events, the number of political executions, the occurrences of successful coups d'etat, the occurrence of unsuccessful coups d'etat and the nature of government.[4]

To proxy for distortionary activity, we examine the degree of exchange rate overvaluation of a country as measured by Dollar (1990). Dollar measures the degree to which countries have an over-valued real exchange rate in 1975, correcting for the Balassa effect, that is the tendency of non-tradables to command higher prices in the richer and developed nations. He accounts for this effect by first examining the relationship between price levels and incomes across countries, and then measuring the degree of divergence of a country's real exchange rate from that of the United States which is unexplained by the Balassa effect.

In theory it is possible for distortionary prices to increase growth rates by inducing higher levels of savings and investment. On the other hand distortions, in particular exchange rate overvaluation, may signal

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[4]See BS (1992) for a critical discussion of the appropriateness of the Gupta index for use in the growth accounting equations as a proxy for political instability.

an inward orientation that can create an inhospitable climate for foreign investment, hindering capital accumulation from abroad. Alternatively, inward orientation may result in wasteful expenditure on the creation of intermediate inputs [Romer (1989)].

Note that the effects of inward orientation which hinder factor accumulation will already be accounted for through the introduction of realized rates of factor accumulation in the regressions below. However, if exchange rate overvaluation has a negative impact upon per capita growth rates in specifications which include factor accumulation rates, the evidence will indicate productivity effects of distortionary trade policies, such as those suggested by Romer.

2.2 Results

The results for regressions run on per capita income growth from 1965 through 1985 is reported in Table 1, using the 7% depreciation rate BS (1992) capital stock data.[5] Regressions were run using ordinary least squares and White's heteroskedasticity-consistent covariance estimation method. One can see that capital stock growth rates, *dK*, enter positively and significantly at the 1% confidence level in all the specifications, as would be predicted by the Cobb-Douglas production function. The capital coefficient is estimated to be approximately 0.25.

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[5] All regressions reported in this paper were also run with the 10% depreciation rate assumption. The results with this data set were universally similar and in some cases even stronger than those reported here. These results are available upon request.

However, since the capital stock data are generated regressors, they are likely to be measured with error. Therefore, the regression is likely to have underestimated α. The standard response to this problem is the reverse regression method. While the direct estimate of α will be biased towards the origin, the reverse regression estimate of α will be biased away from the origin, so that the true coefficient estimate will lie between these points. For example, the coefficient on α estimated from the reverse regression specification for Model 3 is equal to 0.385. The true coefficient estimate should lie somewhere between these two values.

The coefficient on population growth rates, *dPOP*, also enters with the expected negative coefficient, and is generally significant at the 1% confidence level.[6] Note that the magnitude of the coefficient estimate on population growth is very sensitive to the inclusion or exclusion of initial income. For example, Model 2 estimates β to be equal to 0.57, while Model 5 only estimates its value to be 0.25. It follows that the data may or may not indicate the presence of diminishing returns depending upon whether initial income is included in the growth acccounting specification.

As in BS (1992), we find that human capital growth, *dHK*, consistently enters with a negative point estimate, although usually insignificantly at a 5% confidence level. This result is robust to the inclusion of African and Latin American dummies in Model 2. African and Latin American countries experienced large rates of human capital

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[6]The exception is Model 2, in which it enters significantly at the 5% confidence level.

accumulation and disappointing per capita income growth rates during the sample period. However, one can see that including dummies for these countries actually raises the absolute value of the negative point estimate on human capital accumulation. This implies that the experience of these nations cannot totally explain the surprising result reported here. Both region dummies are insignificant, with the *AFRICA* dummy actually entering with a surprising positive sign once one accounts for its poor factor accumulation experience.

The negative point estimate on human capital accumulation is robust to the inclusion of the log of initial wealth, *LGPO*, as shown in Model 3. This implies that this surprising result also cannot be explained by the negative correlation between human capital accumulation and initial per capita income. Initial income itself robustly enters with a negative parameter estimate, usually either significant or close to a 5% confidence level. This provides some support for the convergence hypothesis.

Models 4, 5, and 6 introduce ancillary variables to incorporate other factors which may play a role in determining per capita growth rates. *PIQ* represents average levels of the political instability coefficient obtained from Gupta (1990) and *OVER* represents the degree of overvaluation of the real exchange rate as measured by the Dollar (1990) index. All of these variables enter with the expected negative sign, although none significantly at a 5% confidence level. The *OVER* variable comes relatively close, entering at 12% and 11% confidence levels respectively in Models 4 and 6. In addition, if a dummy for oil-exporting nations is included, the *OVER* variable enters significantly in Model 6 and enter at a 7% significance level in Model 4.

More importantly, the factor accumulation parameter estimates exhibit stability with respect to the inclusion of various combinations of these ancillary variables. This stability is desirable in the light of studies which show that the results of cross-country growth acccounting of this type are likely to be sensitive to the specification chosen [Levine and Renelt (1992)].

Table 2 displays the results of the same set of regressions run for the period 1970 through 1985. By and large, the results are quite similar: Physical capital growth and population growth both enter significantly with their expected signs. The somewhat higher coefficient on physical capital accumulation is now closer to its traditional factor share. The coefficient on physical capital accumulation now enters in the direct regression as high as 0.29, and its reverse regression coefficient for Model 3 is equal to 0.454. Human capital again enters with its surprising negative point estimate, although generally not significantly. Initial per capita income again enters negatively and usually significantly at the 5% confidence level.

The ancillary variables do not markedly affect the parameter estimates on the factor accumulation variables. The *OVER* variable now enters significantly negative at a 5% level of significance. Again, introduction of a dummy for oil-exporting countries increases the coefficient on this variable, and hence its significance, so that it enters for this period at a 1% level of significance. However the political instability variable remains highly insignificant, and enters with the wrong sign.

3. An Alternative Model for Growth Accounting

Despite the plausible parameter estimates obtained for physical capital and population growth rates in Tables 1 and 2, the small role indicated for human capital in the standard growth accounting equations is somewhat troubling. Human capital accumulation is commonly cited as a pre-requisite for development and most countries have government policies which encourage human capital accumulation.

As early as 1966, Nelson and Phelps (1966) pointed out that simply including an index of education or human capital as an additional input would represent a gross misspecification of the productive process. Instead, they argued that education facilitates the adoption and implementation of new technologies, which are continuously invented at an exogenous rate. In particular, they suggested that the growth of technology, or the Solow residual, depends on the gap between its level and the level of "theoretical knowledge," $T(t)$:

$$\text{(2)} \qquad \frac{\dot{A}}{A} = c(H)\left[\frac{T(t) - A(t)}{A(t)}\right].$$

One can see through the specification in equation (2) that the rate at which the gap is closed will depend on the level of human capital, H, through the function, $c(H)$, where $\partial c/\partial H>0$. The theoretical level of knowledge is taken to grow exponentially, so that $T(t)=T(0)e^{\lambda t}$. This model implies that the Solow residual, or the growth of total factor productivity, is influenced by H in the short run. However, in the long run, the Solow residual must settle down to a rate of λ.

More recent theories have modeled the growth of A directly as a function of the educational level H, emphasizing the endogenous nature of growth and technical progress [for example, see Lucas (1988)]. Romer (1990) has studied the role of market incentives that determine the allocation of H between the production of goods and inventive activities which enhance the growth of A, while treating the total quantity of H as exogenous. For simplicity, we will abstract from these important issues relating to the allocation and production of H. We assume that H is exogenously given and that a higher level of H causes a higher level of growth in A.

For the purpose of our cross-country comparisons, however, we cannot ignore the diffusion of technology between countries. We adapt the Nelson and Phelps (1966) framework to allow for the "catch-up" of technology, not to an exogenously growing theoretical level of knowledge, but to the technology of the leading country. For example, for a country i we specify the growth rate of total factor productivity as follows:

$$\text{(3)} \qquad \frac{\dot{A}_i(t)}{A_i(t)} = g(H_i) + c(H_i)\left[\frac{\max_j A_j(t) - A_i(t)}{A_i(t)}\right]. \qquad i=1..n,$$

where the endogenous growth rate $g(H_i)$ and the catch-up coefficient are non-decreasing functions of H_i. Therefore, the level of education not only enhances the ability of a country to develop its own technological innovations, but also its ability to adapt and implement technologies developed elsewhere.

Equation (3) then represents a system of differential equations which are easily analyzed. First we note that a lead country with the highest initial A, say $A_L(0)$, will be overtaken by some other country that has a higher level of education. This follows because the lead country grows at the rate $g(H_L)$, or $A(t)=A_L(0)e^{g(H_L)t}$, while the growth rate of a country with a higher H, say H_i, is larger than $g(H_i)$ since it is also affected by the catch-up factor. Thus $A_i(t)>A_i(0)e^{g(H_i)t}$, and since $g(H_i)>g(H_L)$, there exists some τ such that for $t>\tau$, $A_i(t)>A_L(t)$. Once country i is in the lead however, it can also be overtaken by another country with a lower initial level of technology $A_j(0)$, $[A_j(0)<A_L(0)]$,

but which has a higher level of education, such that $g(H_j)<g(H_L)$.

Note that the technology level A_L of a leader country L cannot be overtaken by another country with a lower level of education. If the follower country, say F, ever caught up, we would have $A_L=A_F$ and the catch-up component of the growth in $A's$ would be equalized, leaving the country with the higher education level to surge ahead.[7]

The observations above imply that irrespective of the distribution of initial levels of technology, given by the vector $A(0)$, at some time $\hat{t}$ the country with the highest level of education must overtake the technology level of all other countries and maintain that lead into the future, unless of course it loses its educational advantage. The dynamics of technology can then easily be characterized beyond $\hat{t}$, and without loss of generality we take $\hat{t}=0$. The technology level of the leading country, say m, grows at the rate $g(H_m)$, so that $A_m(t)=A_m(0)e^{g(H_m)t}$. In general, the growth rates of A_i, for every i, are given by:

$$(4) \qquad \frac{\dot{A}_i(t)}{A_i(t)} = g(H_i) + c(H_i)\left[\frac{A_m(0)e^{g(H_m)t} - A_i(t)}{A_i(t)}\right]$$

which can be simplified to:

$$(5) \qquad \frac{\dot{A}_i(t)}{A_i(t)} = [g(H_i) - c(H_i)] + c(H_i)\left[\frac{A_m(t)}{A_i(t)}\right].$$

This equation has a simple solution:

[7] For the leading country with the highest A, say A_m, this would be true even if the functions $c(H)$ differed across countries since $\underset{j}{Max}\ A_j-A_m=0$.

(6) $$A_i(t) = \left[A_i(0) - \Omega A_m(0) e^{[g(H_i) - c(H_i)]t} + \Omega A_m(0) e^{g(H_m)t} \right]$$

where:

(7) $$\Omega = \left(\frac{c(H_i)}{c(H_i) - g(H_i) + g(H_m)} \right)$$

In the case studied by Nelson and Phelps (1966), $g(H_i)=0$ and H_i affects the growth of A_i only in transition: The asymptotic growth rate is given by the exogenous growth rate of technology. In the case above, the effects of $g(H_i)$ on the growth of A_i persist if $g(H_i)>c(H_i)$ and the convergence to a common growth rate takes much longer than in the case of Nelson and Phelps (1966). Nevertheless, in the long run, the leader must still set the pace as the growth induced by $g(H_m)$ eventually overwhelms the other growth component $g(H_i)$ in each country. This can immediately be seen from the asymptotic ratio $A_i(t)/A_m(t)$:

(8) $$\lim_{t\to\infty} \frac{A_i(t)}{A_m(t)} = \lim_{t\to\infty} \left[\frac{A_i(0) - \Omega A_m(0)}{A_m(0)} \right] e^{[g(H_i) - c(H_i) - g(H_m)]t} + \Omega.$$

which simplifies to:

(9) $$\lim_{t\to\infty} \frac{A_i(t)}{A_m(t)} = \Omega$$

since $[g(H_i) - c(H_i) - g(H_m)]<0$. It follows that A_i and A_m asymptotically grow at the same rate $g(H_m)$.

Nonetheless, a few simple simulations show that the transition period may be extremely long. Note also that a country with a very low level of A can have a much higher growth rate than the leader because of the catch-up effect, while others that are closer to the leader, both in their technology level and their educational attainment, may in fact have lower growth rates than the leader because the catch-up effect may be insignificant relative to the educational gap. It follows that it may be difficult to observe the positive effect of education on the growth of total factor productivity. Therefore, to the extent that low educational attainment leads to or is associated with low levels of technology and income, it may be necessary to control for the catch-up effect, by including the income (or technology) levels in our regressions. The empirical results below tend to confirm these observations.

Finally, the analysis above has ignored the possible positive feedback effects from technology or income growth to the level of education. If educational levels tend to increase with incomes, growth rates may also diverge.

4. **Growth Accounting with Human Capital Stocks Entering into Productivity**

The alternative model presented above provides two mechanisms by which levels of human capital stocks can influence per capita income growth along the transition path. First, the endogenous growth component, $g(H_i)$ has an influence on relative growth rates of technology directly. Second, the catch-up component, which is specified as dependent upon the stock of human capital possessed by a country in the spirit of Nelson and Phelps, also allows levels of human capital to enter into per capita income growth.

It follows that the current model allows for human capital effects to enter in levels, at least in transition before the growth rates of A_i catch up to that of the leader nation. To incorporate this possibility, we introduced human capital stocks in levels into the growth accounting equations run above.[8]

Table 3 reports the results of ordinary least squares estimation using White's heteroskedasticity correction method. Model 1 simply introduces human capital in levels into the basic factor accumulation specification. It can be seen, as was found above, that physical capital accumulation and population growth enter significantly with their predicted signs. However, since initial income levels needed to capture catch-up effects are not included, the performance of human capital appears disappointing. Both in levels and in growth rates, human capital fails to enter significantly, and the point estimates are of incorrect sign.

However, as pointed out above, the human capital rich country need not always be the high growth country because of the catch-up factor. To account for differences in technology levels across countries, we introduce initial income levels, which will capture the role of the catch-up effect. As soon as initial income levels are introduced, human capital enters significantly in levels with the predicted positive sign. This result suggests that catch-up remains a significant element in growth, and that countries with higher education tend to close the technology gap faster than others. The transition towards a common growth rate set by the leading country may be quite long, and stochastic technological innovations by the leader can set countries on new transition paths. Furthermore, the growth in human capital still is highly insignificant and enters with the

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[8] We also ran the same regressions with the log of the human capital stock and obtained essentially identical results. The results of this alternative specification is available upon request.

wrong sign. The results suggest that the role of human capital is indeed one of facilitating adoption of technology from abroad and creation of appropriate domestic technologies rather than entering on its own as a factor of production.[9]

Initial income enters significantly and negatively in all the specifications. This implies some support for the convergence hypothesis. However, given the model above, a negative coefficient estimate on initial income levels may not be a sign of convergence due to diminishing returns, but of catch-up from adoption of technology from abroad. These two forces may be observationally equivalent in simple cross-country growth accounting exercises.

The ancillary variables are introduced in models 3 through 5. The parameter estimates on the factor accumulation variables are robust to the introduction of various combinations of these ancillary variables, which enter with the expected negative sign. However, none of the ancillary variables are statistically significant at the 5% significance level. Relatively, the exchange rate overvaluation variable does better, entering at the 15% level of significance.

Table 4 reports the results of regressions run from 1970 through 1985. It can be seen that the results are quite similar. Physical capital accumulation and population growth enter highly significantly with their

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[9] One caveat is again the possibility of a bias in these coefficient estimates as discussed in Section 2 and in the appendix. However, the coefficient estimates on physical capital are close to its expected factor share and do not indicate a significant upward bias.

expected signs and plausible coefficient magnitudes. Human capital does not enter significantly, either in levels or in growth rates, until one corrects for initial income levels. Subsequent to this correction, human capital enters robustly with a positive coefficient in levels, although it fails to enter significantly in Model 6. Initial income again tends to enter significantly negative, as expected. Finally, the ancillary variables again fail to enter at the 5% level. However, the exchange rate overvaluation variable does consistently enter at the 10% level of significance, so its importance has improved relative to the 1965 to 1985 growth accounting results.

In addition, we used likelihood ratio tests to examine whether human capital in levels should be added to a regression which included growth rate of population and physical and human capital as well as initial per capita income. For both the 1965 through 1985 and 1970 through 1985 periods, the likelihood tests indicated that human capital in levels should be included in the specification at the 1% confidence level.

5. Determinants of Physical Capital Accumulation.

In this section, we examine an alternative way that human capital may indirectly contribute to growth: Human capital may not enter directly as a factor in the aggregate production function, but may encourage accumulation of other factors necessary for growth, particularly physical capital. Lucas (1990) has suggested that one reason that physical capital does not flow to poor countries may be that these countries are poorly endowed with factors complementary to physical capital, so that the marginal product of physical capital in developing countries may not actually be that high, despite its apparent scarcity relative to the developed countries.[10]

Similarly, the poor performance of the ancillary political instability variable in the growth-accounting equations may understate the importance of the stability of political regime in the determination of economic growth. A variety of studies [for example, see Alesina, et al (1990)] have shown in models which do not include factor accumulation levels that political instability is negatively correlated with economic growth. This suggests the possibility that while political instability does not directly affect growth, it may have a positive effect on factor accumulation which does measurably enter into the growth equation. Kormendi and Meguire (1985) have argued that political instability will be negatively correlated with physical capital accumulation because of lack of faith in the assignment of property rights within countries exhibiting political instability. Empirically, they have demonstrated a negative correlation between proxies for political instability and gross investment as a share of income.

If we assume that adjustment of physical capital stocks is costly in the short run, one would expect to find some cross-country differences in marginal products of capital which were not immediately removed through capital flows. However, one would also expect that rates of capital

[10] However, both in the BS (1992) and the smaller SH (1988) data set for which physical capital figures are reported, income-to-capital ratios are negatively related to income levels at a 5% confidence level. Therefore, using a Cobb-Douglas or C.E.S. specification, poorer countries would seem to have higher returns to physical capital inputs.

accumulation, or *I/K*, would tend towards equating these differences in marginal product, holding all else equal. Under a standard adjustment process, it follows that *I/K* should be positively correlated with the current national marginal product of capital, which in turn depends on the current stocks of labor and physical and human capital.

Similarly, it follows that ancillary determinants of the expected return on investment, such as political instability, may also enter into investment as a share of the capital stock if stock adjustments are costly.

We examine the determinants of physical capital accumulation in Table 3. We regress the ratio of gross investment to capital stock on factor stocks: Human capital, physical capital and the population, as well as two ancillary variables; political instability as measured by the Gupta index and overvaluation of the real exchange rate as measured by the Dollar index.

Note that ex-ante, the expected sign on the degree of economic distortion due to exchange rate overvaluation is unclear. This stems from the possibility that overvalued exchange rates and government policies may distort prices in favor of capital-intensive activities. This scenario seems particularly plausible for some developing countries which pursued capital-intensive import-substituting policies rather than export-oriented labor intensive policies. Although such policies should lower the value of total output, they may result in increased physical capital accumulation.

Table 5 reports regressions run for 1965, 1970 and 1975. From the 1965 regressions, it can be seen that physical capital consistently enters with the predicted negative sign at a 1% level of significance. Similarly, population enters positively, although not always significantly, as would be predicted.

Human capital stocks are positively correlated with physical capital accumulation and are significant at a 5% level for all specifications except Model 6. This implies that the role for human capital as an agent in attracting physical capital is vindicated for the 1965 regressions.

Among the ancillary variables, the oil-exporting dummy is highly insignificant for this period, and the regional dummies are insignificant as well, although they enter with their expected negative signs. Political instability consistently enters with the predicted negative sign, although the variable does not enter significantly at the 5% level. The exchange rate overvaluation variable enters insignificantly and changes sign with the inclusion of the political instability index. The poor performance of this ancillary variable may reflect economic policies which favor capital-intensive import-substituting industries.

The regression results for 1970 are similar, although both population variables and human capital stocks now fail to enter significantly at a 5% level of significance. Human capital fairs better than the population variable, consistently entering positively and entering with 10 and 5 percent levels of significance in Models 1 and 5 respectively. The results are quite similar for the ancillary variables as well.

Lastly, the regression results for 1975 data are similar, with the troubling exception that population levels now enter consistently with the wrong sign, although never significantly. Human capital again enters consistently positively, and significantly at the 5% level in Models 1 and 5. The ancillary variables, with the exception of the oil dummy, continue to perform poorly. Political instability now enters with the wrong sign, although it is highly insignificant.

As a first pass at this data, the regressions above provide some interesting results: First, we see that physical capital stocks are consistently negatively correlated with investment as a share of income, which argues against scale economies in physical capital. Second, human capital stocks always enter positively, and usually significantly, in determining rates of physical investment. However, the results for population levels were relatively mixed, as were the performances of the ancillary variables.

The data lends support to the conjecture that human capital may be an important feature in attracting physical capital. Since we know from the growth equations that physical capital accumulation rates play a very important role in determining the rates of per capita income growth, the importance of this role is apparent.

The ancillary variables, particularly *OVER*, seem to have performed somewhat better as determinants of growth in the previous section than in explaining *I/K*. This may suggest that their effect on determining growth rates may work in more subtle ways than through stifling aggregate physical capital accumulation.[11] We should be careful to note that human capital levels are highly negatively correlated with political instability and exchange rate overvaluation. This implies the possibility that

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[11] In a previous study [BS (1992)], we found that political instability does does have a statistically significant negative impact on levels of investment, both gross and net. However, the dependent variable in the current specification determines the rate of physical capital accumulation, which is the relevant term in the growth accounting equations.

multicollinearity may be precluding these ancillary variables from entering into the determination of cross country investment shares. When human capital is omitted from the regression, political instability enters with the predicted negative sign and is statistically significant. The coefficient on exchange rate overvaluation also enters with a negative sign, although the parameter still fails a 5% confidence interval test.[12]

The impact of multicollinearity is particularly striking when one observes the impact of removing African nations from the sample, which diminishes the correlation between human capital and the political instability variable. When the African nations are removed from the 1965 investment specification, political instability enters significantly with a negative sign at a 1% confidence level, while human capital is highly insignificant and enters with the incorrect sign.[13] The coefficients on physical capital and labor are basically unchanged and enter significantly with the expected signs. It appears that this multicollinearity problem precludes distinguishing between the contribution of human capital and political instability to physical capital accumulation rates.

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[12]These regressions are available upon request. We also ran similar specification tests for the growth accounting regressions reported in the previous sections. However, omission of human capital, in both levels and growth rates, failed to have a significant impact on the performance of the ancillary variables in explaining per capita income growth.

[13]This regression is available upon request.

6. Conclusion.

Human capital accumulation has long been considered an important factor in economic development. The results obtained in our initial set of regressions are therefore somewhat disturbing: When one runs the specification implied by a standard Cobb-Douglas production function which includes human capital as a factor, human capital accumulation fails to enter significantly in the determination of economic growth, and even enters measurably negatively in some specifications.

When we introduce a model in which human capital influences the growth of total factor productivity we obtain more positive results. In this model, human capital was affects growth through two mechanisms. First, human capital levels directly influence the rate of domestically produced technological innovation, as in Romer (1990). Second, the human capital stock affects the speed of adoption of technology from abroad, in the spirit of Nelson and Phelps (1966). The significance of this alternative model in terms of its empirical implications is that human capital stocks in levels, rather than their growth rates, now play a role in the determining the growth of per capita income.

The growth accounting results with human capital introduced in levels were quite promising. Human capital consistently entered positively in the determination of economic growth, and usually significantly at a 5% confidence level. In addition, this alternative specification proved relatively parsimonious; an R-squared of 72% was achieved for an extremely heterogeneous group with a specification of only four variables: Physical capital accumulation, population growth, initial income per capita, and average human capital levels. Likelihood ratio tests also indicated that human capital in levels belonged in the specification at a 1% confidence level.

The results vindicate the observations made by Nelson and Phelps in 1966. Treating human capital as a factor of production implies that in the growth accounting regressions human capital should enter in growth rates. However, the standard growth accounting regression fails to deliver this result. We introduce two alternative avenues through which human capital can play a role in economic growth: Both as an engine for attracting physical capital and as a determinant of the magnitude of a country's Solow residual, it appears that a positive role does exist for human capital accumulation in the economic development process.

Appendix

1. Estimation of Aggregate Physical Capital Stocks.[1]

Investment flow data is now available for a large number of countries from the Summers-Heston (1991) data set. However, calculation of capital stocks using this data set requires some mechanism by which initial capital stocks can be estimated. In a simple two-factor neoclassical aggregate production function with constant returns, $Y=K^{\alpha}L^{\beta}$, the ratio of the log of capital to the log of output will be negatively related to the ratio of the log of the country's labor endowment to the log of output:

(A.1) $(\log K/\log Y) = a + b\ (\log L/\log Y) + \epsilon$

where estimates of a and b provide direct estimates of α and β in the neoclassical production function: $\hat{\alpha}=1/\hat{a}$ and $\hat{\beta}=\hat{b}/\hat{a}$.

Estimation of $\hat{a}$ and $\hat{b}$ in equation 1 requires an estimate of K. Therefore, we estimate $\hat{a}$ and $\hat{b}$ using two distinct methods. First, capital stocks in 1985 are available for 29 countries in the 1991 Summers and Heston data set.[2] Using this data, we estimate the magnitude of a and b for

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[1] Much of this section has been taken from BS (1992) in which the estimation methodology is discussed in greater detail.

[2] The countries for which capital stock data is available include Kenya, Zimbabwe, Canada, Dominican Republic, Guatemala, United States, Argentina, Chile, Colombia, India, Israel, Japan, Korea, Philippines, Thailand, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Norway, Spain, Sweden, United Kingdom, and Australia.

this small sample of countries. The regressions results are:

$$(A.2) \qquad (\log K/\log Y) = \underset{(0.014)}{1.203} - \underset{(0.027)}{0.306}\, (\log L/\log Y)$$

where capital is measured in dollars and labor is measured in thousands of units. The numbers in the parentheses represent standard errors. The R-squared for the regression is 31%, which is relatively large considering that we do not adjust for differences in human capital and natural resource endowments.

We use these coefficients to estimate initial capital stocks for countries in the Summers and Heston data set. Capital stock estimates for subsequent years are then directly attainable according to the equation:

$$(A.3) \qquad K_t = K_0(1-\delta)^t + \sum_{i=1}^{t-1} I_i(1-\delta)^{i-t+2}$$

where δ represents the rate of physical capital stock depreciation and K_0 represents the estimated initial capital stock according to equation (2).

Note that the methodology above relies on the assumption that the dependence of capital-output ratios on capital-labor ratios are constant across both countries and time. Once this assumption is made, however, an independent methodology for estimating national capital stocks becomes possible: This methodology consists of positing that such a relationship exists and is constant across time, and then estimating the capital stock series which most closely satisfies this assumption.

Specifically, we use an iterative method for estimating aggregate capital stocks. We start an initial estimate of $\log K_0/\log Y_0$ which satisfies $K_0/Y_0=3$ for the United States. This starting value is consistent with many estimates for this country. Then, using discounted investment flows, we find the implied series of capital stocks, and calculate $\hat{a}$ and $\hat{b}$ in equation (1) by regressing capital-output ratios on capital-labor ratios. These estimated *a* and *b* coefficients are used to update our K_0 estimates and recalculate the capital stock series. The process is repeated until convergence is achieved, i.e. until the likelihood function associated with a given $\hat{a}$ and $\hat{b}$ used is maximized.

The estimation was conducted using 4, 7 and 10 percent rates of depreciation. Convergence was achieved under the 10% and 7% depreciation rate estimates in 8 iterations, and under the 4% depreciation rate estimate in 10 iterations. The final estimated values of *a* and *b* satisfied:

$$(A.4) \qquad (\log K/ \log Y) = \underset{(0.018)}{1.225} - \underset{(0.007)}{0.327} \log L/ \log Y)$$

under the assumption of 10% depreciation:

$$(A.5) \qquad (\log K/ \log Y) = \underset{(0.017)}{1.229} - \underset{(0.007)}{0.317} \log L/ \log Y)$$

under the assumption of 7% depreciation and:

$$(A.6) \qquad (\log K/ \log Y) = \underset{(0.016)}{1.227} - \underset{(0.006)}{0.300} \log L/ \log Y)$$

under the assumption of 4% depreciation with R-squares of 0.32, 0.34 and 0.35 respectively.

Both the series estimated using the implied *a* and *b* from the SH data set and the series estimated from the iterative methodology yield well-correlated magnitudes using any of the 4%, 7% or 10% depreciation rates. Under a 7% depreciation rate estimate, for example, the correlation coefficient between the two series is 98.7%. In addition, the correlation coefficient between the small set of capital stock series available directly from Summers-Heston and those estimated using our iterative method under the assumption of a 7% depreciation rate is 97.7%. In Table 6, we provide the capital stock estimates using the iterative methodology under a 7% depreciation rate assumption for five-year intervals. This is the physical capital stock series which was used in the reported results below.[3]

2. Estimation of Human Capital Stocks.

Human capital stock data was obtained from Kyriacou (1991). Kyriacou estimates human capital levels from the Psacharopoulos and Arriagada [PA (1986)] data set. PA have maesure of years of schooling in the labor force for 99 countries. However, these measures are from a wide variety of years, from the 1960's through the 1980's. From this large set, Kyriacou identifies 42 countries for which average years of schooling in the labor force is available for the mid-1970's: 1974-1977.He estimates the following relationship between average years of schooling in the labor force and past enrollment ratios:

(A.7) $$H75 = 0.0520 + 4.4390PRIM60 + 2.6645SEC70 + 8.0918\ HIGH70$$

where *H75* represents average years of schooling in the labor force, *PRIM60*

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[3]All the results remain essentially the same if we use 4% or 10% depreciation rates. The entire set of capital stock estimates is available upon request.

represents the 1960 primary schooling enrollment ratio, *SEC70* represents the 1970 secondary schooling enrollment ratio, and *HIGH70* represents the 1970 higher education enrollment ratio. His regression has an R-squared of 82% and primary and higher education enrollment ratios enter significantly at a 5% confidence level. Kyriacou then uses these estimated coefficients to extrapolate human capital indexes for other time periods based upon past enrollment ratios. These extrapolated human capital indexes are used in the current study as human capital stock estimates.

3. *Estimation of the Bias*[4]

A well-known difficulty with estimating aggregative production functions is the possibility of a correlation between the error term and the regressors which would yield biased coefficient estimates. For example, a stochastic shock to the production function would typically be expected to result in the faster growth of accumulated inputs in that period. If shocks are also persistent, this will induce a positive correlation between future shocks and future levels of physical and human capital. Looking at average growth rates over long periods does not eliminate these positive correlations [Benhabib and Jovanovic (1990)]. Here, we attempt to identify the sign of the biases on the estimated coefficients. If we can show that the biases on the estimated coefficients are likely to be positive, our estimates will represent upper bounds.

For example, given the following specification:

$$\Gamma Y = c + \alpha\, \Gamma K + \beta\, \Gamma L + \gamma\, \Gamma H + \epsilon \qquad \text{(A.8)}$$

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[4]Much of thhis section is taken from BS (1992) which provides a more detailed discussion of the bias issue.

and that H and K are likely to correlated with the error term while L follows an independent process, OLS estimation is expected to yield biased estimates for the constant term, α, β, and γ equal to:

$$\text{(A.9)} \qquad \begin{bmatrix} \hat{b}_c \\ \hat{b}_K \\ \hat{b}_H \\ \hat{b}_L \end{bmatrix} = \begin{bmatrix} n & \bar{K} & \bar{H} & \bar{L} \\ \bar{K} & a_{kk} & a_{kh} & a_{kl} \\ \bar{H} & a_{hk} & a_{hh} & a_{hl} \\ \bar{L} & a_{lk} & a_{lh} & a_{ll} \end{bmatrix}^{-1} \begin{bmatrix} \bar{a} \\ a_{k\epsilon} \\ a_{h\epsilon} \\ 0 \end{bmatrix}$$

where $\hat{b}_j$ is the expected bias on the estimate of coefficient j, n is the number of observations in the sample, the a_{ij} are the raw moments defined above, and bars represent mean growth rates, for example: $\bar{K}=\sum_{i,t} T_{it}^{-1}(K_{i,t+T_{it}}-K_{i,t})$. As the sample size n gets large, it is easy to show by partitioning the inverse matrix that the biases will tend towards:

$$\text{(A.10)} \qquad \begin{bmatrix} \hat{b}_k \\ \hat{b}_h \\ \hat{b}_l \end{bmatrix} = \begin{bmatrix} a_{kk} & a_{kh} & a_{kl} \\ a_{hk} & a_{hh} & a_{hl} \\ a_{lk} & a_{lh} & a_{ll} \end{bmatrix}^{-1} \begin{bmatrix} a_{k\epsilon} \\ a_{h\epsilon} \\ 0 \end{bmatrix}.$$

The determinant of the matrix, D, will be positive since the matrix is positive semi-definite. Inverting the matrix, the bias on the physical and human capital coefficients are expected to equal:

$$\text{(A.11a)} \qquad \hat{b}_k = D^{-1}[(a_{hh}a_{ll} - a_{hl}^2)(a_{k\epsilon}) + (a_{kl}a_{hl} - a_{kh}a_{ll})(a_{h\epsilon})]$$

$$\text{(A.11b)} \qquad \hat{b}_h = D^{-1}[(a_{kk}a_{ll} - a_{kl}^2)(a_{h\epsilon}) + (a_{kl}a_{hl} - a_{kh}a_{ll})(a_{k\epsilon})].$$

$$\text{(A.11c)} \qquad \hat{b}_L = D^{-1}[(a_{KH}a_{KL} - a_{KL}a_{HH})(a_{K\epsilon}) + (a_{KH}a_{KL} - a_{KK}a_{HL})(a_{H\epsilon})].$$

where $\hat{b}_j$ $(j=K,H,L)$ represents the estimated bias, D represents the determinant of the covariance matrix, which can be signed as positive because the matrix is positive definite, and the a_{ij}'s represent the raw moments.[5]

Given that $a_{j\epsilon}>0$ $(j=K,H)$ we can sign the first terms of both expressions as positive since the covariance matrix is positive semi-definite. However, both expressions contain the second term which has sign equal to that of the expression:

(A.12) $a_{KL}a_{HL} - a_{KH}a_{LL}$.

Since a_{KH} may well be non-negative, and a_{JL} $(J=H,K)$ may also be positive because H and K are accumulated factors while L is assumed to follow an independent stochastic process, the sign of (A.12) is indeterminate, and the sign of the expected bias cannot be obtained analytically. We therefore turn to econometric evidence to obtain information concerning the degree of severity of the potential bias.

Using a bootstrap [Efron (1982)] procedure, we estimated the value of the covariance coefficients in equation (8) by creating 1000 samples from the original sample and computing the covariances of the coefficients in these created samples as population estimates of the population covariances.[6]

Our estimate for a_{HK} was 0.0019 with a standard error of 0.0024, so

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[5]For example: $a_{KL}=\sum_{i,t} T_{it}^{-2} (K_{i,t+T_{it}} - K_{i,t})(L_{i,t+T_{it}} - L_{i,t})$

[6]Note that a bootstrap procedure is desirable because of its ability to estimate the covariance matrix in the presence of heteroscedasticity, which is clearly a problem in this sample.

we cannot statistically reject the possibility that a_{HK} is either very small or zero, either of which would allow us to unambiguously sign the bias on the human and physical capital coefficients as positive by (A.11a) and (A.11b). Nevertheless, we continued by attempting to estimate all the observables in the bias equation. The estimated bias under OLS was expected to equal:

$$\text{(A.13a)} \quad \hat{b}_K = \underset{(79.45)}{71.57}\; a_{K\epsilon} - \underset{(172.53)}{3.06}\; a_{H\epsilon}$$

$$\text{(A.13b)} \quad \hat{b}_H = \underset{(1406.23)}{226.61}\; a_{H\epsilon} - \underset{(172.53)}{3.06}\; a_{K\epsilon}$$

$$\text{(A.13c)} \quad \hat{b}_L = -\underset{(924.02)}{141.01}\; a_{K\epsilon} - \underset{(4913.72)}{594.27}\; a_{H\epsilon}$$

where estimated standard errors are in parentheses. Note that the values of $a_{j\epsilon}$ $(j=H,K)$ are unobservable and hence cannot be estimated.

The large standard errors generated by estimation make strong inferences concerning the sign of the bias unattainable. The point estimates generated by the data clearly suggest a positive bias on the physical and human capital coefficient estimates, and a negative bias on the estimated labor coefficient provided the magnitudes of $a_{H\epsilon}$ and $a_{K\epsilon}$ are not wildly different. The point estimate of $\hat{b}_H$ will be positive if $a_{K\epsilon}/a_{H\epsilon}<74$ and the estimate of $\hat{b}_K$ will be positive if $a_{K\epsilon}/a_{H\epsilon}>1/23$. Moreover, recall that the first component in (A.13a) and (A.13b) can be analytically signed as non-negative because the covariance matrix is positive semi-definite. None of these coefficient estimates are measurably different from zero, and furthermore one cannot reject the null of a non-negative bias on human and physical capital in favor of a negative bias.

Table 1

Growth Accounting Regressions (1965-1985)[1]

(Human capital included as factor of production)

Dep Var	dGDP6585	dGDP6585	dGDP6585	dGDP6585	dGDP6585	dGDP6585
Const	0.014 (0.003)	0.016 (0.003)	0.083 (0.030)	0.061 (0.031)	0.119 (0.038)	0.096 (0.038)
dK	0.253** (0.037)	0.250** (0.041)	0.260** (0.035)	0.250** (0.044)	0.250** (0.037)	0.241** (0.046)
dPOP	-0.429** (0.172)	-0.454* (0.206)	-0.707** (0.187)	-0.603** (0.208)	-0.748** (0.197)	-0.612** (0.210)
dHK	-0.024 (0.015)	-0.043* (0.021)	-0.032 (0.020)	-0.021 (0.019)	-0.037 (0.025)	-0.025 (0.024)
LGPO	——	——	-0.008* (0.003)	-0.005 (0.004)	-0.011** (0.004)	-0.008 (0.004)
OIL	——	0.005 (0.014)	——	——	——	——
PIQ	——	——	——	–0.002 (0.003)	——	-0.002 (0.003)
INWARD	——	——	——	——	-0.008 (0.005)	-0.009 (0.006)
AFRICA	——	0.005 (0.014)	——	——	——	——
LAAMER	——	-0.007 (0.005)	——	——	——	——
Obs	80	80	80	70	78	69
F-Stat	49.187	25.292	41.592	25.114	32.654	20.609
R-Squared	0.660	0.675	0.689	0.662	0.694	0.666

[1] 1965-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate.

Table 2

Growth Accounting Regressions (1970-1985)[1]

(Human capital included as factor of production)

Dep Var	dGDP7085	dGDP7085	dGDP7085	dGDP7085	dGDP7085	dGDP7085
Const	0.013 (0.004)	0.015 (0.004)	0.094 (0.033)	0.069 (0.035)	0.097 (0.036)	0.071 (0.038)
dK	0.272** (0.039)	0.266** (0.049)	0.291** (0.033)	0.253** (0.033)	0.299** (0.041)	0.260** (0.041)
dPOP	-0.536** (0.148)	-0.485* (0.231)	-0.902** (0.209)	-0.677** (0.204)	-0.705** (0.228)	-0.494* (0.225)
dHK	-0.043 (0.031)	-0.062 (0.039)	-0.065* (0.029)	-0.053 (0.029)	-0.035 (0.029)	-0.026 (0.031)
LGPO	———	———	-0.009** (0.004)	-0.007 (0.004)	-0.008* (0.004)	-0.006 (0.004)
OIL	———	0.000 (0.016)	———	———	———	———
PIQ	———	———	———	0.001 (0.004)	———	0.001 (0.004)
INWARD	———	———	———	———	-0.013* (0.006)	-0.012* (0.005)
AFRICA	———	0.001 (0.010)	———	———	———	———
LAAMER	———	-0.009 (0.006)	———	———	———	———
Obs	89	89	89	77	87	76
F-Stat	45.444	23.236	39.745	21.907	33.778	19.894
R-Squared	0.616	0.630	0.654	0.607	0.676	0.634

[1] 1965-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate.

Table 3

Growth Accounting Regressions (1965-1985)[1]

(Human capital enters into productivity factor)

Dep Var	dGDP6585	dGDP6585	dGDP6585	dGDP6585	dGDP6585
Const	0.017 (0.008)	0.120 (0.035)	0.090 (0.038)	0.160 (0.039)	0.127 (0.043)
dK	0.255** (0.039)	0.239** (0.038)	0.239** (0.045)	0.226** (0.041)	0.229** (0.049)
dPOP	-0.470* (0.202)	-0.464* (0.196)	-0.466* (0.208)	-0.532** (0.192)	-0.498* (0.204)
HA6585	-0.0004 (0.001)	0.005** (0.002)	0.004* (0.002)	0.006** (0.002)	0.004* (0.002)
dHK	-0.027 (0.015)	-0.001 (0.023)	———	———	———
LGPO	———	-0.017** (0.005)	-0.012* (0.005)	-0.021** (0.006)	-0.016** (0.006)
PIQ	———	———	-0.002 (0.003)	———	———
INWARD	———	———	———	-0.006 (0.005)	-0.008 (0.005)
Obs	80	80	70	78	69
F-Stat	36.463	37.527	26.719	37.889	22.016
R-Squared	0.660	0.717	0.676	0.725	0.681

[1] 1965-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate.

Table 4

Growth Accounting Regressions (1970-1985)[1]

(Human capital enters into productivity factor)

Dep Var	dGDP7085	dGDP7085	dGDP7085	dGDP7085	dGDP7085
Const	0.019 (0.011)	0.125 (0.035)	0.094 (0.041)	0.116 (0.043)	0.082 (0.049)
dK	0.277** (0.039)	0.279** (0.032)	0.247** (0.034)	0.289** (0.041)	0.257** (0.042)
dPOP	-0.620** (0.190)	-0.714** (0.192)	-0.580** (0.200)	-0.621** (0.209)	-0.466* (0.213)
HA7085	-0.001 (0.001)	0.005* (0.002)	0.004* (0.002)	0.003* (0.002)	0.002 (0.002)
dHK	-0.053 (0.038)	-0.029 (0.024)	———	———	———
LGPO	———	-0.017* (0.005)	-0.013* (0.006)	-0.014* (0.006)	-0.009 (0.007)
PIQ	———	———	0.000 (0.004)	———	———
INWARD	———	———	———	-0.011 (0.006)	-0.011 (0.006)
Obs	89	89	77	87	76
F-Stat	33.889	34.828	23.031	35.332	20.063
R-Squared	0.617	0.677	0.619	0.686	0.636

[1] 1965-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate.

Table 5
Determinants of Investment as a Share of the Capital Stock: 1965, 1970, and 1975[1]

1965

Dep Var	I/K	I/K	I/K	I/K	I/K
Constant	0.084 (0.007)	0.099 (0.012)	0.099 (0.014)	0.092 (0.018)	0.106 (0.022)
K	-1.68E-8** (3.69E-9)	-1.56E-8** (4.34E-9)	-1.74E-8** (3.65E-9)	-1.59E-8** (3.81E-9)	-1.64E-8** (3.69E-9)
POP	6.28E-8* (3.08E-8)	3.50E-8 (3.66E-8)	1.03E-7* (4.46E-8)	5.24E-8 (3.12E-8)	1.03E-7* (4.26E-8)
H	0.007** (0.002)	0.005* (0.002)	0.005* (0.002)	0.007** (0.002)	0.004 (0.003)
OIL	0.005 (0.014)	-0.001 (0.014)	0.005 (0.014)	0.013 (0.015)	0.013 (0.014)
AFRICA	———	-0.014 (0.012)	———	———	———
LAAMER	———	-0.012 (0.008)	———	———	———
PIQ	———	———	-0.010 (0.008)	———	-0.012 (0.008)
INWARD	———	———	———	-0.005 (0.010)	0.002 (0.010)
# Obs	82	82	71	80	70
F-Statistic	4.743	3.563	3.711	3.756	2.970
R-Squared	0.198	0.222	0.222	0.202	0.220

[1] 1970-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate. Gross investment fugres calculated from Summers Heston data set.

Table 5
Determinants of Investment as a Share of the Capital Stock:

(Continued)

1970

Dep Var	I/K	I/K	I/K	I/K	I/K
Constant	0.107 (0.009)	0.116 (0.013)	0.112 (0.014)	0.107 (0.017)	0.111 (0.022)
K	-1.09E-8* (5.30E-9)	-1.17E-8* (5.14E-9)	-1.01E-8 (5.22E-9)	-1.12E-8* (5.22E-9)	-9.57E-9** (5.22E-9)
POP	4.21E-8 (3.84E-8)	2.85E-8 (4.13E-8)	3.12E-8 (3.73E-8)	4.20E-8 (3.92E-8)	2.76E-8 (3.84E-8)
H	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)	0.004* (0.002)	0.003 (0.002)
OIL	0.010 (0.010)	0.007 (0.010)	0.011 (0.010)	0.018 (0.009)	0.016 (0.009)
AFRICA	———	-0.008 (0.012)	———	———	———
LAAMER	———	-0.015 (0.008)	———	———	———
PIQ	———	———	-0.005 (0.005)		-0.005 (0.005)
INWARD	———	———	———	-0.001 (0.010)	0.002 (0.010)
# Obs	91	91	78	89	77
F-Statistic	1.111	1.120	1.004	1.206	0.878
R-Squared	0.049	0.074	0.065	0.068	0.070

Table 5

Determinants of Investment as a Share of the Capital Stock:

(Continued)

1975

Dep Var	I/K	I/K	I/K	I/K	I/K
Constant	0.102	0.104	0.110	0.100	0.116
	(0.007)	(0.017)	(0.011)	(0.016)	(0.018)
K	-1.14E-8**	-9.89E-9**	-7.93E-9*	-1.21E-8**	-8.40E-9**
	(3.49E-9)	(3.80E-9)	(3.29E-9)	(3.48E-9)	(3.31E-9)
POP	-8.56E-9	-1.06E-8	-5.11E-9	-2.99E-9	-2.91E-9
	(2.59E-8)	(2.63E-8)	(2.44E-8)	(2.31E-8)	(2.43E-9)
H	0.003*	0.002	0.001	0.003*	0.001
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
OIL	0.116**	0.116**	0.113**	0.106**	0.106**
	(0.019)	(0.021)	(0.020)	(0.020)	(0.021)
AFRICA	———	-0.003	———	———	———
		(0.014)			
LAAMER	———	0.009	———	———	———
		(0.010)			
PIQ	———	———	0.001		0.002
			(0.004)		(0.004)
INWARD	———	———	———	0.012	-0.005
				(0.092)	(0.009)
# Obs	108	108	89	106	88
F-Statistic	20.124	13.588	16.526	12.661	10.895
R-Squared	0.439	0.447	0.499	0.388	0.447

TABLE 6

CAPITAL STOCK ESTIMATES: ITERATIVE METHOD 7% DEPRECIATION RATE

Summers Heston #	COUNTRY	1960	1965	1970	1975	1980	1985
1	ALGERIA	14408.71	17547.6	24104.97	50980.42	103316.8	164694.4
2	ANGOLA	7745.638	7907.863	10695.02	12836.72	12532.9	12248.14
3	BENIN	2799.485	2292.67	2079.515	2261.272	2806.734	3270.098
4	BOTSWANA	332.7617	348.9764	697.6954	2134.358	3328.167	4536.327
5	BURKINA F	NA	2016.905	2479.971	4182.116	5453.741	6577.449
6	BURUNDI	1443.313	1185.643	1058.404	1086.973	1594.455	2366.46
7	CAMEROON	4859.19	5006.093	5874.408	7387.124	10955.76	17397.49
8	CAPE VERD	324.1363	434.7673	599.913	666:5976	867.6477	1235.391
9	CENTRAL A	1771.025	1836.589	1946.18	1987.987	1766.515	1822.525
10	CHAD	2779.333	3779.393	4566.377	5035.908	5566.051	4486.041
11	COMOROS	NA	NA	NA	NA	NA	406.4848
12	CONGO	1025.267	1179.179	1543.155	2336.888	2640.943	4618.504
13	EGYPT	9411.55	11355.74	12777.99	17214.71	30160.24	47446.41
14	ETHIOPIA	2813.866	3444	4415.468	5124.954	5586.569	6641.107
15	GABON	973.1432	1642.477	2402.895	7159.64	13323.09	16334.15
16	GAMBIA	180.5004	133.8638	102.5347	92.35979	139.7236	254.9916
17	GHANA	7983.82	9270.68	9670.849	10000.94	9895.351	8972.265
18	GUINEA	1926.163	2531.005	3071.012	3604.561	3992.423	4457.605
19	GUINEA-BI	404.0345	678.2856	956.9493	1123.788	1289.994	1423.687
20	IVORY COA	4601.084	4995.211	6381.431	8657.37	15381.93	16496.17
21	KENYA	10209.6	10231.35	12733.48	16749.23	21450.08	24663.53
22	LESOTHO	249.7331	258.4236	334.1906	540.2341	1258.633	1934.104
23	LIBERIA	1828.627	4742.654	5422.448	5883.718	6859.774	5870.94
24	MADAGASCA	7158.635	7125.221	7922.213	8581.684	8954.27	8205.207
25	MALAWI	1348.737	1681.552	2815.64	4323.346	4951.84	4612.975
26	MALI	2388.118	2106.695	2165.358	2223.061	2452.919	2672.343
27	MAURITANI	1137.395	1074.784	1004.46	1496.664	2524.905	3199.97
28	MAURITIUS	2048.805	2213.841	2160.925	3219.838	4292.976	4553.583
29	MOROCCO	9659.954	10463.95	13562.99	19280.82	30121.46	39053.35
30	MOZAMBIQU	13444.61	15477.98	21270.3	26495.25	26304.02	23735.16
31	NIGER	2130.663	2449.928	2744.303	3244.723	4105.638	4248.374
32	NIGERIA	27484	34725.6	44187.07	89583.84	163230.4	168819.9
33	RWANDA	1602.791	1276.443	1145.742	1227.117	1546.277	2228.009
34	SENEGAL	5301.897	5018.317	4931.231	5493.763	5883.277	6217.595
35	SEYCHELLE	NA	NA	NA	NA	391.167	505.9897
36	SIERRA LE	2752.878	2206.001	1980.544	1683.803	1471.15	1388.569
37	SOMALIA	2707.599	2360.35	2295.24	2460.682	4260.2	6139.601
38	SOUTH AFR	99117.65	132541	189850.4	269957	327759.2	386570.4
39	SUDAN	5901.024	4978.988	4352.671	4056.982	4462.588	4678.306
40	SWAZILAND	714.6564	1106.852	1391.904	2155.107	3512.291	3845.972
41	TANZANIA	2876.536	4613.614	8231.311	12616.53	16805.84	18479.73
42	TOGO	748.2511	1028.782	1416.412	2197.361	3829.433	4098.925
43	TUNISIA	7522.284	10463.11	13313.63	16796.6	21985.54	28189.22

TABLE 6

(continued)

Summers Heston #	COUNTRY	1960	1965	1970	1975	1980	1985
44	UGANDA	878.9259	989.1082	1248.144	1309.56	1140.204	1416.85
45	ZAIRE	4978.236	4929.679	5936.752	9149.665	12051.01	15596.08
46	ZAMBIA	12356.02	15127.49	21694.96	28611	24251.68	19331.06
47	ZIMBABWE	7635.986	8365.351	10103.51	14591.46	14778.31	16943.13
48	BAHAMAS	NA	NA	NA	NA	3104.18	3933.76
49	BARBADOS	1298.625	1439.065	1782.18	2222.178	2740.817	3225.507
50	CANADA	273898.1	335356.9	424086.1	543032.6	704622.3	861698
51	COSTA RIC	2954.757	3989.656	5346.22	7683.772	11908.04	12909.53
52	DOMINICA	NA	NA	NA	NA	NA	449.1569
53	DOMINICAN	4779.369	5430.756	7168.667	12867.91	19406.33	23345.92
54	EL SALVAD	3101.151	3712.169	4382.711	5775.696	8080.049	7746.236
55	GRENADA	NA	NA	NA	NA	NA	555.5458
56	GUATEMALA	7136.033	7677.985	9117.987	11485.37	15971.71	16771.38
57	HAITI	4464.109	3591.167	3045.666	3301.584	4586.944	5685.013
58	HONDURAS	2322.076	2751.264	3771.387	4582.95	6604.475	7251.933
59	JAMAICA	6418.269	8344.153	11987.06	15243.7	14141.31	13291.78
60	MEXICO	149568.4	209329.7	309522.9	458248.3	670447.5	834106.5
61	NICARAGUA	4605.079	6564.962	9484.29	12865.1	13554.88	15972.29
62	PANAMA	2979.013	4301.851	7223.259	12401.56	15020.99	17046.81
63	ST.LUCIA	NA	NA	NA	NA	787.5294	1089.257
64	ST.VINCEN	NA	NA	NA	NA	402.7187	530.6937
65	TRINIDAD&	5018.216	6654.338	7102.415	10021.66	18200.96	23024.31
66	U.S.A.	2878770	3472026	4266544	5135914	6178962	7194880
67	ARGENTINA	86681.04	100717.1	120762.1	151603.4	186591.4	178589.5
68	BOLIVIA	6303.226	7853.099	10724.44	15290.77	18930.7	17995.66
69	BRAZIL	187875.9	263346.5	367589.4	623017.6	900525.2	991676.5
70	CHILE	35690.5	46135.17	57790.78	61915.27	66696.29	67986.92
71	COLOMBIA	52775.91	65035.14	81862.62	102126.2	124894.7	151312.7
72	ECUADOR	12790.22	16432.1	22094.35	33037.93	52450.31	61868.88
73	GUYANA	2139.408	2972.834	4151.663	4921.943	5173.1	4655.229
74	PARAGUAY	2195.726	2289.46	2785.651	3883.078	7143.027	10411.51
75	PERU	32299.61	41432.29	50867.21	69335.09	84892.91	97907.69
76	SURINAME	1456.457	1855.869	2089.217	2553.785	3022.444	3092.972
77	URUGUAY	22029.8	22277.6	22202.11	22973.34	31804.75	33962.61
78	VENEZUELA	44393.36	49329.55	57790.43	90973.29	160636.8	173968.3
79	AFGHANIST	8430.532	8155.631	7681.827	7581.741	9329.702	10708.1
80	BAHRAIN	NA	NA	NA	4978.477	11291.15	15208.62
81	BANGLADES	26555.63	29129.53	35463.98	31569.79	32612.48	41508.22
82	BURMA(Mya	7985.933	10604.15	12933.66	14487.93	19773.82	26480.8
83	CHINA	356322	465506.7	765375.6	1370767	2184267	3426360
84	HONG KONG	10276.73	17163.3	22926.01	34126.06	57836.86	85445.61
85	INDIA	274610.8	375164.4	499050.3	632309.8	763685.5	908275
86	INDONESIA	NA	58524.32	75107.77	145640.3	276764.8	546390
87	IRAN	31749.81	47910.89	75856.28	131906.5	192281.5	266937.2
88	IRAQ	27269.88	33484.86	40540.09	80221.59	199252.6	252620.1

TABLE 6

(continued)

Summers Heston #	COUNTRY	1960	1965	1970	1975	1980	1985
89	ISRAEL	16202.03	27374.09	38280.64	62411.36	75801.03	85194.93
90	JAPAN	361381.7	718172	1428702	2386275	3158946	3741429
91	JORDAN	1491.208	1893.327	2700.855	4326.18	9928.203	18073.84
92	KOREA,SOU	24419.27	33557.06	76185.05	143845.3	257985.3	352887.5
93	KUWAIT	44716.39	33851.21	27491.82	25578.48	37810.4	54501
94	MALAYSIA	20400.61	31394.91	45298.88	72867.98	121206.6	205316.5
95	NEPAL	5615.533	5384.545	5452.183	6828.02	10647.71	15193.55
96	OMAN	NA	NA	NA	NA	11768.01	21960.7
97	PAKISTAN	48445.36	84595.67	114333.9	133008	137291.7	140923.9
98	PHILIPPIN	41825.74	58742.14	84455.86	117620.6	177200.5	210610.8
99	SAUDI ARA	18423.61	14285.87	12793.87	18964.29	65978.52	185831.2
100	SINGAPORE	7151.14	8524.085	14290.82	29684.23	47719.47	77589.61
101	SRI LANKA	18154.42	21749.3	28284.19	36096.28	50826.59	67207.52
102	SYRIA	10515.33	13658.47	17807.37	28540.48	54521.65	81948.6
103	TAIWAN	10088.78	16839.62	33565.63	69978.62	123730.7	168075.8
104	THAILAND	23093.71	33754.64	60114.12	88401.53	126043.2	163926.8
105	UNITED AR	NA	NA	15924.67	20405.53	42008.17	60220.77
106	YEMEN, N-	NA	NA	2540.664	3879.36	9756.272	13255.94
107	AUSTRIA	54999.63	79328.23	112065.7	154716.6	196124.8	225039.9
108	BELGIUM	99064.7	129319.7	169759.6	217357.9	263109.2	268564.9
109	CYPRUS	4338.583	5537.565	7462.594	8695.998	10378.54	12603.32
110	DENMARK	61859.52	89949.89	124889.7	157902.7	173185.8	170429.3
111	FINLAND	56662.3	80314.75	105159.2	140596.4	160039.9	180064.7
112	FRANCE	443032	642048.4	944543	1303559	1580024	1720749
113	GERMANY,	670980.1	1002829	1334263	1625870	1872654	2000910
114	GREECE	22886.74	39978.37	64382.07	100016.4	127570	139386.1
115	HUNGARY	NA	NA	49761.13	96081.7	147179.4	169969.4
116	ICELAND	2030.654	2702.156	3546.898	4832.809	5955.847	6921.546
117	IRELAND	18606.14	24261.44	32923.05	45616.33	58306.7	66359.43
118	ITALY	473116	713339.3	959261.1	1204506	1424894	1595186
119	LUXEMBOUR	6658.882	8165.508	9021.268	10335.06	11207.46	12531.93
120	MALTA	1210.868	1609.83	2445.43	2837.72	3518.546	4834.557
121	NETHERLAN	136547.1	188958.6	266975.2	332432.5	371777.6	381171.4
122	NORWAY	54290.04	69988.54	90712.42	119341	145003.4	169652.5
123	POLAND	NA	NA	NA	NA	225014.4	367901.2
124	PORTUGAL	23102.44	34300.84	50218.65	73940.14	95878.17	113136.4
125	SPAIN	158967.7	259761	400623.4	562682.7	666445.8	684300
126	SWEDEN	105998.7	140575	180924.9	217000.7	234281.3	242629.3
127	SWITZERLA	103321.2	153423.2	201896.4	253085.1	275001.5	306870.4
128	TURKEY	57465.47	79943.72	120458.8	191901.8	274382.3	336954
129	U.K.	497220.7	623479.7	789438.2	949030.1	1074756	1164304
130	YUGOSLAVI	42986.78	101230.8	154136.3	219132.7	310984	384392.2
131	AUSTRALIA	187537.4	245344.7	327320.8	404946.9	473280.4	545000.8
132	FIJI	1755.152	2279.558	2913.423	3923.615	5334.069	6003.707
133	NEW ZEALA	32984.29	41311.28	49119.28	66395.39	72183.65	81794.13

TABLE 6

(continued)

Summers Heston #	COUNTRY	1960	1965	1970	1975	1980	1985
134	PAPUA N.G	3311.205	4581.001	9349.055	13337.43	15080.03	16868.1
135	SOLOMON I	NA	NA	NA	NA	853.603	1130.079
136	TONGA	NA	NA	NA	NA	NA	436.2805
137	VANUATU	NA	NA	NA	NA	NA	NA
138	WESTERN S	NA	NA	NA	NA	728.5696	771.6787

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