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THE ROLE OF HUMAN CAPITAL IN ECONOMIC DEVELOPMENT:

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ABSTRACT

We use international cross-country and regional United States 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. 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. Finally, we find that a limited role in explaining growth exists for "ancillary variables," such as political instability and income distribution, once one has accounted for differences in rates of factor accumulation. However, we find that both human capital levels and these ancillary variables affect rates of physical capital accumulation.

1. Introduction

How does human capital or the educational attainment of the labor force affect the output and the growth of an economy? A standard approach is to treat human capital, or the average years of schooling of the labor force, as an ordinary input in the production function. The recent work of Mankiw, Romer and Weil (1992) is in this tradition. An alternative approach, associated with endogenous growth theory,[1] is to model technological progress, or the growth of total factor productivity, as a function of the level of education or human capital. The presumption is that an educated labor force is better at creating, implementing and adopting new technologies, thereby generating growth. In this paper, we attempt to empirically distinguish between these two approaches. At the end we also briefly comment on the impact of some ancillary variables, such as political instability and income inequality, on economic growth and factor accumulation.

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)].[2] In addition, human capital has been proxied in the literature by

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[1] For example, see Romer (1990a,b).

[2] 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.

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 with the use of literacy as a proxy for human capital.[3]

This paper uses estimates of physical and human capital stocks to examine cross-country evidence on the determinants of economic growth. We begin with estimation of a standard Cobb-Douglas production function in which labor and human and physical capital enter as factors of production. Our findings shed some doubt on the traditional role given to human capital in the development process as a separate factor of production. In our first set of results, we find that human capital growth has an insignificant, and usually 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.[4]

Nonetheless, human capital accumulation has long been stressed as a pre-requisite for economic growth. As pointed out by Nelson and Phelps (1966), treating human capital simply as another factor in growth accounting may seriously misspecify its role. Below, we introduce an alternative model which allows human capital levels to directly affect aggregate factor productivity

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[3]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 rates which are close to unity.

[4]See section 2 and appendix.

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. Our findings assign a positive role to the levels of human capital in growth accounting. Our results below generally 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.

As a form of sensitivity analysis of the cross-country results, we examine an analog to the growth equations for manufacturing across states within the United States. Our results for regional United States data support our cross-country findings: Growth in human capital fails to have a measurable impact on the growth in value-added in manufacturing, but states with higher levels of human capital over the period experienced higher rates of growth in value-added in manufacturing than those with low levels of human capital. However, this latter finding was not significant at a five percent confidence level.

An additional role for human capital may be as an engine for attracting other factors, such as physical capital, which also contributes 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 examine the implications of "ancillary variables," including political instability, income distribution, and exchange rate over valuation for investment rates.[5] Our results indicate that levels of human capital play an important role in attracting physical capital. However the ancillary variables fail to measurably affect rate of investment once one accounts for differences in factor accumulation across countries.

This paper is organized into seven sections. 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

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[5]For an analysis of the role of financial variables, see King and Levine (1991).

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 examines the results from similar specifications for regional United States manufacturing data. Section 6 investigates empirically the relationship between human capital stocks and physical capital accumulation rates. Section 7 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_t, is dependent upon three input factors: Labor, L_t, physical capital, K_t, and human capital, H_t. Assuming a Cobb-Douglas technology, $Y_t = A_t K_t^{\alpha} L_t^{\beta} H_t^{\gamma} \epsilon_t$, and taking log differences, the relationship for long-term growth can be expressed as:

$$(1) \qquad (\log Y_T - \log Y_0) = (\log A_T - \log A_0) + \alpha\,(\log K_T - \log K_0)$$
$$+ \beta\,(\log L_T - \log L_0) + \gamma\,(\log H_T - \log H_0) + (\log \epsilon_T - \log \epsilon_0).$$

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_t. This would imply the possibility of biased estimates. In the appendix, we attempt to empirically assess the likely signs of the biases on the coefficient estimates. Our results indicate that there is likely to be an upward coefficient bias on the α and γ estimates, and a downward bias on our estimate of β. In particular, this bias may lead us to overestimate the importance of human and physical capital accumulation in the growth equations.

We estimate equation (1) in the standard growth accounting framework by regressing log differences in income on log differences of factors. If this specification is correct, this methodology would provide estimates of the magnitudes of α, β, and γ. In addition, we introduce a number of "ancillary variables" to allow for some 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. Nevertheless, we estimate a variety of measures of physical capital stocks of nations by using alternative assumptions to generate capital stock estimates from investment flows. Our results do not depend upon our choice of capital stock estimate. The various methodologies used in the construction of the capital stock estimates are described in the appendix.

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, available for 42 countries, and past values of human capital investment, such as enrollment in primary, secondary, and tertiary education. He then extrapolates from these results to a larger set of countries. His methodology used in the construction of the data used in this study is also described in greater detail in the appendix.

Income, population, and labor force data data are acquired from the Summers-Heston (1991) data set. Although one would expect that the labor force, as estimated by the Summers-Heston data set would be a superior measure of the labor force of a country, we would suspect that the accuracy of this measure would vary broadly, and in particular be relatively suspect in less developed countries, where workers in traditional agriculture may or may not be recorded as members of the labor force. As a sensitivity measure, we run all regressions reported below using both population and labor force data. The results with population growth are not reported however, because they were quite similar to those obtained using labor force data.[6]

2.2 Results

Prior to running the formal growth regressions, one can see that the standard specification is unlikely to yield results which imply a strong role for human capital growth by observing the univariate relationship between log differences in income and the log differences in the factors of production. These are shown for the 1965 through 1985 period in figures 1 through 3. While log differences in physical capital and physical labor are shown to be positively correlated with log differences in income, the correlation with log differences in human capital is very close to zero. In addition, this result is not dependent upon our use of the Kyriacou (1992) measure of human capital. Figures 4 shows that an equally weak correlation exists between log differences in income growth and log differences in literacy.[7]

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[6]These results are available upon request. In addition, the labor force estimate for Gabon in 1965 appeared to particularly unreliable, implying a 94% participation rate. The reported results below exclude the country of Gabon. However, none of the qualitative results change when Gabon is included.

[7]Moreover, if we exclude Botswana, which had the unique experience of growing

The results for the growth regressions run on log differences in income from 1965 to 1985 are similar. See Table 1. Regressions were run using ordinary least squares and White's heteroscedasticity-consistent covariance estimation method. One can see that the coefficient on the log difference of capital stocks, *dK*, enters positively and significantly at the 1% confidence level in all the specifications. The capital coefficient estimate for the full sample regression is approximately 0.5.

The coefficient on log differences in "labor," measured by both reported labor and population stocks, *dL,* also enters with the expected positive coefficient, although the coefficient estimate appears to be low and the variable rarely enters significantly at a 5% confidence level.[8]

The most surprising result concerns the coefficient on the log difference in human capital, *dH.* The log difference in human capital always enters insignificantly, and almost always with a negative coefficient. One explanation for the negative coefficient is that a number of countries, most notably many from Africa, began the period with extremely low stocks of human capital. Consequently, those that achieved a modicum of improvement in their educational levels were credited with large improvements in this stock. However, it is well-known that many of these countries did not experience similar improvements in output, implying a small coefficient for γ in the

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seven-fold, the relationship between growth in both human capital and literacy and growth in income actually becomes negative.

[8]When we exclude Botswana, the coefficient on physical labor growth increases to 0.27, while the other results are similar.

growth accounting regressions. Nevertheless, even when we include country dummies to account for the special experiences of these countries (Model 4), the results hold.[9] Therefore, even though the experience of these countries over the period provides evidence against the standard growth accounting framework, these countries alone do not drive the results found in Table 1.

Also, note that these country dummies, as well as the dummy for oil-exporting countries in Model 3, fail to enter significantly once one accounts for disparities in rates of factor accumulation. It seems that proper accounting for capital and labor obviate the necessity for including these dummies. Many previous works which did not include factor accumulation due to lack of capital stock data, such as Barro (1991), found that these dummies entered significantly.[10]

The negative point estimate on human capital accumulation is robust to the inclusion of the log of initial wealth, *LOGGDP*, and cannot be explained by the negative correlation between human capital accumulation and initial income per worker. Initial income itself robustly enters with a negative and highly significant parameter estimate.

We should note that for a specification with an aggregate production function the accumulation of factors are accounted for, and the role of initial income in our regressions is unclear. However, initial income may proxy for initial technological advantage, and as argued in the next section,

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[9]We also found that excluding the African countries from the sample failed to overturn these results.

[10]We thank Paul Romer for pointing this out.

the negative coefficient may be interpreted as a "catch-up" result.[11]

Models 5, and 6 introduce ancillary variables to incorporate other factors which may play a role in determining per capita growth rates. *MID* represents the relative size of the middle class in a country and is the variable used as a measure of income distribution by Persson and Tabellini (1991). Note that the sample size available with the introduction of this variable is much smaller, as income distribution data is relatively scarce. Once one adjusts for differences in rates of factor accumulation, this ancillary variable fails to significantly affect growth, contrary to Persson and Tabellini. However, the variable does enter with the expected positive sign.

The final model introduces political instability, *PIQ*, measured as average annual levels of the political instability coefficient, obtained from Gupta (1990).[12] Note that once again the political instability variable fails to enter significantly once one accounts for differences in rates of factor

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[11] Mankiw Romer and Weil (1991), in their second set of regressions, include both factor accumulation and initial income. However, they use the factor inputs as a proxy for steady state income levels. The distance of initial income from these estimates of steady state levels then defines the distance between a country's initial position and its steady state, which makes it appropriate to include initial income in their specification.

[12] Gupta (1990) uses discriminant analysis of a variety of political events from the Taylor and Jodice (1983) data set to form his index of political instability.

accumulation.

In addition, we attempted to make some adjustment for the composition of output of a country. Recent literature [Stokey (1991), Young (1991), and Lucas (1992)] has suggested that the composition of output of a nation may have an influence on its ability to produce new products through "learning-by-doing" effects. However, the data available across large cross-country samples is limited to broad composition aggregates. We examined the importance of manufacturing as a share of total output as well as the share of two sub-groups within manufacturing which appear to be relatively technology intensive; machinery and transportation, and chemicals. The data was obtained for 1970 and 1986 from the World Development Report and the average was used as a proxy for the average output shares over the period.

Our results indicate that these ancillary variables perform similarly to those above.[13] On their own, the shares of manufacturing and machinery and transportation enter positively and significantly when one adjusted for the catch-up effect by including initial income. However, when factor accumulation rates are included, the variables fail to significantly influence growth. The share of chemicals consistently fails to enter significantly, whether or not we account for factor accumulation. However, these inconclusive results may be driven by the level of aggregation to which we were constrained.

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

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[13] These regression results are available upon request.

results of cross-country growth accounting of this type are likely to be sensitive to the specification chosen [Levine and Renelt (1992)].

3. An Alternative Model for Growth Accounting

The small role indicated for human capital in the standard growth 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, however, Nelson and Phelps (1966)[14] suggested 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," $T(t)$:

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

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

[14]More recently, Romer (1990b) has also argued that the level of human capital may have an influence on growth of A, both directly and through its effect on the speed of the "catching-up" process.

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:

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

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 over taken 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 over taken 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 over taken 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.[15]

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 $g(H_m)$,

[15] 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 $\underset{j}{Max}\, A_j - A_m=0$.

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:

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

where:

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

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 $A_i(t)/A_m(t)$:

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

which simplifies to:

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

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.[16]

4. Growth Accounting with Human Capital Stocks Entering into Productivity

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[16] Unless, of course, diminishing returns to education sets in. That is, if the functions g and c in (4) asymptotically become flat.

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 the log of human capital stocks in levels into the growth accounting equations run above.

Table 2 reports the results of ordinary least squares estimation using White's heteroskedasticity correction method. Model 1 simply substitutes the log of average human capital levels for log differences of human capital. Physical capital accumulation and labor force growth enter with their predicted signs, but labor force growth fails to enter significantly. However, 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.

Nevertheless, as pointed out above, the human capital rich country need not always be the high growth country because of the catch-up factor. Therefore, Model 1 is likely to be misspecified. To account for differences in initial technology levels across countries, we introduce initial income levels in Model 2, 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. It is not particularly surprising that this transition effect appears in twenty year growth experiences. 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. 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.[17]

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. The likelihood tests indicated that human capital in levels should be included in the specification with a 1% level of confidence.

Initial income enters significantly and negatively in all the specifications. This may imply 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.

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[17] 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.

The ancillary variables are introduced in models 3 through 6. The positive and significant coefficient estimate on levels of human capital is robust to the introduction of variables, with the exception of the income distribution variable *MID*. However, the sample size is severely curtailed by the introduction of this variable.

With the exception of the Latin American dummy, note that none of the ancillary variables are statistically significant at the 5% confidence level. As above, once one accounts for differences in rates of factor accumulation, the residual role for characteristics such as political stability and skewness of income distribution appears to be limited.[18]

5. Evidence from Regional United States Manufacturing Data.

There are a number of reasons why one might be suspicious of results from cross-country regressions: First, the data is of uneven quality and may not be comparable across countries. Second, the implicit assumption that the technology is identical across countries is unrealistic. Third, it has been suggested that the methodology used in the construction of the Summers-Heston (1991) data set may itself drive some of the results found in the literature [Blomström, et al (1992)].

For all of these reasons, it would be desirable to check the results found for human capital accumulation above against an alternative sample of

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[18]The composition variables, such as the share of manufacturing and machinery and transportation in output, were also run with human capital in log levels. These variables still failed to enter significantly once one accounted for factor accumulation.

aggregate growth patterns. In this section, we examine the evidence from the long-term growth experiences of the manufacturing sector of states in the United States from 1960 through 1980.

This sample possesses some attributes which are desirable relative to the cross-country regressions: 1. The data are superior and are obviously comparable across states. 2. The technology available in manufacturing across the United States is much more homogeneous than that internationally available across countries. 3. Superior sources exist for physical and human capital measures.

The data set for the regressions was constructed in the following manner: Physical capital stock data was constructed by assuming the initial capital-output ratios were constant across states. This allowed for estimation of physical capital stocks in manufacturing using sums of discounted flows obtained from the Annual Survey of Manufactures.[19] Data on median educational attainment of the population by state was obtained for 1960 and 1980 from the Census of Population. Employment and value added in the manufacturing sector was also obtained from the Annual Survey of Manufactures.

Given this data, we replicated the growth regressions run above using both log differences and levels of human capital. Our results are reported in Table 3. Model 1 shows the standard growth accounting framework, with log differences in human capital. It can be seen that log differences in

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[19] Due to budgetary problems, investment flows in manufacturing were not available by state for 1979 through 1981. Consequently, we use estimated growth in the physical capital stock from 1959 through 1979, rather than the 1960 through 1980 measures used for the other variables.

human capital enter with a small and statistically insignificant positive coefficient. The results in Model 2, which adds initial value-added per worker, are similar, with the exception that log differences in human capital now enter with a negative point estimate.

Models 3 and 4 show human capital entering in log levels. As above, human capital enters insignificantly, and with a negative sign, when one fails to correct for initial differences in value-added per worker. However, Model 4 shows that once this correction is made, human capital in levels enters with a positive coefficient, although not statistically significant at a five percent level. The failure of human capital to enter with a statistically significant coefficient may in part be due to the fact that there is little disparity in educational attainment across U.S. state data.

Note that initial value-added per worker consistently enters with a statistically significant negative sign. This may be interpreted as weak evidence in favor of convergence. However, as above, we can interpret this finding in terms of the model above as reflecting the impact of the "catch-up" phenomenon, which appears to exist even across states within the United States.

6. Determinants of Physical Capital Accumulation.

In this section, we examine an alternative channel for human capital to contribute to growth: Human capital 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.[20]

Similarly, the poor performance of the ancillary political instability and income distribution variables in the growth-accounting equations may understate the importance of the political regime or of income distribution in the determination of economic growth. A variety of studies [for example, see Alesina, et al (1990), and Person and Tabellini (1990)] have shown that political instability or a skewed income distribution is negatively correlated with economic growth. This raises the possibility that while political instability or a skewed income distribution does not directly affect growth, it may have a negative effect on factor accumulation. 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 accumulation, or I/K, would tend towards equating these differences in

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[20] However, income-to-capital ratios in the current data set are negatively related to income levels at a 5% confidence level. Therefore, assuming a Cobb-Douglas or C.E.S. specification, poorer countries would seem to have higher returns to physical capital inputs.

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.

We examine the determinants of physical capital accumulation in Table 4. We regress the ratio of gross investment to capital stock on factor stocks: Human capital, physical capital and the labor force, as well as ancillary variables including dummies for oil exporting, African and Latin American countries, as well as the size of the middle class, which was shown to have an impact on growth in in Person and Tabellini. In addition, we introduce Gupta's measure of political instability in the determination of physical capital accumulation for 1965 and 1970, and over valuation of the real exchange rate as measured by Dollar's index (1990) for 1985.[21] The latter two measures are not available for all three time periods.

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[21]For details on the construction of this index, see Dollar (1990). Note that ex-ante, the expected sign on the degree of economic distortion due to exchange rate over valuation is unclear. This stems from the possibility that over valued 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.

Tables 4, 5, and 6 reports regressions run for 1965, 1970 and 1985 respectively. From the 1965 regressions, it can be seen that physical capital consistently enters with the predicted negative sign at a 5% level of significance, with the exception of Model 4 which has the curtailed income distribution sample. Similarly, the labor force enters positively, although not always significantly, as would be predicted.

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

The ancillary variables, once we have accounted for factor endowments, perform very poorly. Note that both political instability and income distribution enter insignificantly and with the incorrect sign. 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.

The regression results for 1970 are similar. Note that levels of human capital continues to be robustly positively correlated with rates of physical capital accumulation. The results for the ancillary variables are again disappointing once we account for factor accumulation. Note that income distribution fairs even more poorly, entering significantly with the incorrect sign.

Lastly, the regression results for 1985 are less satisfying. Physical capital stocks fail to enter significantly, and sometimes enter with the incorrect sign. Labor stocks enter with the correct sign, and is usually significant at or close to a 10% confidence level. An exception is the regression with the country dummies. The dummies now enter significantly, and their inclusion leaves the factor endowments with almost no explanatory power. Perhaps the strong macroeconomic shocks experienced by these countries during this period preclude us from obtaining results as intuitive as those of the other years. Nevertheless, the human capital variable exhibits surprising robustness, almost always entering significantly positive. The other ancillary variables are insignificant. However, the over valuation index enters with the correct sign and is close to a 10% significance level.

In addition, since political instability data was not available for this year, we examine an alternative measure, *INWARD*, which represents Dollar's (1992) measure of exchange rate over-valuation. One might suggest that an over-valued exchange rate is a sign of inward orientation. Although the variable enters with the predicted negative sign, it is not statistically significant, reinforcing the pattern that the ancillary variables fail to enter once one has accounted for factor accumulation levels.

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 labor stock 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 performance of the ancillary variables is somewhat surprising.

As was the case above, we found that once one accounted for stocks of factor endowments, there was little role left to play for both income distribution and political instability. However, we should be careful to note that human capital levels are highly correlated with these ancillary variables. This implies the possibility that 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, income distribution and political instability enter with their respective predicted signs and are usually statistically significant, however exchange rate over-valuation is still statistically insignificant.[22]

7. 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 dissappointing: 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 with a negative point estimate.

When we introduce a model in which human capital influences the

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[22] 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. These regressions are available upon request.

growth of total factor productivity we obtain more positive results. In this model, human capital 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 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, our empirical findings fail 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. These theories are vindicated to some degree by the empirical evidence from aggregate production function data, both across countries and regionally within the United States.

Appendix

1. Estimation of Aggregate Physical Capital Stocks.

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. The capital stock estimates used in the regressions reported above were obtained from utilizing the limited 29 country sample of the Summers-Heston (1991) data set for which capital stock data was available. In a standard three-factor neoclassical aggregate production function with constant returns, $Y=K^{\alpha}L^{\beta}H^{\gamma}$, the relationship between these variable in logs satisfies:

$$\text{(A.1)} \qquad \log Y = A + \alpha \log K + \beta \log L + \gamma \log H + \epsilon .$$

For the limited sample of countries for which capital stock data was available for 1980 and 1985, our coefficient estimates for this relationship using the Kyriacou measure for H were:

$$\text{(A.2)} \qquad \log Y = \underset{(0.235)}{3.391} + \underset{(0.056)}{0.614} \log K + \underset{(0.052)}{0.349} \log L + \underset{(0.198)}{0.189} \log H + \epsilon .$$

where standard errors are indicated in parenthesis. The R-squared for the regression is 0.974, which is relatively large considering that we do not adjust for differences in natural resource endowments. The regression had 58 observations.

We then used these coefficients to estimate initial capital stocks, K_0, for the remaining countries in the Summers and Heston data set. Given the estimates of initial capital stocks, capital stock estimates for subsequent years are then directly attainable according to the equation:

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

where δ represents the rate of physical capital stock depreciation and K_0 represents the estimated initial capital stock according to equation (2). The regressions reported above were run under the assumption of 7% depreciation, although we also generated capital stocks assuming 4% and 10% depreciation and got very similar regression results.

We also use alternative methodologies to estimate the initial capital stock. First, we use an iterative procedure, based upon the assumption that the relationship above would be constant across both countries and time. We started with an initial estimate of $logK_0$ - $logY_0$ 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 $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\gamma}$ in equation (A.1). These estimated 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 set of coefficient estimates is maximized. Finally, we also simply use the output-capital ratio of three, found for the United States, to estimate the initial capital stock.

The log differences in capital stocks estimated by these processes were all very highly correlated. For example, the correlation between log differences in the capital stock used in the reported regression and that estimated by the iterative method was 98.7%. This is not surprising, since the initial capital stock estimated for most countries for 1950 was relatively depreciated by the 1965 beginning of the sample. Consequently, our results do not depend upon our choice of capital stock estimation method.

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 measure 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.4) $$H75 = 0.0520 + 4.4390PRIM60 + 2.6645SEC70 + 8.0918\ HIGH70$$

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

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:

(A.5) $$\Gamma Y = c + \alpha\, \Gamma K + \beta\, \Gamma L + \gamma\, \Gamma H + \epsilon$$

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:

(A.6) $$\begin{bmatrix} \hat{b}_c \\ \hat{b}_K \\ \hat{b}_H \\ \hat{b}_L \end{bmatrix} = \begin{bmatrix} n & \bar{K} & \bar{H} & \bar{L} \\ \bar{K} & a_{kk} & a_{kh} & a_{kl} \\ \bar{H} & a_{hk} & a_{hh} & a_{hl} \\ \bar{L} & a_{lk} & a_{lh} & a_{ll} \end{bmatrix}^{-1} \begin{bmatrix} \bar{a} \\ a_{k\epsilon} \\ a_{h\epsilon} \\ 0 \end{bmatrix}$$

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:

(A.7) $$\begin{bmatrix} \hat{b}_k \\ \hat{b}_h \\ \hat{b}_l \end{bmatrix} = \begin{bmatrix} a_{kk} & a_{kh} & a_{kl} \\ a_{hk} & a_{hh} & a_{hl} \\ a_{lk} & a_{lh} & a_{ll} \end{bmatrix}^{-1} \begin{bmatrix} a_{k\epsilon} \\ a_{h\epsilon} \\ 0 \end{bmatrix}.$$

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:

(A.8a) $$\hat{b}_k = D^{-1}[(a_{hh}a_{ll} - a_{hl}^2)(a_{k\epsilon}) + (a_{kl}a_{hl} - a_{kh}a_{ll})(a_{h\epsilon})]$$

(A.8b) $\hat{b}_h = D^{-1}[(a_{kk}a_{11} - a_{k1}^2)(a_{h\epsilon}) + (a_{k1}a_{h1} - a_{kh}a_{11})(a_{k\epsilon})]$.

(A.8c) $\hat{b}_L = D^{-1}[(a_{KH}a_{KL} - a_{KL}a_{HH})(a_{K\epsilon}) + (a_{KH}a_{KL} - a_{KK}a_{HL})(a_{H\epsilon})]$.

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.[23]

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.9) $a_{KL}a_{HL} - a_{KH}a_{LL}$.

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.9) 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 our sample data for 1965 through 1985 growth, we estimated the coefficients in equation (A.8). The standard errors of these estimates were then obtained by using a bootstrap [Efron (1982)] procedure, by creating 1000 samples from the original sample and computing the covariances of the coefficients in these created samples as population estimates of the

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

population covariances.[24] Our estimates of equation (A.8) were:

$$\hat{b}_k = D^{-1}[\ \underset{(0.002)}{0.008}\ (a_{k\epsilon}) + \underset{(0.001)}{0.002}\ (a_{h\epsilon})] \qquad \text{(A.10a)}$$

$$\hat{b}_h = D^{-1}[\ \underset{(0.003)}{0.012}\ (a_{h\epsilon}) + \underset{(0.001)}{0.002}\ (a_{k\epsilon})]. \qquad \text{(A.10b)}$$

$$\hat{b}_L = D^{-1}[\ -\ \underset{(0.004)}{0.008}\ (a_{k\epsilon}) - \underset{(0.005)}{0.010}\ (a_{h\epsilon})]. \qquad \text{(A.10c)}$$

While the unobservability of $a_{k\epsilon}$ and $a_{h\epsilon}$ preclude a definitive statistical conclusion, our results are strongly supportive of our conjecture that the estimation process would yield an upward bias on the physical and human capital coefficients and a downward bias on the labor coefficient. The first term in each expression of the predicted sign and statistically significant. While the second terms just miss being statistically significant at a 5% level, they are always close to significance and more importantly, are of the proper sign.

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[24]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.

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Table 1

Cross-Country Growth Accounting Results Standard Specification

(1965-1985)

Dependent Variable: DGDP 1965-1985

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Const	0.269 (0.004)	1.947 (0.000)	1.871 (0.000)	1.968 (0.000)	1.127 (0.000)	1.654 (0.000)
DK	0.457** (0.000)	0.545** (0.000)	0.555** (0.000)	0.530** (0.000)	0.607** (0.000)	0.472** (0.000)
DL	0.209 (0.317)	0.130 (0.429)	0.164 (0.319)	0.225 (0.245)	0.362* (0.026)	0.219 (0.117)
DH	0.063 (0.425)	-0.059 (0.314)	-0.043 (0.516)	-0.080 (0.215)	-0.028 (0.671)	-0.031 (0.600)
LOGGDP	——	-0.190** (0.000)	-0.185** (0.000)	-0.190** (0.000)	-0.143** (0.001)	-0.152** (0.000)
OIL	——	——	-0.097 (0.491)	——	——	——
AFRICA	——	——	——	-0.024 (0.871)	——	——
LAAMER	——	——	——	-0.107 (0.103)	——	——
MID	——	——	——	——	0.675 (0.381)	——
PIQ	——	——	——	——	——	-0.057 (0.316)
Obs	78	78	78	78	40	67
F-Stat	26.609	37.693	30.228	25.610	27.740	22.736
R-Squared	0.519	0.674	0.677	0.684	0.803	0.651

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Table 2

Cross-Country Growth Accounting Results Human Capital in Log Levels

(1965-1985)

Dependent Variable: DGDP 1965-1985

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Const	0.452 (0.000)	2.110 (0.000)	2.087 (0.000)	2.074 (0.000)	1.148 (0.011)	1.734 (0.000)
DK	0.503** (0.000)	0.492** (0.000)	0.497** (0.000)	0.469** (0.000)	0.598** (0.000)	0.435** (0.000)
DL	0.113 (0.603)	0.271 (0.109)	0.277 (0.107)	0.413* (0.035)	0.384* (0.050)	0.314 (0.067)
LOGH	-0.099 (0.144)	0.159* (0.023)	0.153* (0.038)	0.203* (0.004)	0.044 (0.758)	0.113 (0.141)
LOGGDP	———	-0.242** (0.000)	-0.239** (0.000)	-0.246** (0.000)	-0.159 (0.064)	-0.185** (0.000)
OIL	———	———	-0.026 (0.834)	———	———	———
AFRICA	———	———	———	0.000 (0.999)	———	———
LAAMER	———	———	———	-0.137* (0.040)	———	———
MID	———	———	———	———	0.764 (0.327)	———
PIQ	———	———	———	———	———	-0.042 (0.430)
Obs	78	78	78	78	40	67
F-Stat	27.908	41.719	32.954	29.568	27.676	23.896
R-Squared	0.531	0.696	0.696	0.714	0.803	0.662

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Table 3

Growth Accounting Results: U.S. Manufacturing by State

(1960-1980)

Dependent Variable: DVA1960-1980

	Model 1	Model 2	Model 3	Model 4
Const	0.293	3.775	0.331	2.804
	(0.001)	(0.004)	(0.709)	(0.009)
DH	0.032	-0.216	———	———
	(0.883)	(0.368)		
DK	0.236**	0.199*	0.238	0.201
	(0.009)	(0.032)	(0.970)	(0.090)
DL	0.673**	0.727**	0.671**	0.724**
	(0.000)	(0.000)	(0.000)	(0.000)
$LOGVA_0$	———	-0.371**	———	-0.375**
		(0.006)		(0.005)
LOGH	———	———	-0.331	0.398
			(0.879)	(0.320)
Obs	51	51	51	51
F-Stat	77.047	71.168	77.010	71.596
R-Squared	0.831	0.861	0.831	0.862

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Table 4

Determinants of Physical Capital Accumulation 1965

Dependent Variable: DK/K 1965

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Const	-0.004	-0.003	0.019	0.031	-0.003	-0.013	0.047
	(0.577)	(0.685)	(0.211)	(0.358)	(0.815)	(0.614)	(0.000)
K	-1.87E-11**	-1.86E-11**	-1.26E-11*	-9.60E-12	-1.74E-11**	2.48E-12	1.92E-12
	(0.001)	(0.002)	(0.054)	(0.152)	(0.002)	(0.713)	(0.807)
H	0.010**	0.010**	0.007**	0.006*	0.010**	——	——
	(0.000)	(0.000)	(0.010)	(0.022)	(0.000)		
L	2.36E-07*	2.37E-07*	1.28E-07	8.61E-08	1.76E-07	1.03E-08	4.02E-07**
	(0.027)	(0.029)	(0.237)	(0.310)	(0.153)	(0.895)	(0.002)
OIL	——	0.005	——	——	——	——	——
		(0.738)					
AFRICA	——	——	-0.028*	——	——	——	——
			(0.044)				
LAAMER	——	——	-0.005	——	——	——	——
			(0.638)				
MID	——	——	——	-0.031	——	0.166*	——
				(0.783)		(0.025)	
PIQ	——	——	——	——	0.002	——	-0.026**
					(0.751)		(0.000)
Obs	80	80	80	40	70	50	97
F-Stat	12.556	9.341	9.239	1.789	8.163	1.517	6.889
R-Squared	0.331	0.333	0.384	0.170	0.334	0.090	0.182

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Table 5

Determinants of Physical Capital Accumulation 1970

Dependent Variable: DK/K 1970

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Const	0.017 (0.099)	0.015 (0.176)	0.031 (0.028)	0.098 (0.000)	-0.017 (0.302)	0.071 (0.005)	0.057 (0.000)
K	-2.03E-11** (0.001)	-2.06E-11** (0.001)	-1.81E-11** (0.005)	-7.49E-12 (0.215)	-1.97E-11** (0.004)	2.66E-12 (0.706)	3.19E-12 (0.593)
H	0.008** (0.000)	0.009** (0.000)	0.007** (0.007)	0.006** (0.003)	0.008** (0.002)	——	——
L	1.72E-07 (0.136)	1.66E-07 (0.111)	1.17E-07 (0.317)	7.37E-08 (0.291)	1.53E-07 (0.175)	-1.16E-08 (0.843)	1.72E-08 (0.847)
OIL	——	0.015 (0.359)	——	——	——	——	——
AFRICA	——	——	-0.015 (0.317)	——	——	——	——
LAAMER	——	——	-0.005 (0.627)	——	——	——	——
MID	——	——	——	-0.208 (0.009)	——	-0.049 (0.484)	——
PIQ	——	——	——	——	0.002 (0.765)	——	-0.014* (0.032)
Obs	88	87	87	42	76	49	97
F-Stat	4.372	4.372	1.744	1.744	3.363	0.139	1.294
R-Squared	0.176	0.176	0.159	0.159	0.159	0.009	0.040

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Table 6

Determinants of Physical Capital Accumulation 1985

Dependent Variable: DK/K 1985

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Const	0.004	0.004	0.030	0.008	0.026	0.003	0.036
	(0.563)	(0.566)	(0.017)	(0.666)	(0.081)	(0.889)	(0.000)
K	-2.55E-14	-2.21E-14	5.03E-13	8.16E-13	4.69E-13	2.35E-12	2.10E-12
	(0.988)	(0.989)	(0.776)	(0.710)	(0.781)	(0.157)	(0.091)
H	0.002*	0.002*	-0.000	0.002	0.001	——	——
	(0.037)	(0.036)	(0.946)	(0.310)	(0.296)		
L	9.33E-08	9.30E-08	3.03E-08	1.09E-07	6.89E-08	8.93E-08	4.96E-08
	(0.096)	(0.076)	(0.516)	(0.101)	(0.186)	(0.120)	(0.244)
OIL	——	0.000	——	——	——	——	——
		(0.980)					
AFRICA	——	——	-0.022*	——	——	——	——
			(0.041)				
LAAMER	——	——	-0.022*	——	——	——	——
			(0.001)				
MID	——	——	——	-0.015	——	0.037	——
				(0.790)		(0.476)	
INWARD	——	——	——	——	-0.000	——	-0.000*
					(0.113)		(0.019)
Obs	94	94	94	46	93	48	100
F-Stat	2.164	1.605	3.603	1.178	2.314	1.315	2.861
R-Squared	0.067	0.067	0.170	0.103	0.095	0.082	0.082

2-tail significance in parenthesis. * indicates 5% confidence level, ** indicates 1% confidence level.

Figure 1: Income vs. Human Capital

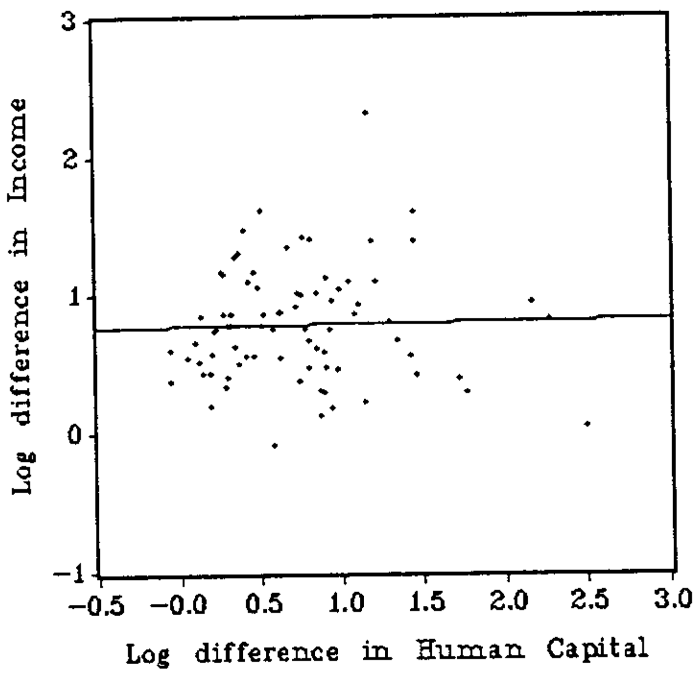

Figure 2: Income vs. Physical Capital

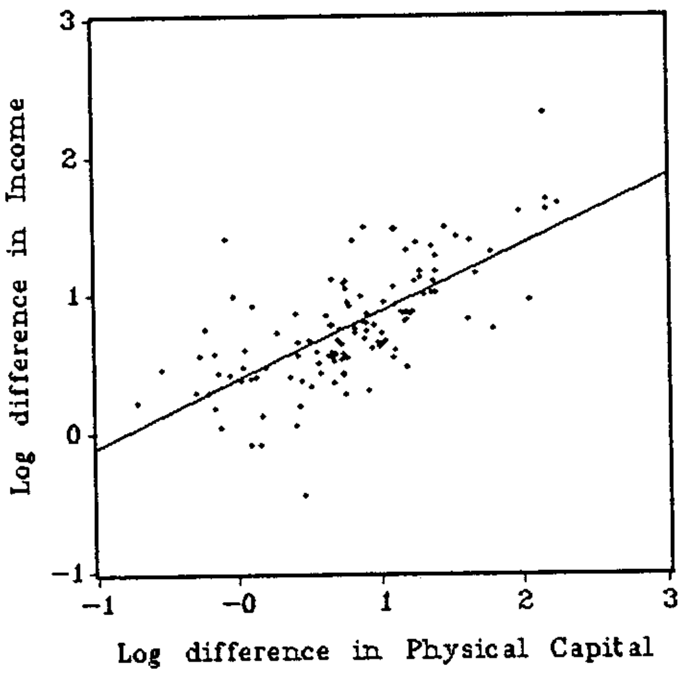

Figure 3: Income vs. Labor

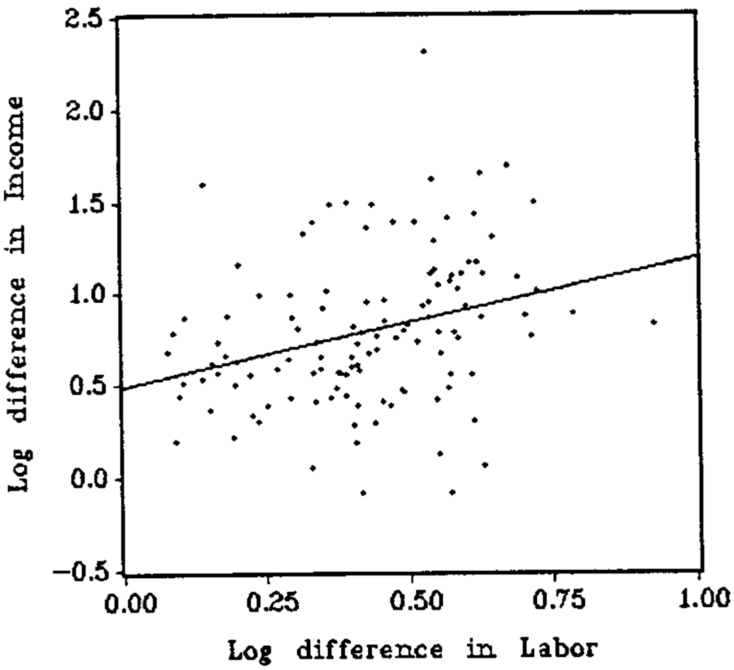

Figure 4: Income vs. Literacy