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GROWTH ACCOUNTING WITH PHYSICAL AND HUMAN CAPITAL ACCUMULATION

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ABSTRACT

Using a growth accounting method based upon a Cobb-Douglas production function, we derive a reduced form equation which directly links growth in per capita income levels to rates of growth in factors of production. Estimation of this equation, however, requires estimates of physical and human capital stocks, because the use of investment to income ratios are inappropriate if capital-output ratios vary across countries and time. We construct estimates of physical and human capital accumulation rates. We then use this data in growth accounting estimation.

We find that human capital accumulation rates do not enter into per capita income growth once physical capital accumulation rates are correctly specified. However, human capital does contribute positively to physical capital accumulation rates, which measurably enter into growth. Similarly, domestic political instability is shown to affect growth indirectly, through its impact on physical capital accumulation, rather than directly entering into the growth accounting equation.

1. Introduction.

A large literature has recently developed in which cross-country estimation of aggregate production functions are used to investigate the determinants of economic growth. This literature [for example, see Barro (1991)] typically runs a cross-sectional estimation of economic growth on a list of right-hand side variables which are believed to contribute either positively or adversely to economic development.

Using a growth accounting method based on a Cobb-Douglas production function, we derive an equation which directly links growth rates in per capita output to rates of accumulation of factor inputs. However, efforts to utilize this methodology are confronted by difficult data problems. For example, while data on gross investment as a share of income is widely available, the growth accounting method calls for the rate of net investment as a share of the physical capital stock. Construction of this variable would require physical capital stock data for a large number of countries, which is not readily available. The use of the investment to income ratio as a proxy for net physical capital accumulation rates requires the strong assumption that capital output ratios are similar across countries.

Similarly, the construction of data for human capital growth rates is hindered by the lack of stock data for a large cross section of countries. Previous empirical studies have tended to use enrollment ratios or growth in literacy rates as proxy variables. Enrollment ratios are inadequate for a growth accounting method since at best they represent rates of investment in human capital, rather than growth rates of human capital. Literacy rates have been used as stock variables, but there are a number of well-known empirical problems associated with the use of literacy rates in a cross-sectional framework: These include large quality of measurement differences across countries, biases introduced by the skewness of sampling towards urban areas, and the fact that developed countries typically have literacy rates very close to unity.

An alternative framework which allows for cross-country growth accounting estimation which does not require factor stock data has been presented by Mankiw, Romer, and Weil (1990). These authors estimate an "augmented Solow model" which includes human as well as physical capital in a cross-country regression framework. By assuming a neoclassical production function and incorporating the steady-state properties of that model, Mankiw, Romer and Weil derive a functional form which they then estimate in levels, rather than growth rates. Their steady-state assumption allows them to estimate a production function which is directly derived from theory on the basis of sums of discounted flows, avoiding the need of stock estimates for physical and human capital.

Since the empirical evidence concerning convergence seems mixed, it would be desirable to estimate the growth accounting equations without making any steady-state assumptions. Of course, this methodology requires incorporating explanatory variables for which stock data are not readily available. In this paper, we first construct proxies for the data needed under the growth accounting methodology using a variety of alternative estimation techniques. We then estimate the growth accounting equations which theory directly predicts. Lastly, we use errors-in-variables diagnostics to investigate the power of the tests we have run with constructed data. This methodology allows us to reconsider the role of alternative factors in the determination of cross-country growth performance, as well as re-examine the "convergence hypothesis" found in the literature.

We construct physical capital stock data, using two alternative methodologies described below to estimate initial capital stocks and capital series data on investment flows obtained from the Summers and Heston (1991) data set. The final capital stock series used in the reported regressions below is satisfies the consistency requirement that the profile of initial capital-output ratios is consistent with those of the overall capital series.

The capital stock series generated by these methods are quite closely correlated with each other, with a correlation coefficient of 98.6%. In addition, the Summers-Heston data set provides capital stock estimates for a small set of countries. The correlation coefficient between the capital stock series used in the reported regressions and those available directly from Summers and Heston is 97.7%. The close correlations are robust to a number of alternative depreciation rate estimates.

Estimates of stocks of human capital were acquired from work by Kyriacou (1990). Kyriacou estimates human capital stocks for a large set of countries by using estimated coefficients of the relationship between current educational composition of the labor force, acquired from Psacharopoulos and Ariagada (1986) and past enrollment ratios in primary, secondary and tertiary schooling. He then uses the estimated coefficients to estimate human capital stocks for a large set of countries. These human capital stock estimates appear reasonable and have been used in other studies [for example, see Sala-i-Martin (1991)]. As a form of sensitivity analysis, we also uses rates of growth in literacy across countries as a proxy for rates of growth in the human capital stock, bearing in mind all the caveats associated with the use of literacy rates discussed earlier.[1]

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[1] We note, nonetheless, that our data on rates of growth in human capital stocks are highly correlated with estimated rates of growth in literacy.

Our results are generally in accordance with the literature, with a few notable exceptions. We find that growth in the human capital stock enters either insignificantly or measurably negatively in per capita growth. This surprising result may in part be traced to the performance of African countries in the sample. These countries started out the estimation period with very low human capital stocks and hence experienced relatively large growth rates in these stocks. However, even with the African countries removed from the sample, human capital accumulation fails to enter significantly positive in explaining per capita growth.

This finding raises the issue of the role of human capital in the determination of economic growth. It has been suggested [Lucas (1990)] that the lack of human capital has been responsible for low rates of physical capital accumulation in developing countries. One may conjecture that complementarity between human and physical capital drives this relationship, as low levels of human capital depress the returns on physical capital. Below, we also examine the influence of human capital stocks on physical capital accumulation, both for a single year in a cross section and for averages over relatively lengthy periods. We take into account, however, that an alternative deterrent to physical capital investment may be the degree of political instability in the developing nation. Political instability may hinder the ability of governments to commit to property right assignments, and hence leave a country an undesirable location for investment. Alternatively, political instability may directly lower the marginal product of capital in a developing country by disrupting economic activity. To account for cross-country differences in political instability, we use Gupta's (1990) constructed political index.[2]

Our results show that both human capital and political instability enter into physical capital accumulation rates, although not always measurably at a five percent level. However, political instability fails to enter measurably into economic growth, once physical capital growth has been introduced. This suggests that political instability does not affect economic growth directly through disruption of the aggregate production function. Nevertheless, the strong dependence of economic growth rates on rates of physical capital accumulation imply that both political stability and human capital accumulation play a strong indirect role in the determination of economic growth, through their impact on a country's ability to attract both domestic and foreign physical investment.

The remainder of the paper is organized into five sections: Section 2 introduces the methodology used in the estimation of aggregate physical stocks for a large set of countries. Section 3 uses this data to run growth accounting regressions which are directly predicted from theory. Section 4 then addresses the empirical determinants of physical capital accumulation. Section 5 concludes.

2. Estimation of Aggregate Physical Capital Stocks.

Investment flow data is now available for a large number of countries from the Summers-Heston (1990) data set. However, calculation of capital stocks using this data set requires some mechanism by which initial capital stocks can be estimated. In addition, the use of this data for

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[2] Reported results for political instability were robust to alternative proxies for political instability, such as data used on revolutions and coups from the Barro (1991) data set.

growth accounting purposes requires a fairly early estimate of the capital stock, implying that the initial capital stock estimate will play a large role in the determination of aggregate capital stock growth rates.

One possibility would be to arbitrarily set initial capital stocks to zero, and then calculate sufficiently far into the future to periods where initial capital stocks have little share in total capital stock estimates. However, relatively few developing countries have investment flow data prior to 1955, and some have none prior to 1960. Starting ten years in the future, at 1965, the initial capital stock would still retain 48% of its initial value at a 7% depreciation rate, and 35% under a 10% depreciation rate. It follows that an initial capital stock estimate of zero would seriously overestimate capital stock growth rates for countries which begin with relatively large capital stocks.

Alternatively, a capital-output ratio of three has been used in the literature as a rule of thumb. Numbers close to this ratio have been estimated for the United States. However, capital will have a lower share in the output of countries less abundantly endowed with capital than the United States. This empirical fact is already observable from the small set of countries for which capital stocks are available in the Summers-Heston data set. Using the arbitrary number of three as a proxy for the initial capital stock would seriously overestimate the initial capital stocks of these countries.

Ideally, one would like to use a proxy that takes into account both the income level of the developing country and that country's initial capital-labor ratio. In a simple two-factor aggregate production function, the output-to-capital ratio will be inversely related to the country's capital-labor ratio:

(1) $$K/Y = \alpha + \beta\, K/L + \epsilon.$$

Estimation of α and β in equation 1 would require an estimate of K, which of course is unavailable for the large sample of countries we wish to use in our empirical work.

We estimate α and β using two distinct estimation methods. First, capital stocks have been estimated for 29 countries in the Summers and Heston data set for 1985.[3] Using this data, we estimate the magnitude of α and β for this small sample of countries. The regressions results are:

$$K/Y = \underset{(0.224)}{0.579} + \underset{(0.003)}{0.025}\ K/L \tag{2}$$

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 75%, which is relatively large considering that differences in human capital and natural resource endowments are not included in the regression.

Equation (2) gives us an estimate for K_0 given Y_0 and L_0. This estimate represents an improvement over an approach that ignores the labor 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:

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

[3] 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.

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 with initial estimates of K_0 which are equal to three times initial capital stocks. Then, using discounted investment flows, we find the implied series of capital stocks, and calculate α and β in equation (1) by regressing capital-output ratios on capital-labor ratios. These estimated α and β coefficients are used to update our K_0 estimates and recalculate the capital stock series. The process was repeated until convergence was achieved, ie. until the α and β used to calculate initial capital stocks yielded end-of-period estimates for α and β sufficiently close to their beginning of period estimates.

The estimation was conducted using both 7 and 10 percent rates of depreciation. Convergence was achieved under the 10% depreciation rate estimate in 9 iterations, and under the 7% depreciation rate estimate in 9 iterations. The final estimated values of α and β satisfied:

$$K/Y = \underset{(0.416)}{1.000} + \underset{(0.001)}{0.056}\ K/L \qquad (4)$$

under the assumption of 10% depreciation and:

$$K/Y = \underset{(0.501)}{1.268} + \underset{(0.001)}{0.054}\ K/L \qquad (5)$$

under the assumption of 7% depreciation with R-squares of 0.456 and 0.461 respectively.

Comparison of equation (3) with equations (4) and (5) reveals that the different methodologies yield somewhat different capital stock estimates. In particular, since estimated K is increasing in α and β, the second methodology will yield larger capital stock estimates than the first.

However, when used to calculate rates of physical capital stock accumulation, both the series estimated using the implied α and β from the SH data set and the series estimated from the iterative methodology yield quite consistent estimates, both under the assumption of 7% and 10% depreciation rates. Under a 7% depreciation rate estimate, the correlation coefficient between the two series was 98.6%.

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 the appendix, 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.[4]

3. Growth Accounting Equations.

3.1 Methodology.

Consider an aggregate production function in which output is dependent upon three types of inputs: labor, L, physical capital, K, and human capital, H: $Y_t = K_t^{\alpha} L_t^{\beta} H_t^{\gamma}$. Taking logs, this production function can be approximated in growth terms as:

$$(6) \qquad \Gamma Y = \alpha\ \Gamma K + \beta\ \Gamma L + \gamma\ \Gamma H$$

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

[4]The entire set of capital stock estimates is available upon request.

and γ can then be directly estimated using equation (6).[5]

Data for estimation were acquired from a variety of sources. Stocks and growth rates of physical capital, *K* and *dK*, were estimated in the previous section for two alternative periods of growth, 1965-1985 and 1970-1985. Raw data on investment flows was obtained from the Summers-Heston 1988 (SH) data set.

Human capital stock estimates, *H* and *dH*, for this period have been acquired from Kyriacou (1990). Kyriacou estimates human capital stocks by first estimating the relationship between educational attainment of the labor force in 1975, which is available for 42 countries, and past values of human capital investment, such as enrollment in primary, secondary and tertiary education. He then uses these estimated coefficients to calculate human capital stock estimates for a relatively large set of countries. Rates of human capital accumulation can then be directly calculated. As a form of sensitivity analysis, we also proxy for human capital growth with rates of growth in literacy rates, *LIT* and *dLIT*. Raw data for literacy rates were obtained from the World Development Report, various issues. The two measures of human capital growth are positively correlated, with an estimated correlation coefficient of 68%.

A proxy for national political instability, *PIQ*, was obtained from Gupta (1990). Gupta uses discriminant analysis to identify political instability by measuring the influence of ten explanatory variables on incidents of political violence. The variables considered by Gupta include

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[5]Estimation of the production function in levels is subject to all the caveats discussed in Benhabib and Jovanovic (1990). If stochastic shocks to the production function are random walks, however, estimating the coefficients using growth rates can overcome these difficulties.

the number of political demonstrations, the number of riots, the number of political strikes, the number of deaths from political violence, the number of assassinations, the number of armed attack events, the number of political executions, the occurrence of successful coups d'etat, the occurrence of unsuccessful coups d'etat, and the nature of government.

The Gupta index has some drawbacks due to its "event study" construction. For example, due to the limited amount of realized political instability in Mexico, that country is consistently erroneously reported as more politically stable than the United States. However, the overall index is closely correlated with other measures of political instability that have been used in the literature, such as the number of revolutions and coups as well as assassinations and strikes available from the Barro (1991) data set. We also ran the regressions reported below with these variables substituted for the Gupta index and experienced similar results.

Data for population stocks and growth rates, *POP and dPOP*, as well as income stocks and growth rates, *GDP* and *dGDP* were obtained from the SH data set. The dummy variables identifying oil-exporting countries, *OIL*, Latin American countries, *LA*, and sub-Saharan African countries, *AFRICA*, were obtained from the Barro (1991) data set.

As suggested by equation (6) above, growth rates of physical capital, human capital, and labor, along with a number of other potential explanatory variables, were then regressed on growth rates of income per capita using ordinary least squares with White's heteroscedasticity correction method.

3.2 Results.

Results for per-capita income growth from 1970 through 1985 are reported in Table 1 using the iterative-method capital stock estimates under a 7% depreciation rate assumption.[6] Capital stock growth rates consistently enter positively and significantly in per-capita income growth, as would be predicted by the Cobb-Douglas production function.

Similarly, and as predicted, population growth also tends to enter significantly negative at the 5% confidence level, only failing to enter measurably when African and Latin American dummies are included.[7] However, the large population growth rates associated with these countries implies collinearity between these dummies and population growth, which explains the diminished coefficient estimate. Regressions were also run using the Barro (1991) net fertility variable growth variable. It also entered significantly negative, and yielded coefficient estimates for the other parameters similar to those reported here.

The most surprising result concerns the coefficient on human capital growth. It can be seen that human capital is consistently estimated to enter negatively into human capital growth, although not always measurably. Most importantly, human capital does not enter significantly when African and Latin American dummies are included, suggesting that these dummies proxy for nations which achieved large rates of human capital growth without experiencing similarly large increases in per capita income growth.

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[6] Since capital stock growth rate estimates were quite similar, regressions run with the alternative stock series yielded quite similar results. These results are available upon request. The reported series was chosen because it yielded a capital-output ratio for the United States in 1985 which was closest to 3.

[7] When the dependent variable is per capita income growth, the coefficient on population should be negative if there are diminishing returns to labor.

Note that the measurably negative coefficient estimates on human capital growth rates are robust to the inclusion of initial wealth in Model 4. This implies that the correlation between high rates of human capital growth and low levels of initial per capita wealth does not explain the reported results. In addition, the use of growth rates for literacy as a proxy for human capital accumulation rates reported in Models 5 and 6 also yields negative coefficient estimates, although the estimates are not measurable at a 5% confidence level.

Political Instability, as measured by the Gupta index is introduced in Model 3, and fails to enter significantly. In fact, the variable enters with the wrong sign. This implies that political instability does not enter into per capita income growth, once one has accounted for relative rates of factor accumulation across countries.

When we also include initial wealth, it enters negatively, but not significantly, as a predictor of economic growth, providing relatively weak evidence for the convergence hypothesis.

The Oil, Africa, and Latin America dummies all enter with expected signs, but fail to enter significantly, except for the Latin American dummy in Model 2. This gives some indication that the inclusion of relative rates of factor accumulation are sufficient to explain the growth disparities across these groups of countries. Note that use of other variables, such as the investment-income ratios used in Barro (1991) left significant negative estimates for the African dummy variable.

The estimation results for longer growth periods are shown in the second half of Table 1. Growth rates for human capital are available for 1965 through 1985 while growth rates in literacy are available from 1960 through 1985. In each case the longest available period was reported.

It can be seen that the results are quite similar to those shown in the 1970 through 1985 regressions. Capital accumulation enters positively while population growth enters negatively. Both rates of factor accumulation enter significantly. Human capital accumulation, either measured by the Kyriacou index or growth in literacy rates, again enters with a negative sign, although never measurably at a 5% confidence level. Political instability again enters negatively, although not significantly. The same is true for initial income per capita.The country dummies all enter with the same sign, although the Latin American and African dummies are measurably negative for the 1960 through 1985 growth period.

Using the growth accounting methodology above, equation (6) implies that α, β, and γ can be directly estimated from the regression results above. From Table 2, one can see that the coefficient estimate on population growth was approximately -0.4, which would imply an estimate of β of 0.6. The coefficient on γ was similarly estimated to be approximately -0.06, although usually the estimate was not measurably different from zero. Capital accumulation was estimated to have a coefficient value of approximately 0.24.

However, it is likely that the estimation technique used to estimate the capital stock growth growth rate described in the previous section only did so with error. Under the presence of errors in variables, the direct α coefficient estimate will either be biased towards or away from zero, depending upon the nature of the errors which occurred in the generation of the explanatory variable data. The standard response to this problem is the reverse regression method. If, for example, the direct regression estimate is biased towards the origin, the estimate from the reverse regressions will be biased away from the origin. The true estimate of α therefore will lie between those generated by the direct and reverse regressions.

Table 2 presents the bands of estimates for α, the capital share coefficient, which incorporates the regression results for both the direct and reverse regressions. It can be seen that the reverse regression coefficient estimates were above those obtained through the direct regressions, implying that under the assumption that the capital stock series was measured with error, the direct regressions yielded estimates which were biased towards the origin. This implies that the conclusion that capital accumulation enters positively in the determination of per capita income growth is robust to errors in variables diagnostics. The α coefficient estimates associated with capital accumulation range from a lowest level of 0.12 to a highest level of 0.44. When combined with estimates of 0.60 for the labor share and -0.06 for human capital accumulation, the possibility of constant returns to scale in the production function cannot be ruled out, although the true α estimate would have to lay at the high end of its possible range.

4. Sources of Factor Accumulation.

The results above suggest that neither political instability nor human capital accumulation enter into growth accounting equations when one accounts for rates of aggregate factor accumulation. Nevertheless, proxies for political instability variables and human capital stocks have been shown in the literature to enter positively in models of aggregate growth.

This inconsistency may be resolved if human capital accumulation and political instability are correlated with rates of physical capital accumulation, since physical capital accumulation has been shown to consistently enter as an important determinant of per capita income growth.

There is reason to believe that this is the case. Lucas (1990) has suggested that one reason that physical capital does not flow to poor countries is that their marginal products of capital are actually not higher than those of more developed countries due to their poor relative endowments of human capital. Similarly, Kormendi and Meguire (1985) have argued that political instability will be negatively correlated with physical capital accumulation because of a lack of faith in the assignment of property rights within countries exhibiting political instability. Empirically, they show that proxies for political instability are negatively correlated with gross investment as a share of income.

Given the production function above, the marginal product of capital will be correlated with the aggregate physical capital stock, the stock of labor, and the stock of human capital. Given that human capital and labor are complementary to physical capital, one would expect that the marginal product of physical capital would be positively related to the aggregate labor and human capital stocks. However, the sign of the dependence of the marginal product of capital on the physical capital stock depends upon whether there are aggregate increasing returns in physical capital.

Given that adjustment of physical capital stocks is costly, one would expect that differences in marginal products could exist in the short run across countries which were not eradicated by instantaneous capital flows. However, one would expect that rates of capital accumulation would tend towards equating marginal products of physical capital, holding all else equal. This would imply that capital accumulation rates would be positively correlated with aggregate marginal products of capital in any given year.

To test this hypothesis and examine the impact on capital accumulation of domestic political instability, we examine the determinants of physical capital accumulation. We regress the aggregate physical capital stock, the human capital stock and the domestic population stock on gross and net rates of physical capital accumulation. In addition, we examine the role played by political instability, as proxied by the Gupta index. Lastly, we include a dummy for oil countries as these countries may have experienced rapid capital accumulation due to favorable terms of trade changes during the estimation period. We examine regressions for the determinants of gross and net physical capital accumulation for 1965, 1970, and 1975, the years for which human capital stock data was available.[8]

The results of the regressions are reported in Table 3. It can be seen that both gross and net rates of physical capital accumulation are strongly and measurably correlated with human capital stocks for all three years. In addition, political instability enters negatively in the determination of both gross and net physical capital accumulation for all three years, although only measurably for gross rates of investment. However, given that investment flows can exhibit very volatile patterns, even this finding appears to be quite robust. The data appears to support the conjecture that the role for human capital and political instability to affect growth is through their impact on rates of physical capital accumulation.

Two puzzling results appear in the results in Table 3. First, both gross and net investment rates are consistently positive in the existing physical capital stock. These results are not surprising for gross rates of physical capital investment, but a neoclassical model with diminishing returns to physical capital would predict negative coefficients for net physical capital investment. However, the coefficient estimate is positive for both 1965 and 1970, although only measurably positive for 1970. The coefficient does enter negatively, although not measurably for 1975. One

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[8]Lack of investment data for many developing countries for 1985 precluded inclusion of this year in the study.

possible explanation for the positive coefficient on capital may be some degree of increasing returns.

Second, and perhaps more surprising, the population coefficient, which theory would suggest should enter positively, enters negatively and significantly for gross capital accumulation in 1970 and 1975. This finding is particularly puzzling because of the inclusion of the political instability variable, which should account for many of the factors which might be correlated with large populations to explain this result. One possible explanation may be that population growth is not a very good proxy for the growth in the labor force. However, population levels enter positively for all three years for net investment, and measurably for 1965.

5. Conclusion.

We first estimated the aggregate physical capital stocks of a large set of countries. We found that once rates of physical and human capital accumulation are introduced into the estimation, human capital fails to enter measurably into the determination of economic growth. Previous investigations have found that other proxies, such as enrollment ratios, enter significantly into growth accounting regressions. The results above suggest that once rates of physical capital accumulation are accurately represented, human capital accumulation rates may not add much.

Nonetheless, this does not imply that human capital accumulation fails to play an important role in the determination of economic growth. In the second set of regressions, we show that human capital stocks are highly correlated with both gross and net rates of investment in physical capital. Since physical capital is shown to play a significant role in the determination of per capita income growth rates, human capital accumulation may act as an engine for attracting physical capital.

Our findings for political instability were quite similar. Political instability as measured by a number of proxies has been shown in the literature to be negatively correlated with economic growth. However, there appear to be two channels through which political instability could have this effect: First, it could adversely affect economic performance directly, through strike activity and disruption of economic activity. This would imply that political instability should enter into the determination of growth even after accounting for rates of factor accumulation. In growth accounting regressions above, we showed that this channel is not empirically significant.

Second, political instability could affect economic growth through its impact on factor accumulation. We showed that political instability has a measurable negative impact on net rates of physical capital accumulation. Since physical capital accumulation plays such a large role in the determination of economic growth, political instability can influence aggregate growth rates by affecting the environment in which economic decisions concerning the rates of physical capital accumulation are made.

The empirical tests had mixed implications for the convergence hypothesis. While initial income levels did not enter into the growth equations with a significant negative coefficient, errors in variables diagnostics indicated that one cold not reject the hypothesis of constant returns to scale in production. On the other hand, the capital stock estimates indicated a positive relationship between the existing capital stock and net rates of physical capital accumulation. This provides some evidence in favor of an increasing returns to scale technology.

The remaining results are quite consistent with those that have been previously found in the literature. As expected, physical capital enters positively and measurably in per-capita income growth, while growth in population enters measurably negatively.

The primary policy conclusions which emerge from the study concern the role of human capital accumulation in economic growth. When one uses the factor accumulation rate estimates indicated by the theory, it becomes clear that the role of human capital in economic growth is to aid in attracting physical capital from both domestic and foreign investment. This fact is most clearly shown in the experience of African nations over the study period. As a group, these nations managed to achieve quite impressive growth rates in human capital while failing to see those achievements result in enhanced rates of economic growth.

Table 1

Growth Accounting Regressions[1]

Dep Var	dGDP7085	dGDP7085	dGDP7085	dGDP7085	dGDP7085	dGDP7085
Const	0.011 (0.003)	0.015 (0.004)	0.012 (0.004)	0.021 (0.007)	0.007 (0.003)	0.001 (0.003)
dK	0.238** (0.033)	0.208** (0.042)	0.202** (0.038)	0.246** (0.032)	0.309** (0.035)	0.293** (0.034)
dPOP	-0.384* (0.145)	-0.263 (0.209)	-0.483** (0.156)	-0.588** (0.199)	-0.471** (0.100)	-0.477** (0.145)
dHK7085	-0.062* (0.032)	-0.071 (0.042)	-0.036 (0.026)	-0.065* (0.031)	——	——
dLIT7085	——	——	——	——	-0.037 (0.037)	-0.041 (0.047)
GPO	——	——	——	-1.27x10 (7.64x10)	——	——
OIL	——	0.008 (0.015)	0.013 (0.015)	——	——	0.007 (0.004)
PIQ	——	——	0.003 (0.004)	——	——	——
AFRICA	——	-0.006 (0.009)	——	——	——	-0.002 (0.008)
LAAMER	——	-0.011 (0.005)	——	——	——	-0.007 (0.004)
Obs	88	88	77	88	79	79
F-Stat	35.108	18.682	17.167	27.037	41.438	21.382
R-Squared	0.556	0.580	0.547	0.566	0.624	0.641

[1] 1970-1985. Capital stock estimated by iterative method with 7% assumed depreciation rate.

Table 1

(continued)

Dep Var	dGDP6585	dGDP6585	dGDP6585	dGDP6585	dGDP6085	dGDP6085
Const	0.015 (0.003)	0.020 (0.004)	0.020 (0.005)	0.017 (0.006)	0.014 (0.007)	0.025 (0.006)
dK	0.222** (0.043)	0.191** (0.055)	0.184** (0.058)	0.223** (0.044)	0.170** (0.034)	0.124* (0.034)
dPOP	-0.379* (0.176)	-0.287 (0.202)	-0.398* (0.175)	-0.416* (0.209)	-0.219 (0.219)	0.064 (0.202)
dHK6585	-0.021 (0.015)	-0.030 (0.019)	-0.018 (0.018)	-0.021 (0.016)	——	——
dLIT7085	——	——	——	——	-0.001 (0.008)	0.093 (0.078)
GPO	——	——	——	-3.73×10^{-7} (7.79×10^{-7})	——	——
OIL	——	0.010 (0.014)	0.017 (0.015)	——	——	0.001 (0.015)
PIQ	——	——	-0.004 (0.004)	——	——	——
AFRICA	——	-0.005 (0.007)	——	——	——	-0.034** (0.009)
LAAMER	——	-0.010* (0.004)	——	——	——	-0.021** (0.007)
Obs	77	77	67	77	61	57
F-Stat	30.877	16.713	14.587	22.891	13.022	12.016
R-Squared	0.559	0.589	0.544	0.560	0.407	0.590

TABLE 2

Reverse Regression Estimates for dK Variable

	1960-1985		1965-1985		1970-1985	
	α_L	α_H	α_L	α_H	α_L	α_H
Iterative Method						
7% Depreciation	0.170	0.421	0.222	0.404	0.238	0.441
10% Depreciation	0.159	0.381	0.201	0.364	0.198	0.387
Summers-Heston Method						
7% Depreciation	0.117	0.271	0.184	0.321	0.190	0.375
10% Depreciation	0.136	0.304	0.180	0.324	0.172	0.358

TABLE 3

Determinants of Levels of Investment 1965, 1970, and 1975

Dep Var	dK1965	I1965	dK1970	I1970	dK1975	I1975
Constant	1234.8	23346.5	2543.8	296.11	-102.13	-3211.9
	(2238.2)	(15510.5)	(2679.2)	(147.56)	(2090.9)	(15316.0)
K	0.024**	0.004	0.027*	0.0002*	0.026**	-0.001
	(0.004)	(0.008)	(0.010)	(0.0001)	(0.021)	(0.014)
Pop	0.059*	0.069	0.041	-0.0017*	0.026	-0.193
	(0.028)	(0.078)	(0.028)	(0.0006)	(1.223)	(0.068)
H	1239.6*	18903.8**	1155.3*	182.01**	582.35	26784.4
	(511.08)	(2671.1)	(455.49)	(20.173)	(380.60)	(2810.0)
PIQ	-3530.2	-34177.3*	-4406.6	-397.63**	-206.23	-39913.1**
	(2203.8)	(13228.9)	(2777.5)	(108.76)	(1187.7)	(10030.0)
OIL	47.758	12667.1	1076.3	532.54*	8828.8**	91846.9*
	(1355.4)	(7660.5)	(0.655)	(190.03)	(2130.8)	(34452.9)
# Obs	70	70	77	76	88	88
F-Statistic	51.661	23.51	23.161	28.516	49.054	32.439
R-Squared	0.801	0.647	0.619	0.670	0.749	0.664

* Significant at 5% confidence level

** Significant at 1% confidence level

TABLE 4

CAPITAL STOCK ESTIMATES: ITERATIVE METHOD 7% DEPRECIATION RATE

COUNTRY	Summers Heston #	1960	1965	1970	1975	1980	1985
ALGERIA	1	26495.92	30378.65	39012.24	70735.43	125850.8	180490
ANGOLA	2	8583.504	8656.398	11509.71	13564.11	12945.74	12430.49
BENIN	3	2716.555	2231.903	2030.364	2217.67	2770.544	3258.466
BOTSWANA	4	319.9042	336.9099	674.5771	2065.058	3241.098	4511.349
BURKINA F	5	NA	2524.079	2806.991	4387.499	5572.873	6643.633
BURUNDI	6	1708.04	1368.972	1183.346	1172.61	1633.708	2401.821
CAMEROON	7	5278.457	5257.075	5988.044	7435.14	11001.35	17533.63
CAPE VERD	8	224.2389	345.4814	511.0985	600.692	826.5238	1215.039
CENT AFRI	9	1710.878	1771.483	1873.579	1936.248	1727.83	1795.657
CHAD	10	3007.913	3937.122	4665.476	5072.416	5607.249	4519.848
CONGO	12	1133.137	1335.859	1756.213	2603.397	2966.503	4896.246
EGYPT	13	12377.64	13429.62	14171.29	18181.37	30852.89	47803.83
ETHIOPIA	14	5496.06	5306.507	5710.646	6032.333	6229.898	7108.484
GABON	15	868.7038	1632.032	2536.164	6689.202	11674.17	14630.23
GAMBIA	16	349.3415	259.0085	197.4084	174.8959	275.4276	395.5555
GHANA	17	8312.536	9799.193	10201.9	10440.29	10187.75	9186.557
GUINEA	18	2260.718	2786.463	3245.665	3712.012	4024.518	4486.278
GUINEA/BI	19	397.6427	675.4168	956.0919	1127.954	1309.385	1439.694
IVORY COA	20	5123.043	5418.751	6714.421	8999.383	15295.11	16535.76
KENYA	21	8376.05	8628.998	11109.33	15207.38	19959.16	23604
LESOTHO	22	304.9036	298.8026	367.5185	572.1246	1302.578	1976.958
LIBERIA	23	1467.452	4256.805	4928.398	5456.166	6506.598	5647.135
MADAGASCA	24	7381.502	7201.741	7867.145	8459.408	8868.861	8147.823
MALAWI	25	1552.012	1811.074	2874.252	4322.286	4938.584	4602.135
MALI	26	2843.954	2422.914	2377.138	2374.96	2563.381	2751.242
MAURITANI	27	1092.149	1044.441	987.414	1478.23	2517.21	3236.11
MAURITIUS	28	1998.848	2162.221	2128.221	3113.942	4161.541	4460.754
MOROCCO	29	10895.95	11278.96	14041.09	19449.3	30150.24	39085.3
MOZAMBIQU	30	14058.85	15838.89	21398.7	26530.01	26384.04	23803.53
NIGER	31	2503.798	2737.947	2980.325	3469.887	4339.848	4418.559
NIGERIA	32	44093.39	48390.92	57350.85	104113.7	179792.6	179332.1
RWANDA	33	1867.913	1462.615	1279.281	1323.019	1614.437	2280.039
SENEGAL	34	5445.241	5109.538	4995.513	5539.076	5923.264	6246.584
SIERRA LE	36	2828.23	2260.572	2017.73	1715.217	1493.958	1403.459
SOMALIA	37	2885.113	2496.435	2407.994	2568.051	4351.126	6197.984
SOUTH AFR	38	93233.18	130203.5	190836.4	271160.1	329366.6	387849.8
SUDAN	39	7061.119	5792.477	4925.925	4465.046	4759.038	4876.77
SWAZILAND	40	542.2356	949.3284	1230.784	1953.085	3257.832	3631.938
TANZANIA	41	3496.97	4704.096	7707.108	11585.81	15658.26	17646.48
TOGO	42	847.2229	1109.11	1478.846	2244.898	3799.595	4071.462
TUNISIA	43	7746.7	10645.13	13485.91	16938.17	22140.34	28180.14
UGANDA	44	1472.807	1405.011	1541.463	1516.971	1284.886	1518.326
ZAIRE	45	7063.163	6334.462	6723.832	9359.368	11964.03	15554.57
ZAMBIA	46	9637.565	12051.61	16729.59	23122.71	20263.56	16632.7
ZIMBABWE	47	7160.783	7905.034	9803.916	14412.94	14680.55	16904.87
BARBADOS	49	1031.634	1296.806	1786.514	2273.582	2848.817	3325.925
CANADA	50	298335.2	354877.7	441439.9	557874.8	716569.4	868240.4

TABLE 4

(continued)

COUNTRY	Summers Heston #	1960	1965	1970	1975	1980	1985
COSTA RIC	51	3369.665	4238.903	5480.085	7818.317	11927.76	12964.07
DOMINICAN	53	4979.91	5509.494	7124.413	12432.93	18794.23	22906.8
EL SALVAD	54	3744.044	4112.052	4605.714	5857.031	7855.898	7583.327
GUATEMALA	56	7327.182	7673.052	8921.485	11167.3	15470.58	16399.34
HAITI	57	4746.629	3789.343	3180.721	3397.696	4630.841	5715.291
HONDURAS	58	2175.759	2607.311	3625.636	4489.922	6427.51	7146.952
JAMAICA	59	5890.786	7919.165	11663.01	15043.25	13961.68	13211.55
MEXICO	60	159875.1	217069.1	315363.1	462575.9	671192	831075.6
NICARAGUA	61	4598.356	6312.641	9000.648	12211.21	13505.42	15890.09
PANAMA	62	2694.122	4048.006	6889.102	11857.08	14588.11	16825.61
TRINIDAD&	65	5411.238	7411.654	8305.763	11444.83	19060.97	23589.04
USA	66	4199571	4375132	4867559	5528094	6450942	7392193
ARGENTINA	67	96881.34	107256.1	125035.7	153983.7	187643.6	178893.4
BOLIVIA	68	6010.183	7662.556	10565.26	15195.58	18931.34	17938.1
BRAZIL	69	170741.3	248504.6	354753.5	608779.5	884933	980712.3
CHILE	70	34934.12	44812.43	55340.83	59144.79	64228.83	66072.94
COLOMBIA	71	50453.22	63678.13	81213.22	101797.1	124283.4	150860.3
ECUADOR	72	11450.93	15351.39	21223.66	32720.85	51888.09	61207.4
GUYANA	73	1694.605	2460.937	3530.584	4247.644	4589.588	4237.278
PARAGUAY	74	2586.33	2574.831	2996.58	4045.011	7270.462	10494.14
PERU	75	32738.14	41987.65	51067.59	69190.16	84521.29	97433.19
SURINAME	76	857.9456	1288.06	1534.468	1981.126	2444.904	2614.145
URUGUAY	77	21207.27	21496.59	21456.45	22232.98	31084.71	33351.25
VENEZUELA	78	51289.39	58695.92	71909.29	108009.1	179457.3	186972.8
AFGHANIST	79	10108.76	9331.789	8503.592	8164.384	9768.309	11013.23
BANGLADES	81	37141.63	36375	40306.31	34942.08	35017.07	43304.07
BURMA	82	9256.461	11519.67	13583.53	14971.82	20084.49	26677.07
CHINA	83	626441.7	653795.8	896449.7	1462341	2246877	3468221
HONGKONG	84	10030.42	17421.16	23632.94	35166.56	59270.67	87145.8
INDIA	85	343841.8	422008.1	529557.9	651631.7	775639.9	916382.1
INDONESIA	86	NA	88108.56	99707.22	170513.3	301220	562373.2
IRAN	87	46243.8	68508.71	112716.2	177453.5	233192.9	295398.9
IRAQ	88	29600.01	36638.36	44690.01	81098.65	185479.9	233670.6
ISRAEL	89	15522.5	26909.24	37688.72	61704.8	75013.84	84424.97
JAPAN	90	392073.5	721462.8	1384550	2283032	3047271	3665386
JORDAN	91	1382.984	1799.121	2614.711	4270.154	9899.065	18157.32
KOREA	92	28627.48	36439.63	77731.39	144241.3	256420	351746
MALAYSIA	94	19590.09	30665.05	45156.28	74082.81	122023.4	206092.4
NEPAL	95	7343.554	6677.799	6425.978	7611.506	11295.09	15659.2
PAKISTAN	97	50330.53	83639.07	111655.6	130308.2	134899.6	139269.6
PHILIPPIN	98	45399.11	61042.76	85434.55	117572	177024.8	210611
SAUDI ARA	99	29332.13	22787.29	21140.48	27480.26	88148.73	201636.7
SINGAPORE	100	5900.932	7408.091	13251.26	28128.73	45801.8	75604.48
SRI LANKA	101	17813.85	21512.16	28153.83	36231.16	50920.18	67255.48
SYRIA	102	12143.49	15634.36	20114.42	30942.52	56942.79	83687.82
TAIWAN	103	12375.25	18247.82	33964.41	69328.6	122728.3	167754
THAILAND	104	25188.66	34812.87	59641.89	86924.97	124004.4	162279.9
AUSTRIA	107	54970.62	78692.04	110617.1	152304.3	193580	223391.6

TABLE 4

(continued)

COUNTRY	Summers Heston #	1960	1965	1970	1975	1980	1985
BELGIUM	108	94882.81	125188.2	164382.3	209859.9	254469.6	262773.6
CYPRUS	109	3697.983	5067.529	7047.532	8354.54	10139.92	12444.2
DENMARK	110	55627.43	83866.4	117465.2	149447.8	165576.7	165250
FINLAND	111	49873.87	74690.08	100067.1	135457.5	155416.7	177173.6
FRANCE	112	455239.3	643068.1	930911.7	1275855	1551912	1703749
GERMANY	113	695785.7	1013904	1330460	1604220	1843806	1981582
GREECE	114	23944.84	40411.63	64146.26	99153.71	126583.3	138441.3
ICELAND	116	1992.327	2711.386	3584.865	4825.978	5927.928	6908.386
IRELAND	117	16583.39	22780.98	31600.11	44077.11	57111.25	65763.14
ITALY	118	450753.3	689580.9	929555.2	1173424	1399588	1579155
LUXEMBOUR	119	5433.376	7207.045	8145.416	9450.805	10510.12	12048.58
MALTA	120	959.9633	1320.645	2059.301	2470.393	3232.594	4634.668
NETHERLAN	121	135130	185711.9	259492.7	322542.3	364094.4	375925.4
NORWAY	122	47710.85	66301.26	88550.78	118555.3	147613.5	171155.8
PORTUGAL	124	22586.78	33018.74	48361.91	71222.47	93240.47	111283
SPAIN	125	162888.3	260066.6	396379.9	554283.3	655559.9	677158.8
SWEDEN	126	102080.4	135066	173209.8	207648.9	225850.3	237084.4
SWITZERLA	127	114419.7	163026	209846.5	260026.6	280149.4	310637
TURKEY	128	65904.65	85003.86	122687.4	191338.4	272801.1	336306
UNITED KI	129	594949.4	690138.6	833528.5	983598.6	1104617	1185472
YUGOSLAVI	130	46887.79	103192.1	154038.3	217278	307623.6	380931.7
AUSTRALIA	131	171667.8	231099.1	313551.3	391091.3	461343.7	535423
FIJI	132	1358.084	1998.824	2750.003	3821.847	5197.708	5911.238
NEW ZEALA	133	29937.57	38496.62	46505.41	63375.1	69748.92	79912.7
PAPUA NEW	134	3026.122	4327.912	8951.08	12752.67	14361.77	16357.87

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