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The Empirics of Growth: An Update

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Over the past decade, there has been an explosion of empirical research on economic growth and its determinants. Despite this large volume of work, many of the central issues of interest remain unresolved. For instance, no consensus has emerged about the contribution of capital accumulation versus improvements in total factor productivity in accounting for differences in economic growth. Nor is there agreement about the role of increased education or the importance of economic policy as determinants of economic growth. Indeed, results from the many studies on a given issue frequently reach opposite conclusions. And two of the main empirical approaches -- growth accounting and growth regressions -- have themselves come under attack, with some researchers going so far as to label them as irrelevant to policymaking.

In this paper, we argue that, when properly implemented and interpreted, both growth accounts and growth regressions are valuable tools, that can -- and have -- improved our understanding of growth experiences across countries. We also show that careful attention to issues of measurement and consistency goes a long way in explaining the apparent contradictions among findings in the existing empirical literature. Thus, we combine growth accounts and growth regressions with a focus on measurement and procedural consistency to address the issues raised above. The growth accounts are constructed for 84 countries that represent 95 percent of the world's GDP and 85 percent of the population, over a period of 40 years from 1960 to 2000.[1] This also enables us to compare growth experiences across two 20-year time periods: 1960-80 versus 1980-2000.

[1] Our sample includes countries from all regions of the global economy with populations in excess of one million, and for which we have national accounts spanning the last 40 years. The largest groups of excluded countries are those of Eastern Europe and the former Soviet Union. A list of countries, by region, is given in Appendix 1.

Understanding characteristics and determinants of economic growth requires an empirical framework that can be applied to large groups of countries over a relatively long time frame. Growth accounts and growth regressions provide such frameworks in a way that is particularly informative because the two approaches can be used in concert, enabling researchers to explore the channels (factor accumulation versus factor productivity) through which various determinants influence growth. While the information provided is, perhaps, best considered descriptive, it can generate important insights that are complementary to those gained from in-depth case studies of selected countries, or from estimation of carefully specified econometric models that are designed to test specific hypotheses.

Growth accounts provide a means of allocating observed output growth between the contributions of changes in factor inputs and a residual, total factor productivity (TFP), that measures a combination of changes in efficiency in the use of those inputs and changes in technology. These accounts are extensively used within the industrial countries for the evaluation of sources of change in productivity growth, the role of information technology, and differences in the experience of individual countries.[2]

In his recent, comprehensive assessment, Hulten (2001) aptly describes the approach as "a simple and internally consistent intellectual framework for organizing data… For all its flaws, real and imagined, many researchers have used it to gain valuable insights into the process of economic growth."[3]

Despite its extensive use within the industrial countries, growth accounting has done surprisingly little to resolve some of the most fundamental issues under debate in the development literature. For example, the major objective of growth accounting is to distinguish between the contributions of increased capital per worker and improvements in factor productivity. Yet, we can observe widely divergent views on this issue ranging between the claims of some that capital accumulation is an unimportant part of the growth process and others that identify capital accumulation as the fundamental determinant of growth.

The criticism of growth accounting has been concentrated in three areas. First, total factor productivity is measured as a residual. As discussed in detail by Hulten, the residual

[2] Recent examples of growth accounting analyses for industrial countries are: Oliner and Sichel (2000), Jorgensen (2001), and OECD (2003).

[3] Hulten (2001, p. 63).

provides a measure of gains in economic efficiency (the quantity of output that can be produced by a given quantity of inputs), which can be though of as shifts in the production function. But such shifts reflect a myriad of determinants, in addition to technological innovation, that influence growth but that were not accounted for by the measured increases in factor inputs. Examples include the implications of sustained political turmoil, external shocks, changes in government policies, institutional changes, or measurement errors. Therefore, this residual should *not* be taken as an indicator of technical change.

A second concern focuses on whether the decomposition is sensitive to underlying assumptions about the nature of the production process and/or to measures of changes in output and the inputs. In principle, growth accounts can be constructed to yield estimates of TFP that are independent of the functional form and the parameters of the production process. This requires assuming a sufficient degree of competition that factor earnings are proportionate to factor productivities and the availability of data on factor shares of income. In practice, data limitations require us to use fixed income shares, which is consistent with a more limited set of production functions. But given that factor shares (appropriately adjusted for self-employment) do not appear to differ systematically across countries, this approach seems quite reasonable. Some of the key measurement concerns are addressed in detail in the body of this paper.

Finally, an accounting decomposition cannot (and is not intended to) determine the fundamental *causes* of growth. Consider a country that has had rapid increases in both accumulation of capital per worker and in factor productivity. This methodology does not provide a means to identify whether the productivity growth caused the capital accumulation (such as by increasing the expected returns to investment), or whether the capital accumulation made additional innovations possible. Growth accounting is a framework for examining the *proximate sources of growth*. And application of a consistent and transparent procedure across a wide range of countries, combined with robustness checks, generates useful benchmarks that facilitate broad cross-country comparisons of economic performance.

Growth regressions have also come under considerable fire. Using this approach, a great many researchers have regressed indicators of output growth on a vast array of potential determinants. But recent summaries of this literature have called its usefulness into question, largely due to the purported instability of the resulting parameter estimates.[4] As we discuss in section 3 of the paper, this critique has gone too far. In fact, most of the variability of the results can be explained by variation in the sample of countries, the time period, and the additional explanatory variables included in the regression. We argue that there is a core set of explanatory variables that has been shown to be consistently related to economic growth, and that the importance of other variables should be examined conditional on inclusion of this core set. Thus, in implementing growth regressions, we restrict attention to estimations based on a common sample of countries, common time period, and a common set of conditioning variables.

A second concern with growth regressions is that many of the explanatory variables of interest are likely to be endogenous. We note that our conditioning variables include initial conditions that can be considered predetermined by an individual country. However, for other variables, including institutional quality, openness and especially policy measures, the concern about endogeneity is certainly valid. Recent work has identified instruments for institutional quality and for trade share based indicators of openness and we have used these instruments in our analysis as discussed below. However, no effective instruments are available for the key macroeconomic policy variables. In this context, we interpret the regression results descriptively.

We also limit our discussion to a consideration of the variations in income growth over the past 40 years. While analysis of the sources of international differences in income levels (sometimes called development accounting) has become increasingly popular in recent years, we believe it paints too pessimistic a picture of the opportunities to improve economic performance. In a levels formulation, it is difficult to define a set of exogenous initial conditions beyond geography and perhaps colonial governance, and the income differences seem largely predetermined by events in the distant past.

Furthermore, the differences between the analyses of levels and rates of growth are less than they seem. The level of income in 2000 can be viewed as a simple combination of the level of income in an earlier year (say, 1960) and the change since then. Given the importance of convergence issues, nearly all empirical studies of growth include the initial level of income as a

[4] For example, see Levine and Renault (1992), Durlauf and Quah (1999) and Lindauer and Pritchett (2002).

conditioning variable. Thus, at the empirical level the two approaches differ primarily in that the growth studies treat developments up to the initial year as predetermined, and do not attempt to explain the earlier history. In our data set, 30 percent of the cross-national variance in purchasing-power-parity income per capita in 2000 is attributed to events since 1960, and 70 percent to the prior millennium.

In the following sections of this paper, we explain the construction of a consistent set of growth accounts covering a dominant portion of the global economy. We then use growth accounts and growth regressions to examine three issues: (1) the relative importance of capital accumulation and TFP in raising income per capita; (2) the significance of improvements in the quantity and quality of education, a factor emphasized by the international aid organizations; and (3) the sources of the sharp differences in growth performance in the period before and after 1980.

Construction of the Accounts

Growth accounts have long provided a conceptual structure for analyzing growth in the industrial countries. However, it is only in the last decade that the development of multi-country data sets has made it possible to extend the analysis to a large number of developing countries. Among the more important data sets are the World Development Indicators (WDI) of the World Bank, the Penn World Tables (PWT), population and labor force data compiled by the United Nations and measures of educational attainment compiled by Robert Barro and Jong-Wha Lee. We have relied primarily on data from the WDI for developing countries and from the Organization for Economic Co-operation and Development (OECD) for industrial countries. We have also been able to compare the basic information for some of the early years with the national income accounts file underlying version 6 of the PWT.

Growth accounts are consistent with a wide range of alternative formulations of the relationship between the factor inputs and output. It is only necessary to assume a degree of competition sufficient to ensure that the earnings of the factors are proportionate to their factor productivities. The shares of income paid to the factors can then be used to measure their importance in the production process. Unfortunately, consistent measures of factor income are unavailable for individual countries, compelling us to use fixed income-share weights to construct the indexes. In those countries where they can be measured appropriately, labor shares are considerably more similar across countries (and over time) than conventional measures imply, suggesting that this is not a serious simplification.[5] While the assumption that income shares weights are fixed over time is only consistent with a more limited set of production functions, it is consistent with the data available for the OECD countries.

In this exercise we assume a constant returns to scale production function of the form

(1) $$Y = AK^{\alpha}(LH)^{1-\alpha}.$$

The capital share, α, is assumed equal to 0.35 for the entire sample. H is a measure of educational attainment, used to adjust the workforce for quality change. We report our results in a form that decomposes the growth in output per worker (*y/l*) into the contributions of growth in capital per worker (*k/l*), increases in education per worker (*h*), and the contribution of improvements in TFP (*a*):

(2) $$y/l = \alpha\left(k/l\right) + (1-\alpha)h + a.$$

Much of the controversy over the relative contribution to growth from increases in factor inputs versus changes in TFP results from differences in the measures of capital and labor inputs. These measures are discussed briefly here and in more detail in the following two sections.

We assume that growth in capital services is proportional to the capital stock, which we estimate with a perpetural inventory model,

(3) $$K_t = K_{t-1}(1-d) + I_t,$$

where the depreciation rate, d, equals 0.05. The basic investment data are taken from a World Bank study that incorporated information extending back as far as 1950.[6]

Our measure of labor input is based on labor force data from the International Labor Organization. The use of labor force instead of population data implies that our measure reflects

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[5] Most of the debate has been over the magnitude of the capital share. Cross-national variations in the share can be traced largely to differences in the importance of the self-employed, whose earnings are assigned to property income in the national accounts. After adjusting for the labor component of the earnings of the self-employed, Englander and Gurney (1994) found that income shares in OECD countries were relatively stable and largely free of trend, but there were significant cyclical variations. Gollin (2002) concludes that the adjusted measures of factor shares are roughly similar across a broad range of industrial and developing countries. He finds no systematic differences between rich and poor countries. In contrast, Harrison (2003) argues that labor shares do vary over time in most countries, but she is unable to differentiate between the capital and labor income of the self-employed.

[6] Nehru and Dhareshwar (1993). We adjusted their estimates for revisions in the investment series after 1960, a higher rate of depreciation, and extended the series to 2000.

variations in the proportion of the population that is of labor force age and in age and gender-specific labor force participation rates. (However, for many countries participation rates are interpolated between census years.) Comprehensive measures of unemployment rates and annual hours of work are unavailable. We also allow for differences in educational attainment by relating human capital, H, to average years of schooling, s, assuming a seven percent return to each year: [7]

(4) $$H = (1.07)^{S}.$$

Results of our growth accounting decomposition are shown in figure 1 and table 1 for seven major regions.[8] Table 1 reports the results for each decade and over the entire period, distinguishing the contribution of physical from that of human capital.[9] Figure 1 shows how growth patterns have evolved over time. In each sub-chart, the dashed line marked 'K/L contribution' shows the contribution of increased (physical and human) capital per worker to growth in output per worker. The thin line shows the contribution of changes in factor productivity. The multiplication of the two indexes equals output per worker, shown by the heavy line. We note that growth accounting is not intended for analysis of short-term fluctuations but analysis of economic growth over the longer term. Not surprisingly, capital's contribution trends relatively smoothly over time, with most of the year-to-year fluctuations in income per worker reflected in TFP.

Consider first the total of all the countries in our sample. Over the entire period (1960-2000) world output grew, on average, by 4 percent per year while output per worker grew by 2.3 percent per year. Table 1 shows that increases in physical capital per worker and improvements in TFP each contributed roughly 1 percent per year to growth while increased human capital added about 0.3 percent per year.

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[7] Estimated returns to schooling average 7% in high income countries, compared with 10% in Latin America and Asia and 13% in Africa. (See the summary in Bils and Klenow, 2000) Our earlier work also explored implications of assuming a 12% return.

[8] GDP weights have been used to construct the regional averages. The weights are averages of GDP over the 1960-2000 period using the 1996 PPP exchange rates of version 6 of the Penn World Table. Regional weights in the "world" are as follows: industrial countries, 0.67; Latin America, 0.10; East Asia, 0.05; China, 0.06: South Asia, 0.07; Africa, 0.03; and Middle East, 0.03.

[9] Results for individual countries are available from the authors.

East Asia (excluding China) is the fastest growing region, with output per worker increasing by 3.9 percent per year over the period 1960-2000. But TFP among these countries grew no more rapidly than the overall world average.[10] A now common finding in growth accounting studies is that East Asia's rapid growth does not appear to have been a story of strong gains in TFP due to adopting existing technologies and catching up to the efficiency frontier. Instead, the region's rapid growth is associated in part with an above average contribution from gains in human capital, and most importantly, with large and sustained increases in physical capital. The contribution of increased physical capital per worker is more than twice the global average. In contrast, the industrial countries did have very rapid TFP growth prior to 1970, consistent with their "catching up" to the U.S. In this comparison, China is treated separately because of its dominant size, phenomenal growth, and questions about the accuracy of the reported measures of GDP growth.[11]

Sub-Saharan Africa is the slowest growing region with output per worker rising just 0.6 percent per year (1960-2000). For these countries, increased capital per worker contributed only 0.5 percent per year to growth, half the global average. Modest increases in education before 1980 implied a smaller contribution from increased human capital than for most other non-industrial regions. But the primary reason for Africa's slow growth is the evolution of factor productivity, which declined in every decade since 1970.

Capital Versus TFP

The summary of the growth accounts in table 1 highlights the fact that **both** capital accumulation and total factor productivity growth have made important contributions to growth of output per worker. At the global level, we find that their contributions are roughly equal, but there have been substantial variations in their relative importance across regions and time.

The relative importance of capital accumulation and TFP as sources of growth has long been a subject of contention, dating back to the famous debate between Denison and Griliches

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[10] Alwyn Young's (1994) careful analysis was one of the first to document this point.

[11] Our measures are based on the data of the World Development Indicators, but several researchers have argued that China's growth rate is overstated. See, for example, Heston (2001), Wu (2002), and Young (2000).

and Jorgenson.[12] It has re-emerged with surprising vehemence, however, in the development literature.[13] The neoclassical growth model of Solow highlights the importance of technological change as the primary determinant of long-run steady-state growth. However, by assuming that everyone has access to the same technology, the model also assigns a large role to the accumulation of physical and human capital for countries that are in a transitional or 'catch-up' phase. In contrast, endogenous growth theories often incorporate a role for physical and human capital in determining steady-state growth, and argue that differences in technology contribute to variations in the speed of convergence.

Empirical studies reach surprisingly different conclusions about the role of capital accumulation versus TFP. Representing the neoclassical perspective, Mankiw, Romer and Weil (1992) conclude that differences in physical and human capital account for roughly 80 percent of the observed international variation in income per capita. In contrast, Klenow and Rodriguez-Clare (1997) argue in favor of a more substantial role for differences in technological efficiency, claiming that TFP accounts for 90 percent of the cross-national variation in growth rates. Particularly sharp rejections of the importance of capital accumulation are provided by Easterly and Levine (2001), and Easterly (2001).

Why are the empirical results so divergent? In large part, the differences reflect three basic measurement issues. First, some researchers rely on investment shares to proxy changes in the capital stock. Second, some value investment in domestic prices, while others use an international price measure. Finally, some measure the contribution of capital by the change in the capital-output ratio, instead of by the change in the capital-labor ratio. Each of these issues is discussed below.

Investment Rate Versus the Capital Stock. The choice between the investment rate and the change in a constructed measure of the capital stock has surprisingly important implications for empirical analysis. Several growth accounting studies, including that of Mankiw, Romer and Weil, use a formulation of the production relationship that replaces the growth in the capital

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[12] A series of articles and replies in the *Survey of Current Business* 49 (May, part 2, 1972)

[13] The dispute over the relative importance for output growth of increases in capital per worker versus improvements in TFP is discussed in the survey by Temple (1999), especially pp. 134-41. For a perspective that emphasizes the role of TFP see Easterly and Levine (2001).

stock in equation (2) with an approximation based on its steady-state relationship with investment as a share of GDP. The change in the capital stock is given by

(4) $\Delta K = I - dK$,

Dividing through by K and assuming a steady-state constant value (γ) for the inverse of the capital-output ratio allows the rate of change of the capital stock (k) to be measured by the investment rate (i = I/Y):

(5) $k = i\,\gamma - d$.

A production relationship, such as that given by equation (2), can be re-written to replace k with the steady-state approximation (5), yielding the formulation used in many past cross-national growth studies,

(2') $y/l = \alpha(\gamma i - d) + (1-\alpha)(l + h) + a$.

The use of the investment rate has an obvious advantage. It avoids the measurement problems introduced by the choice of an initial capital stock and an assumed rate of depreciation. However, the assumption of a constant capital-output ratio seems particularly unreasonable for studying the growth experiences of a highly diverse group of countries, many of which seem very far from conditions of steady-state. It also seems unreasonable to assume the same capital-output ratio across a sample of countries at very different stages of development.

Strikingly, figure 2 shows that there is very little correlation between the change in the capital stock and the mean investment rate in our sample, even over a period as long as 40 years (The R^2 for the bivariate regression is just 0.08). The newly-industrializing economies of Asia stand out with very high capital stock growth rates; but, because of equally rapid output growth, they do not have unusually high shares of output devoted to investment. In contrast, Guyana and especially Zambia – two countries with very slow output growth – are conspicuous for the small changes in their capital stocks despite high average investment shares.

It is also easy to show that the change in the capital stock -- not the investment rate -- is the better measure of the contribution of capital to output growth. The regressions reported in table 2 confirm that changes in the capital stock explain far more of the growth in output per worker over the full 40-year period (the adjusted R^2 equals 0.67 versus just 0.25 using the investment rate). The same is true for both 20-year sub-periods.[14] Indeed, this basic result is robust to all specifications we tried, including those to be discussed later in the paper, which control for additional right-hand side variables.

Purchasing Power Parity. The second source of variation in the empirical findings arises from the use of international price data from the Penn World Table (PWT) in some studies versus data in national currency values in others.[15] There is a strong preference for international prices over national prices and commercial exchange rates in cross-country comparisons of standards of living(such as GDP per capita). However, the choice is much less clear for other comparisons, particularly those involving the composition of aggregate demand. The PWT uses three separate purchasing power parities (PPPs) to construct its international price measures of investment, consumption, and government expenditures. Thus, in the process of converting to international prices, the PWT dramatically alters the expenditure shares of GDP in each country.[16]

In particular, conversion to international prices results in a new and very different measure of the investment share of GDP. Note that average international prices are dominated by the experience in the large industrial countries where labor is relatively expensive and capital is relatively cheap. Since investment heavily reflects prices of capital goods, investment shares for low income countries are much smaller when measured in international prices than when measured in national prices. The opposite is true for the share of GDP devoted to government expenditures, which typically has a large labor component. As a result, conversion to international prices induces a systematic and large change in investment shares, reducing them in low-income countries while raising them for the most developed countries.[17]

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[14] In these regressions, all variables are scaled by the change in the labor force. Finally, we note that the stronger correlation between output growth and the investment rate in the 1980-2000 period is consistent with the finding of a stronger correlation between investment and capital accumulation in the later decades.

[15] We made this point in our previous work, Bosworth, Collins and Chen (1996). Related issues have recently been explored in Hsieh and Klenow (2003).

[16] Other published measures of purchasing power parity often report a single PPP exchange rate at the level of total GDP, leaving its composition unchanged.

[17] The change in the expenditure shares in the conversion to international prices also results in a somewhat different measure of the growth in aggregate output compared to the estimate derived from domestic prices. For more discussion of these issues in the context of the "Gerschenkron effect" see Nuxoll (1994).

Panel A of figure 3 provides a cross-national comparison of the average investment share based on national and international prices.[18] It is evident that the correlation between the two measures is surprisingly low (For our 84-country sample, the correlation between the average investment share measured in national versus international prices is only 0.60 and the R^2 from the bivariate regression is 0.26.). From a comparison of panels B and C, it is also evident that conversion to international prices introduces a strong positive correlation between the investment rate and the level of income per capita. No such correlation exists when investment is measured in national prices. For these reasons, the choice between national and international prices will play an important role in studies, such as Mankiw, Romer, and Weil, that rely on the investment rate to measure the capital input. We also note that nearly all of the studies that estimate the relationship between the *level* of income, as opposed to its rate of change, and the capital stock value the latter at international prices using the PPP for investment goods. Such a construction builds in a strong positive correlation between income and capital per worker.[19]

In a growth accounting context, we believe that the capital input should be valued in the prices of the country in which it is used. Profit-maximizing firms make production decisions based on the relative prices of capital and labor in their own domestic markets. However, because the PWT converts to international prices using the PPP exchange rate of a single year, the growth of real investment spending is the same in international and national prices. Thus, the choice between these two measures matters less for those studies that rely on changes in a constructed measure of the capital stock to measure capital services. It will only alter the level of the capital stock.

Induced Investment. Our accounting decomposition measures the importance of capital to the growth of output per worker in terms of the change in the capital-labor ratio. However, some researchers argue that the focus on changes in the capital-labor ratio overstates the role of capital and undervalues TFP because it ignores the fact that investment is endogenous in the sense that a portion of the change in capital is induced by an increase in TFP. Thus, they

[18] Figure 3 refers to the period 1960-1998, due to the more limited availability of the PWT data.

[19] The correlation between average investment rates and growth in output per worker is somewhat larger when the national price measure used in the regressions reported in table 2 is replaced by the international price measure. None-the-less, changes in capital stocks continue to significantly out-perform investment measured in international prices.

maintain that “growth in physical capital induced by rising productivity should be attributed to productivity.”[20]

These researchers propose an alternative benchmark that limits capital’s contribution to increases in the capital-output ratio. That is, they rewrite equation (2) as

$$(2'') \qquad y/l = \left(\frac{\alpha}{1-\alpha}\right)\left(k/y\right) + h + \frac{a}{1-\alpha}.$$

These alternative formulations are based on exactly the same measures of ‘a’, ‘k’ and ‘h’. However, they imply very different interpretations of how each contributes to growth. In particular, the last term in (2’’) can be interpreted as the contribution of changes in TFP under the strong assumption that it induces increases in capital just sufficient to maintain the capital-output ratio. In effect, the investment rate is assumed equal to the capital-output ratio times the rate of growth of output (a simple accelerator relationship).

By restricting the contribution of capital to variations in the capital-output ratio, equation (2") automatically expands the role of TFP. Compared with Equation (2), TFP is “adjusted”, or scaled upwards, by $1/(1-\alpha)$ -- equal to 1.54 in our formulation. Equation (2’’) is analogous to the formulation used by Hall and Jones (1999). Klenow and Rodriguez-Clare (1997) go even further in that they also assume a fully endogenous response of human capital to income growth. In their version, the contributions of both physical and human capital are restricted to increases in excess of the growth in output. As we illustrate below, the result, of course, is a dominant role for the TFP residual.

It is certainly true that capital investment is partly an induced response to changes in GDP associated with variations in TFP. Thus, it has long been recognized that the assumption of wholly exogenous capital, as in the decomposition given by (2), leads to an overstatement of capital’s contribution and an understatement of the contribution of TFP growth (Hulten, 1975). But it seems equally extreme to assume that the capital stock will simply and automatically adjust in a simple proportionate fashion to *all* deviations in the rate of growth of output induced by changes in TFP. Investment decisions are likely to be influenced by a large number of factors, such as the availability of finance, taxes, and other aspects of the investment environment, as well as changes in TFP.

[20] Klenow and Rodríguez-Clare (1997, p. 97). See Also Barro and Sala-I-Martin (1995, p. 352).

This perspective suggests that an ideal representation would be somewhere between the two extremes of changes in the capital-labor ratio and changes in the capital-output ratio. However, it is important to point out that the extent to which investment is in fact endogenous is a distinct issue from the preferred approach to measuring capital's contribution to growth. One can recognize that changes in the capital stock are at least partially induced by changes in TFP without concluding that measures of capital's contribution to growth should exclude this induced portion. Indeed, some growth models suggest that technological gains are embodied in new capital, creating a potential two-way interaction between capital accumulation and TFP growth.[21] The potential endogeneity of *both* the factor inputs and TFP reinforces our prior caution against using growth accounts to infer a casual interpretation of the growth process.

A dispute over the relative importance of capital accumulation and TFP can hardly be resolved by definitional changes. We have chosen to report capital's contribution in terms of the capital-labor ratio because, as discussed above, the steady-state assumption of a constant capital-output ratio seems unreasonable for a sample that is dominated by developing countries. Including the induced portion seems to us consistent with a focus on the proximate sources of growth. We also note that, despite long-standing awareness of this issue in the extensive literature that applies growth accounting to industrial countries, every study of which we are aware measures capital's contribution in terms the capital-labor ratio.

A Variance Decomposition. Is the *variation* in growth of output per worker across countries primarily accounted for by variations in growth of TFP, as researchers such as Klenow and Rodríguez-Clare (1997) and Easterly and Levine (2000) have claimed?[22] In this section, we discuss alternative perspectives on the relative importance of capital accumulation, educational attainment, and TFP for our sample of countries.

The variance of *y/l* is equal to the sum of the variances of each of three components (physical capital, education and TFP) plus twice the sum of the three covariances. The existence of non-zero covariances implies that there is no unique way to allocate the variance of *y/l* among

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[21] Klenow and Rodriguez-Clare (1997) assume a constant investment rate in a steady-state growth path in arguing that this concern is unfounded. However, as noted by Jones (1997 p. 110) in his comment on their paper, "If all countries were in their steady-states, then, as is well known, all growth would be attributable to TFP growth. In this sense, the KR methodology is, in some ways, set up to deliver their result."

[22] Surprisingly, researchers who use the K/Y formulation continue to attribute most of the *trend* growth in GDP per capita to growth in the inputs (Klenow and Rodriquez-Clare, 1997, p. 94).

the three components. Following Klenow and Rodriguez-Clare (1997) we first divide the covariance terms equally among components, measuring the contribution of each component as its covariance with *y/l* divided by the variance of *y/l*.[23] The top row of table 3a reports the resulting decomposition of the variance in growth of output per worker among the contributions of capital per worker, education, and the residual estimate of TFP. This is based on the decomposition in equation (2) for the entire 40-year period. We find that 43 percent of the variation in growth of output per worker is associated with variations in physical capital per worker, compared with only 3 percent with education, and 54 percent with TFP. If the sample is weighted by population, the importance of education is increased while that for physical capital declines.

The third line of Table 3a reports the alternative decomposition based on equation (2"), limiting the capital contribution to variation in the capital-output ratio. As shown, the contribution of TFP rises to 83 percent of the total while the contribution of physical capital falls to just 12 percent, consistent with the claim that capital accumulation is an unimportant contributor to growth. The result is clearly related to the shift in the accounting framework between the equation (2) -- and the equation (2'') formulations of TFP.

Table 3b shows the pieces underlying the variance decomposition. The entries in this table can be used to construct upper and lower bounds for the contributions of capital and TFP under each of the alternatives. For example, in the *k/l* formulation, the weight on the contribution of physical capital would range from 0.27 to 0.57 depending on whether none or all of the relevant covariance terms were allocated to capital.[24] Similarly, the weight on the contribution of capital could range from 0.24 to 0.01 under the k/y formulation.

The main source of the relatively large contribution of TFP in the *k/y* formulation is its much larger variance in the third row of Table 3a. This is a direct consequence of scaling. (0.90 = 0.40 $/(1-\alpha)^2$). However, the reduced contribution of capital is not due to the difference in the

[23] In other words, we define the contribution of each component as its own variance plus its covariances with both other components, scaled by the variance of growth in output per worker. For example, 0.43 in the top row of Table 3a is equal to 0.27 + 0.14 + 0.02 from the top row of Table 3b. Baier, Dwyer and Tamura (2002) explore alternative decompositions.

[24] The upper bound for the contribution of increases in k/l is given by the variance of the contribution of k/l plus twice the sum of the two relevant covariances, divided by the variance of y/l. This is equal to 0.27 + .03 + .27 = 0.57.

variance of *k/l* versus *k/y*.[25] Instead, it arises from the fact that the covariance between the contribution of capital and TFP switches from positive (based on *the k/l* formulation), to negative (based on the *k/y* formulation). The positive correlation between growth in *k/l* and TFP in the first line of table 3a could be taken as supporting the view that the capital accumulation was induced by productivity gains. However, this is just one of a number of plausible explanations, including the possibility that both productivity gains and capital accumulation were spurred by other common factors. Indeed, we would expect to observe a positive correlation between these variables. On the other hand, the negative correlation between growth in TFP and *k/y* suggests to us that this formulation has indeed gone too far.[26] And it is also somewhat surprising that these variables show such little relation to each other under either formulation. The adjusted R-squared from regressing the changes in *k/l* or in *k/y* on changes in TFP are just 0.17 and 0.07 respectively.

We conclude that both capital (physical and human) accumulation and improvements in economic efficiency are central to the growth process. For most purposes, the emphasis on determining which is most exogenous or most important seems misplaced. Policies that aim to promote TFP growth will also tend to promote capital formation, and vice versa. An emphasis on either of the two extremes offers few insights into the growth process. In sum, we agree strongly with Charles Jones (1997, p. 110), in his comment on Klenow and Rodriguez-Clare. He states "oftentimes readers want an all or nothing answer…. A better answer, I think, is that both traditional inputs and productivity play large and important roles."

The Contribution of Education

A second area of dispute involves the role of education. Relying on a large body of microeconomic evidence of a strong relationship between education and earnings, several growth accounting studies, including our own, adjust the workforce for improvements in educational

[25] The variances of *k/l* and *k/y* are 0.55 and 0.48 respectively. In Table 3b, recall that all entries are scaled by the variance of *y/l* (equal to 2.03).

[26] Klenow and Rodriguez-Clare also report a negative correlation between growth in TFP and *k/y*. However, they suggest that this "could indicate an overstatement of the contribution of *k/y* … (implying that)…the role of A is even larger" (p. 96). We find this view unconvincing.

attainment.[27] However, as discussed below, at the macroeconomic level, a number of recent studies have been unable to find a correlation between economic growth and increased educational attainment. This result has been used as a basis for rejecting the microeconomic evidence and for arguing that the focus of governments and the multilateral organizations on raising levels of literacy and average educational attainment has been misplaced (Easterly, 2001).

As an aside, the problem may be unrealistic expectations. Given that average years of schooling change very slowly, the effects on output growth may be hard to detect in the international data. Under our assumption that the social and private returns are equal to seven percent, the average annual contribution of education to output growth is only 0.3 percent per year (table 1), and the standard deviation across the 84 countries is just 0.2 percent.

Increases in education could have an impact on economic growth through two different channels. First, more education may improve the productivity or quality of workers. This is the formulation we employ in multiplying the quantity of workers by an index of average educational attainment, and imputing the return to education from microeconomic studies. Specifically, we assume a 7 percent return to an additional year of schooling -- a value near the lower boundary of the results from the microeconomic studies. Thus, for a country such as the United States in 1990 with an average level of educational attainment near 12 years, the effective labor supply is treated as 2.25 times the number of persons.

An alternative formulation, adopted by Mankiw, Romer and Weil (1992) and Klenow and Rodrigruez-Clare (1997), specifies human capital (education) as an independent factor in the growth process, that can augment labor, physical capital and TFP. The relationship with TFP reflects the view that an educated workforce is better able to implement new technologies and to generate ideas for improving efficiency. Designing an empirical test to distinguish between these two channels is very difficult. Thus, both suggest potential justifications for expecting a positive correlation between gains in educational attainment and growth.

Compared with the long history of microeconomic studies aimed at estimating the relationship between income and educational attainment, empirical macroeconomic studies are relatively recent. This work was greatly stimulated by Robert Barro and Jong-Wha Lee (1993, 2000), who developed a comprehensive data set on schooling, covering a large number of

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[27] A summary of the microeconomic studies covering a variety of countries is available in Psacharopoulos (1994) or Bils and Klenow (2000).

countries over an extended time period. They use national censuses and surveys at 5-year intervals beginning in 1960 to infer the proportion of the working age population with various levels of schooling.[28] However, large gaps in the census data require them to make extensive use of enrollment information to extrapolate and interpolate the census information.

Early studies, including both those of Mankiw, Romer, and Weil (1992) and Barro and Sala-i-Martin (1995), found a significant positive association between cross-national differences in the initial endowment *level* of education and subsequent rates of growth. And Barro (2001) has explored the link between growth and a variety of schooling level indicators.[29] However, later studies that examined the relationship between changes in years of schooling and changes in average incomes failed to find a significant association.[30]

There are three potential explanations for the failure to replicate the microeconomic results at the aggregate level: (1) the social return to education, as reflected in the aggregate data, may be much less than the private return that underlies the micro-analysis; (2) there may be measurement errors in the data; and (3) cross-national variations in educational attainment may fail to account for variations in the quality of education. The following sections examine each of these issues in turn.

Social Versus Private Returns. There is a long-standing debate over how to interpret the coefficient on years of schooling in the microeconomic analyses of wage differentials. Does it reflect the skill gains from education (Becker, 1964)? Or does the educational process simply sort people by native abilities, thereby providing a convenient indicator ("signal") of hard-to-observe characteristics (Spence, 1973)? If the latter process dominates, aggregate gains would be limited to a somewhat better matching of workers and jobs, and would be substantially overstated by estimates of the private return. On the other hand, a case can also be made that the true social or aggregate gains exceed the private returns because an educated workforce accelerates innovation and its introduction into the production process.

[28] The Barro-Lee data distinguish among three levels of schooling – primary, secondary, and tertiary – and between those who initiate a level of schooling and those who complete it.

[29] Even the linkage between growth and schooling level has been called into question. Bils and Klenow (2000) use a calibration model to argue that less than a third of this relationship should be interpreted as reflecting the impact of schooling on growth.

[30] See, for example, Benhabib and Spiegel (1994), Bils and Klenow (2000), Pritchett (2001), Easterly and Levine (2001) and Temple (2001).

Problems in designing a microeconomic study that can fully distinguish between the roles of signaling and skill improvement make it difficult to rule out the possibility that empirical estimates do reflect signaling, thereby overstating the actual return to schooling. However, efforts to use natural experiments, such as episodes of change in compulsory education requirements or other changes in schooling that are uncorrelated with ability, have found little evidence of a significant upward bias in the estimated return.[31] From this perspective, the fact that finding a positive association between increased average years of schooling and economic growth has been so difficult in the macroeconomic analysis -- even in those studies that control for other factors – is puzzling.

Some researchers suggest that the benefits of education are not fully realized because of a failure to integrate improvements in education with other important elements of the growth process. That is, the creation of skills offers no benefits if the technology and infrastructure do not exist to make use of them. Although this explanation sounds plausible, it is not consistent with the fact that the correlation between growth and changes in educational attainment is also weak in samples limited to OECD economies.

Data Measurement. Nearly all of the contributors to the empirical literature recognize that measurement error might account for the lack of association between economic growth and gains in educational attainment. In one of the first efforts to seriously explore this issue, de la Fuente and Doménech (2000, 2001) found large variations in the classification of educational attainment over successive censuses of many OECD countries. They developed a new estimate of educational attainment that adjusts for classification changes, and that appears to evolve over time in a much smoother fashion (reduced signal-to-noise) than the Barro-Lee data.[32] The two measures of average educational attainment have similar levels, but there is almost no correlation of the changes over a 30-year period. When they use their data to estimate a model similar to that of the prior studies, they obtain a much stronger correlation between the accumulation of human capital and economic growth: a coefficient on the change in educational attainment near that implied by the Mankiw, Romer and Weil study. They concluded that measurement

[31] A survey of some of the major studies is provided by Ashenfelter, Harmon, and Osterbeek (1999). See as well an earlier paper by Griliches (1977).

[32] Classification issues include inconsistencies in the treatment of vocational and technical training, as well as changes in numbers of years associated with different levels of schooling.

problems were responsible for most of the prior difficulties in discerning a positive return to education. However their analysis was limited to the OECD countries.

A second global data set, covering 95 countries, has been developed by Cohen and Soto (2001) as an extension of prior work done at the OECD. They compute educational attainment at the beginning of each decade for the period of 1960 to 2000. For some countries, they had more recent census information than that used by Barro and Lee. But a more important difference arises from their use of age-specific data in the available censuses to construct estimates of educational attainment for each age-cohort in other years for which direct observations were missing. That is, the educational attainment of a specific age cohort is assumed to be the same at successive ten-year periods. Thus, they only use enrollment data to fill missing age cohort cells. They also report significant differences between national sources and the data available from the multilateral agencies used by Barro and Lee. However, for many countries, their series are based on information from a single census. As with de la Fuente and Doménech, Cohen and Soto point to excessive volatility over time in the Barro-Lee data that appear to reflect changes in national classifications.

Cohen and Soto (2001) and Soto (2002) use their data to examine the relationship between economic growth and years of schooling. Using a variety of specifications and econometric techniques, they estimate returns to schooling in the range of 7 to 10 percent, close to the average of the microeconomic studies. They argue that prior difficulties in finding a positive correlation were partially related to measurement problems. Krueger and Lindahl (2001) also stressed the importance of measurement error in their evaluation of the micro and macroeconomic evidence. As we will argue below, measurement error does seem to be major problem for the macroeconomic studies. However, we are not convinced that any one of the available data series is clearly preferable to the alternatives.

We have data from the Barro-Lee and Cohen-Soto data sets for 75 matching countries in our sample for the period 1960-2000.[33] A comparison of the average years of schooling over the period is shown in panel A of figure 4. The two series are very highly correlated – with a

[33] We can also make use of a third data set compiled by Nehru, Swanson, and Dubey (1995) that is attractive because it relies only on school enrollment data. The disadvantage is that this data set is limited to the 1960-87 period. We also undertook a 3-way comparison that Iincluded this alternative data. None of the conclusions reported in the text were altered and these results are omitted from the discussion for ease of presentation.

correlation coefficient of 0.95. But the Cohen-Soto estimates are generally higher, and there are a few countries where the differences exceed two years of schooling. Some of the variation can be traced to different methods for estimating completion rates, where the census information is particularly limited.[34]

The correspondence between the two education data sets is much poorer in terms of changes, however. For the 40-year changes, shown in panel B of figure 4, the correlation between the two series is only 0.54. On average, the Cohen-Soto data indicate greater improvement in years of schooling, and the differences are large in a significant number of countries. (Bolivia, Jordan, and Norway have the largest discrepancies). The correspondence is even worse for 10-year changes, with correlations for the four sub-periods ranging between 0.3 and 0.4.[35]

Both the Cohen-Soto and the Barro-Lee data differ substantially from those of de la Fuente and Doménech. For a common group of 20 OECD countries, the 30-year change (1960-90) in years of schooling reported by de la Fuente and Doménech has a -0.03 coefficient of correlation with the corresponding changes reported by Barro-Lee and a 0.48 correlation with the changes reported by Cohen-Soto. For the same data, the correlation between the Barro-Lee and Cohen-Soto measures is –0.05. Such large differences among the estimates are surprising, given the expectation that information from the OECD countries would be the most reliable. Cohen and Soto report results from growth regressions in which their measure of changes in schooling enters significantly while the Barro and Lee measure does not. On this basis, they argue that their series should be preferred over the Barro and Lee data. However, we find no such result using our sample. Instead, a variety of growth regressions that incorporate the two measures of human capital provide little basis for choosing between them.

[34] Cohen and Soto, like de la Fuente and Domenech, typically assume that everyone who starts a given level of schooling completes it. This implies large differences between alternative data series in the ratio of those completing given levels of schooling to those attending. For example, in the Cohen and Soto data, there are many countries for which everyone entering higher education is assumed to complete it. In contrast, in the Barro and Lee data, the ratio of completers to attenders varies widely in some countries over short time periods. Both approaches generate some implausible results.

[35] The Nehru, Swanson, and Dubey (1995) measure also shows a relatively low correlation with the other two series.

Alternatively, we could view the two measures as proxies for the true value, and search for alternative ways to combine them that would yield the best measure. Unfortunately, none of the approaches we explored to combining the two proxies proved satisfactory.

First, we use instrumental variables in a regression equation relating growth in income per capita to growth in physical capital per worker and to changes in schooling. This is simply a regression version of our growth accounting formulas, (2) and (4):

$$(7)\ \Delta \ln\left(\frac{Y}{L}\right) = \alpha_1 \Delta \ln\left(\frac{K}{L}\right) + \alpha_2 \Delta s\ .$$

If the private and social returns to schooling are equal, we would expect the coefficient on Δs to be about 0.045 (0.07 *(1-α)). Under the assumption that the measurement errors are uncorrelated, each of the proxies is a valid instrumental variable for the other. However, all variations of this regression resulted in estimates of the coefficient on the change in schooling that were small or negative and always statistically insignificant.

Second, following Krueger and Lindahl (2001), we construct a reliability measure for each proxy, based on its covariance with the alternative measure divided by its variance. We obtain 0.64 for the Cohen-Soto series and 0.44 for Barro-Lee. These reliability measures suggest that the larger weight be assigned to the Cohen-Soto series. However, we are doubtful about the value of this criterion. Since they share a common covariance, the reliability measures will differ only because the two proxies have different variances. But there is no particular reason here to believe that the variable with lower cross-national variance has less measurement error.

Finally, we implemented an approach suggested by Lubotsky and Wittenberg (2001). Here, both proxy measures are included in the estimate of equation (7), and the regression weights are used to form a new composite variable. They argue that this “post hoc” estimate is superior to any “a priori” set of weights. In an equation based on 40-year changes that included physical capital per worker, the coefficient on the Barro-Lee measure was positive; but the coefficient on the Cohen-Soto measure was negative, and neither approached statistical significance.

We conclude that there is substantial evidence of measurement error. However, none of the alternative approaches yields a convincing way to choose between or to combine information from the available schooling proxies. Thus, we opted to adopt a measure of educational attainment based on the simple average of the Cohen-Soto and Barro-Lee estimates of years of schooling.

Educational Quality. The use of years of schooling as the measure of educational attainment does not incorporate any adjustment for variations in quality. This is likely to be a far more serious problem for international comparisons of the correlation between incomes and education than for microeconomic studies since the quality of education within a country might be relatively homogeneous. Despite general agreement that the quality of education varies substantially across countries, obtaining quality measures for a large number of countries is difficult.

The most extensive empirical analysis is that of Hanushek and Kimko (2000) who developed indexes of educational quality for 38 countries based on international tests of academic performance in mathematics and science over the period 1965-91. To infer that differences in academic performance are reflected in the quality of the workforce, we must assume that country differences in test performance are persistent over long periods of time. Hanushek and Kimko also sought to associate their quality indexes with other correlates of educational performance in order to extend the quality measure to a larger number of countries. Thus, for 30 directly-measured countries, they estimated a statistical relationship between the educational quality index and indicators such as: primary-school enrollment rate, average years of schooling, expenditures per student, population growth, and regional dummies.[36] The resulting estimates were used to generate predicted values for an additional 49 countries, 36 of which are in our sample.

Using this expanded data set, Hanushek and Kimko found a strong correlation between their measure of educational quality and increases in GDP per capita. At the same time, the quality variable had the effect of eliminating any significant correlation between the quantity of schooling and economic growth.

We used an updated set of correlates from the World Development Indicators (2002) to re-estimate and extend the Hanushek-Kimko measure of education quality to our full set of 84 countries. In addition, we added Chile to the analysis of directly-measured countries in order to

[36] One problem with the estimated relationship is that most of the correlation of quality is with the enrollment rate (a quantity measure) and the regional dummies. Thus, there is no right-hand side variable that is strongly identifiable as a measure of quality.

have at least two countries, Chile and Brazil, on which to base a regional adjustment for Latin America.[37] The details are provided in appendix 2.

Empirical Estimates. Regression estimates of the relationship between education and economic growth are shown in table 4. The dependent variable is the average annual log change in real GDP per worker over the 40-year period of 1960-2000 for our 84-country sample. The first column shows the simple correlation with the corresponding growth in physical and human capital per worker and the initial 1960 level of years of schooling. The estimated coefficient on physical capital is larger than the 0.35 that we assumed for construction of the growth accounts, but such a result would be expected because of the bias that results from the endogeneity of both capital accumulation and total GDP. The coefficient on the change in human capital is closer to its value of 0.65 used in the growth accounts, but it is statistically insignificant. We find a stronger correlation between growth and the initial level of the educational attainment than with its rate of change.

In the second column, the coefficient on physical capital is constrained to the hypothesized value of 0.35. In this case the coefficients on the level and rate of change of educational attainment become statistically very significant. Thus, we find support for the argument of Krueger and Lindahl that it is critical to control for the role of physical capital. However, the coefficient on the change in human capital is now too large to represent the augmenting effect of education on the workforce. Column 3 reflects the effects of adding a set of additional conditioning variables that have been found to be consistently correlated with growth.[38] They are discussed more fully in the next section, but they have the effect of reducing the coefficients on the changes in physical and human capital to be close to our hypothesized values. However, neither of the coefficients on the education variables are statistically significant.

Finally, columns 4 and 5 show the effect of including the measure of educational quality.[39] Our results in column 4 are very similar to those of Hanushek and Kimko in that the

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[37] The Hanushek and Kimko estimates used only Brazil, and all other Latin American countries were scaled relative to Brazil.

[38] They include initial income and life expectancy, the standard deviation of the terms of trade, a measure of geographical distance from the equator, and the quality of government institutions.

[39] These results are based on the quality measure that we derived from the WDI data, but the measure of Hanushek-Kimko, as augmented by Wöessman (2000), performed nearly as well.

quality variable is statistically significant, but it comes at the cost of reducing the role of educational attainment. Furthermore, it is not robust to inclusion of the set of conditioning variables, as shown in column 5. In particular, the loss of significance is associated specifically with a measure of the quality of government institutions that we discuss more fully in the next section. While the notion that the quality of education matters for growth is eminently sensible, we cannot distinguish it from more general concepts of the quality of government institutions. As we demonstrate in appendix 2, the quality of governing institutions is the single best correlate to identify cross-national differences in the measures of educational quality.

Macroeconomic evidence of the contribution of education to growth is clearly much weaker than that derived from microeconomic studies. Resolution of this issue is complicated by the substantial measurement error implied by differences in the magnitude of cross-national improvements in educational attainment among alternative data sets. We were not able to distinguish among the various measures and have relied on a simple average of the results from two large independent studies. Finally, like Hanushek and Kimko, we find quality of education to be significantly correlated with the growth. But we lack any effective means of measuring its change over time. Furthermore, it is highly correlated with measures of the quality of governing institutions and may simply be a proxy for this broader concept.

Economic Growth: 1960-80 versus 1980-2000

The last two decades mark a remarkable collapse of growth in much of the global economy. Table 5 provides a regional summary of the change in growth for our sample of 84 countries over the 20 years before and after 1980. On average, the growth of output per worker slowed from an annual rate of 2.5 percent in 1960-80 to only 0.8 percent in 1980-2000, a deceleration of 1.7 percentage points. The slowdown was of equal magnitude in the industrial and the developing countries, and it is apparent in all regions except South Asia. Furthermore, both lower rates of physical capital accumulation and TFP growth were important contributors to the slowdown. On average across countries, a lower rate of physical capital accumulation accounted for about 40 percent (-0.7/-1/7) of the slowdown, but it was less important as a source of the cross-country variation, 0.28 percent. (As above, this variance decomposition splits the covariance terms equally among pairs of components.) Changes in educational attainment were of minor importance in all cases.

However, the averages also mask some important exceptions. The three countries with the largest acceleration of growth were China, India, and Uganda. The situation of Uganda differs from the other two because the 1970s and early 1980s were a time of internal strife and chaos. Thus, while growth was relatively strong in the 1980-2000 period, the turnaround is mainly a reflection of negative growth in the earlier period. On the other hand, the performance of China and India has been extraordinarily important both because they achieved a significant acceleration of growth after 1980, and because they represent a large proportion of the world's population and an even larger percentage of the world's poor. In much of our empirical analysis, they are only two out of 84 countries, but weighted by population, they represent 45 percent of the global total and 56 percent of developing countries.

The disproportionate impacts of China and India are highlighted in table 6, where the post-1980s slowing of global growth is transformed into an acceleration if the country experiences are weighted by population. Measured as a simple average of the 84 countries, the global growth in per capita income slowed by 1.7 percentage points; whereas, based on population weighting, it accelerated by 0.7 percentage points. The fact that two of the largest – and poorest -- countries grew far more than the average translates into a major reduction in global poverty, and suggests a much different perspective on the post-1980 experience.[40]

Alternatively, the use of GDP weights has the effect of translating the sample into one that emphasizes the growth experience of the industrial countries, which account for two-thirds of aggregate output, but only one fifth of the population. The implication for the magnitude of slowdown in growth, shown in column 3, is intermediate between the simple average and population weights, implying a change in the average growth rate of -0.9 percent.

In this section, we use a combination of the growth accounts and regression analysis to explore the sources of the change in growth before and after 1980. While the last decade has witnessed a large number of empirical studies of the growth process, nearly all of that research has focused on identifying the sources of variation across countries for a single time period stretching from 1960 to the present. Much less effort has been devoted to exploring the sources

[40] See Deaton (2003) for a detailed discussion of the use of national accounts versus survey data to study trends in global poverty.

of change between sub-periods.[41] In part, the emphasis on a single period has been dictated by the need to measure changes over relatively long periods in order to exclude cyclical complications. However, two 20-year periods should be of sufficient length to minimize the role of cyclical factors, while greatly expanding the range of observed variation in growth rates. In addition, following our approach in Collins and Bosworth (1996) we can combine the growth accounting decomposition with regression analysis to explore the channels through which various factors influence growth in income per worker. Is it principally through their effects on capital accumulation or through stimulating improvements in the efficiency of resource use, TFP?

As part of our effort to compile a standard set of growth accounts over a 40-year period, we have also culled a set of principle determinants of growth from the empirical literature and expanded that data where necessary to cover our 84 countries. We use regression analysis to relate economic growth over the full 40-year period to some basic measures of initial conditions, external shocks, and policy. This specification is largely drawn from the existing empirical literature. We then use that specification to explore the extent to which the various determinants operate through the channels of capital accumulation versus improvement in TFP. Finally, the specification is applied to the two 20-year sub-periods to determine the extent to which we can account for the sharp changes in growth performance.

In recent years, the use of regression analysis to explore the determinants of growth has encountered significant criticism. Some surveys of that literature, for example, conclude that it has all been for naught, and that the regression analysis has been a disservice to policymakers because the research has failed to adequately communicate the extent of parameter instability (Lindauer and Pritchett 2002). Levine and Renelt (1992) argue that few of the empirical relationships in the growth literature display a 'robust' correlation with economic growth.[42] Many of the concerns arise out of the extreme heterogeneity of the sampled population of

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[41] A recent exception is Dollar and Kraay (2002) which included an analysis of the role of trade using decadal data. Islam (1995) used panel data based on 5-year averages.

[42] Sala-i-Martin (1997) argues that the extreme-bounds test used by Levine and Renelt is too strict. Using a cumulative density function, he finds that nearly half of the 59 variables that he tested should be viewed as potentially important regressors. Similar conclusions were obtained by Fernandez, Ley, and Steel (2001) using a Baysian framework. However, one disappointing aspect is that most of the variables identified in these studies are religious or geographic measures that are largely beyond the control of policymakers.

economies (Kenny and Williams (2001) and Brock, Durlauf and West (2003).[43] On the other hand, while cross-national regressions should be only one of several methods, evaluation of hypotheses in terms of their consistency with a wide range of empirical experiences needs to be a central component of any effort to build a coherent explanation of the growth process.[44]

We try to improve on this evaluation process through standardization, thereby removing an important reason that results in the literature have varied. It is important to compare regression results using a standard set of countries, standard time periods, and a standard set of conditioning variables.[45] By conditioning variables, we mean a set of determinants that have been found to be important in a large number of studies. In this process, some experimentation with alternative, but equally plausible, measures of a given determinant is unavoidable. But the emphasis ought to be on the consistency of the results for a general determinant, not the specific measure. In addition, we examine the robustness of the regression results across subsets of the data set (rich, poor) and sub-periods (pre – and post-1980). Finally, we note that restricting the data to exclude transition economies as well as the smallest countries and city states omits country groups that may be particularly unusual.

40-year Sample. Our basic measures of the determinants of growth are summarized in table 7. In developing the indicators of initial conditions we have relied heavily on prior work by Barro and Lee (1994) and Hall and Jones(1999). The 1960 level of income per capita (in international prices) is measured as a ratio to the United States' level, and serves to capture the convergence process. Life expectancy in 1960, relative to the United States, is included as a measure of initial health conditions.[46] At the suggestion of one of our discussants, we have

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[43] Brock, Durlauf and West (2003, p. 296) apply econometric techniques that account for model uncertainty to growth analysis. Somewhat surprisingly they conclude that there are "important respects in which our new approach did not provide particularly different insights from what one obtains from OLS exercises."

[44] One might think that these concerns could be addressed using panel data to increase the number of observations, by defining the dependent variable as growth in each country over shorter time periods. We do consider twenty year periods later in this section. However, we are not convinced that analysis of even shorter periods provides a means to address the same issues.

[45] In contrast, studies such as Baier, Dwyer and Tamura (2002) combine observations in which growth is measured over different time periods of varying length across countries.

[46] Other studies have included the initial level of per capita income and life expectancy in logarithmic form. We use the levels versions only because they fit slightly better and are less collinear with other included variables.

included the log of population in 1960 and a trade instrument among our measures of initial conditions.[47] Population is a dimension of country size, and the trade instrument can be viewed as a measure of a country's predisposition for trade. We examined several measures of geographical factors and obtained the most significant results with a composite average of the number of frost days and tropical area.[48] A list of other geography indicators we considered is provided in Appendix 3. All five of the variables discussed above are considered exogenous in our regressions.

We also explored a number of alternative indicators of institutional quality (see Appendix 3), obtaining the greatest significance with a composite variable constructed by Knack and Keefer (1995) from information in the International Country Risk Guide.[49] This index dominated alternatives obtained from Kaufman, Kraay, and Zoido-Lobatón (2002), and substituted for a large number of cultural measures, such as the proportion of the population identified with specific religions used by Sala-i-Martin (1997). It also largely eliminated any independent role for the constructed measure of educational quality from the prior section. We included the institutional quality measure with the initial conditions, even though it is likely to be somewhat endogenous and determined by policy. (All of our results were robust to the use of colonial mortality rates as an instrument for institutional quality as suggested by Acemoglu et al. (2001). However, this instrument is only available for 52 of the countries in our sample.) Unfortunately, we have no effective measure of the change in institutional quality between our two twenty-year sub-period because our indicator is drawn from survey data for 1982.

A regression that relates these six conditioning variables to growth in output per worker is shown in column 1 of table 8. Those variables account for three-fourths of the cross-national

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[47] The significance of the population measure is not sensitive to the inclusion of China and India. The trade instrument is taken from Frankel and Romer (1999) and Frankel and Rose (2002). It is created by regressing the bilateral trade of countries i and j on: distance from principle cities, the extent of common borders, common language, land area, population of trading partner, and whether or not they are landlocked. The predicted values are aggregated over all trading partners.

[48] The percentage of tropical land area is from Gallup and Sachs (1998). The average number of frost days is from Masters and McMillan (2001). The two measures were converted to standard deviates and assigned equal weights. Noting that percent tropical and frost days are negatively and positively correlated with growth, respectively, our weights are – 0.5 and +0.5.

[49] It is an equally-weighted average of 1982 values for: (1) law and order, (2) bureaucratic quality; (3) corruption, (4) risk of expropriation, and (5) government repudiation of contracts. It is scaled from zero to one, and larger values represent better institutions.

variation in growth over the 1960-2000 period. The convergence variable and the composite measure of institutional quality have particularly high levels of statistical significance. Column 2 shows the effect of adding the contribution of capital as a regressor. While it is obviously highly endogenous, it shows that the growth account measure of the capital contribution greatly improves the R^2. In contrast, inclusion of the investment rate (column 3) results in a statistically insignificant coefficient, illustrating the conclusion above that it is a very poor proxy for the capital contribution.

In column 4, the model is expanded to include three policy indicators: the average rate of inflation, the government budget balance, and a measure of trade openness computed in Sachs and Warner (1995).[50] All three of these measures have the expected signs in the regression for output per worker, but only the budget balance is statistically significant at conventional levels. We note that the coefficient estimate and significance of the Sachs-Warner index is unaffected by exclusion of the trade instrument.

The weak, negative role for inflation is particularly noteworthy in view of the emphasis frequently placed on it in policy discussions. However, we should stress that our analysis examines the long-run association between inflation and growth, not the obvious short-run inverse relationship between inflation crises and growth. Following Bruno and Easterly (1998), we allow the set of nine countries with inflation rates more than one standard deviation above the mean to enter the regression with a separate coefficient, but it was near zero and statistically insignificant.

As noted above, these policy indicators should be considered endogenous. However, we have no plausible instruments for inflation or the budget balance. Furthermore, the Frankel, Romer, and Rose trade instrument is only weakly correlated with the Sachs-Warner indicator. When we removed it from the regression and attempted to use it as a instrumental variable for Sachs-Warner, it performed poorly in the first-stage regression. Thus, we present OLS results, which should be interpreted descriptively. Like growth accounts, these regressions can not be used to infer the underlying causes of growth.

We explored the significance of a large number of other potential explanatory variables, but omitted them in the final regressions because they did not play a role when our set of

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[50] While we recognize that there are the disagreements about the best interpretation of the Sachs-Warner indicator, we considered it because so many other studies have used it as trade policy measure.

conditioning variables were also included. The complete list is given in Appendix 4. In particular, we tested several measures of financial development from Levine, Loayza and Beck (2000). Private credit as a ratio to GDP was often statistically significant, but not in combination with the other policy variables. Their preferred measure, the ratio to GDP of private credit extended by financial intermediaries, was available for just 61 of our countries. We computed a comparable series, covering only deposit banks, for 81 countries. The 40-year average of the variable is statistically significant, with a p-value of 0.035, in a regression with the set of conditional variables shown in column 3 of table 8, and marginally significant in the presence of the policy variables. However, we were concerned about its obvious endogenity. In regressions that restricted the measure to its average value in the first 10 years of the sample, it was very insignificant.[51] We were unable to identify other instruments that could be used to control more explicitly for the endogeneity problems. We also found no role for variations in the real exchange rate, and the standard deviation of the terms of trade (a measure of external shocks) was not consistently significant.

Furthermore, we experimented with a large number of alternative measures of trade openness, reflecting the extensive literature that has developed around the issue. In addition to the indicators discussed above, we tried various measures of the share of trade in GDP (Dollar and Kraay, 2002, and Alcalá and Ciccone, 2001), and an openness index from Quinn and Inclán (1997). We found these measures to be positively correlated with growth when the number of other conditioning variables was limited; but inclusion of the full set of conditioning variables reduced the coefficient on the trade variable to near zero, sometimes turning it negative. This was particularly evident for regressions that included the measure of institutional quality. In this respect, our results are very similar to those of Rodrik, Subramanian, and Trebbi (2002).[52]

The implications for the channels through which the variables influence growth are shown in columns 6 and 8. By construction, the coefficient for each variable in column 4 is identically equal to the sum of its coefficients in columns 6 and 8. In most respects, the results are in accord with prior expectations. The convergence process is evident both through capital

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[51] We encountered a similar problem in the 20-year samples. The financial depth variable was very insignificant when limited to the average of the first 5 years.

[52] We also experimented with various instrumental variable estimates for the trade and institutions variables in ways that paralleled the work by Rodrik et al and Dollar and Kraay. They did not materially alter our results and are not reported.

accumulation and the efficiency of resource use. Similarly, the influences of geographical factors and population are equally evident through both channels. Life expectancy and especially the quality of institutions have relatively greater effects through the channel of TFP improvements. Variations in the budget balance have their primary impact on capital accumulation, presumably because budget deficits are a competing use of national saving. One surprise is that the correlation of both the trade instrument and trade openness with growth appears to operate through capital accumulation rather than TFP. Much of the theoretical literature has emphasized the efficiency gains from trade.

Finally, the implications of including regional effects are shown in columns 5, 7, and 9. These further reduce the significance of the policy variables. They have the largest impact on capital accumulation, with a significant positive effect for East Asia and negative effects for Latin America and Africa. However, none of the regional variables is statistically significant in the regression for TFP.

A striking aspect of these regressions is the relatively minor evidence of a direct role for conventional government policies. Instead, the most important determinants of growth appear to be factors that cannot be changed substantially in the short-run. We would also stress that combining the growth account decomposition with regression analysis affords a focus on the determinants of TFP in a fashion that cannot be duplicated by the simple inclusion of the investment share as a regressor.

The 20-Year Samples. The regression results for the two sub-periods are reported in table 10. Regional means for the right-hand side variables for each period are shown in table 9. The measures of institutional quality, the trade instrument and geography do not change across the two samples. Initial income, life expectancy, and population are measured at the beginning of each sub-period. All the other variables are averages over the sub-period. The basic results for growth in output per worker are shown in columns 1 and 2 of table 10. Overall, they are quite similar to those reported for the full 40-year sample, although there is some decline in statistical significance.[53] Budget policy plays a less important role in the second period, while geography, institutional quality, the trade instrument, and the Sachs-Warner index all become more

[53] The number of observations declines for the earlier sub-period because of missing values for the measures of fiscal balance. We imposed a requirement that values had to exist for at least half of the period for a specific observation to be included in the cross-national regression.

significant, with larger coefficients. These results are consistent with the view that trade and openness to trade became a more important contributor to growth after 1980. The reduced role for the institutional quality variable in the first period may reflect the fact that all of the observations on that indicator are drawn from survey information for 1982; but its statistical significance in the second period supports the argument that causation runs primarily from institutional quality to growth rather than the converse. The largest change between the two sub-periods is in the size of the constant term, which shows a decline of 5 percentage points of growth between the first and second sub-periods.[54] Finally, the inclusion of the regional effects had little substantive impact, and they are not reported.

The corresponding channel regressions are reported in columns 5-6 and 8-9. Again, in most respects, the results are consistent with those from the 40-year sample. The convergence process is evident in both capital accumulation and TFP, as are both life expectancy and population in the second period. However, the previously noted differences between the two sub-periods in the relative roles of geography, institutional quality and the trade instrument are all concentrated in the TFP component. Indeed, both geography and the trade instrument are statistically insignificant in the first period. The Sachs-Warner trade measure continues to be significant only in the regressions for capital accumulation.

The regressions for the two sub-periods seem quite similar in their basic conclusions; yet a test for a structural change in the relationship between the two periods is highly significant. This significance comes largely from the constant term, geography and the trade instrument. Allowing these three to vary between the two sub-periods raises the p-value in the test for structural change from 0.000 to 0.23. Similarly, for TFP, we can strongly reject the null hypothesis of no structural change if only the constant term is allowed to shift, but cannot reject this null if the coefficients on both geography and the trade instrument are allowed to shift also. (The corresponding p-values are 0.00 and 0.27 respectively.) In contrast, when only the constant is allowed to vary, the test for structural change in all other parameters of the channel regression for capital's contribution yields a p-value of 0.31.[55]

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[54] The net change is much less because of offsetting changes in the coefficients on other variables, such as the trade instrument and geography.

[55] The instability of the coefficient estimates for the trade instrument and population raises questions about the interpretation of the role of these variables.

These points are even more evident in the pooled regressions shown in columns 3, 7, and 10, where we allowed for shifts in the constant, the trade instrument and geography. The exogenous decline in the growth rate is estimated at –2.1 percentage points, compared to the simple sample average of –1.7 percent reported in table 5. The shift in the growth rate is equally evident for both the contribution of capital per worker and TFP, but the changing roles of the trade instrument and geography are evident only in the TFP equation.

A final exploration of the stability of the statistical relationship is provided by the population-weighted regression shown in column 4. The weights will, of course, give a dominant role to the experience of China and India; but a weighted regression provides a useful test of the stability of the specification. In this case, there is still evidence of a large shift in the constant term and geography, but no role for the trade instrument or institutional quality. It also strenghtens the negative role for inflation, while weakening the association with the budget.

Does this model account for the sharp changes in growth rates after 1980? We explore that issue by using the coefficients from the pooled regression in column 3 of table 10 to calculate the expected change in growth between the pre- and post-1980 periods. For the 84-country sample, the correlation between the predicted and actual changes, shown in figure 5, is only 0.39 and the variance of the predicted changes is only one-quarter that of the actual changes. Table 11 provides a regional summary, in which the total predicted change in growth is divided into two pieces. The column labeled "Shift terms" separates out the combined effects of shifts in the constant and in the coefficients on geography and the trade instrument (Recall that these variables are identical across sub-periods). The contribution of those variables that actually change between the two periods is reported in the column labeled "Variables." This makes clear that most of the predicted change in the growth rates is coming from the negative shifts in the constant term and coefficients for geography and trade instrument.

The basic problem is that the most significant variables are those that do not change between the two periods, and the measures of policy, which do change over time, have small coefficients with limited statistical significance. The regression analysis has focused on identifying factors that are correlated with the cross-national variation in growth rates; but those same factors appear to do little to account for the variation in growth over time. The exceptions are China and the industrial countries. For China the predicted acceleration is coming from a large improvement in life expectancy between 1960 and 1980. The predicted slowing of growth in the industrial countries can be traced to a sharp deterioration in public budgets and a reduced role for convergence after 1980. Finally, both East and South Asia have performed better than expected after 1980, while Latin America and the Middle East have fallen short.

Sensitivity to Country Groupings. Our sample includes a very heterogeneous group of countries. Do our averaged results apply to specific country groups? To some extent, we explored this issue earlier in terms of the sensitivity of some of the results to population weighting. Here we extend the sensitivity analysis by estimating the relationships reported in tables 8 and 10 for various country subgroups. We report in table 12 the results for the 62 developing economies in our sample (column 2), the 42 countries with above median income per capita in 1960 (column 3), and the 42 low-income countries in column (4). The full sample results from table 8 are reproduced for comparison (column 1). The regression results are strikingly similar across these groups. Convergence is somewhat more evident in the low-income countries (as expected), and the Sach-Warner openness measure seems least important for the richer countries (unexpected). Any effort to explore smaller, more specific samples resulted in serious problems of multicolinearity. However, for the 19 African countries, we should note that the problems extended beyond multicollinearity because the R^2 was typically only in the range of 0.25-0.35.

We can also combine the analysis of the subgroups with the examination of the 20-year periods before and after 1980. These results are reported in Table 13. As shown, the shift in the intercept, and in the coefficients on instrumented trade and geography between the two periods in the aggregate sample are all primarily due to shifts for the low income country group. In addition, the convergence term for low-income countries becomes much more important in the second period. Somewhat surprisingly, the increased importance of institutional quality after 1980 is entirely due to a change for the high-income countries.

Thus, we find surprisingly small differences between determinants of growth between high and low-income countries over our entire time period. However, we do find evidence that shifts in parameter estimates across time periods are sensitive to country groupings, with more substantive shifts for the low-income half of the sample.

Conclusion

Contrary to much of the recent literature, we conclude that growth accounting and growth regressions -- the main tools for empirical analysis of cross-national differences in economic growth -- can both yield consistent and useful results. In addition, we have argued that much of the apparent variability in the conclusions from earlier studies can be traced to measurement problems, differences in data or definition, and, in the regression analyses, failure to include other conditioning variables. To address some of these problems, we have developed a set of growth accounts over the period of 1960 to 2000 covering 84 countries, which represent a preponderance of the world economy. Combining these data with additional variables allows us to examine a wide range of competing hypotheses over a common group of countries and common time periods.

Much of the debate and dissatisfaction with the empirical analyses centers around disputes over the relative contribution of capital accumulation versus improvements in TFP and the importance of education. In both of these instances, measurement issues play a central role. With respect to the debate over capital accumulation versus TFP, we would emphasize that both are important, and that some of the prior research understates the role of capital because of inadequate measurement of the capital input. In particular, we would stress the inappropriate use of an average of the investment rate as a proxy for the change in capital. Despite concerns about the assumed rate of capital depreciation, relatively simple measures of the change in the capital stock display a much stronger correlation with output growth than the investment rate, and yield estimates of capital's contribution that are close to hypothesized values. We have identified two additional issues. First, some studies fail to recognize that measuring investment rates in international prices induces a positive correlation between investment and income levels, further compounding the problem. Second, some studies formulate the decomposition so as to focus on variations in the ratio of capital-to-output instead of capital-per-worker. We illustrate that this definitional presentation change underplays the role of capital relative to changes in TFP.

With respect to the role of education, we agree with the critics in finding only a weak correlation between economic growth and aggregate measures of improvements in educational attainment. However, rather than concluding that education does not matter, we would stress the problems introduced by difficulties of accurately measuring cross-national variations in educational attainment and adjusting for differences in educational quality. We find a surprisingly low correlation among the alternative measures of changes in educational attainment. And while we find strong evidence that available indicators of educational quality are strongly correlated with growth, this finding is not robust to the inclusion of broader indicators of institutional quality. We also note that even an optimistic valuation of the return to education would lead to only small differences in economic growth rates.

Within our framework, a very large portion of the cross-national variation in economic growth experiences over the past 40 years can be related to differences in initial conditions, and government institutions. In particular, the finding of a strong negative association between initial income and subsequent growth provides very robust support for a process of conditional convergence. Similarly, life expectancy in the initial year (as a measure of health), and population are positively associated with growth. There is also a strong correlation between growth and the quality of governing institutions (such as law and order, absence of corruption, and protection of property rights). Other variables that are consistently significant are geographical location (temperate versus tropical climate), and an indicator of a country's predisposition to trade.

In contrast, we found only limited evidence associating macroeconomic policies and the Sach-Warner indicator of openness with growth. Equally notable, some factors that are often cited in the literature did not display a consistent correlation with growth. For example, we experimented with a wide variety of alternative measures of trade openness and found their role to be insignificant in the presence of the other variables mentioned above. Much of the variation in growth experiences appears to be more closely tied to differences in the initial conditions, rather than the short-term policies of governments. In addition, while research has identified some of the factors responsible for cross-national variations in rates of economic growth, it has been far less effective in identifying the sources of change over time. Overall, we find that the variables important in accounting for differences among countries provide little insight into the change in growth rates between the 20-year periods before and after 1980.

By combining growth regressions with growth accounting, we are able to explore the channels through which various determinants are related to economic growth. In particular, the accounting decomposition provides a much more informative way to focus on determinants of changes in TFP than the frequently adopted alternative of including investment rates as a regressor. We find that geography and especially initial income are related to growth through both channels. Thus, both capital accumulation and TFP exhibit convergence. Changes in TFP are positively related to institutional quality, and life expectancy. Capital accumulation is more closely associated with budget balance, and somewhat surprisingly, with measures of trade disposition and openness.

Furthermore, some of the parameter estimates exhibit sensitivity to variations in the sample, especially when parameter shifts over time are compared for different country groups. Of particular interest, indicators of geography and predisposition to trade appear to have become more important (especially for low income countries) since 1980. There is also considerably more evidence of catch-up for the poorer countries in the later time period.

In conclusion, we believe that the cross-national analysis provides some confirming evidence of the role of various contributors to growth. But it cannot stand alone, and it requires careful attention to measurement concerns. The disappointments are: (1) the analysis yields surprisingly little insight into the sources of a widespread (excluding China and India) slowing of growth after 1980; and (2) we find relatively minor roles for macroeconomic policies.

References

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review* 91(5): 1369-1401.

Alcalá, Francisco, and Antonio Ciccone. 2001. "Trade and Productivity." Discussion Paper 3095. London, UK: Centre for Economic Policy Research (December).

Ashenfelter, Orley, Colm Harmon and Hessel Oosterbeek. 1999. "A Review of Estimates of the Schooling/Earnings Relationship, with Tests for Publication Bias." *Labour Economics* 6(4): 453–470.

Baier, Scott, Gerald P Dwyer Jr. and Robert Tamura. 2002. "How Important Are Capital and Total Factor Productivity for Economic Growth?" Working Paper 2002-2a, Federal Reserve Bank of Atlanta (April).

Barro, Robert and Xavier Sala-i-Martin. 1995. *Economic Growth*. MIT Press.

Barro, Robert. 2001. "Education and Economic Growth," in John Helliwell (editor), *The Contribution of Human and Social Capital to Sustained Economic Growth and Well-Being* (Paris: OECD); 13-41.

Barro, Robert and Jong-Wha Lee. 2000. "International Data on Educational Attainment, Updates and Implications." Working Paper 7911. Cambridge, MA: National Bureau of Economic Research (September).

______, and Jong-Wha Lee. 1993. "International Comparisons of Educational Attainment." *Journal of Monetary Economics* 32(3): 363-394.

Becker, Gary S. 1964. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. New York: NBER and Columbia University Press.

Benhabib, Jess, and Mark M. Spiegel. 1994. "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross- Country and Regional US Data." *Journal of Monetary Economics* 34(7): 143-173.

Bils, Mark and Peter J. Klenow. 2000. "Does Schooling Cause Growth?" *American Economic Review* 90(5): 1160-83.

Bosworth, Barry P., Susan M. Collins and Yu-chin Chen. 1996. "Accounting for Differences in Economic Growth." In Akira Kohsaka and Koichi Ohno (editors) *Structural Adjustment and Economic Reform: East Asia, Latin America, and Central and Eastern Europe*. Tokyo: Institute of Developing Economies.

Brock, William A., Steven Durlauf and Kenneth D. West. 2003. "Policy Evaluation in Uncertain Economic Environments" *Brookings Papers on Economic Activity*, 1:2003, 235-301.

Center for International Comparisons. 2001. *Penn World Tables Version 6.* Philadelphia, PA: University of Pennsylvainia.

Cohen, Daniel and Marcelo Soto. 2001. "Growth and Human Capital: Good Data, Good Results." Technical Papers 179. Organization for Economic Cooperation and Development (September).

Collins, Susan M. and Barry P. Bosworth. 1996. "Economic Growth in East Asia: Accumulation versus Assimilation." *Brookings Papers on Economic Activity*, 2:1996, 135-203.

De la Fuente, Ángel, and Rafael Doménech. 2001. "Educational Attainment in the OECD, 1960-1995." Unpublished paper. Institúto de Análisis Económico (January).

______, and Rafael Doménech. 2000. "Human Capital in Growth Regressions: How Much Difference does Data Quality Make?" Working Paper 262. Organization for Economic Cooperation and Development (October).

Deaton, Angus. 2003. "Measuring Poverty in a Growing World or Measuring Growth in a Poor World." Working Paper 9822. Cambridge, MA: National Bureau of Economic Research (July).

Dollar, David, and Aart Kraay. 2002. "Institutions, Trade, and Growth." *Carnegie-Rochester Conference Series on Public Policy*, forthcoming (July).

Durlauf, Steven N. and Danny T. Quah. 1999. "The New Empirics of Economic Growth." In John Taylor and Michale Woodford (editors) *Handbook of Macroeconomics*. North-Holland.

Easterly, William. 2001. *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics.* Cambidge, MA: MIT Press.

______, and Ross Levine. 2001. "It's Not Factor Accumulation: Stylized Facts and Growth Models." *World Bank Economic Review* 15(2): 177-219.

Englander, A. Steven and Andrew Gurney. 1994. "OECD Productivity Growth: Medium-Term Trends." *OECD Economic Studies* 22: 111-154.

Fernandez, Carmen, Eduardo Ley, and Mark Steel. 2001. "Model Uncertainty in Cross-Country Growth Regressions." *Journal of Applied Econometrics* 16(5): 563-76.

Frankel, Jeffrey, and David Romer. 1999. "Does Trade Cause Growth?" *American Economic Review* 89(3): 379-99.

Frankel, Jeffrey and Andrew Rose. 2002. "An Estimate of the Effect of Common Currencies on Trade and Income." *Quarterly Journal of Economics* 117(2): 437-466.

Gallup, John L. and Jeffrey D. Sachs. 1998. "The Economic Burden of Malaria." Unpublished paper. Center for International Development, Harvard University (October).

Gollin, Douglas. 2002. "Getting Income Shares Right." *Journal of Political Economy* 110(2): 458-74.

Griliches, Zvi. 1977. "Estimating the Returns to Schooling: Some Econometric Problems." *Econometrica* 45(1): 1-22.

Hall, Robert E. and Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *The Quarterly Journal of Economics* 114(1): 83-116.

Hanushek, Eric, and Dennis D. Kimko. 2000. "Schooling, Labor Force Quality, and the Growth of Nations." *The American Economic Review* 15(5): 1184-1208.

Harrison, Ann. 2003. "Has Globalization Eroded Labor's Share? Some Cross-Country Evidence." University of California, Berkeley, mimeo (May).

Heston, Alan. 2001. "Treatment of China in PWT 6." Unpublished paper. Philidelphia: PA: University of Pennsylvania (December).

Hsieh, Chang-Tai and Peter J. Klenow. 2003. "Relative Prices and Relative Prosperity." Working Paper No. 9701. Cambridge, MA: National Bureau of Economic Research (May).

Hulten, Charles R. 2001. "Total Factor Productivity: A Short Biography." in Charles Hulten, Edward R. Dean, and Michael Harper (editors) *New Developments in Productivity Analysis*, Studies in Income and Wealth Vol. 63, Chicago: University of Chicago Press: 1-54.

______. 1975. "Technical Change and the Reproducibility of Capital." *American Economic Review*, 65 (5): 956-65.

Islam, Narzul. 1995. "Growth Emprics: A Panel Data Approach." *Quarterly Journal of Economics* 110(4): 1127-70.

Jones, Charles. 1997. "Comment on: 'The Neoclassical Revival in Growth Economics: Has It Gone Too Far?' " In *National Bureau of Economic Research Macroeconomics Annual 1997*, edited by Ben S. Bernanke and Julio Rotemberg. Cambridge, MA: MIT Press. 107-113.

Jorgenson, Dale W. 2001. "Information Technology and the U.S. Economy." *American Economic Review* 91(1): 1–32.

Kaufmann, Daniel, Aart Kraay, and Pablo Zoido-Lobatón. 2002. "Governance Matters II—Updated Indicators for 2000/01." Working Paper No. 2772. Washington, D.C.: World Bank Policy Research Department (February).

Kenny, Charles, and David Williams. 2001. "What Do We Know About Economic Growth? Or, Why We Don't Know Very Much," World Development, 29 (1); 1-22.

Knack, Stephen and Philip Keefer. 1995. "Institutions and Economic Performance: Cross-country Tests Using Alternative Institutional Measures. " *Economics and Politics* 7(3): 207-227.

Klenow, Peter, and Andrés Rodriguez-Clare. 1997. "The Neoclassical Revival in Growth Economics: Has It Gone Too Far?" In *National Bureau of Economic Research Macroeconomics Annual 1997*, edited by Ben S. Bernanke and Julio Rotemberg. Cambridge, MA: MIT Press. 73-103.

Krueger, Alan, and Mikael Lindahl. 2001. "Education for Growth: Why and For Whom?" *Journal of Economic Literature* 39(4): 1101-36.

Levine, Ross, Norman Loayza and Thorsten Beck. 2000. "Financial Intermediation and Growth: Causality and Causes." *Journal of Monetary Economics* 46(1): 31-77.

______, and David Renelt. 1992. "A Sensitivity Analysis of Cross-Country Growth Regressions." *American Economic Review* 82(4): 942-63.

Lindauer, David L. and Lant Pritchett. 2002. "What's the Big Idea? The Third Generation of Policies for Economic Growth." *Economía* 3(1): 1-39.

Lubotsky, Darren, and Martin Wittenberg. 2001. "Interpretation of Regressions with Multiple Proxies." Papers 457. Princeton, NJ.: Princeton University Department of Economics (August).

Masters, William A., and Margaret S. McMillan. 2001. "Climate and Scale in Economic Growth." *Journal of Economic Growth* 6(3): 167-186.

Mankiw, N. Gregory, David Romer, and David N. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107(2): 407-438.

Nehru, Vikram and Ashok Dhareshwar. 1993. "A New Database on Physical Capital Stock: Sources, Methodology and Results." *Revista Análisis de Económico* 8(1): 37-59.

______, Eric Swanson and Ashutosh Dubey. 1995. "A New Database on Human Capital Stock in Developing and Industrial Countries: Sources, Methodology, and Results." *Journal of Development Economics* 46(2): 379-401.

Nuxoll, Daniel A. 1994. “Differences in Relative Prices and International Differences in Growth Rates.” *American Economic Review* 84(5): 1423-38.

Oliner, Stephen D. and Daniel. E. Sichel. 2000. “The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?” *Journal of Economic Perspectives* 14(4): 3–22.

Organization for Economic Cooperation and Development (OECD). 2003. *Sources of Growth in OECD Countries*, Paris

Pritchett, Lant. 2001. “Where has all the Education Gone?” *World Bank Economic Review* 15(3): 367-391.

Psacharopoulos, George. 1994. “Returns to Investment in Education: A Global Update.” *World Development* 22(9): 1325-43.

Quinn, Dennis P., Carla Inclán, and A. Maria Toyoda. 2002. “How and Where Capital Account Liberalization Leads to Economic Growth.” prepared for Presentation at The 2001 Annual American Political Science Association Convention (August).

______, and Carla Inclán. 1997. "The Origins of Financial Openness: A Study of Current and Capital Account Liberalization." *American Journal of Political Science* 41(3):771-813.

Rodriguez, Francisco, and Dani Rodrik. 2001. “Trade Policies and Economic Growth: a Skeptic’s Guide to the Cross-National Evidence,” in Ben Bernanke and Kenneth S. Rogoff (editors), *NBER Macroeconomics Annual 2000*, pp. 261-325.

Rodrik, Dani, Arvind Subramanian, and Francesco Trebbi. 2002. “Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development.” Working Paper 9305. Cambridge, MA: National Bureau of Economic Research (October).

Sachs, Jeffrey D., and Andrew Warner. 1995a. “Economic Reform and the Process of Global Integration.” *Brookings Papers on Economic Activity*, 1:1995, 1-95.

Sala-i-Martin, Xavier. 1997. “I Just Ran Two Million Regressions.” *American Economic Review* 87(2): 178-83.

Soto, Marcelo. 2002. “Rediscovering Education in Growth Regressions.” Technical Paper No. 202, OECD Development Centre (November).

Spence, A. Michael. 1973. “Job Market Signaling.” *Quarterly Journal of Economics* 87(3): 355-79.

Temple, Jonathan. 1999. “The New Growth Evidence.” *Journal of Economic Literature* 37(1): 112-156.

Wöessmann, Ludger (2000) “Specifying Human Capital: A Review, Some Extensions, and Development Effects.” Working Paper 1007. Kiel, Germany: Kiel Institute of World Economics (October).

Wu, Harry X. 2002. “How Fast Has Chinese Industry Grown? Measuring the Real Output of Chinese Industry, 1949-97.” *Review of Income and Wealth* 48(2): 179-204.

Young, Alwyn. 1994. “Lessons from the East Asian NICS: A contrarian view.” European Economic Review, 38 (3-4): 964-973.

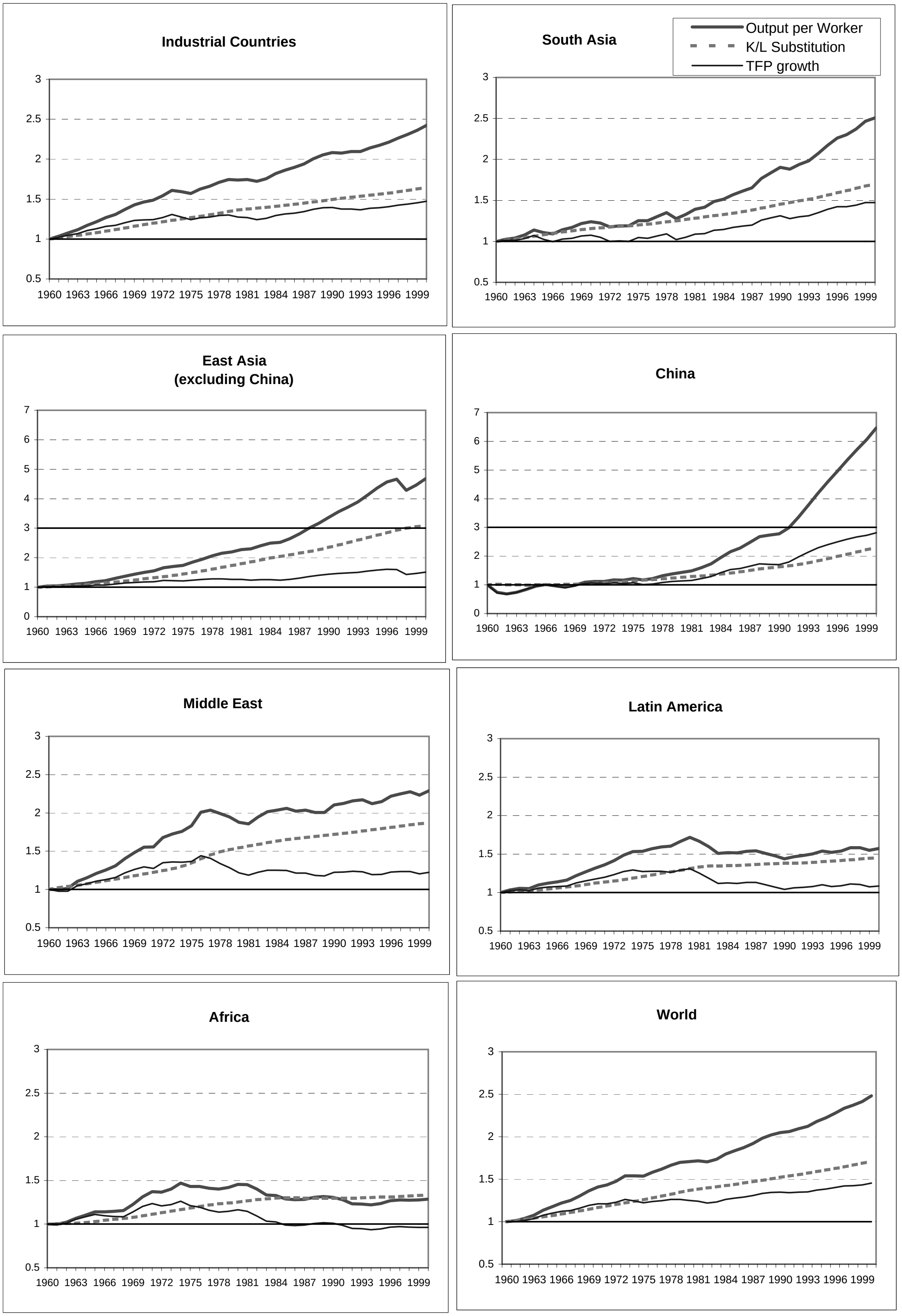
______, 2000. “Gold into Base Metals: Productivity Growth in the People’s Republic of ChinaDuring the Reform Period.” Working Paper 7856. Cambridge, MA: National Bureau of Economic Research (August).

Table 1. Sources of Growth, Regions, 1960-2000

Region/Period	Output	Output per Worker	Contribution of: Physical Capital	Education	Factor Productivity
World (84)					
1960-70	5.1	3.5	1.2	0.3	1.9
1970-80	3.9	1.9	1.1	0.5	0.3
1980-90	3.5	1.8	0.8	0.3	0.8
1990-2000	3.3	1.9	0.9	0.3	0.8
1960-2000	4.0	2.3	1.0	0.3	0.9
Industrial Countries (22)					
1960-70	5.2	3.9	1.3	0.3	2.2
1970-80	3.3	1.7	0.9	0.5	0.3
1980-90	2.9	1.8	0.7	0.2	0.9
1990-2000	2.5	1.5	0.8	0.2	0.5
1960-2000	3.5	2.2	0.9	0.3	1.0
China (1)					
1960-70	2.8	0.9	0.0	0.3	0.5
1970-80	5.3	2.8	1.6	0.4	0.7
1980-90	9.2	6.8	2.1	0.4	4.2
1990-2000	10.1	8.8	3.2	0.3	5.1
1960-2000	6.8	4.8	1.7	0.4	2.6
East Asia less China (7)					
1960-70	6.4	3.7	1.7	0.4	1.5
1970-80	7.6	4.3	2.7	0.6	0.9
1980-90	7.2	4.4	2.4	0.6	1.3
1990-2000	5.7	3.4	2.3	0.5	0.5
1960-2000	6.7	3.9	2.3	0.5	1.0
Latin America (22)					
1960-70	5.5	2.8	0.8	0.3	1.6
1970-80	6.0	2.7	1.2	0.3	1.1
1980-90	1.1	-1.8	0.0	0.5	-2.3
1990-2000	3.3	0.9	0.2	0.3	0.4
1960-2000	4.0	1.1	0.6	0.4	0.2
South Asia (4)					
1960-70	4.2	2.2	1.2	0.3	0.7
1970-80	3.0	0.7	0.6	0.3	-0.2
1980-90	5.8	3.7	1.0	0.4	2.2
1990-2000	5.3	2.8	1.2	0.4	1.2
1960-2000	4.6	2.3	1.0	0.3	1.0
Africa (19)					
1960-70	5.2	2.8	0.7	0.2	1.9
1970-80	3.6	1.0	1.3	0.1	-0.3
1980-90	1.7	-1.1	-0.1	0.4	-1.4
1990-2000	2.3	-0.2	-0.1	0.4	-0.5
1960-2000	3.2	0.6	0.5	0.3	-0.1
Middle East (9)					
1960-70	6.4	4.5	1.5	0.3	2.6
1970-80	4.4	1.9	2.1	0.5	-0.6
1980-90	4.0	1.1	0.6	0.5	0.1
1990-2000	3.6	0.8	0.3	0.5	0.0
1960-2000	4.6	2.1	1.1	0.4	0.5

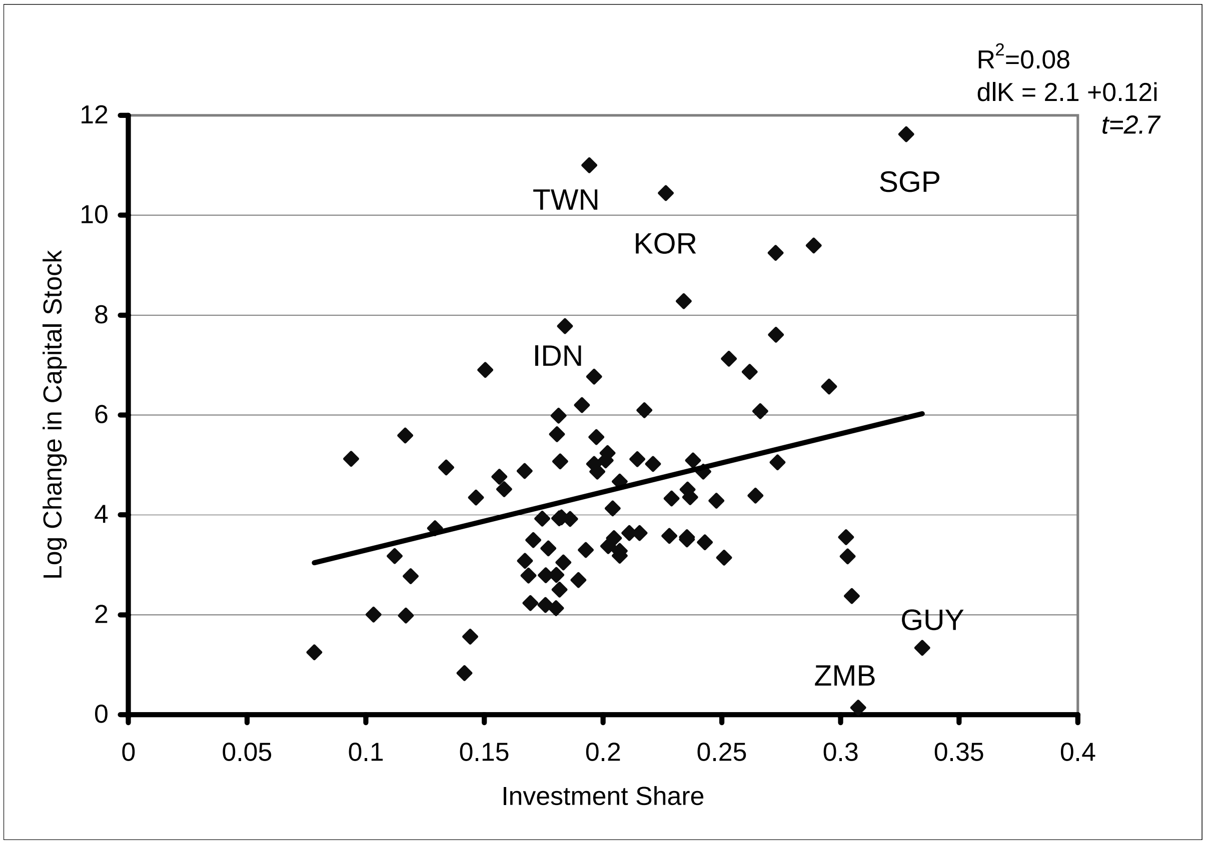
Note: Regional averages are GDP weighted.

Figure 1. Sources of Growth, Regions, 1960-2000



Source: Authors' calculations as explained in text.

Figure 2. Comparison of Investment Share and Change in the Capital Stock, 1960-2000
84 countries, national prices



Source: Capital stock constructed as explained in text, see also Appendix 3.

Table 2. Comparative Performance, Investment and the Change in the Capital Stock
84 countries

	Dependent Variable: Growth in Output per Worker					
	1960-2000		1960-80		1980-2000	
	(1)	(2)	(1)	(2)	(1)	(2)
Growth in physical capital per worker	0.56 *13.0*		0.38 *8.9*		0.70 *13.5*	
Investment share per worker		0.13 *5.3*		0.05 *2.5*		0.21 *7.7*
Summary Statistics:						
Adjusted R^2	0.67	0.25	0.48	0.06	0.69	0.41
Standard Error	0.82	1.24	1.08	1.46	1.04	1.42

Notes: T-statistics are reported in italics, constant term is included but not reported. Growth in capital per worker is measured as mean of annual log changes (x100), investment per worker is measured as a share of GDP in constant national prices.
Source: Capital stock constructed as explained in text, see also Appendix 3.

Figure 3. Investment in National and International Prices, 1960-98
84 countries

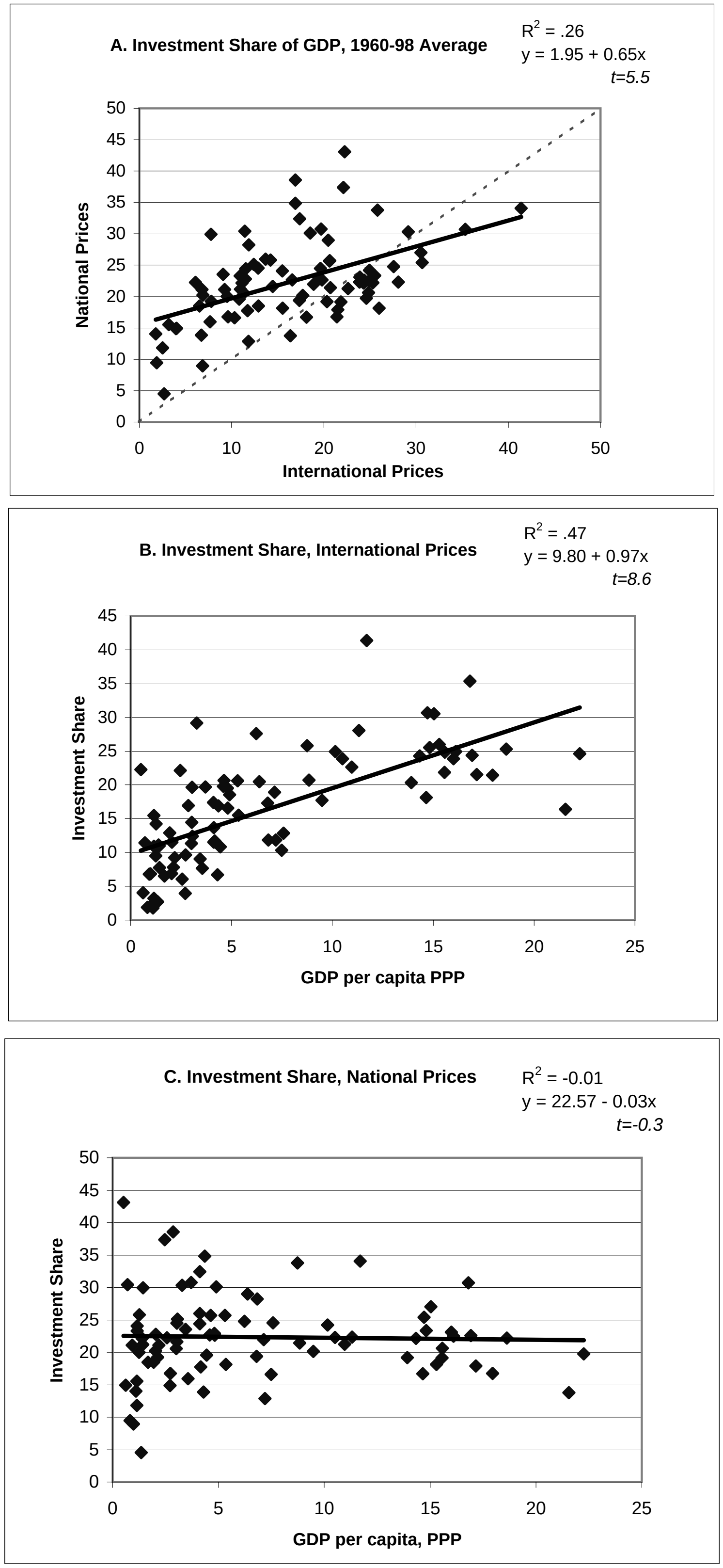
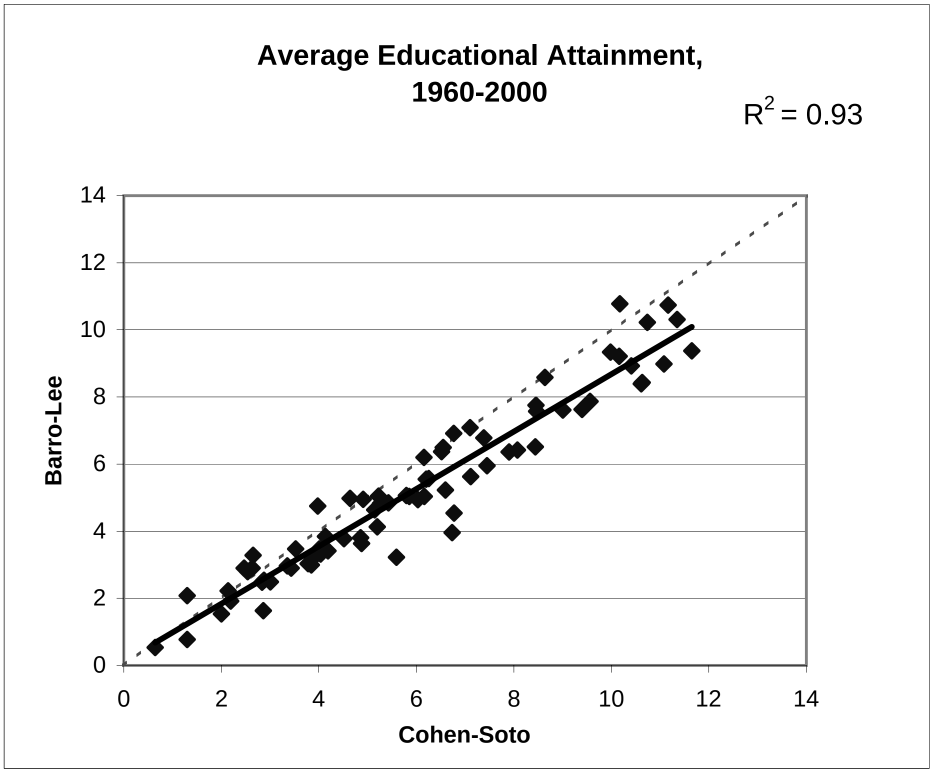


Figure 4. Comparing Measures of Educational Attainment, 1960-2000



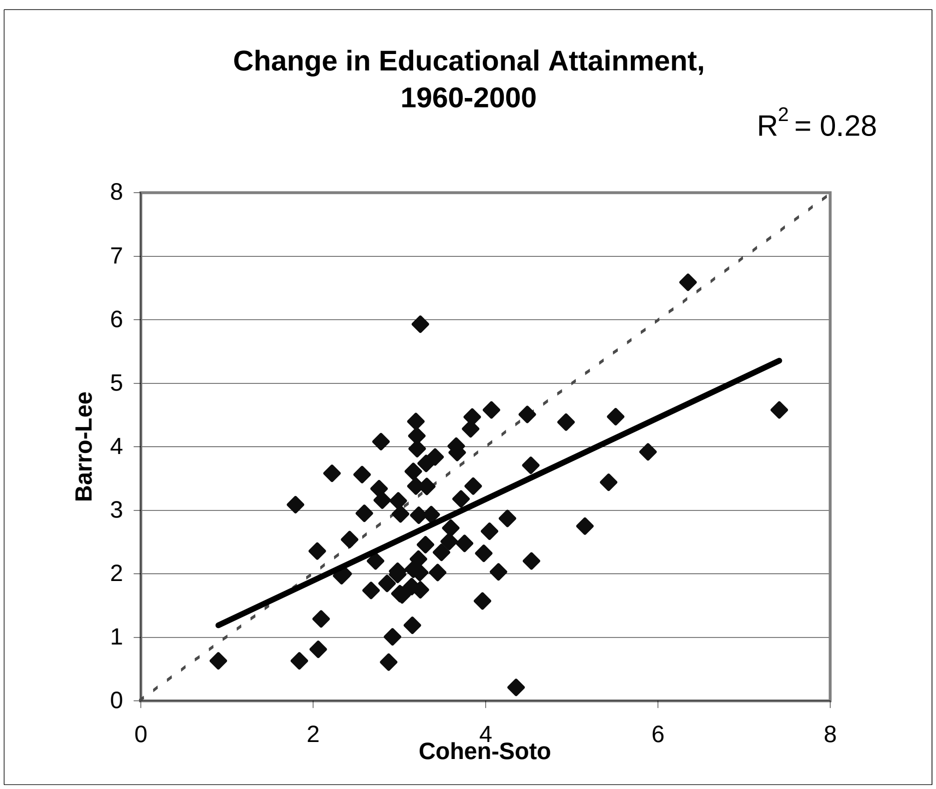


Table 3a. Variance/Covariance Analysis of Income per Worker, 1960-2000

	Contribution to Y/L:		
Equation	Physical Capital	Education	Factor Productivity
(1) Unweighted, K/L	0.43	0.03	0.54
(2) Pop. Weighted, K/L	0.37	0.09	0.54
(3) * Unweighted, K/Y	0.12	0.05	0.54

Table 3b. Variance/Covariance Analysis of Income per Worker, 1960-2000

	Contribution to Y/L:					
	Variance			2 * Covariance		
Equation	*Var(K*)*	*Var(H*)*	*Var(A*)*	*Covar(K*,H*)*	*Covar(K*,A*)*	*Covar(H*,A*)*
(1) Unweighted, K/L	0.27	0.01	0.40	0.03	0.27	0.02
(2) Pop. Weighted, K/L	0.14	0.01	0.30	0.06	0.39	0.09
(3) * Unweighted, K/Y	0.24	0.01	0.95	0.03	-0.26	0.04

Note: For rows (1) and (2) the contribution of each factor (K*, H*, and A*) to the growth in output per worker is defined as in Equation 2 of the text. For row (3) contributions are defined as in Equation 2''.

Table 4. Educational Attainment, Quality, and Economic Growth, 1960-2000

	Dependent Variable: Growth in Output per Worker				
Independent Variable:	(1)	(2)	(3)	(4)	(5)
Growth in physical	0.51	0.35	0.27	0.48	0.27
capital per worker	*11.5*	--	*6.2*	*10.5*	*6.0*
Growth in human	0.74	1.55	0.55	0.82	0.53
capital per worker	*1.4*	*3.0*	*1.3*	*1.6*	*1.3*
Initial level of average	0.11	0.13	0.08	0.07	0.07
years of schooling	*3.5*	*3.7*	*1.4*	*1.8*	*1.0*
Educational quality	--	--	--	0.02	0.01
	--	--	--	*2.2*	*0.7*
Initial conditions (6) included	no	no	yes	no	yes
Constant	-0.41	-0.51	-4.25	-0.90	-4.53
	-1.4	*-1.6*	*-3.9*	*-2.5*	*-3.9*
Summary Statistics					
Adjusted R^2	0.71	0.70	0.84	0.72	0.84
Observations	84	84	84	84	84

Note: T-statistics are in italics. Initial conditions include: GDP per capita in 1960, life expectancy in 1960, log population in 1960, trade instrument, geography, and institutional quality.
Source: Human and physical capital calculated as explained in text. Educational quality measure is expanded to 84 countries using data from the WDI (2002) as shown in equation (3) in Appendix 2. Initial conditions and education measure are as described in Appendix 3.

Table 5. Decomposition of the Change in Output Growth Between (1960-1980) and (1980-2000)
annual percentage change

	Average Growth Rate:		Change in Growth Rate:			
				Contribution of:		
	Output per worker		Output per worker	Physical Capital	Education	Factor Productivity
	1960-80	*1980-2000*				
World						
mean	2.5	0.8	-1.7	-0.7	0.0	-1.0
cov/var				*0.28*	*-0.01*	*0.73*
Developing Countries (62)						
mean	2.3	0.6	-1.7	-0.7	0.0	-1.1
cov/var				*0.26*	*-0.01*	*0.75*
Africa (19)						
mean	1.4	-0.3	-1.7	-0.9	0.1	-1.0
cov/var				*0.25*	*-0.02*	*0.78*
East Asia with China (8)						
mean	4.1	3.9	-0.2	-0.3	0.0	0.0
cov/var				*0.40*	*0.01*	*0.59*
East Asia without China						
mean	4.3	3.4	-1.0	-0.5	0.0	-0.4
cov/var				*0.44*	*0.06*	*0.51*
Latin America (22)						
mean	2.0	-0.5	-2.4	-0.6	0.0	-1.8
cov/var				*0.14*	*0.00*	*0.86*
Middle East (9)						
mean	3.3	1.0	-2.3	-1.1	0.1	-1.3
cov/var				*0.35*	*0.02*	*0.63*
South Asia (4)						
mean	2.0	2.6	0.6	-0.1	0.1	0.6
cov/var				*0.51*	*-0.02*	*0.51*
Industrial (22)						
mean	3.1	1.5	-1.6	-0.7	0.0	-0.8
cov/var				*0.43*	*-0.02*	*0.59*
Greatest increase in growth (25 countries)						
mean	2.0	2.4	0.4	0.0	0.0	0.4
cov/var				*0.24*	*-0.01*	*0.76*
China	2.2	7.1	4.9	1.8	0.0	3.2
India	1.3	3.5	2.2	0.4	0.1	1.7
Uganda	-1.1	2.3	3.4	-0.5	0.2	3.7
Greatest decrease in growth (25 countries)						
mean	3.0	-0.5	-3.5	-1.1	0.0	-2.5
cov/var				*0.31*	*-0.02*	*0.71*

Note: The contribution is measured as the covariance of the average log change of income per worker with the change in the factor contribution divided by the total variance of the log change in income per worker.

Source: Authors' calculations as explained in text.

Table. 6 Alternative Measures of Change in Growth of Output per Worker Between (1960-1980) and (1980-2000)
annual percentage change

	Linear unweighted	Population weighted	GDP weighted
World	-1.7	0.7	-0.9
Developing Countries	-1.7	1.3	-0.4
Africa	-1.7	-2.1	-2.6
East Asia	-1.0	-0.9	-0.9
East Asia (with China)	-0.2	3.5	2.2
Latin America	-2.4	-3.2	-3.1
Middle East	-2.3	-2.2	-2.3
South Asia	0.6	1.7	1.8
Industrial	-1.6	-1.5	-1.2
Greatest increase (25 countries)	0.4	2.5	0.8
Greatest decrease (25 countries)	-3.5	-3.6	-3.7

Source: Authors' calculations as explained in text, see also Appendix 3.

Table 7. Summary Values By Region, 1960-2000

	Initial Conditions and External Shocks:						*Policy:*		
	Initial income per capita	Life expectancy	Log of Population	Frankel-Romer-Rose Trade Instrument	Geography	Institutional Quality	Budget Balance	Change in Inflation	Average Sachs-Warner Openness
Developing Countries (62)	0.17	49.90	15.76	0.08	-0.55	0.48	-3.53	16.43	0.27
	0.11	*9.67*	*1.48*	*0.07*	*0.73*	*0.14*	*3.03*	*16.35*	*0.33*
Africa (19)	0.11	41.59	15.52	0.06	-0.90	0.47	-4.98	13.30	0.08
	0.09	*5.93*	*0.91*	*0.04*	*0.37*	*0.12*	*2.15*	*7.65*	*0.24*
East Asia (8)	0.12	52.54	17.04	0.14	-0.34	0.61	-0.92	8.69	0.66
with China	*0.05*	*9.67*	*1.77*	*0.15*	*1.11*	*0.20*	*2.39*	*9.01*	*0.38*
Latin America (22)	0.25	55.44	15.19	0.08	-0.71	0.43	-3.16	25.07	0.28
	0.11	*7.64*	*1.24*	*0.04*	*0.56*	*0.13*	*3.37*	*23.02*	*0.25*
Middle East (9)	0.21	52.79	15.59	0.11	0.26	0.49	-3.08	12.51	0.36
	0.08	*9.98*	*1.48*	*0.07*	*0.66*	*0.10*	*2.58*	*10.23*	*0.40*
South Asia (4)	0.08	47.04	17.85	0.10	-0.23	0.42	-4.98	8.03	0.06
	0.02	*8.97*	*1.55*	*0.03*	*0.67*	*0.12*	*3.53*	*0.56*	*0.13*
Industrial Countries (22)	0.62	70.26	16.24	0.13	1.08	0.91	-1.96	6.35	0.91
	0.22	*2.24*	*1.53*	*0.09*	*0.45*	*0.11*	*2.56*	*3.25*	*0.20*
China	0.04	36.32	20.32	0.04	1.32	0.57	-1.03	4.03	0.00
India	0.07	44.33	19.89	0.06	-0.36	0.58	-5.08	7.67	0.00

Note: Numbers in italics are regional standard deviations. Variables are defined in Appendix 3. Source: See Appendix 3.

Table 8. Regressions of Growth on Initial Conditions, External Shocks, and Policy, 1960-2000

	Growth in Output per Worker					*Contribution of Capital per Worker*		*Contribution of Total Factor Productivity*	
Independent	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	-2.27	-1.49	-2.94	-1.64	-0.57	-0.52	0.64	-1.12	-1.22
	-2.2	*-1.8*	*-2.7*	*-1.6*	*-0.5*	*-0.6*	*0.8*	*-1.3*	*-1.1*
Contribution of	--	0.78	--	--	--	--	--	--	--
capital per worker	--	*6.9*	--	--	--	--	--	--	--
Investment share	--	--	2.76	--	--	--	--	--	--
	--	--	*1.6*	--	--	--	--	--	--
Income per capita	-6.29	-4.02	-5.89	-6.24	-5.18	-2.89	-2.18	-3.35	-3.00
	-10.4	*-7.0*	*-9.2*	*-10.7*	*-8.9*	*-6.2*	*-4.8*	*-6.7*	*-5.3*
Life expectancy	0.07	0.04	0.06	0.06	0.06	0.02	0.02	0.04	0.04
	5.6	*4.4*	*4.9*	*5.0*	*4.1*	*2.4*	*1.6*	*3.6*	*2.9*
Log of population	0.29	0.16	0.29	0.28	0.19	0.16	0.08	0.12	0.11
	4.8	*3.0*	*4.8*	*4.7*	*3.0*	*3.4*	*1.6*	*2.4*	*1.8*
Trade Instrument	4.77	2.26	4.53	3.55	2.51	2.24	1.66	1.31	0.85
	4.1	*2.3*	*3.9*	*3.0*	*2.2*	*2.4*	*1.9*	*1.3*	*0.8*
Geography	0.53	0.33	0.51	0.48	0.40	0.22	0.17	0.27	0.23
	4.1	*3.1*	*3.9*	*3.9*	*3.0*	*2.2*	*1.6*	*2.5*	*1.8*
Institutional quality	2.84	2.29	2.72	2.34	2.66	0.34	0.35	2.00	2.31
	4.5	*4.5*	*4.3*	*3.6*	*3.7*	*0.7*	*0.6*	*3.6*	*3.3*
Change in inflation	--	--	--	-0.01	0.00	0.00	0.00	0.00	0.00
	--	--	--	*-1.1*	*-0.9*	*-0.7*	*-0.4*	*-0.6*	*-0.6*
Budget balance	--	--	--	0.06	0.03	0.06	0.03	0.01	0.00
	--	--	--	*2.3*	*1.1*	*2.6*	*1.2*	*0.3*	*0.1*
Sachs-Warner Openness	--	--	--	0.48	0.18	0.44	0.04	0.04	0.13
	--	--	--	*1.7*	*0.6*	*1.9*	*0.2*	*0.2*	*0.5*
Regional dummies?	*no*	*no*	*no*	*no*	*yes*	*no*	*yes*	*no*	*yes*
Summary Statistics									
Adjusted R^2	0.75	0.84	0.75	0.77	0.82	0.53	0.64	0.57	0.56
Standard error	0.72	0.57	0.71	0.69	0.61	0.55	0.48	0.59	0.60
Observations	84	84	84	84	84	84	84	84	84

Note: T-statistics are reported in italics, variables are as described in Appendix 3.
Source: Authors' calculations, also see Appendix 3.

Table 9. Summary Values By Region, 1960-80 and 1980-2000

	Income per Capita		Life Expectancy		Log of Population		Budget Balance		Change in Inflation		Average Sachs-Warner Openness	
	1960-80	*1980-2000*	*1960-80*	*1980-2000*	*1960-80*	*1980-2000*	*1960-80*	*1980-2000*	*1960-80*	*1980-2000*	*1960-80*	*1980-2000*
Developing Countries (62)	0.17	0.18	49.90	58.84	15.76	16.27	-3.18	-3.96	10.90	22.68	0.19	0.37
	0.11	*0.13*	*9.67*	*9.32*	*1.48*	*1.49*	*2.77*	*4.06*	*10.94*	*28.45*	*0.35*	*0.37*
Africa (19)	0.11	0.09	41.59	48.92	15.52	16.06	-4.84	-5.26	8.33	18.27	0.07	0.15
	0.09	0.09	*5.93*	6.71	*0.91*	0.94	*2.95*	2.46	*4.23*	13.00	*0.24*	0.30
East Asia (8)	0.12	0.21	52.54	65.48	17.04	17.52	-1.53	-0.56	11.52	6.10	0.60	0.82
with China	*0.05*	*0.15*	*9.67*	*5.60*	*1.77*	*1.76*	*1.79*	*3.44*	*15.82*	*3.16*	*0.43*	*0.37*
Latin America (22)	0.25	0.24	55.44	63.83	15.19	15.67	-2.28	-4.07	14.50	37.40	0.16	0.39
	0.11	*0.11*	*7.64*	*6.11*	*1.24*	*1.28*	*2.15*	*5.23*	*14.42*	*41.32*	*0.31*	*0.27*
Middle East (9)	0.21	0.26	52.79	62.77	15.59	16.10	-2.92	-3.21	8.25	16.92	0.25	0.50
	0.08	*0.13*	*9.98*	*6.64*	*1.48*	*1.51*	*3.14*	*2.51*	*5.22*	*15.79*	*0.43*	*0.41*
South Asia (4)	0.08	0.07	47.04	56.38	17.85	18.34	-5.94	-5.63	7.39	8.75	0.03	0.09
	0.02	*0.02*	*8.97*	*8.04*	*1.55*	*1.57*	*1.77*	*3.96*	*2.02*	*1.88*	*0.05*	*0.19*
Industrial Countries (22)	0.62	0.74	70.26	74.26	16.24	16.41	-0.84	-3.06	7.16	5.73	0.88	0.98
	0.22	*0.16*	*2.24*	*1.38*	*1.53*	*1.52*	*2.63*	*2.95*	*3.14*	*3.75*	*0.30*	*0.07*
China	0.04	0.04	36.32	66.84	20.32	20.70	.	-1.04	0.97	6.84	0.00	0.00
India	0.07	0.06	44.33	54.18	19.89	20.35	-3.93	-6.28	6.68	8.66	0.00	0.00

Note: Numbers in italics are regional standard deviations. Variables are defined in Appendix 3. Source: See Appendix 3.

Table 10. Regressions of Growth on Initial Conditions, External Shocks, and Policy, 1960-80 and 1980-2000

	Growth in Output per worker				*Contribution of Capital per worker*			*Contribution of Total Factor Productivity*		
Independent Variable	1960-80 (1)	1980-2000 (2)	*pooled* 1960-2000 (3)	*weighted* 1960-2000 (4)	1960-80 (5)	1980-2000 (6)	*pooled* 1960-2000 (7)	1960-80 (8)	1980-2000 (9)	*pooled* 1960-2000 (10)
Constant	0.28	-4.79	-0.90	1.41	-0.04	-1.81	-0.43	0.32	-2.99	-0.48
	0.2	*-2.8*	*-0.8*	*0.9*	*0.0*	*-2.0*	*-0.6*	*0.2*	*-2.1*	*-0.5*
Shift in constant	--	--	-2.14	-0.96	--	--	-0.73	--	--	-1.41
	--	--	*-7.5*	*-2.6*	--	--	*-3.8*	--	--	*-5.7*
Income per capita	-6.51	-7.42	-6.71	-7.98	-3.20	-2.69	-2.84	-3.32	-4.73	-3.87
	-7.9	*-6.8*	*-10.1*	*-11.8*	*-4.5*	*-4.8*	*-6.3*	*-4.3*	*-5.3*	*-6.7*
Life expectancy	0.07	0.07	0.07	0.14	0.02	0.03	0.02	0.05	0.04	0.05
	3.7	*3.2*	*5.2*	*6.6*	*1.1*	*2.8*	*2.6*	*2.9*	*2.1*	*4.0*
Log of Population	0.25	0.35	0.29	0.29	0.15	0.20	0.17	0.09	0.16	0.13
	2.8	*3.8*	*4.6*	*3.6*	*2.1*	*4.0*	*3.9*	*1.1*	*2.1*	*2.3*
Trade Instrument	3.46	6.54	2.29	-1.51	4.12	2.08	3.10	-0.66	4.46	-0.80
	2.0	*3.5*	*1.4*	*-0.5*	*2.8*	*2.2*	*2.7*	*-0.4*	*3.0*	*-0.6*
Shift in trade instrument	--	--	4.61	-0.35	--	--	-0.16	--	--	4.78
	--	--	2.18	-0.09	--	--	-0.11	--	--	2.60
Geography	0.37	0.71	0.24	0.49	0.41	0.15	0.21	-0.05	0.56	0.03
	1.9	*3.3*	*1.4*	*2.3*	*2.5*	*1.4*	*1.8*	*-0.3*	*3.2*	*0.2*
Shift in geography	--	--	0.59	0.55	--	--	0.13	--	--	0.46
	--	--	3.36	2.71	--	--	1.11	--	--	3.02
Institutional quality	2.09	3.78	2.74	0.86	0.22	0.69	0.42	1.88	3.09	2.31
	2.2	*3.4*	*3.8*	*0.8*	*0.3*	*1.2*	*0.9*	*2.1*	*3.4*	*3.7*
Change in inflation	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00
	-0.5	*-1.8*	*-2.2*	*-3.2*	*-0.6*	*-1.9*	*-1.8*	*0.0*	*-1.0*	*-1.2*
Budget balance	0.14	0.05	0.08	0.06	0.04	0.04	0.04	0.10	0.01	0.04
	3.2	*1.4*	*2.9*	*1.3*	*1.1*	*2.4*	*2.3*	*2.4*	*0.2*	*1.6*
Sachs-Warner Openness	0.32	1.19	0.66	0.76	0.19	0.68	0.45	0.13	0.51	0.21
	0.9	*2.6*	*2.3*	*2.1*	*0.6*	*2.8*	*2.4*	*0.4*	*1.4*	*0.9*
Summary Statistics										
Adjusted R^2	0.60	0.64	0.70	0.77	0.34	0.52	0.49	0.30	0.50	0.50
Standard error	0.96	1.12	1.05	1.10	0.83	0.58	0.71	0.91	0.91	0.91
Observations	77	84	161	161	77	84	161	77	84	161

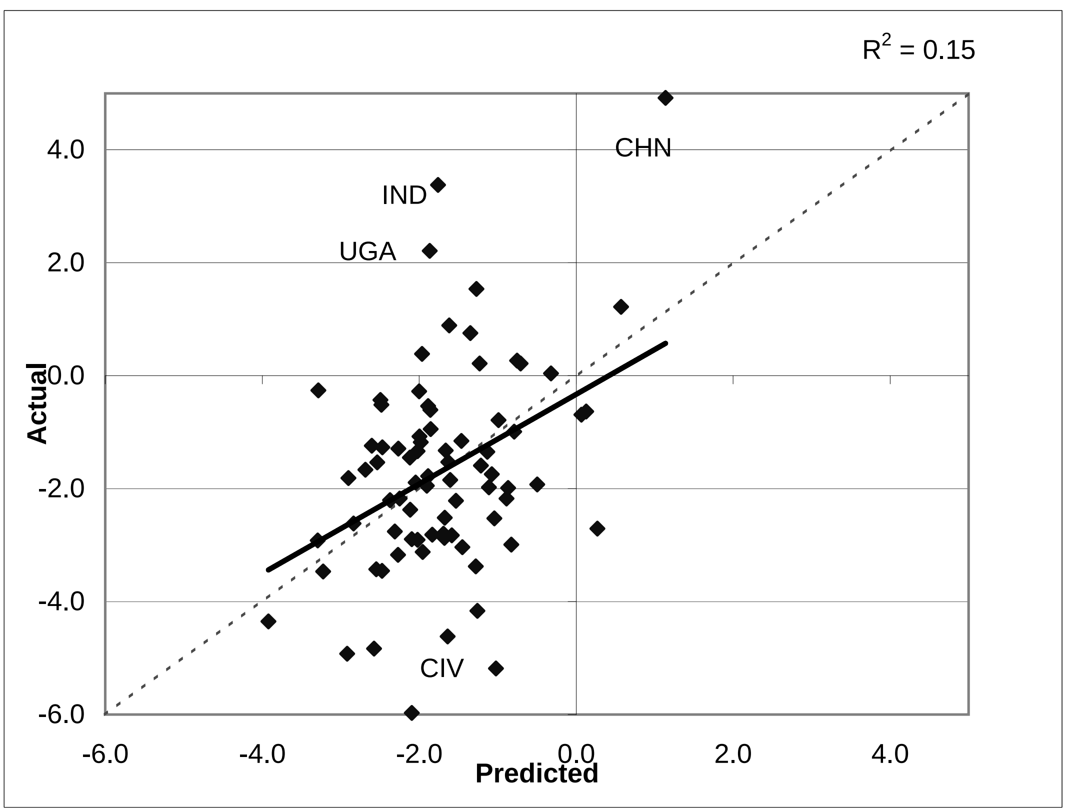
Note: T-statistics are reported in italics. Variables are as described in Appendix 3. Regression in column (4) weighted by population.
Source: Authors' calculations, also see Appendix 3.

Table 11. Explained change in growth of output per worker between 1960-80 and 1980-2000

	Actual	Predicted Change			
	Change	Total	Variables	Shift terms	Residual
Developing Countries	-1.7	-1.7	0.4	-2.1	0.0
Africa	-1.7	-2.0	0.4	-2.4	0.2
East Asia	-1.0	-1.5	0.2	-1.8	0.6
East Asia (w/China)	-0.2	-1.2	0.5	-1.7	1.0
Latin America	-2.4	-1.9	0.3	-2.2	-0.5
Middle East	-2.4	-1.3	0.3	-1.5	-1.2
South Asia	0.4	-1.4	0.5	-1.9	2.5
Industrial	-1.5	-1.7	-0.8	-0.9	0.1
Greatest increase (25 countries)	0.4	-1.3	0.3	-1.6	1.6
China	4.9	0.8	2.0	-1.2	4.1
India	0.9	-1.6	0.5	-2.1	2.5
Uganda	3.4	-1.8	0.8	-2.6	5.1
Greatest decrease (25 countries)	-3.5	-2.0	0.0	-2.0	-1.6

Note: Shift terms and coefficients are based on equation (3) of table 10. China has no budget data 1960-80, so in order to include China in this analysis it was assumed that the change in this variable between the two periods was zero.
Source: Authors' calculations.

Figure 5. Change in Growth of Y/L between 1960-80 and 1980-2000



Source: Authors' calculations.

Table 12. Sensitivity Analysis of Growth Regression, 40 year perioc

Independent Variable	**Full Sample** (1)	**Developing Countries** (2)	**High-Income Countries** (3)	**Low-Income Countries** (4)
	Dependent Variable: Growth in Y/L, 1960-2000			
Constant	-1.64	-2.19	-0.43	-1.68
	-1.6	*-1.4*	*-0.3*	*-0.7*
Income per capita	-6.24	-7.26	-5.08	-8.19
	-10.7	*-5.6*	*-7.7*	*-2.4*
Life expectancy	0.06	0.07	0.06	0.07
	5.0	*5.0*	*3.2*	*3.6*
Log of Population	0.28	0.33	0.18	0.31
	4.7	*3.9*	*2.4*	*2.8*
Instrumented Trade	3.55	4.03	3.47	3.14
	3.0	*2.3*	*2.2*	*1.5*
Geography	0.48	0.61	0.55	0.62
	3.9	*4.2*	*3.2*	*2.9*
Institutional quality	2.34	2.60	2.13	2.43
	3.6	*3.5*	*1.8*	*2.6*
Change in inflation	-0.01	-0.01	0.00	-0.01
	-1.1	*-1.0*	*-0.4*	*-1.2*
Budget balance	0.06	0.06	0.04	0.04
	2.3	*1.6*	*0.8*	*1.1*
Sachs-Warner Openness	0.48	0.69	0.07	1.21
	1.7	*2.1*	*0.2*	*2.8*
Summary Statistics				
Adjusted R^2	0.77	0.80	0.77	0.80
Standard error	0.69	0.68	0.61	0.71
Observations	84	62	42	42

Note: Samples for columns (3) and (4) are divided by median income per capita in 1960. T-statistics in parentheses. Variables are as described in Appendix 3.
Source: Authors' calculations, see also Appendix 3.

Table 13. Sensitivity Analysis of Growth Regression, 20 year perioc

Independent Variable	*Dependent Variable: Growth in Y/L*			
	High-Income		**Low-Income**	
	1960-80	1980-2000	1960-80	1980-2000
	(1)	(2)	(3)	(4)
Constant	-0.05	-1.41	1.64	-6.13
	0.0	*-0.7*	*0.4*	*-1.7*
Income per capita	-6.28	-5.24	-4.35	-11.67
	-7.1	*-3.9*	*-0.8*	*-2.5*
Life expectancy	0.09	0.08	0.06	0.09
	3.0	*1.7*	*1.8*	*2.7*
Log of Population	0.35	0.06	0.09	0.50
	3.4	*0.5*	*0.5*	*2.7*
Instrumented Trade	4.46	4.47	2.13	12.17
	2.1	*2.0*	*0.7*	*3.1*
Geography	0.72	0.60	0.36	0.78
	2.8	*2.3*	*0.9*	*2.3*
Institutional quality	0.45	4.10	3.38	2.59
	0.3	*2.3*	*1.9*	*1.7*
Change in inflation	-0.02	0.00	0.01	-0.01
	-1.5	*0.0*	*0.3*	*-0.6*
Budget balance	0.11	0.05	0.13	0.02
	1.7	*0.8*	*1.8*	*0.5*
Sachs-Warner Openness	-0.31	1.04	0.78	1.56
	-0.7	*1.3*	*1.2*	*2.6*
Summary Statistics				
Adjusted R^2	0.65	0.64	0.53	0.72
Standard error	0.84	0.91	1.14	1.15
Observations	42	42	35	42

Note: Samples for columns (3) and (4) are divided by median income per capita in 1960. T-statistics in parentheses. Variables are as described in Appendix 3.
Source: Authors' calculations, see also Appendix 3.

Appendix 1. Country Sample, by Regional Grouping

East Asia (8)	**Industrial (22)**	**Middle East and North Africa (9)**
China	Australia	Algeria
Indonesia	Austria	Cyprus
Korea	Belgium	Egypt
Malaysia	Canada	Iran
Philippines	Denmark	Israel
Singapore	Finland	Jordan
Taiwan	France	Morocco
Thailand	Germany	Tunisia
	Great Britain	Turkey
Latin America (22)	Greece	
Argentina	Iceland	**Sub-Sahara Africa (19)**
Bolivia	Ireland	Cameroon
Brazil	Italy	Cote d' Ivoire
Chile	Japan	Ethiopia
Colombia	Netherlands	Ghana
Costa Rica	New Zealand	Kenya
Dominican Rep.	Norway	Madagascar
Ecuador	Portugal	Malawi
El Salvador	Spain	Mali
Guatemala	Sweden	Mauritius
Guyana	Switzerland	Mozambique
Haiti	United States	Nigeria
Honduras		Rwanda
Jamaica	**South Asia (4)**	Senegal
Mexico	Bangladesh	Sierra Leone
Nicaragua	India	South Africa
Panama	Pakistan	Tanzania
Paraguay	Sri Lanka	Uganda
Peru		Zambia
Trinidad & Tobago		Zimbabwe
Uruguay		
Venezuela		

Appendix 2
Measures of Education Quality

The original analysis by Hanuschek and Kimko (2000) estimated a statistical relationship between their index of educational quality and a set of indicators from the Barro-Lee (1993) data set for 30 countries who participated in the testing. This relationship was then used to predict educational quality for an additional 49 countries, 36 of which are in our sample. That relationship is reported in column 1 of table A2-1. We expanded the 30-country sample to include Chile because we wanted to have at least two countries, Chile and Brazil, on which to base the placement of Latin American countries. In the Hanushek-Kimko series the Latin America measures are all relative to Brazil and appeared to be too high. The result of that addition is shown in column 2.[1] The right-hand-side variables, except population growth and educational attainment, were updated from the 2002 World Development Indicators and are average values over the period of 1970-2000. Population growth and the average years of schooling are both measured over the period of 1960-2000. We also were able to add China, Mozambique and Nigeria for which data were not reported in the Barro-Lee data set.. The resulting equation that we used to construct the revised index of education quality is reported in column (3). Finally, because of the correlation reported in the text between the measure of education quality and the quality of government institutions, we show in column 4 a regression for the 34-country sample that includes the measure of institutional quality. It is highly significant, but it alters and reduces the role of several other variables.

The index of educational quality was extended to the remaining countries in our sample using the equation shown in column (3) and data drawn from the WDI. Two of the countries in the 34-country sample, Swaziland and Hong Kong, are not in our sample. In table A2-2, we show the original Hanushek-Kimko index in column (1). For those countries that were not in their sample, we show estimates provided by Wöessman (2000). His estimates are based on countries that are similar in region and income level. Column (2) reports our estimates based on equation 3 of table A2-1. Finally, the estimate of school quality using the quality of government institutions is in column (3).

[1] The Hanuschek and Kimko study excluded Chile because the test score data came from an earlier decade.

A2-1. Educational Quality Data: Prediction Models for QL2

	Barro-Lee data		WDI data	
Independent Variable	(1)	(2)	(3)	(4)
Constant	-28.40	-23.01	9.97	-47.98
	-1.0	*-0.6*	*0.5*	*-2.3*
Primary enrollment	73.28	68.71	15.78	24.87
	2.5	*1.7*	*0.9*	*1.7*
Education expenditure	170.37	155.52	96.68	-198.02
	1.0	*0.9*	*0.5*	*-1.2*
Population growth	-417.00	-398.13	-265.28	483.20
	-1.6	*-1.4*	*-1.2*	*2.0*
Education years	0.97	0.90	2.99	0.58
	0.8	*0.8*	*3.1*	*0.6*
Institutional quality	--	--	--	85.65
	--	--	--	*4.4*
Regional Dummies:				
East Asia	13.77	13.15	15.22	10.85
	2.9	*2.0*	*2.6*	*2.3*
Latin America	0.20	-12.65	-11.09	-9.67
	0.0	*-1.6*	*-1.5*	*-1.7*
Africa	8.71	7.50	9.47	11.46
	2.5	*0.7*	*1.2*	*1.9*
Summary Statistics				
Adjusted R^2	0.56	0.55	0.55	0.74
Observations	30	31	34	34
Mean predicted QL2	40.6	35.2	33.1	25.4

Note: T-statistics are reported in italics. Equation (1) is taken from Hanushek and Kimko (2000). The re-estimate of column (2) adds Chile. Column (3) and (4) are based on updated data from the WDI(2002). Column (4) adds the measure of institutional quality.

A2-2. Measures of Educational Quality

Country	QL2*	QL2WB	QL2_inst	Test Countries	Woessman extension
Argentina	48.5	26.0	22.3	0	0
Australia	59.0	59.0	59.0	1	0
Austria	56.6	55.6	55.4	0	0
Belgium	57.1	57.1	57.1	1	0
Bangladesh	43.0	5.3	2.8	0	1
Bolivia	27.5	4.0	5.4	0	0
Brazil	36.6	36.6	36.6	1	0
Canada	54.6	54.6	54.6	1	0
Switzerland	61.4	61.4	61.4	1	0
Chile	24.7	24.7	24.7	1	0
China	64.4	64.4	64.4	1	0
Cote d' Ivoire	39.1	40.4	44.7	0	1
Cameroon	42.4	0.2	42.5	0	0
Colombia	37.9	25.9	24.2	0	0
Costa Rica	46.2	32.1	35.2	0	0
Cyprus	46.2	34.2	33.2	0	0
Germany	48.7	48.7	48.7	1	0
Denmark	61.8	54.5	57.9	0	0
Dominican Rep.	39.3	22.8	20.3	0	0
Algeria	28.1	24.9	28.5	0	0
Ecuador	39.0	28.3	28.3	0	0
Egypt	26.4	23.6	25.8	0	0
Spain	51.9	51.9	51.9	1	0
Ethiopia	37.6	12.7	12.5	0	1
Finland	59.6	59.6	59.6	1	0
France	56.0	56.0	56.0	1	0
Great Britain	62.5	62.5	62.5	1	0
Ghana	25.9	35.8	34.9	0	1
Greece	50.9	41.4	37.1	0	0
Guatemala	40.1	3.4	1.5	0	1
Guyana	51.5	-3.9	0.8	0	0
Honduras	28.6	13.4	14.5	0	0
Haiti	38.4	-11.1	-12.1	0	1
Indonesia	43.0	39.7	38.9	0	0
India	20.8	20.8	20.8	1	0
Ireland	50.2	50.2	50.2	1	0
Iran	18.3	18.3	18.3	1	0
Iceland	51.2	64.0	61.4	0	0
Israel	54.5	54.5	54.5	1	0
Italy	49.4	49.4	49.4	1	0
Jamaica	48.6	13.1	17.6	0	0
Jordan	42.3	42.3	42.3	1	0
Japan	65.5	65.5	65.5	1	0
Kenya	29.7	42.3	46.1	0	0
Korea	58.6	58.6	58.6	1	0
Sri Lanka	42.6	22.8	20.8	0	0
Morocco	35.8	32.1	34.8	0	1

A2-3. Measures of Educational Quality (continued)

Country	QL2*	QL2WB	QL2_inst	Test Countries	Woessman extension
Madagascar	37.6	34.3	32.4	0	1
Mexico	37.2	29.8	29.2	0	0
Mali	37.9	2.4	3.3	0	1
Mozambique	27.9	27.9	27.9	1	0
Mauritius	55.0	52.3	51.2	0	0
Malawi	37.1	32.4	31.2	0	1
Malaysia	54.3	51.8	56.2	0	0
Nigeria	38.9	38.9	38.9	1	0
Nicaragua	27.3	19.3	19.9	0	0
Netherlands	54.5	54.5	54.5	1	0
Norway	64.6	64.6	64.6	1	0
New Zealand	67.1	67.1	67.1	1	0
Pakistan	42.8	13.9	11.3	0	1
Panama	46.8	9.7	12.0	0	0
Peru	41.2	17.6	16.8	0	0
Philippines	33.5	33.5	33.5	1	0
Portugal	44.2	44.2	44.2	1	0
Paraguay	40.0	23.0	19.8	0	0
Rwanda	37.2	22.7	22.3	0	1
Senegal	39.1	24.2	25.5	0	1
Singapore	72.1	72.1	72.1	1	0
Sierra Leone	37.6	16.6	14.7	0	1
El Salvador	26.2	-0.6	-1.6	0	0
Sweden	57.4	57.4	57.4	1	0
Thailand	46.3	46.3	46.3	1	0
Trinidad & Tobago	46.4	22.7	22.5	0	0
Tunisia	40.5	25.8	30.6	0	0
Turkey	39.7	38.1	35.4	0	0
Thailand	56.3	56.3	56.3	1	0
Tanzania	37.5	34.7	35.4	0	1
Uganda	37.4	20.8	19.0	0	1
Uruguay	52.3	19.5	18.1	0	0
United States	46.8	46.8	46.8	1	0
Venezuela	39.1	26.0	28.0	0	0
South Africa	51.3	52.0	54.2	0	0
Zambia	36.6	33.0	32.2	0	0
Zimbabwe	39.6	38.6	43.7	0	0

QL2* -- Educational Quality. Source: Hanushek and Kimko (2000) and Woessman (2000)
QL2WB -- Educational Quality extended with updated WDI series
QL2_inst -- Educational Quality extended with WB data and institutional quality.
Source: Hanushek and Kimko and authors' calculations
Test Data -- is 1 if Hanushek and Kimko had test scores, 0 if value is predicted
Woessman -- is 1 if QL2 data came from Woessman's estimation, 0 otherwise

Appendix 3. Variable Sources and Definitions

Sources:

World Development Indicators (WDI)
Organization for Economic Cooperation and Development, Statistical Compendium (OECD)
Penn World Tables, Version 6.0 (PWT6.0)
International Financial Statistics (IFS)

Definitions:

Investment. Domestic fixed investment in national prices, taken from OECD for industrial countries and WDI for developing countries. Investment in international prices, taken from PWT 6.0.
GDP. Gross domestic product in real national prices used for constructing growth accounts, taken from WDI and filled in with data from OECD. Gross domestic product in real international prices is used for computing GDP weights and calculating the investment share, taken from PWT 6.0.
Labor force. Economically active population, taken from WDI.
Educational attainment. Average educational attainment of population 15 and over, an average of series from Barro and Lee (2000) and Cohen and Soto (2001). The annual average is used to construct the human capital index.
Population. Total population, used in constructing population weights, is taken from WDI.

Variables used in regressions:
Initial level of average years of schooling. Average educational attainment of population 15 and over, an average of series from Barro and Lee (2000) and Cohen and Soto (2001). Initial period is 1960 or 1980.
Initial income per capita. Income per capita relative to the United States, data from PWT 6.0 and WDI. Initial period level.
Life expectancy. Years of life expectancy, expressed as the difference from United States' level, are from the WDI for the initial period.
Log of Population. Natural log of total population, data from WDI. Period average.
Frankel-Romer-Rose Trade Instrument. The trade instrument is computed as the predicted values from a regression model where the bilateral trade share is related to a set of fixed characteristics and averaged over the trading partners as explained in Frankel and Rose (2002).
Geography. Average of frost days and tropical land area, data from Rodrik et. al. (2002).
Institutional quality. International Country Risk Guide assessment of institutional quality, data from Knack and Keefer (1995). Level in 1982.
Budget balance. General government budget surplus/deficit as a percent of GDP, data from OECD for industrial countries, African Development Bank since 1980 for African countries, and WDI and IMF data for all other countries. Annual average level.
Change in inflation. Annual log change in national consumer price index from the IFS. Annual average change.
Sachs-Warner openness. Openness dummy variable from Sachs and Warner (1995). Average years "open" over period.

Appendix 4. Additional Variables

A. Other Variables Tried in Growth Regressions

Financial Depth

Financial Risk component (ICRG)
Private credit (%GDP)
Private credit measure from Levine/Loyoza/Beck

International Integration

Current/capital account openness, levels and change (Quinn)
Capital account openness indicator (IMF)
Trade (%GDP), in real and nominal terms

Exchange Rate Indicators

Real exchange rate, change and std. dev. (3 measures)
Black market premium (average)

Educational Indicators

Average education years, levels and change (3 measures)
Educational quality (3 measures)

Social & Political Indicators

Index of ethnolinguistic fractionalization
Index of civil and political freedoms
Population growth
Revolutions
War casualties

Institutions

Institutional quality
(Kauffman, Kraay, Zoido-Lobatón)
Corruption
Government Effectiveness
Regulatory Quality
Rule of Law
Political Stability
Voice and Accountability
Institutional Quality Composite Index (ICRG)
Political Risk
Economic Risk
Financial Risk
Constraint on the executive
Economic Organization Indicator

Geography

Frost Area
Frost Days
Latitude
Average temperature
Percentage of land in tropics
Total land area
Landlocked dummy
Malaria Index

B. Variables Tried as Instruments

Percent of population speaking European languages
Predicted trade from Frankel-Romer gravity model
Settler Mortality