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Scott L. Baier, Clemson University
Gerald P. Dwyer Jr., Federal Reserve Bank of Atlanta
Robert Tamura, Clemson University

Abstract: The authors examine the relative importance of the growth of physical and human capital and the growth of total factor productivity (TFP) using newly organized data on 145 countries that span more than one hundred years for twenty-four of these countries. For all countries, only 3 percent of average output growth per worker is associated with TFP growth. This world average masks interesting variations across countries and regions. Of the nine regions, TFP growth accounts for about twenty percent of average output growth in three regions and between ten and zero percent in the other three regions. In three regions, TFP growth is negative on average. The authors use priors from theories to construct estimates of the relative importance of the variances of aggregate input growth and TFP growth for the variance of output growth across countries. Across all countries, variation in aggregate input growth per worker could account for as much as 35 percent of the variance of the growth of output per worker across countries, and variation in TFP growth could account for as much as 87 percent of that variance. Much of the importance of the variance of TFP growth appears to be associated with negative TFP growth.

JEL classification: O47, O50, O57, O30, N10

Key words: economic growth, capital, human capital, total factor productivity, growth accounting

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Please address questions regarding content to Scott L. Baier, Economics Department, 222 Sirrine Hall, Clemson University, Clemson, South Carolina 29634-1309, 864-656-4534, 864-656-4192 (fax), sbaier@clemson.edu; Gerald P. Dwyer Jr., Research Department, Federal Reserve Bank of Atlanta, 1000 Peachtree Street, N.E., Atlanta, Georgia 30309-4470, 404-498-7095, 404-498-8810 (fax), gdwyer@dwyerecon.com; or Robert Tamura, Economics Department, 222 Sirrine Hall, Clemson University, Clemson, South Carolina 29634-1309, 864-656-1242, 864-656-4192 (fax), rtamura@clemson.edu.

How Important Are Capital and Total Factor Productivity for Economic Growth?

How much of the growth in output per worker is associated with growth in physical and human capital per worker and how much is due to technology, institutional change and other factors? An economy's output is a positive function of physical and human capital given the technology. Assumptions of constant returns to scale and competitive factor markets make it possible to calculate the growth rate of output implied by the growth of physical and human capital; deviations of actual output from this implied growth rate are due to changes in technology, institutional change, failure of the twin assumptions of constant returns to scale and competitive factor markets, and other factors. These deviations are called growth in total factor productivity (TFP) although these deviations include much more than what is suggested by the word "productivity" and probably are more fairly called the "residual" or "Solow residual" in growth.

This type of analysis, called "growth accounting", preceded the theoretical contributions to growth theory by Solow (1956) and Swan (1956), but many more papers succeeded them. Abramovitz (1956) found that only 10 percent of output growth per person in the United States from 1869-78 to 1944-53 is associated with growth of factors of production, and 90 percent of output growth is associated with growth of TFP. Solow (1957) found that the accumulation of physical capital accounts for roughly 12 percent of output growth per hour worked in the United States from 1900 to 1949 with the remaining 88 percent attributed to growth of TFP. While later work has reduced this unexplained residual, it is far from zero (Kendrick 1961; Denison 1985; Jorgenson, Gollop and Fraumeni 1987; Maddison 1995; Klenow and Rodriguez-Clare 1997a; Jones 1997). In short, such estimates indicate that the part of economic growth associated with growth of physical and human capital is dwarfed by the unexplained part.

The purpose of this paper is to estimate the relative importance of physical and human capital growth and TFP growth for output growth using a new, more comprehensive data set than has been previously available. Our data set covers more countries for a longer period than other data sets. Our data set also includes the growth of human capital, as do some recent analyses of growth but not larger data sets currently in use. Our computations are similar to those presented by Abramovitz (1956), Solow (1957), Kendrick (1961), Denison (1985) and others.

Perhaps most startling, we find that TFP growth is an unimportant part of average output growth across all countries. We find that weighted-average TFP growth is only about 0.13 percent per year, which is about eight percent of growth of output per worker. Eight percent is far from previous estimates of 50 percent or more of growth of output per worker. If not weighted by the size of the labor force and the years for which we have data, average TFP growth across these countries actually is negative: -0.71 percent per year: This means that, if one of our 145 countries is chosen at random with equal probability, the expected growth rate of TFP is -0.71 percent per year. This hardly is suggestive of technological progress, unless one thought that much of recent history is technological regress. This is improbable, and we think that this decline in TFP is most likely due to institutional retrogression and armed conflicts.

This startling overall finding, however, masks a far more interesting tale by countries, which are aggregated into regions for some of our analysis. TFP growth is: 25 percent of output growth per worker for the Western Countries including the United States; 20 percent for Southern Europe; and 18 percent for Newly Industrialized Countries. While not on the order of 50 percent or more, this is not essentially zero either. On the other hand, Central and Southern Africa, Central and Eastern Europe and the Middle East have negative TFP growth even when weighted by the size of the labor force and years. Something more than introduction of new technology is necessary to explain much of these data.

Even though unimportant in terms of average output growth for all countries, the variance of output growth per worker across all countries is more closely associated with the variance of TFP growth per worker than with the variance of physical and human capital growth per worker. As for the average growth rates, the analysis by regions reveals patterns. This predominance of the importance of variation of TFP growth is confined to Central and Eastern Europe, Central and Southern Africa and Latin America. For the Western Countries, Southern Europe, the NICs and North Africa, variation of growth of physical and human capital per worker may account for 90 percent or more of the variation of output growth per worker. The predominance of TFP growth for explaining the variance of output growth for some regions may seem contradictory to the low mean of TFP growth, but it is not. The low mean of TFP growth and nontrivial variance of TFP growth suggest that negative TFP growth is an important part of the variation in growth across countries, a conclusion reinforced by the analysis by regions.

The structure of the paper is simple. The first section briefly discusses the logic of the calculations and the analytical underpinnings of our new data set.[1] The second section presents the growth accounting in analysis of mean growth rates. The third section presents our analysis variance decomposition across countries. The paper ends with a brief conclusion.

I. ACCOUNTING FOR GROWTH AND THE DATA

The data set that we use in this paper has more depth and more breadth than previously available data used for growth analysis. The analysis of growth requires many years of data. In order to be sure that relatively high frequency phenomena such as business cycles are not affecting the outcome, a single growth observation should cover at least 10 years, and more likely 20 years.

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[1] A detailed Data Appendix which provides information on our data sources is available on request and at our web sites.

The heavily used data set provided by Summers and Heston (1988, 1991, 1998) is a large cross section with limited time-series information. Summers and Heston's data set contains information on 152 countries but no information on any country prior to 1950. At ten year intervals, Summers and Heston's data include 487 observations. Their data set also has one important deficiency: it does not contain information on human capital. Information on human capital is available from Barro and Lee (1993), which contains information only since 1960. The merged data set using the information on human capital available in Barro and Lee contains 397 observations. At twenty year intervals, the number of observations falls to about 200 observations since 1960. Our data set includes quite a few more observations: 752 observations at ten year intervals and 321 observations at twenty year intervals. While our data set contains only 145 countries, we observe per worker values of output, physical capital and human capital for each country for an average of 57 years. Our data on 145 countries extend backward beyond 1900 for 24 of the 145 countries.

An alternative long coverage data set is Maddison (1995). A drawback to Maddison's data is that it primarily contains information on per capita output. While informative for some purposes, there are no corresponding data on aggregate inputs: physical and human capital. Maddison includes data on the physical capital stock for six countries and a function of years of schooling for three countries but no data on human capital. As a result, Maddison's data themselves are not sufficient to analyze the relationship between output and inputs including human capital.

The countries in our data include 98 percent of the population of the world in 1999 (Brunner 1999). For each of these countries, we calculate output per worker, physical capital per worker, and human capital per worker. In this paper, we summarize many of our findings with results by region in addition to reporting results for each country.[2] Each of the 145 countries is included in one of nine regional groups. Figure 1 shows the countries included in our analysis and the groups in which they are included. While these groupings are arbitrary to some extent, the basic criteria are geographical proximity, data availability for similar durations and similar levels of income in the 1990s.[3]

Our primary source of data is B. R. Mitchell's three volumes, *International Historical Statistics* (1998a, 1998b, 1998c). Mitchell provides data on income, the labor force, population, the demographic breakdown of the population by age groups, investment rates, and school enrollments which we use in our investigation. We update these data to more recent years and supplement them by data from Maddison (1995), Summers and Heston (1998) and the *World Development Report 2000/2001* (World Bank 2000). These data are used to calculate per capita output in 1985 United States dollars, per worker output in 1985 United States dollars, the stock of physical capital per worker in 1985 United States dollars, and the average level of education and experience acquired by people employed.[4] While subject to measurement error, these data provide information on a broad set of countries over periods that cover about all the years possible with currently available data. As a check on the reliability of these data, we compare the overlapping years of the data set with other existing data sets.

The overlapping years of our data are highly correlated with existing data sets, which gives us more confidence that the data for the non-overlapping years are reasonable measures of the data they intend to represent. Our numbers on output per worker share original data sources with Summers and Heston's data; hence our finding a correlation that is essentially unity reassures us that there are no dramatic transcription

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[2] Appendix Table 1 provides average values for all of the data for the countries individually.

[3] Our groupings are similar to those in Lucas (1998).

[4] We convert each currency's real value into United States dollars using Purchasing Power Parity calculated by Summers and Heston in the overlapping years.

differences but is not very informative otherwise. More informative is the correlation of 0.97 between the overlapping values of our real output per worker (which equals income per worker) and Maddison's values of real income per person, which suggests that any differences between these estimates is relatively unimportant. The investment numbers underlying the physical capital stock also are from the same underlying sources as Summers and Heston's data, so this correlation again mainly assures us that transcription differences do not loom large. The correlation of overlapping estimates of our average education and Barro and Lee's estimates is 0.84 (25 and older) and 0.85 (15 and older.)

A. *Growth Accounting Framework*

We use income per worker rather than the more usual measure of economic growth, income per person, as do recent contributions by Mankiw, Romer and Weil (1992) and Klenow and Rodriguez-Clare (1997a).[5] We assume that the relationship between output and resources can be summarized by an aggregate production function which can be written

$$Y(t) = A(t)F(K(t), H(t)) \tag{1}$$

where $Y(t)$, $K(t)$ and $H(t)$ are output, physical capital and human capital at t and the parameter $A(t)$ represents the level of technology, TFP, at t. Writing the production function this way restricts changes in the production function to Hicks-neutral changes in TFP. If social marginal products equal private ones and there is perfect competition, equation (1) implies that

$$a = y - a k - (1 - a)h, \tag{2}$$

[5] Kuznets (1966, p. 1) defines economic growth as a sustained increase in output per person or per worker.

where ″ is capital's share of income and a lower-case letter denotes the growth rate of a variable per worker.[6] While the factor shares, a and $1 - a$ generally vary over time, we assume that such variation is relatively unimportant for our estimates. The growth rate of TFP per worker, a, in equation (2) is a residual computed from the other variables which are observable.[7] We use equation (2) to estimate the growth rate of TFP per worker as well as the variation in its growth over time and across countries.

The TFP growth rate per worker in equation (2) need not represent only technological change and may not represent technological change at all. Measurement errors in output and physical and human capital can appear in TFP growth. Deviations of social and private marginal products can but need not result in terms included in TFP growth (Barro 1999), as can increasing returns. In addition, changes in property rights and economic regime can result in apparent TFP changes, although it is not clear whether such changes might be interpreted as changes in the difference between the social and private marginal products. Furthermore, changes in technology can be reflected in the growth of physical and human capital. In short, there are many possible explanations of changes in TFP per worker.

For our estimates in this paper, we use a capital share ″ equal to one-third. This is in the range of the careful cross-country estimates by Gollin (2001) of 0.25 to 0.35. Using a common capital share for all years for all countries may seem like a dramatic restriction. Nevertheless, if we limited our analysis to countries for which we can reliably estimate income shares, that analysis would use a small fraction of our

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[6] Almost all estimates of the importance of TFP include some adjustment for expansion of the economy. Some attempt a further adjustment. For example, Klenow and Rodriguez-Clare (1997b) and Hall and Jones (1999) present estimates based on output per unit of human capital, a formulation suggested by Solow's model with endogenous K growth and exogenous A and H growth. This analysis attributes all exogenous changes in output per unit of human capital to technology. It is not self-evidently desirable or plausible to make such exogeneity assumptions. We think it is more likely that human and physical capital and technology all have endogenous and exogenous components, which means such transformed numbers are likely to be less informative than numbers not so transformed.

[7] The framework does not assume that aggregate production is Cobb-Douglas.

data. Furthermore, the data requirements in many countries would be overwhelming, because it would be important to separate sole proprietors', including farmers', income into labor and capital components. It is not obvious that the errors introduced by such estimates of labor and capital income would be less than those introduced by using common income shares across countries.

B. *Output Per Worker*

Mitchell (1998a, 1998b, 1998c) provides both nominal and real income per person through 1992. We use the overlapping years with the Summers and Heston data set to calculate real exchange rates between the local currencies and the Summers and Heston (1991) values in 1985 United States dollars. We then apply this real exchange rate back through time. For 1999 incomes, we use the values in the *World Development Report 2000/2001* (World Bank 2000) and convert these values to 1985 United States dollars using the United States Gross Domestic Product deflator.

Our analysis focuses on the growth rates of output and inputs relative to the labor force. For simplicity, we often will refer to, for example, output per worker by which we mean output per member of the labor force. Using output per worker instead of output per person simplifies our empirical analysis with no obvious loss in the informativeness of that analysis.

Figure 2 shows the behavior over time of the growth rates of output per worker for the nine regions. The slopes of the lines in Figure 2 are growth rates because the vertical scale is proportional. In order to get reliable estimates of the growth rates, we have to undertake some involved computations. The value in the figure for output per worker in 1999 is the weighted average of the countries' output per worker in 1999. The weights are the 1999 share of the labor force in the region, which gives countries with larger labor forces more weight in the region. We then compute the weighted average growth rate for 1990 to 1999; the level of 1990 output per worker in the figure is the 1990 level of output per worker implied by this average growth rate. We then compute the weighted average growth rate for 1980 to 1990 for the countries with data in both 1980 and 1990; the level of 1980 output per worker in the figure is the 1980 level of output per worker implied by this average growth rate. We apply this procedure as long as we have data on countries that are at least 50 percent of the 1999 labor force. With this estimation procedure, the growth rate of output per worker for every period always is the growth rate of output per worker for the countries for which we have data over that time period. On the other hand, the level of output per worker for any years other than 1999 and 1990, when we have data for all countries, is not necessarily the actual level for the countries for which we have data.[8] Besides not having data available for the same periods for all countries, we do not always have data for exactly the same year for all countries. When data are not available for a particular year, we use output per worker in surrounding years to interpolate the data.[9] While this procedure would be problematic for some purposes such as a time-series analysis of the data, it has no effect on any of our conclusions. Perhaps the most obvious side effect for our purposes is interpolation's smoothing of the growth rates.

In Figure 2, the region called the Western Countries always has the highest output per worker.[10] Some regions narrow the gap with the Western Countries while other regions fall behind, a result similar to that emphasized by Quah (1996), Pritchett (1997), Jones (1997) and Lucas (2000). Overall though,

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[8] If the figure simply showed the weighted average level of output per worker in each year, the growth rates generally would not be the same as the growth rates computed for countries for which we have data at both the beginning and end of a period. If countries added to the data set have output per worker higher or lower than the average for the other countries, the growth rate over the period would be higher or lower because of the addition of the countries .

We repeated the computations with 1988 weights, 1980 weights and the average of 1970, 1980 and 1988 weights and the differences were small.

[9] When necessary, we assume a constant growth rate between the surrounding years and interpolate to obtain data for the precise year used in the figure. We use the same procedure for all the series other than schooling, for which we assume constant arithmetic growth.

[10] The region called the *Western Countries* includes Northern and Western European countries as well as the United States, Canada, Australia and New Zealand.

we think that we see a general pattern of convergence. Perhaps the most striking thing to us in Figure 2 occurs in recent years: real output per worker decreases for several regions. Measured output per worker falls in the Middle East from 1980 to 1999. These decreases in output reflect decreases in output per worker in Iran which has 42 percent of the labor force in the Middle East, and Iraq which has 13 percent of the labor force. Perhaps not surprisingly given the turmoil associated with the downfall of Communism, measured real output per worker in Eastern Europe falls from 1990 to 1999. More surprising, at least to us, is the 14 percent decrease in real output per worker in Latin America from 1980 to 1999 and by 13 percent in Central and Southern Africa from 1980 to 1999.[11] In the modern history represented in Figure 2, there is nothing similar to these decreases other than for the decade including World War II. The recent decreases in output growth have been noted by Rodrik (1999), Carpena and Santos (2000), Easterly (2001), Evrensel (2001) and others. There is no settled explanation, although Figure 2 makes it clear that the recent period for these regions is atypical compared to other times and places. Hence, there is no support in our data, which is all or virtually all of the data available, for a conjecture such as Easterly's (2001, p. 154) that "the 1980-98 period represents a return to the long-run tendency of rich and poor countries to diverge."

C. *Physical Capital Per Worker*

We use the perpetual inventory method to calculate the capital stock per worker. We have data on investment for almost all years. We compute the capital stock at the end of each decade by assuming that the ratio of investment to income is equal to the average value for available years in that decade. The annual depreciation rate is 7 percent and the growth rate of output per year is constant between observations.

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[11] There are no countries added to these regions after 1970, so compositional effects do not explain these differences.

Figure 3 shows the evolution of capital stocks per worker for the nine regions. As in Figure 2, we weight each country in each region by the size of its labor force relative to the total labor force in the region. The Western Countries start with the highest stock of physical capital per worker, but are overtaken by the Newly Industrialized Countries (NICs) by 1999.[12] Similar to output per worker, some regions have higher growth rates than the Western Countries, but not all do. Decreases in the measured capital stock per worker are not the sources of the decreases in output per worker in the Middle East, Latin America or in Central and Southern Africa from 1980 to 1999. The growth rate of capital is negative in the Middle East from 1990 to 1999, but the measured level still is higher in 1999 than in 1980. While the growth rate of capital in Central and Southern Africa is less from 1980 to 1999 than for earlier years, it still is positive and comparable to the growth rate in the Western Countries. The growth rate of capital per worker in Latin America also is lower from 1980 to 1999 than for earlier years, but this lower growth rate still is positive and does not reflect the time series pattern of output per worker, which falls from 1980 to 1990 and the increase from 1990 to 1999.

D. *Years of Schooling, Experience and Human Capital Per Worker*

Our measure of human capital per worker in each country reflects both average education and average number of years employed. We compute education using formulas similar to those used by Barro and Lee (1993). The average number of years of schooling for an employed person is calculated from enrollments in primary and secondary schools and higher education in combination with the age distribution of the population. These data are used to calculate the fraction of the population that has some primary schooling, some secondary schooling, and some college education. We use the age distribution of the population to estimate the age distribution of those employed because the data available to us do not

[12] The Newly Industrialized Countries include Hong Kong, Japan, Singapore, South Korea and Taiwan.

include the age distribution of the labor force.[13] We also use the same level of education for men and women because we do not have enrollment data by gender.

Figure 4 shows the average years of schooling completed per worker for the nine regions. The Western Countries have a history of much higher education than the rest of the world. The Western Countries have an average education of 3.18 years in 1870, higher than the initial value for any other region, and this region has an average education of 12.4 years in 1999, the highest in the figure. Only since World War II has other regions' average education risen to the Western Countries' level of education in 1870.

Human capital per worker is computed from average education, Ed, and average experience, Ex. We do not have data on wages in the individual countries, which would allow us to compute contributions from increased education as suggested by Jorgenson and Griliches (1967). The transformation from educational attainment and experience to human capital instead is based on estimated parameters of earnings regressions. The evidence of substantial diminishing average returns to years of schooling indicates that it is important to distinguish between primary, secondary and higher education. Average years of schooling completed, Ed, is divided into years of primary schooling, P, years of intermediate schooling, I, and years of secondary and higher education, S.[14] We assume that primary school must be completed in order to attend intermediate school and that primary and intermediate school must be completed in order to attend secondary and higher education. We further assume that primary school attendance continues for up to four years, secondary school attendance continues for up to four more years, and secondary and higher education continues for all later years. With these assumptions, knowing average attained education

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[13] We have no reason to think that our estimates of human capital are seriously compromised even though changes in the age distribution of the labor force are not just mirror images of changes in the age distribution of the labor force.

[14] Higher education is not necessarily college education. Ed is the average number of years of school completed in a country and $Ed = P + I + S$.

is sufficient to compute the average number of years of primary, intermediate, and secondary and higher education.[15] We compute average experience using Mitchell's demographic data to compute average age less average years of schooling and six years before attending school.[16] With subscripts for country and year suppressed for simplicity, human capital then can be computed from

$$H = H_0 \exp(f_p P + f_i I + f_s S + l_1 Ex + l_2 Ex^2) \tag{3}$$

where H is human capital, H_0 is the level of human capital with no schooling or experience, N_p, N_i and N_s are parameters on years of primary, intermediate, and secondary plus higher education, and 8_1 and 8_2 are parameters on years of work experience, Ex, and experience squared.

We estimate human capital per worker using equation (3), relying on the results of estimates of wage regressions from different times and places for the estimated parameter values. Psacharopoulos (1994) summarizes the very large body of evidence on the relationship between wages and years of schooling and wages across countries in the world. Following Hall and Jones (1999, p. 89), we use the following numbers as the point estimates: for the first four years of schooling, each additional year of schooling increases earnings by 13.4 percent; each additional year for the next four years of schooling increases the wage rate by 10.1 percent; and every year thereafter increases the wage rate by 6.8 percent.[17] Klenow and Rodriguez-Clare (1997a) report estimates of the returns to education and

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[15] If the average number of years of schooling is less than four years of schooling, then $P = Ed$, $I = 0$, and $S = 0$. If the average number of years of schooling is greater than four but less than eight, then $P = 4$, $I = Ed - 4$, and $S = 0$. If the average number of years of schooling is greater than eight, then $P = 4$, $I = 4$, and $S = Ed - 8$.

[16] Knowing average years of schooling in the adult population, Y_s, and the average age of the population 6 to 64 not in school, *Age*, plus an assumption that school attendance begins at six years of age permits us to compute average years of work experience from $Y_w = Age - Y_s - 6$.

[17] Psacharopoulos (1994) also presents estimates that vary by broad region of the world, which could be (continued...)

experience from a cross section of 48 countries. These coefficients on experience and experience squared are 0.0495 and -0.0007. In sum, we use $f_p = 0.134,\ f_i = 0.101,\ f_s = 0.068,\ l_1 = 0.05,$ and $l_2 = -0.0007$ in equation (3).

Figure 5 shows human capital for the regions. The level of human capital itself does not have much content because there is a normalization associated with the level of human capital with zero schooling and labor-force experience, H_0. Hence, we set the level of human capital for the Western Countries to unity in 1870 and use the same normalizing constant for the other regions.[18] The level of human capital is uniformly higher in the Western Countries although the growth rates in other regions generally are higher. The percentage differences between the Western Countries and three other regions especially – the NICs, Central and Eastern Europe, Southern Europe, and Latin America – are less in 1999 than at any time earlier in the 1900s. After a dramatic growth rate from 1950 to 1960, the growth rate of human capital in the region with the least human capital – Central and Southern Africa – still is positive but it actually is lower than for any other region. Hence, decreases in human capital are not behind the decreases in output in Latin America and Central and Southern Africa.

E. *Total Factor Productivity Growth Per Worker*

Figure 6 shows the levels of TFP for the regions. TFP does not increase uniformly for any of the regions. Even for the Western Countries, the range of TFP growth rates over decades is from 1.7 percent per year from 1950 to 1960 to -1.1 percent per year from 1910 to 1920. Some other regions have more sustained decreases in TFP at times. The most sustained decreases in TFP are for Central and Southern

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[17](...continued)
the basis of a more refined analysis.

[18] This sets $H = H_0 \exp(f_p P + f_i I + f_s S + l_1 Ex + l_2 Ex^2)$ to unity for the Western Countries in 1870, not H_0. If we set $H_0 = 1$ for the Western Countries, the scales of the figures would differ by a normalizing constant and the tables later in the paper would not differ at all.

Africa, a region that has negative growth of TFP at a rate of -1.85 percent per year for the 29 years from 1970 to 1999. Even before the decrease in real output from 1980 to 1999, Central and Southern Africa stands out in terms of having little growth and negative TFP growth. It is not necessary to suppose deteriorating technology to explain decreases in TFP. Many other factors, including decreases in competition in markets, increases in government regulation, and disruptions in private markets due to armed conflict, can account for these developments. That said, just as the decreases in real output in Central and Southern Africa are atypical, these large, sustained decreases in TFP are atypical. We conclude that the available data imply that it would be anachronistic to suppose that this divergence in real output and especially TFP across regions is anything other than a phenomena of the period since World War II.

II. GROWTH ACCOUNTING

How much of economic growth is associated with growth in aggregate input – physical and human capital weighted by factor shares – and how much with growth in TFP? Any average can be misleading. For all of our data, the weighted average growth rates of output and TFP per worker are 1.65 and 0.13 percent per year.[19] While this almost negligible growth rate of TFP seems a little surprising in light of Figure 6, we find it less surprising knowing that the growth rates of output and TFP per worker are 1.62 and 0.40 percent per year for the Western Countries – a non-negligible growth rate of TFP relative to the growth of output per worker. For the United States, we estimate growth rates of output and TFP per worker of 1.68 and 0.53 percent per year. For all countries, eight percent of output growth is associated with TFP growth. For the Western countries, 25 percent of output growth is associated with TFP growth. For the United States, 32 percent of output growth is associated with TFP growth.

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[19] We use a weighted average across the countries, with weights equal to 1999 labor force and the number of years for which we have data rather than a simple average across countries. We explain our reasons in this section.

A. *Comparison with Earlier Estimates*

How different are our estimates than those made by others? There have been many breakdowns of economic growth into parts associated with aggregate input growth and parts associated with TFP growth. We compare our estimates with selected earlier estimates. Table 1 presents some influential estimates of output growth, input growth and TFP growth by Abramovitz (1956), Solow (1957), Kendrick (1961), Denison (1985) and Maddison (1995.) Different methods are used by these various authors. Still, the estimates by Abramovitz, Solow, Kendrick and Denison all indicate that there has been substantial TFP growth in the United States and that output growth bears little relationship with the growth of physical and human capital. Abramovitz's estimate is that growth of inputs accounts for 10 percent of output growth per person; Solow's is 12 percent of output growth per worker; Kendrick's is 20 percent of output growth per person; and Denison's is 32 percent of output per person employed. The only numbers dramatically different than the others are those by Maddison, whose estimates are for total output, not for output per person or per worker. Maddison's estimate is that growth of inputs accounts for 82 percent of total output growth in the United States from 1820 to 1992.

Table 2 compares these estimates to ours. Our estimate for the United States is that TFP growth accounts for only 32 percent of output growth per worker, which is a far cry from the earlier estimates in Table 1. In Table 2, we decompose the differences between our estimate and these earlier ones into the pertinent factors. The first and last columns provide our estimate and these earlier estimates. The columns in between provide changes in TFP growth relative to output growth associated with the various factors. We start from our estimate. The factors that can account for differences in the fraction of output growth can be allocated reliably into differences in the time period, the growth rates of capital and human capital, and a residual category. This residual category reflects differences in growth adjustment, differences in income shares, possibly differences in the definition of income, and no doubt many other differences. This residual category is not systematically large relative to the difference between our estimate and earlier estimates, which at the least means that these residual differences are not overwhelming.

Table 2 seems to split up in a natural way between the earlier estimates by Abramovitz and Solow and the later estimates by Kendrick and Denison. The differences between our estimates and those by Abramovitz and Solow are fairly evenly split between differences in time period, growth of physical capital and growth of human capital. Our adjustment for schooling and experience and Abramovitz's and Solow's lack of one is the major conceptual difference between our figures and theirs. The difference due to time period is interesting and large: TFP is 50 percent of growth using data up to either 1950 or 1953, and only 32 percent of growth if data through 1999 are included in the computations. If more recent estimates of investment are more accurate and our estimate of the implied capital stock is no worse, then capital growth is more important than they estimated. The differences between our estimates and those by Kendrick and Denison are less due to time period and the growth rate of human capital, although these differences remain.[20] Differences in the growth rate of physical capital loom relatively large. If we used Kendrick or Denison's estimate of the growth rate of physical capital with no allowance for conceptual differences associated with the differences in income measure, our estimates of the relative importance of TFP for their time periods would increase from 38 and 37 percent, respectively, to 65 and 76 percent. These estimates also would imply, though, that the ratio of physical capital to output decreases over time, a result that seems implausible and would be quite surprising (Kuznets 1966; King and Levine 1994).

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[20] Kendrick includes growth of human capital through changes in relative earnings across industries. Denison (1985, p. 15) uses relative earnings to estimate the contribution of education to output and does not attempt to estimate the effect of experience.

Maddison estimates the importance of inputs for total output, and our estimates in Table 2 are estimates using output per worker. Hence, they are not directly comparable. Even so, there is less difference between our estimate and Maddison's than with the other estimates.

B. *Estimates of Average Growth and Total Factor Productivity Growth for Regions*

Table 3 shows weighted and unweighted averages of the data for the regions and for the world. The weighted averages weight the data for each country by the country's labor force in 1999 and the number of years for which we have data. The unweighted averages give the same weight to the smallest country, Guyana with 254 thousand workers, and the largest country, China with 696 million workers! Averages weighted by labor force give more importance to the larger countries, which we think is helpful for interpreting the data. We also have big differences in the number of years for which we have data on countries. We have data on 16 of the 145 countries only since 1990 and for 103 of the countries only since 1950. We also have data for 24 countries for over 100 years. The unweighted averages give the same weight to the 16 countries for which we have data for 119 or more years and the 16 countries for which we have data for 9 years. Nine years is unlikely to be representative, especially if the country is new. Weighting by the number of years gives more weight proportionately to countries for which we have more data. These averages weighted by labor force and number of years can answer the question: What happened to the typical worker in a typical year for which we have data? Because unweighted averages also can be informative, we report them as well. Unweighted averages can answer the question: What happened to the typical country for the period for which we have data on each country?

Weighting is important for evaluating the overall average as well as for evaluating the averages for individual regions. The unweighted average growth rate of TFP per worker in Table 3 is an astounding -0.71 percent per year. This is quite inconsistent with our impression from Figure 6, which has negative TFP growth rates but not predominately so. The weighted averages show that our overall impression of positive

TFP growth per worker is correct even if the weighted average is not exactly large: only 0.13 percent per year. Across all countries, our data support a statement that little of output growth per worker can be associated with TFP growth. For the Western Countries, though, the weighted average TFP growth per worker is 0.40 percent per year, which is about 25 percent of the growth of output per year. For a few regions, the weighted averages show noticeable similarities in the share of growth in output per worker associated with growth in TFP: 25 percent for Western Countries; 20 percent for Southern Europe; and 18 percent for the NICs. A plausible generalization for these regions is that about 20 percent of output growth per worker is associated with TFP growth. Latin America falls somewhat below these regions with growth of TFP per worker being 14 percent of output growth. The other regions with positive growth of TFP per worker have TFP growth on the order of 10 percent of output growth: North Africa with TFP growth with 11 percent; and Asia with 10 percent. The other three regions do not even have positive TFP growth for the data available.

Overall, we conclude that TFP growth per worker is a somewhat important part of average output growth per worker, but the lion's share of the growth in output per worker can be attributed to growth of aggregate input per worker even for the Western Countries, Southern Europe and the NICs. For the rest of the world, TFP growth has been noticeably less important on net when it is even positive.

The weighting is important for the averages for some regions, perhaps most obviously Latin America and Central and Eastern Europe in Table 3. The unweighted average TFP growth rate for Latin America is negative and the weighted average is positive. The unweighted growth rates of output, physical capital and TFP are negative for Central and Eastern Europe; the weighted growth rate of only TFP is negative. The individual data by country in the Appendix show why the weighting has these effects. In Latin America, the countries with substantial negative growth rates of TFP are small. Central and Eastern Europe has a large number of new countries in 1990, and the unweighted average is dramatically affected by these countries. The averages without these countries also are informative because 1990 to 1999 is a short period, and this is a period with substantial disruption for these countries. The remaining countries are Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Russia and Yugoslavia. All weighted and unweighted average growth rates for these countries, most of which have data extending backward to the 1920s or further, are positive.[21]

III. ESTIMATES OF VARIABILITY ACROSS COUNTRIES

While TFP does not account for a large fraction of the average growth of output per worker, it may account for much of the variance across countries as argued by Klenow and Rodriguez-Clare (1997a) and Easterly and Levine (2000). They suggest that variance of aggregate input growth explains almost none of the variance of output growth across countries; variance of TFP growth explains virtually all of the variance of output growth across countries.

A. *Possible Estimators of Relative Variances*

What is an informative way to relate the variation of the growth rates? Let y be the growth rate of output per worker, x be the growth rate of the aggregated inputs per worker, i.e. $x = \alpha k + (1-\alpha)h$, and a be the growth rate of TFP per worker. By definition,

$$\mathrm{Var}(y) = \mathrm{Var}(x) + 2\mathrm{Cov}(x,a) + \mathrm{Var}(a) \tag{4}$$

which implies that

$$1 = \frac{\mathrm{Var}(x)}{\mathrm{Var}(y)} + \frac{\mathrm{Var}(a)}{\mathrm{Var}(y)} + 2\frac{\mathrm{SD}(x)\mathrm{SD}(a)}{\mathrm{Var}(y)}\, r_{x,a}, \tag{5}$$

where $r_{x,a}$ is the correlation of the growth rates of x and a. If the correlation of TFP growth and output growth due to aggregate input growth were zero, the first term would be the fraction of the variance of

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[21] Even though the region's average is affected by deleting these countries, the world average is little affected.

output growth due to variability of aggregated input growth, which also is the R^2 from a regression of output growth on aggregate input growth, and the second term would be the fraction of output growth due to TFP growth. In short, the least-squares decomposition would apply with TFP growth in the role of the residual. More generally, the least-squares decomposition does not apply because the correlation of TFP growth and output growth due to aggregate input growth is not zero. As a result, it is impossible to uniquely estimate the fractions of output growth due to aggregate input growth and TFP growth absent some other assumption about the correlation of output growth due to aggregate input growth and TFP growth. One strategy would be to use the relative variances and ignore the covariance. This strategy would result in relative variances that do not add up to one if the correlation is nonzero; the relative variances can be greater than one if the correlation of aggregate input growth TFP growth is negative. Another strategy is to allocate one half of the correlation to each relative variance, a solution advocated by Klenow and Rodriguez-Clare (1997a). This strategy creates relative variances that also can exceed one if the correlation is negative.

We take a different tack by creating two alternative estimates of the relative variances. These estimates alternatively attribute all of the correlation of aggregate input and TFP growth to either aggregate input or to TFP growth. As a result, each of these estimates of the relative variances has a complement with which it adds up to one. One way of explaining the underlying logic of these decompositions is statistical: the first representation assumes that all changes in output growth that are predictable by aggregate input growth are due to aggregate input growth; the second representation assumes that all changes in output growth that are predictable by TFP growth are due to TFP growth. Another way of stating it is: the first decomposition assumes that the correlation of aggregate input growth and TFP growth reflects unmeasured effects of input growth; the second decomposition assumes that the correlation of aggregate input growth and TFP growth reflects unmeasured effects of TFP growth.

The first decomposition attributes to aggregate input growth all output growth predictable by aggregate input growth, which is consistent with a model of endogenous technological growth arising from capital accumulation in Romer (1986), Lucas (1988) and Tamura (1992,2001a,b). This decomposition can be written:

$$\frac{\left(\mathrm{SD}(x)+\mathrm{SD}(a)r_{x,a}\right)^2}{\mathrm{Var}(y)}+\frac{\left(1-r_{x,a}^2\right)\mathrm{Var}(a)}{\mathrm{Var}(y)}=1. \tag{6}$$

The first term in equation (6) is the fraction of variation in output growth due to variation in aggregate input growth if all correlation of aggregate input growth and TFP growth reflects effects of growth in aggregate input. The second term is the fraction of variation in output growth not due to aggregate input growth; with this assumption about TFP growth, this fraction due to TFP growth is itself a fraction of $\mathrm{Var}(a)/\mathrm{Var}(y)$ that goes to zero as $r_{x,a}$ goes to one.[22]

The second decomposition is the fraction of variation of output growth due to variation of TFP growth if all correlation of aggregate input growth and TFP growth reflects effects of TFP growth. For example, the correlation might reflect differences in input growth rates induced by differences in TFP growth, which is consistent with the standard neoclassical growth model augmented to include exogenous technological progress. It is also consistent with endogenous technological change models such as Romer (1990). Some insight into this decomposition can be gained from the representation:

$$\frac{\left(1-r_{x,a}^2\right)\mathrm{Var}(x)}{\mathrm{Var}(y)}+\frac{\left(\mathrm{SD}(a)+\mathrm{SD}(x)r_{x,a}\right)^2}{\mathrm{Var}(y)}=1. \tag{7}$$

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[22] One way of seeing that the least squares decomposition holds for this representation is to note that the variance decomposition is $Var(y)=b_{y,\hat{y}}^2 Var(\hat{y})+Var(e_{y,\hat{y}})$ where $b_{y,\hat{y}}$ is the regression coefficient from a regression of y on $\hat{y}$ and $e_{y,\hat{y}}$ is the regression's residual, TFP in this application.

The second term in equation (7) is the fraction of variation in output growth due to variation in TFP growth if all correlation of aggregate input growth and TFP growth reflects growth in TFP. The first term is the fraction of variation in output growth not due to TFP growth; with this assumption about TFP growth, the fraction due to aggregate input growth is itself a fraction of $\mathrm{Var}(x)/\mathrm{Var}(y)$ that goes to zero as $r_{x,a}$ goes to one.[23]

When the correlation of aggregate input growth and TFP growth is positive, these decompositions can be interpreted as alternative upper bounds on the importance of variation in aggregate input growth and TFP growth. The first decomposition attributes apparent variation in TFP growth to aggregate input growth; the second attributes apparent variation in aggregate input growth to TFP growth. A zero correlation poses no particular difficulties. In fact, our estimates would be the same as relative variances.

What if the correlation of aggregate input growth and TFP growth is negative though? The theories mentioned above do not provide immediate support for plausible interpretations under these circumstances. One possible interpretation of a negative correlation is that there is a mistake in aggregate input growth that induces an opposite movement in TFP growth. For example, aggregate input might be increased beyond its marginal product and TFP might fall since output does not rise as much as would be predicted otherwise. Another possible interpretation is that there is a common factor that affects aggregate input growth and TFP growth in opposite ways. Emigration of people with more human capital than the average person in the country is one possibility for such a factor, because emigration of people with more human capital would lower human capital used in production relative to our estimates and we would overestimate human capital

[23]The least squares decomposition holds for this representation also because the variance decomposition is $Var(y) = Var(e_{y,a}) + b_{y,a}^{2} Var(a)$ where $b_{y,a}$ is the regression coefficient from a regression of y on a and $e_{y,a}$ is the regression's residual.

used in domestic production. The precise interpretation of the decompositions would depend on details of the interpretation of factors that create the negative correlation.

B. *Relative Variances for All Data*

Table 4 presents estimates of the relative importance of aggregate input and TFP growth for the variance of output growth across countries. The table is based on unweighted estimates of the variance of output growth across countries. We do not show weighted estimates of these numbers because the point is to estimate the variance of output growth *across countries*, not across workers in the world.[24] All series in this and the next section are measured per worker, as have all of the series presented thus far. We seldom use the phrase "per worker" because it gets repetitious, but it should be understood for all of our discussion.

After the columns showing the region and number of countries, the first and second columns in Table 4 show the variances of aggregate input growth and TFP growth relative to output growth. These two measures will add up to unity only if the correlation of aggregate input growth and TFP growth is zero, which it generally is not. In fact, the variances of aggregate input relative to output are greater than one for Asia and the Middle East. For all countries, the relative variances of aggregate input growth and TFP growth add up to only 0.87, noticeably less than one. This deviation from one is due to the positive correlation of aggregate input growth and TFP growth across all countries, shown in the third column of

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[24]The unweighted statistics are informative about the variance across countries however large or small the countries may be, and the weighted statistics are more informative about the history confronted by the typical member of the labor force in our set of countries. Weighting by number in the labor force would be tantamount to attempting to estimate the personal distribution of income with these data. We see no useful purpose served by such an attempt. There might be a purpose to weighting the relative variances by years, but we see no reason to assume that variances are proportional to the number of years of data. We examine the relationship between the variances and the number of years in the next section.

Table 4. There is substantial diversity in the correlation of aggregate input growth and TFP growth across regions, with a range from 0.97 for Southern Europe to -0.56 for the Middle East.

At first glance, the negative correlations of aggregate input growth and TFP growth for three regions seem odd, but the correlations that are large in magnitude are in Asia and the Middle East. Examination of the individual countries suggests that country-specific explanations for these negative correlations may be important. In Asia, Vietnam and Nepal have the second and third most negative growth rates of TFP – -1.80, and -1.58 percent per year – and they have the second third highest growth rates of aggregate input – 3.34 and 3.09 percent per year. In the Middle East, Yemen and Saudi Arabia are the two countries with the most negative TFP growth – -6.33 and -2.99 percent per year – and these countries also have the highest growth rates of aggregate input – 5.89 and 3.69 percent per year.

The final two columns of Table 4 show our two estimates of the decomposition of output growth. These decompositions add up to one with the correct complement, which as a consequence is not shown. The decomposition in the next to last column of Table 4 assumes that the correlation of aggregate input growth and TFP growth reflects effects of input growth. The decomposition in the last column assumes that the correlation of aggregate input growth and TFP growth reflects effects of TFP growth.

For all the countries taken together, aggregate input growth is relatively unimportant compared to TFP growth. If all of the correlation of aggregate input growth and TFP growth reflects effects of aggregate input growth, as the next to last column of Table 4 supposes, then aggregate input growth accounts for 32 percent of the variance of output growth across these countries, with TFP growth accounting for the remaining 68 percent. Alternatively, if all correlation of aggregate input growth and TFP growth reflects effects of TFP growth, then TFP growth accounts for 84 percent of the variance of output growth across these countries and aggregate input growth accounts for 16 percent. Interpreting these two estimates as rough upper bounds on the importance of aggregate input growth and TFP growth, we conclude that these estimates suggest that TFP growth accounts for on the order of 68 to 84 percent of the variation of output growth, with aggregate input growth accounting for 16 to 32 percent of the variation of output growth.

This predominance of the importance of TFP growth appears to be confined to Central and Eastern Europe, Central and Southern Africa and Latin America. For the Western Countries, aggregate input growth accounts for as much as 90 percent of the variance of output growth; in Southern Europe aggregate input growth accounts for as much as 98 percent of variance of output growth. The other regions in which the growth of aggregate input accounts for about 90 percent of output growth is the set of NICs and North Africa, for which as much as 94 and 88 percent, respectively, of the variance of output growth can be accounted for by aggregate input growth.[25] For the regions with no more than 50 percent of the growth of output associated with growth in aggregate input – Central and Eastern Europe, Asia, the Middle East, Central and Southern Africa and Latin America – none of them has an unweighted average growth rate of TFP in Table 3 that is positive.

These estimates do not suggest that the relative importance of TFP growth for the growth of output per worker across countries is solely due to the growth of technology. Instead, the relationship between negative TFP growth rates and the importance of TFP for the variance of output growth in a region suggests that other developments such as institutional changes, legal changes and armed conflicts are the important ones for understanding why variability of TFP growth is a very important part of differences in growth experiences around the world.

The evidence concerning the relative importance of the variance of TFP growth and aggregate input growth in the Western Countries is not very informative. The upper bound estimate of each is on the order of 0.90. This means that the range of estimates of the importance of aggregate input and of TFP growth are from 10 to 90 percent. Someone with a strong prior in terms of aggregate input or TFP growth of course

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[25] This is consistent with the more detailed analysis by Alwyn Young (1995).

would find little reason to revise that prior, essentially because there is a high correlation of aggregate input growth and TFP growth across these countries.[26] We start off with a diffuse prior, on the other hand, and find it plausible that the variance of the growth of aggregate input per worker and of TFP are equally important for explaining the variance of the growth of output per worker in the Western Countries. In some other regions and across all countries, however, variation in TFP growth is relatively more important.

C. *Relative Variances for Common Periods*

Our data cover quite different periods for the various countries and this could affect our conclusion above. In this section, we examine whether this real possibility is correct. Because our data span a large number of countries for long periods, we also can examine another question: how long a period is necessary to draw reliable conclusions about the relative importance of aggregate input and TFP growth? It is obvious that a single year would be too short a period. Transitory developments and measurement error could overwhelm the long-term growth of the economy. Is ten years enough? Forty years? Is one hundred years necessary?

Table 5 presents estimates of the relative variance of output growth associated with aggregate input growth and TFP growth for common periods and shows the implications of the period length for the estimates. We start with the countries for which we have 100 years of data ending in 1999 and repeatedly chop 20 years off the beginning of the period until we hit 1980, at which point we chop off 10 years and compute the statistics for the last 10 years, 1990 to 1999.[27] Our data end in 1999 for all countries and all

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[26] Arguably that prior cannot be based on the data for the Western Countries or Southern Europe since we have the universe of available data for those regions.

[27] We did similar computations starting with various lengths of periods, for example, 100 years, 80 years, etc. We then computed combined statistics for the 100-year period for 50 years, 25 years and finally 12.5 years. We found that effects of specific time periods explained numerous aspects of the statistics, at which point we shifted to the computations in the text.

periods end in that year in order to have roughly the same time period for each country. The number of countries included falls as the time period lengthens because many countries do not have data for as many as 100 years, although the computations for 100 years do include 24 countries. The first three columns show the time period, the number of countries and the interval in the overall time period.

The fourth through sixth columns of Table 5 show the standard deviations of the growth of output, aggregate input and TFP. All of these standard deviations increase as data over shorter periods are used to calculate the standard deviations, which is consistent with transitory developments being more important over shorter periods. The next two columns of Table 5 show the simple estimates of the relative variances and the last two columns of Table 5 show our estimates of the importance of the variance of the growth of aggregate input and TFP.

TFP growth appears to be a substantial portion of the variance of growth of output over periods of any length. TFP growth is as much as 80 percent of the variance of the output growth for the 100 years from 1900 to 1999. This fraction is about the same for 100 years as it is for 40 or even 20 years for the same set of countries. It would be wrong though to conclude that the growth of aggregate input is unimportant.

For the 24 countries for which we have data for at least 100 years, growth of aggregate input also appears to be a substantial portion of the variance of the growth of output: as much as 64 percent for the whole period. This fraction changes little, rising or falling a little, until the period is shortened to less than the last 40 year interval, 1960 to 1999, of the 100 years available for these countries.

The relative importance of the growth of aggregate input and TFP changes relatively little as the period is shortened and more countries are added, at least until the set of observations is broadened to include the 129 countries with data for at least the last 20 years. For the period 1980 to 1999, the growth of aggregate input appears to be a small part of the variance of the growth of output compared to the growth of TFP. This conclusion follows for the period 1990 to 1999 as well, with the exception of the countries with at least 100 years of data.

The estimates of the relative importance of the variance of aggregate input growth and TFP growth indicate that the decompositions generally are not sensitive to the time period or their length. As would be expected, the variance of TFP growth, a residual in the computations, falls as the period length increases. The variance of output growth and aggregate input growth also fall, with the relative variances little affected until the period length is shortened to the twenty years from 1980 to 1999.

IV. **CONCLUSION**

Our new set of data covering 145 countries over a long time span provides evidence that little of the average growth of output per worker is directly due to the growth of TFP: eight percent for all of the countries. This conclusion, however, reflects substantial variance across countries – TFP accounts for about 20 percent of the average growth of output per worker in the Western Countries, Southern Europe and the NICs. Other regions have less, negligible and negative growth of TFP. These negative growth rates are consistent with the importance of institutional changes and conflicts. Our evidence indicates that, over long periods of time, the growth of output per worker is associated with accumulation of physical and human capital and technological change. At first glance, this conclusion might seem innocuous at best, but it is controversial in indicating that the growth of physical and human capital is important for growth.

Variation of the growth of aggregate input per worker and of TFP growth also are important in accounting for variation in the growth of output per worker. For all of our data, we conclude that variation in TFP growth is substantially more important than variation in aggregate input growth. There are interesting patterns by region though that are informative. We conclude that the variance of the growth of aggregate input and TFP are roughly equally important for Western Europe and Southern Europe. For the regions with negative average TFP growth rates, variation in the growth of TFP is substantially more important than variation in the growth of aggregate input per worker. This result is consistent with these negative growth rates being associated with institutional changes in some countries that have negative effects on output per worker in those countries and with armed conflicts involving some but not all countries.

At least with the data currently available, our evidence suggests that growth analysis with less than a forty-year span may reach erroneous conclusions. We find that an analysis based on data the last 20 years – 1980 to 1999 – would reach quite different conclusions than one based on the last 40 years – 1960 to 1999.[28] A seemingly innocuous presumption that 20 years is long enough for analysis of growth would be wrong, at least for this particular period.

Our data span a long enough period that they can be used to address interesting, detailed questions. We have data spanning the introduction of central banking and fiat money in many of these countries. We are in the process of exploring whether these institutional changes and more general financial development and financial repression affect the growth of output, aggregate input, and TFP. Our results suggest that institutional developments, emphasized by North (1988), Grier and Tullock (1989) and Hall and Jones (1999) and possibly disruptions associated with armed conflict are important determinants of economic growth. Our data make it possible to examine the ability of such developments to explain why some countries grow and some countries do not, and also why even the countries that have economic growth on average sometimes grow and sometimes do not grow.

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[28] The last forty years is the usable part of the Summers and Heston data when human capital is included in the analysis.

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Figure 1

Countries and Groups

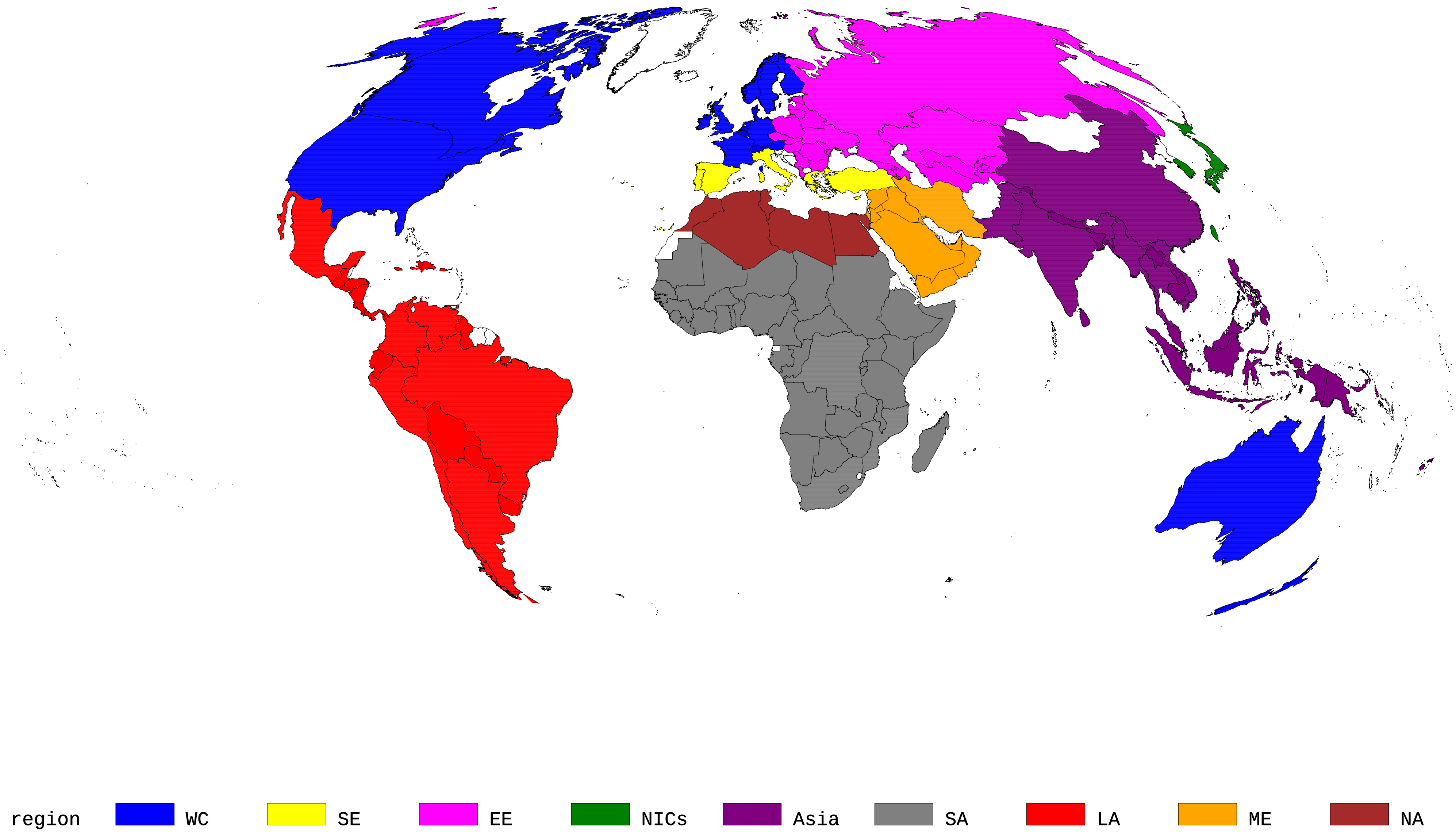


Figure 2

Output per Worker

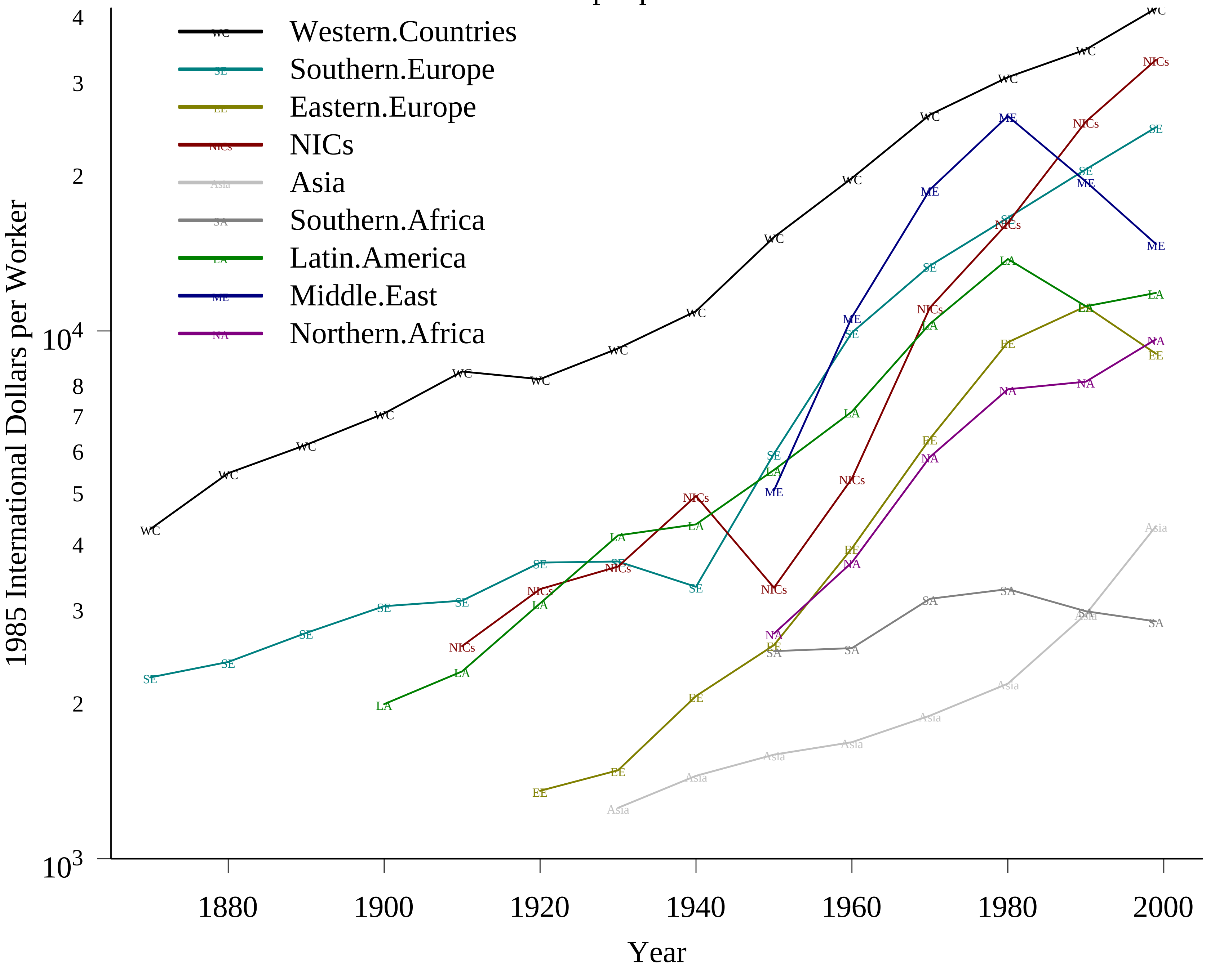


Figure 3

Capital per Worker

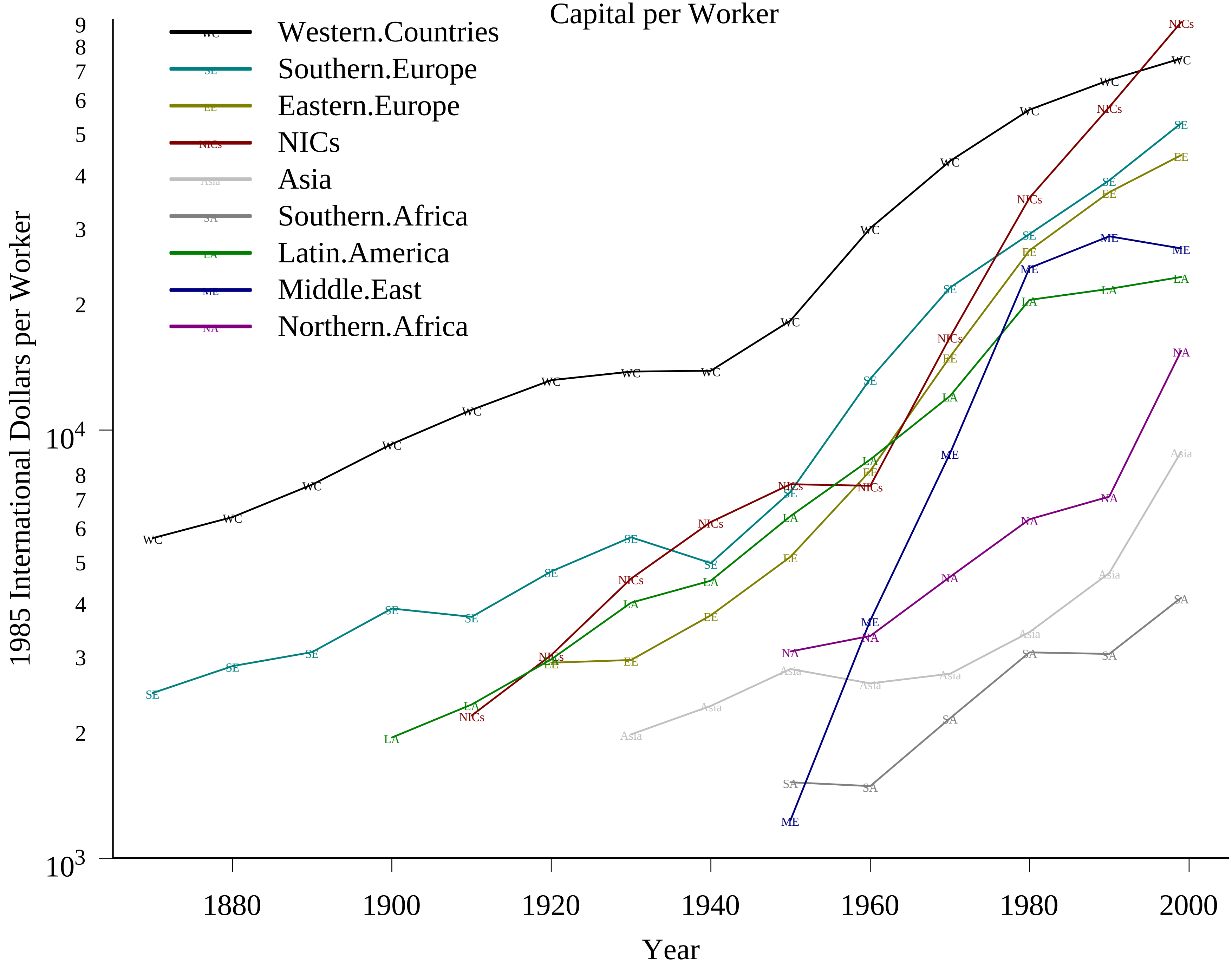
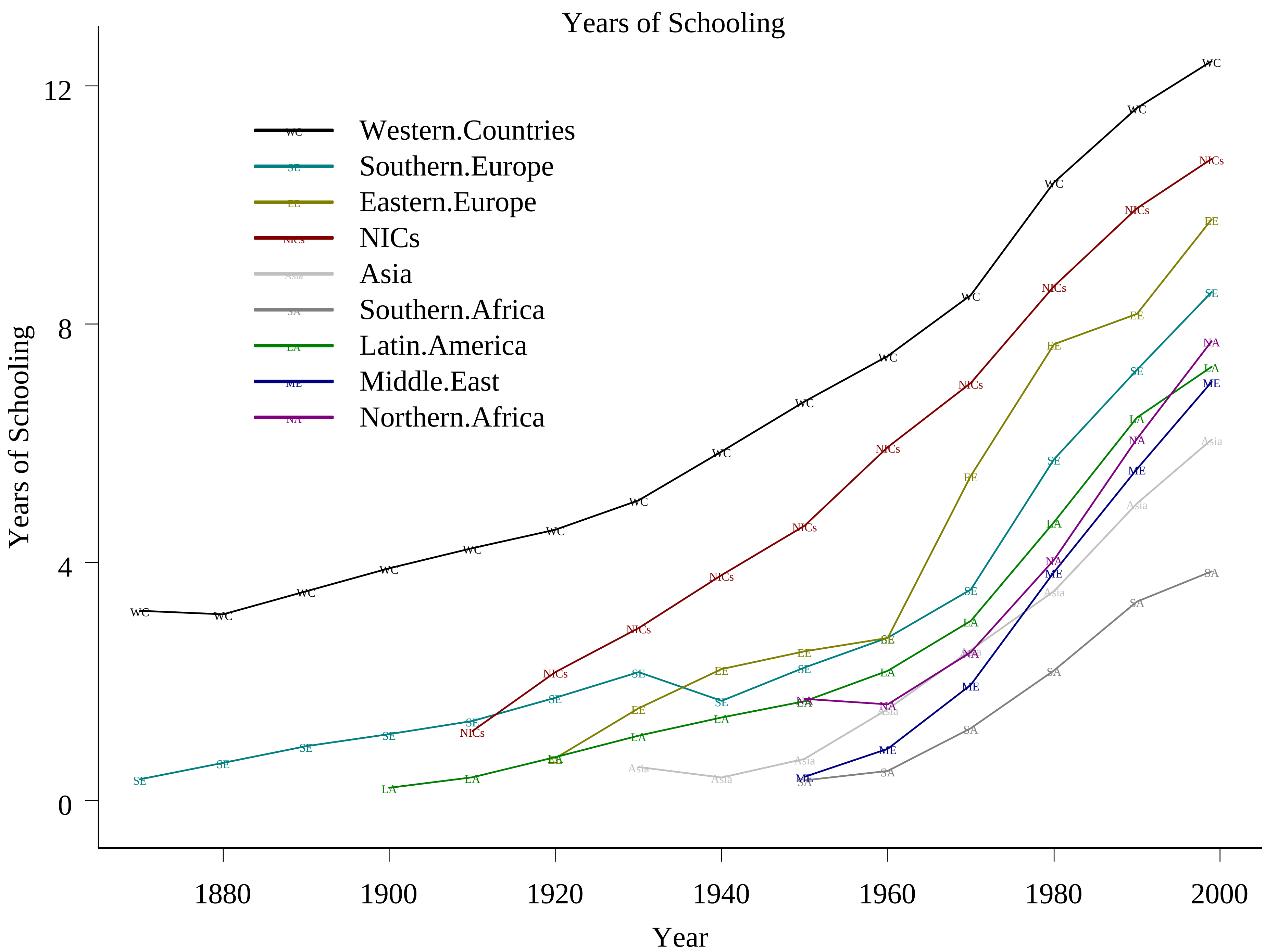


Figure 4



Years of Schooling
Years of Schooling
Year
0
4
8
12
1880
1900
1920
1940
1960
1980
2000
Western.Countries
Southern.Europe
Eastern.Europe
NICs
Asia
Southern.Africa
Latin.America
Middle.East
Northern.Africa

Figure 5

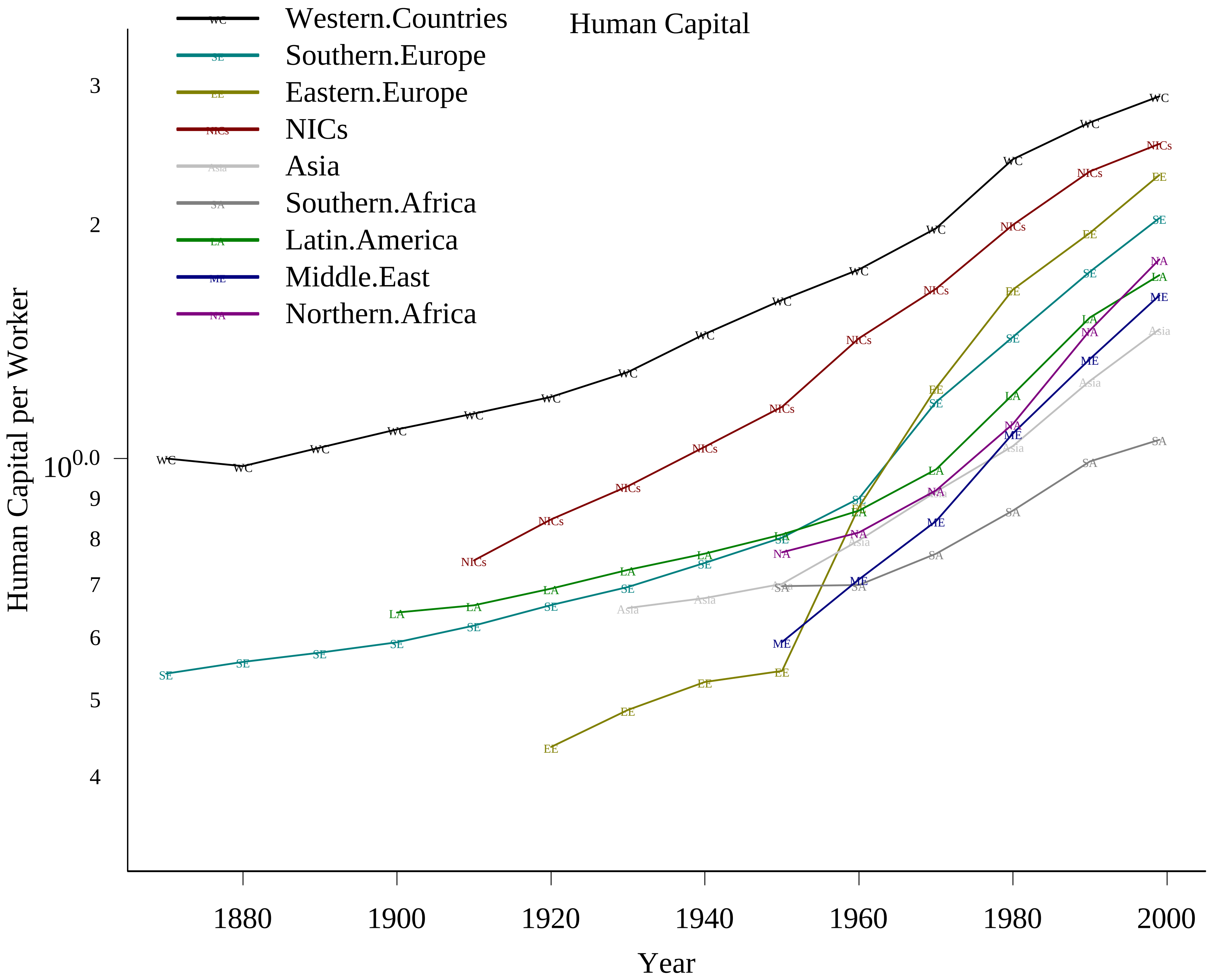
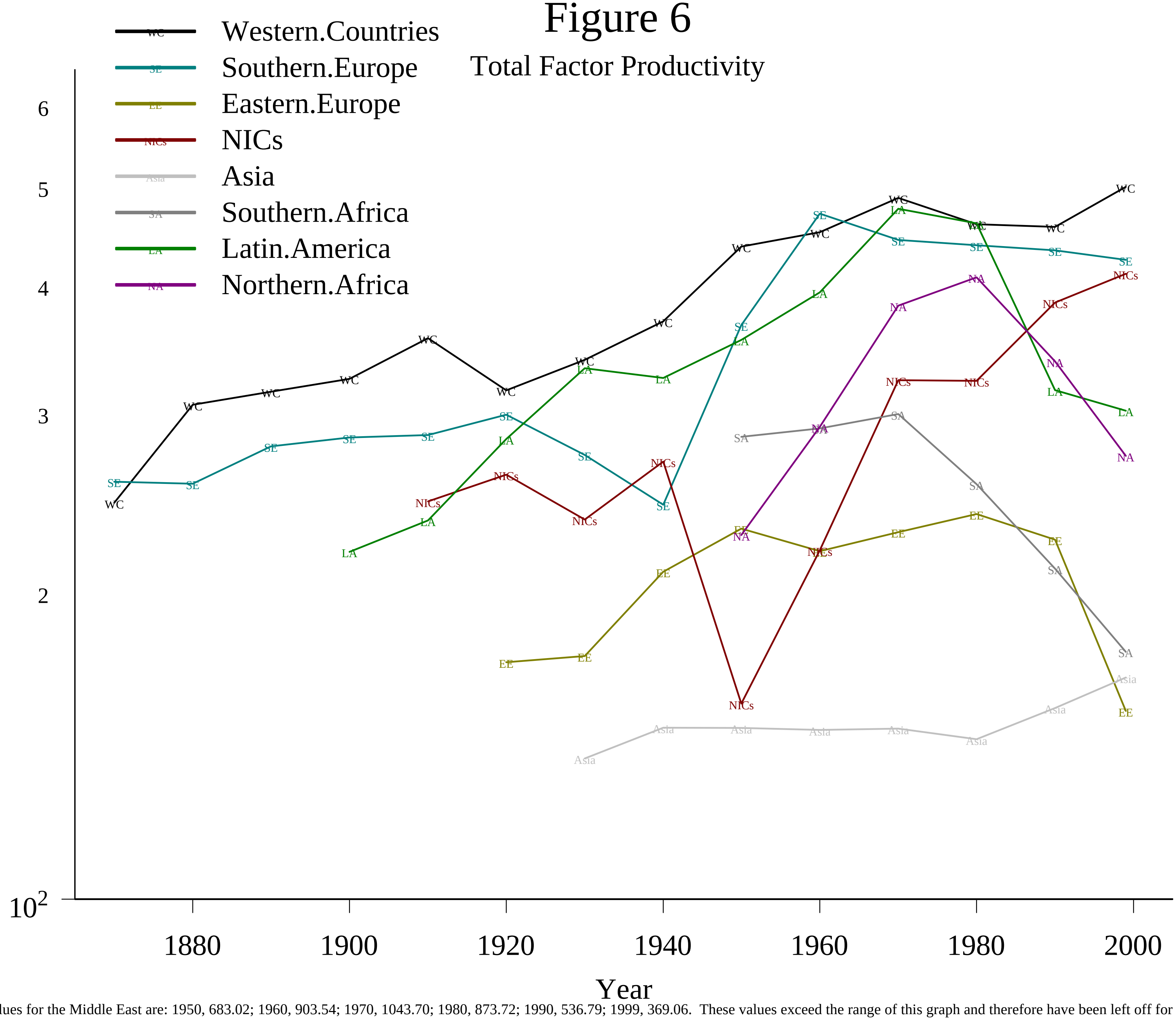

Human Capital
Western.Countries
Southern.Europe
Eastern.Europe
NICs
Asia
Southern.Africa
Latin.America
Middle.East
Northern.Africa
Human Capital per Worker
Year
1880
1900
1920
1940
1960
1980
2000
$10^{0.0}$
2
3
4
5
6
7
8
9

Figure 6

Total Factor Productivity



The TFP values for the Middle East are: 1950, 683.02; 1960, 903.54; 1970, 1043.70; 1980, 873.72; 1990, 536.79; 1999, 369.06. These values exceed the range of this graph and therefore have been left off for graphical purposes.

Table 1

EARLIER ESTIMATES OF THE IMPORTANCE OF INPUT AND PRODUCTIVITY GROWTH FOR OUTPUT GROWTH

INVESTIGATOR	BEGINNING YEAR	ENDING YEAR	INCOME MEASURE	LABOR MEASURE	GROWTH ADJUSTMENT	GROWTH RATE OF INCOME	GROWTH RATE OF CAPITAL	GROWTH RATE OF LABOR	GROWTH RATE OF TFP	FRACTION OF GROWTH ASSOCIATED WITH TFP
Abramovitz	1869-78	1944-53	NNP	Hours	Per person	1.86	1.46	-0.08	1.68	0.90
Solow	1900	1948	Nonfarm Private GNP	Hours	Hours	1.79	1.70	0	1.48	0.88
Kendrick	1889	1957	NNP	Weighted hours	Per person	2.0	1.2	0.1	1.6	0.80
Denison[a]	1929	1982	Potential NI	Weighted hours	Per person employed	1.48	1.34	0.16	1.01	0.68
Maddison	1820	1992	GDP	Hours Worked	None	3.61	4.18	1.77	0.63	0.18

Sources: Abramovitz (1956, Table 1, p. 8); Solow (1957, pp. 315, 316); Kendrick (1961, Table 8, p. 84 and Table 29, p. 85); Denison (1985, Table 3-4, p. 87; Table 4-2, p. 93; and Table 8-3, p. 113); and Maddison (1995, Tables K-1, K-2, pp. 253-55; Table 2-5, pp. 41-42).

"N/A" denotes "not available".

a. The growth rates of capital and labor are growth rates in nonresidential business. Denison also includes land as a factor of production separate from capital.

Table 2

OUR ESTIMATES FOR SIMILAR TIME PERIODS OF THE IMPORTANCE OF INPUT AND PRODUCTIVITY GROWTH FOR OUTPUT GROWTH

		Difference Due to					
Investigator for Comparison	Our Estimate of Fraction of Growth Rate of Income Associated with TFP	Time Period	Growth Rate of Physical Capital	Growth Rate of Human Capital	Time Period and Growth of Aggregate Input	Other Factors	Fraction of Growth Associated with TFP
Abramovitz	0.317	0.181	0.106	0.163	0.450	0.136	0.903
Solow	0.317	0.184	0.182	0.148	0.513	-0.003	0.827
Kendrick	0.317	0.063	0.273	0.114	0.450	0.033	0.800
Denison	0.317	0.057	0.388	0.072	0.517	-0.151	0.682
Maddison	0.150	-0.022	0.026	0.184	0.138	-0.113	0.175

Note: Human capital estimates are the education and experience adjustments indicated in the text. Growth rates including TFP are per person in the labor force for the comparisons other than with Maddison, for which the growth rates are for the totals.

Table 3
AVERAGE GROWTH OF OUTPUT AND INPUTS BY REGION

REGION	*GROWTH RATE PER WORKER*				*TFP GROWTH RELATIVE TO OUTPUT GROWTH*
	OUTPUT	CAPITAL	HUMAN CAPITAL	TFP	
			WEIGHTED AVERAGE		
All Countries	1.65	2.37	1.10	0.13	0.08
Western Countries	1.62	1.99	0.86	0.40	0.25
Southern Europe	1.78	2.28	1.01	0.35	0.20
Central and Eastern Europe	2.12	3.41	1.61	-0.07	-0.03
NICs	2.72	4.03	1.32	0.50	0.18
Asia	1.62	2.15	1.13	0.16	0.10
Middle East	1.19	4.76	2.10	-1.78	-1.50
North Africa	2.16	2.73	1.52	0.25	0.11
Central and Southern Africa	0.44	2.91	1.09	-1.24	-2.80
Latin America	1.63	2.32	0.95	0.22	0.14
			UNWEIGHTED AVERAGE		
All Countries	1.00	2.27	1.44	-0.71	-0.71
Western Countries	1.91	2.41	1.01	0.44	0.23
Southern Europe	2.66	3.16	1.16	0.84	0.32
Central and Eastern Europe	-0.66	-0.21	1.86	-1.84	2.79
NICs	3.59	5.51	1.84	0.54	0.15
Asia	1.51	2.67	1.53	-0.39	-0.26
Middle East	0.47	3.63	1.97	-2.04	-4.30
Northern Africa	2.61	3.24	1.86	0.30	0.11
Central and Southern Africa	0.56	2.48	1.17	-1.04	-1.87
Latin America	1.41	2.40	1.39	-0.32	-0.23

When the new countries in Central and Eastern Europe in 1990 are deleted from the computations, the average growth rates of output, physical capital, human capital, and TFP are: weighted, 2.59, 3.87, 1.57, and 0.26 percent per year; and unweighted, 3.44, 4.84, 1.36, 0.93 percent per year;

Table 4
THE RELATIVE VARIABILITY OF PHYSICAL AND HUMAN CAPITAL AND TOTAL FACTOR PRODUCTIVITY

REGION	NUMBER OF COUNTRIES	*RELATIVE VARIANCE OF* AGGREGATE INPUT	*RELATIVE VARIANCE OF* TFP	*CORRELATION OF AGGREGATE INPUT AND TFP*	*VARIANCE DECOMPOSITION WITH ALL CORRELATION ASSOCIATED WITH* AGGREGATE INPUT	*VARIANCE DECOMPOSITION WITH ALL CORRELATION ASSOCIATED WITH* TFP
All Countries	145	0.162	0.708	0.190	0.320	0.837
Western Countries	16	0.354	0.225	0.753	0.900	0.851
Southern Europe	6	0.232	0.277	0.970	0.983	0.987
Central and Eastern Europe	24	0.053	0.740	0.522	0.461	0.955
NICs	5	0.850	0.058	0.202	0.941	0.188
Asia	16	1.070	0.843	-0.482	0.351	0.177
Middle East	10	1.180	1.094	-0.560	0.250	0.191
North Africa	5	0.709	0.145	0.328	0.876	0.409
Central and Southern Africa	40	0.263	0.550	0.247	0.484	0.754
Latin America	23	0.263	0.877	-0.146	0.140	0.744

Table 5

THE RELATIVE IMPORTANCE OF PHYSICAL AND HUMAN CAPITAL AND TOTAL FACTOR PRODUCTIVITY FOR DIFFERENT TIME INTERVALS

			Standard Deviation of			*Relative Variance of*		*Variance Decomposition with All Correlation Associated with*	
Time Period	Number of Countries	Time Interval	Output	Aggregate Input	TFP	Aggregate Input	TFP	Aggregate Input	TFP
1900-1999	24	1900-1999	0.490	0.247	0.327	0.253	0.446	0.643	0.800
		1920-1999	0.566	0.313	0.365	0.306	0.415	0.646	0.739
		1940-1999	0.705	0.471	0.405	0.445	0.329	0.699	0.593
		1960-1999	0.993	0.541	0.557	0.336	0.356	0.714	0.731
		1980-1999	1.279	0.591	1.109	0.214	0.752	0.250	0.787
		1990-1999	2.132	0.778	1.594	0.365	0.748	0.408	0.859
1920-1999	33	1920-1999	0.631	0.437	0.512	0.479	0.659	0.353	0.528
		1940-1999	0.745	0.519	0.587	0.485	0.622	0.384	0.519
		1960-1999	1.204	0.676	0.901	0.315	0.560	0.452	0.692
		1980-1999	1.919	0.888	1.821	0.214	0.901	0.114	0.792
		1990-1999	2.946	1.207	2.881	0.168	0.957	0.067	0.836
1940-1999	47	1940-1999	0.935	0.569	0.666	0.371	0.507	0.503	0.637
		1960-1999	1.405	0.686	1.031	0.238	0.539	0.512	0.785
		1980-1999	2.167	0.904	1.857	0.174	0.734	0.278	0.829
		1990-1999	3.288	1.245	3.045	0.143	0.858	0.142	0.857
1960-1999	116	1960-1999	1.830	0.872	1.369	0.227	0.559	0.491	0.794
		1980-1999	2.616	1.041	2.398	0.158	0.840	0.160	0.842
		1990-1999	4.379	1.518	4.172	0.120	0.908	0.093	0.880
1980-1999	129	1980-1999	2.633	1.068	2.404	0.164	0.833	0.167	0.836
		1990-1999	4.468	1.525	4.310	0.116	0.930	0.075	0.884
1990-1999	145	1990-1999	4.712	1.514	4.452	0.103	0.893	0.108	0.897

Appendix Table 1
AVERAGE GROWTH OF OUTPUT AND INPUTS BY COUNTRY

		GROWTH RATE PER WORKER				
COUNTRY	FIRST YEAR	OUTPUT	CAPITAL	HUMAN CAPITAL	TFP	TFP RELATIVE TO OUTPUT
Western Countries						
Australia	1861	1.66	2.06	0.94	0.35	0.21
Austria	1880	2.07	2.57	1.02	0.54	0.26
Belgium	1846	1.92	2.38	0.88	0.54	0.28
Canada	1871	1.58	2.13	1.14	0.12	0.07
Denmark	1871	2.20	2.24	1.10	0.72	0.33
Finland	1850	1.48	1.96	1.00	0.17	0.11
France	1850	1.61	2.04	0.91	0.33	0.20
Germany	1880	2.59	3.24	1.11	0.78	0.30
Ireland	1926	3.62	3.98	1.87	1.06	0.29
Netherlands	1849	1.74	2.17	0.86	0.44	0.25
New Zealand	1911	2.03	2.72	1.06	0.42	0.21
Norway	1855	2.05	2.68	0.89	0.57	0.28
Sweden	1860	1.59	2.46	0.83	0.22	0.14
Switzerland	1888	1.65	2.27	1.01	0.23	0.14
United Kingdom	1831	1.10	1.71	0.80	0.01	0.00
United States	1870	1.68	1.89	0.79	0.53	0.32
Southern Europe						
Cyprus	1950	6.03	6.66	1.81	2.62	0.43
Greece	1910	2.85	3.41	1.24	0.89	0.31
Italy	1861	1.79	2.57	0.96	0.30	0.17
Portugal	1849	1.97	2.46	0.75	0.65	0.33
Spain	1857	1.34	1.77	0.82	0.21	0.16
Turkey	1935	1.99	2.12	1.36	0.38	0.19
Central and Eastern Europe						
Albania	1990	1.23	-3.09	0.25	2.08	1.70
Armenia	1990	-10.11	-5.77	1.68	-9.33	0.92
Azerbaijan	1990	-6.40	-4.41	2.92	-6.90	1.08
Belarus	1990	-1.02	1.21	1.80	-2.63	2.57
Bulgaria	1934	2.37	3.40	1.08	0.52	0.22
Czechoslovakia	1921	3.75	4.76	1.51	1.17	0.31
East Germany	1950	7.03	10.81	1.47	2.48	0.35
Estonia	1990	1.92	1.12	2.25	0.05	0.02
Georgia	1990	-0.88	-3.18	2.05	-1.20	1.37
Hungary	1890	2.85	3.18	0.81	1.25	0.44
Kazakhstan	1990	-0.65	-1.24	2.47	-1.89	2.91
Kyrgystan	1990	-6.40	-5.40	3.24	-6.79	1.06
Latvia	1990	4.27	1.12	0.35	3.66	0.86

Lithuania	1990	0.44	-0.96	1.35	-0.15	-0.35
Moldova	1990	-8.20	-2.88	2.41	-8.86	1.08
Poland	1931	3.22	2.72	1.48	1.33	0.41
Romania	1930	4.68	4.95	1.46	2.07	0.44
Russia	1917	1.98	3.72	1.74	-0.41	-0.21
Slovak Republic	1990	9.19	0.58	1.66	7.89	0.86
Tajikstan	1990	-11.06	-7.48	3.39	-10.87	0.98
Turkmenistan	1990	-4.06	-5.24	3.21	-4.48	1.10
Ukraine	1990	-6.51	-2.85	1.76	-6.75	1.04
Uzbekistan	1990	-5.06	-5.32	2.98	-5.30	1.05
Yugoslavia	1920	1.65	5.21	1.36	-0.98	-0.59
Newly Industrialized Countries						
Hong Kong	1960	4.52	6.40	2.41	0.79	0.18
Japan	1890	2.62	3.67	1.23	0.58	0.22
Singapore	1963	5.02	8.18	2.67	0.53	0.11
South Korea	1910	2.66	4.76	1.49	0.10	0.04
Taiwan	1905	3.15	4.56	1.39	0.71	0.23
Asia						
Bangladesh	1970	-1.03	0.61	1.43	-2.19	2.13
Cambodia	1980	2.69	5.05	0.92	0.41	0.15
China	1933	1.98	2.51	1.31	0.28	0.14
Fiji	1960	1.29	1.23	2.24	-0.62	-0.48
India	1904	1.33	1.54	0.81	0.28	0.21
Indonesia	1951	1.76	4.21	1.72	-0.78	-0.44
Laos	1980	1.05	-3.48	1.90	0.93	0.88
Malaysia	1960	3.10	6.05	2.10	-0.31	-0.10
Myanmar	1941	0.25	-1.43	0.78	0.20	0.79
Nepal	1960	1.51	6.34	1.49	-1.58	-1.04
Pakistan	1951	1.32	2.06	0.86	0.06	0.05
Papua New Guinea	1960	1.21	4.01	0.93	-0.74	-0.62
Philippines	1939	2.07	2.04	1.95	0.09	0.04
Sri Lanka	1946	1.64	3.57	1.93	-0.82	-0.50
Thailand	1937	2.52	3.82	1.32	0.38	0.15
Vietnam	1980	1.54	4.53	2.75	-1.80	-1.17
Middle East						
Iran	1956	1.56	3.02	2.26	-0.95	-0.61
Iraq	1950	1.14	5.51	1.86	-1.92	-1.68
Israel	1948	3.10	4.64	2.20	0.10	0.03
Jordan	1960	1.36	4.16	1.61	-1.09	-0.81
Kuwait	1980	-0.35	-4.58	1.55	0.12	-0.33
Oman	1970	0.67	4.63	2.11	-2.28	-3.42
Saudi Arabia	1960	0.70	7.73	1.70	-2.99	-4.24
Syria	1953	0.76	4.37	2.25	-2.19	-2.90
United Arab Emirates	1980	-3.74	-6.42	1.89	-2.89	0.77

Yemen	1970	-0.44	13.24	2.27	-6.33	14.37
Northern Africa						
Algeria	1948	3.00	3.04	1.85	0.76	0.25
Egypt	1917	2.00	2.63	1.41	0.19	0.09
Libya	1960	3.68	4.99	2.47	0.38	0.10
Morocco	1951	1.77	2.54	1.36	0.02	0.01
Tunisia	1956	2.61	2.99	2.20	0.15	0.06
Central and Southern Africa						
Angola	1960	-3.02	1.48	0.68	-3.97	1.31
Benin	1960	-0.66	1.92	1.03	-1.98	2.99
Botswana	1960	5.37	8.72	2.28	0.97	0.18
Burkina Faso	1960	1.56	4.82	0.46	-0.34	-0.22
Burundi	1960	-1.13	-0.24	0.67	-1.49	1.33
Cameroon	1960	-0.12	3.47	1.64	-2.37	19.00
Central African Republic	1960	0.94	0.21	0.92	0.25	0.27
Chad	1960	-0.17	1.50	0.76	-1.18	6.74
Congo	1960	-0.78	1.50	2.53	-2.97	3.81
Ethiopia	1950	0.56	5.53	0.39	-1.53	-2.75
Gabon	1960	3.76	5.06	1.25	1.25	0.33
Gambia (The)	1960	2.30	5.50	1.17	-0.30	-0.13
Ghana	1960	0.66	0.82	1.93	-0.90	-1.36
Guinea	1960	1.88	1.18	0.56	1.12	0.60
Guinea-Bissau	1960	0.24	0.36	0.80	-0.42	-1.73
Ivory Coast	1960	0.77	2.11	1.02	-0.61	-0.79
Kenya	1962	0.78	1.77	1.91	-1.09	-1.40
Lesotho	1960	4.47	12.72	1.38	-0.65	-0.15
Liberia	1960	-0.50	-0.12	1.12	-1.21	2.44
Madagascar	1960	-1.42	1.62	0.62	-2.36	1.67
Malawi	1960	0.37	0.88	0.58	-0.31	-0.83
Mali	1960	0.22	2.66	0.39	-0.92	-4.27
Mauritania	1960	1.33	1.46	0.94	0.21	0.16
Mauritius	1960	1.54	0.82	2.26	-0.24	-0.16
Mozambique	1960	-3.10	3.49	0.65	-4.69	1.51
Namibia	1960	2.10	1.70	2.30	-0.01	0.00
Niger	1960	0.35	1.47	0.40	-0.40	-1.15
Nigeria	1952	0.08	3.76	1.12	-1.91	-22.43
Rwanda	1960	-1.43	1.37	1.05	-2.58	1.81
Senegal	1970	0.61	2.18	1.10	-0.85	-1.39
Sierra Leone	1961	-2.16	3.08	0.99	-3.84	1.77
Somalia	1960	-2.03	1.15	0.60	-2.81	1.38
South Africa	1946	2.75	2.94	1.57	0.73	0.27
Sudan	1970	1.34	1.20	1.15	0.17	0.13
Tanzania	1960	0.61	3.74	1.00	-1.29	-2.12

Togo	1960	3.44	4.82	1.62	0.77	0.22
Uganda	1959	1.81	4.45	1.33	-0.54	-0.30
Zaire	1950	1.53	2.65	1.17	-0.13	-0.08
Zambia	1950	-3.10	-3.10	1.41	-3.03	0.98
Zimbabwe	1950	0.62	-1.66	2.19	-0.29	-0.47
Latin America						
Argentina	1895	1.62	2.21	1.17	0.11	0.07
Bolivia	1950	0.75	1.31	1.55	-0.72	-0.97
Brazil	1872	1.65	2.18	0.70	0.46	0.28
Chile	1895	1.59	2.27	1.13	0.09	0.06
Columbia	1917	1.40	1.91	1.10	0.03	0.02
Costa Rica	1951	2.26	3.45	1.76	-0.05	-0.02
Dominican Republic	1950	2.73	4.09	1.90	0.11	0.04
Ecuador	1950	1.15	3.32	2.12	-1.36	-1.18
El Salvador	1950	1.60	2.18	1.34	-0.02	-0.01
Guatemala	1950	1.54	2.57	1.01	0.02	0.01
Guyana	1946	1.03	2.51	1.09	-0.53	-0.51
Haiti	1950	1.53	3.83	0.91	-0.34	-0.22
Honduras	1930	0.77	1.41	1.14	-0.46	-0.59
Jamaica	1953	1.52	3.60	1.77	-0.85	-0.56
Mexico	1895	1.91	2.67	1.03	0.33	0.17
Nicaragua	1950	0.38	1.73	1.55	-1.23	-3.26
Panama	1950	1.77	2.74	1.87	-0.39	-0.22
Paraguay	1939	1.00	1.35	1.22	-0.26	-0.26
Peru	1908	1.49	2.60	1.27	-0.22	-0.15
Puerto Rico	1960	3.21	2.03	1.69	1.41	0.44
Trinidad	1960	-0.68	1.10	1.80	-2.25	3.31
Uruguay	1939	1.59	1.74	1.50	0.01	0.01
Venezuela	1936	0.55	2.41	1.46	-1.22	-2.21