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THE MYSTERY OF HUMAN CAPITAL AS ENGINE OF GROWTH, OR WHY THE US BECAME THE ECONOMIC SUPERPOWER IN THE 20TH CENTURY

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ABSTRACT

This paper offers a thesis as to why the US overtook the UK and other European countries in the 20th century in both aggregate and per-capita GDP, as a case study of recent models of endogenous growth where human capital is the "engine of growth". The conjecture is that the ascendancy of the US as an economic superpower owes in large measure to its relatively faster human capital formation. Whether the thesis has legs to stand on is assessed through stylized facts indicating that the US led other OECD countries in schooling attainments per adult population over the 20 century, especially at the secondary and tertiary levels. While human capital is viewed as the direct facilitator of growth, the underlying factors driving the US ascendancy are linked to the superior returns the political-economic system in the US has so far offered individual human capital attainments, both home-produced and imported.

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PROLOGUE

Common to the bulk of the "new" economic growth and development literature is the idea that the process by which less developed countries break out of a poverty trap and achieve steady, self-sustaining growth in real per-capita income is predicated on persistent production and accumulation of "human capital". The concept is wrapped up in three layers of mystery: a. unlike physical capital, human capital is not a tangible asset. How, then, can we account for it empirically? b. What dictates its continuous formation over time? c. How is such formation transformed into growth in real output and personal income?

One of the objectives of this presentation is to unwrap this apparent mystery through an exposition of a general-equilibrium paradigm of economic development where human capital is the engine of growth, its accumulation is enabled by parental and public investments in children's education, and underlying "exogenous" institutional and policy variables are ultimately responsible for **both** human capital formation and long-term growth. The model is developed in the context of a competitive market economy in which human capital, measured **imperfectly** by quantitative indicators of schooling and training, is competitively rewarded and efficiently allocated to productive activities. The model also recognizes, however, the role of externalities affecting the accessibility and financing costs of schooling, the efficiency of the economy's labor and product markets, and the spillover effects emanating from workers possessing higher education and skill on the productivity of other workers, which may vary across countries. Furthermore, the way these externalities are "internalized" may also vary by the institutional and legal framework governing the market economy, and as a consequence of accommodating economic and educational public policies, especially in so far as higher education is concerned. Such variations can ultimately explain differential long-term growth patterns in different countries.

A more specific objective of the presentation is to illustrate the power of the "human capital hypothesis" to explain observed differences in long-term growth dynamics across specific countries. The case in point is the emergence of the US as the world economic superpower. While the UK and Europe in general were the world's economic leader in the late 18th and much of the 19th century, and while the US was a relatively poor country in the early part of the 19th century, in the last few decades of that century, and especially during the 20th century, the US developed considerable advantage over the UK and other major European countries in terms of not just gross domestic product, but per-capita GDP as well. What may be less known is that over the same period the US has developed a considerable gap over Europe in the **schooling attainments** of its labor force, and especially in higher education attainments. The gap remained significant through the entire century, although it narrowed considerably in the latter decades of the 20th Century and is continually narrowing in this decade. Largely accounting for this gap was the massive high school movement of 1915-1940, but an independent gap emerged as early as the 1860s with the US foray into tertiary education beginning with the first Morrill act of 1862, and continuing especially with the massive higher education movement post WWII. A basic argument of this paper is that the US lead in educational attainments, especially at the tertiary level since the late 19th century, is a major, and perhaps **the** major instrument through which it overtook Europe as the economic superpower in the 20th century.

To illustrate the case empirically, it is worth noting that by popular measures of real income used in international comparisons (GDP, adjusted by Purchasing Power Parity), the US maintains a considerably larger level of per-capita income relative to practically all top 25 countries in the World, including even small tax-heaven countries (see **Table A**). But in the early1800s the US had a level of GDP and GDP per-capita level considerably below that of the UK and it was not until 1872 for GDP and 1905 for GDP per-capita when the US has overtaken the UK. Figures 1 and 2 illustrate the comparisons poignantly. Note that both the US and UK graphs relating the logarithm of GDP or GDP per-capita to chronological time appear over the long haul, despite year to year and cyclical fluctuations, to assume the shape of an upward-sloping straight line, the slope of which represents the long-term annual growth rate of GDP and GDP per-capita, respectively. The fundamental difference is that the **slopes** of the lines are higher for the US relative to the UK. In other words, the US has overtaken the UK because its long-term **growth rate** has been higher: Over the 131-year period 1871-2003, the US GDP growth rate has been 3.3% per annum v. UK's 1.91%, and the US per-capita GDP growth rate has been 1.87% v. 1.419 in the UK.[1] My basic thesis, consistent with endogenous growth theory, is that the difference in per-capita income growth rates is attributable not to the growth of labor and physical inputs, including land or other natural resources, but to the greater rate of human capital formation. Both superior human capital formation and its impact on growth, however, are ultimately attributable to underlying institutional and policy factors. In what follows I will first elaborate on this hypothesis, and proceed with evidence supporting it.

1. The "mystery" of growth – the human capital hypothesis

What accounts for differences in wealth across nations has been a key puzzle of economic science since Adam Smith. Logically, the question involves both static and dynamic elements: why are some nations doing better than others economically at a point in time, and why some nations become more successful than others over time. In the terminology of the current literature on economic growth and development, this distinction relates to determinants of the **level**, as opposed to the **rate of growth,** of per-capita real income, taking the latter to represent a scalar measure of economic welfare.

A significant advance in the modern economics treatment came about with the neo-classical growth model, which identifies key factors contributing to a steady-state **level** of per-capita income and its associated capital-labor ratio (K/L), under any exogenously given rate of population growth and level of production technology. The model thus attributes **growth** in per-capita income over time, which is a better measure of private economic welfare than aggregate income, strictly to exogenous technological shocks. This inference can be conveniently illustrated via the following "neo-classical" aggregate production function:

$Y = B(T)F(L, K)$, where Y is the economy's aggregate output, F is a constant-returns-to-scale production function summarizing the impact of convention labor (L) and physical capital (K) inputs on production, and B(T) represents the process by which "technology" (T) augments the impact of these inputs. Under an exogenously given technology, the neo-classical growth model suggests that the steady-state level of **per-capita** real income (y) is given by:

(1) $y^* \equiv B(T)f(k^*)$, where $k^* \equiv (K/L)^*$ is the "golden rule" capital to labor ratio.

Growth in y* thus occurs through exogenous technological advances. The role of technology, B(T), can be interpreted more broadly to include any and all factors that enhance the utilization of the stocks of labor and physical capital resources available to the economy at a point it time. In principle, therefore, institutional and legal frameworks that facilitate the emergence and operational efficiency of the market economy within which economic resources are utilized are also subsumed by this factor – a point which will be further underscored in later sections. Like technology, these factors are assumed to be exogenously given to the economy. They affect the **level** of output per-capita at a point in time.

In the last 200 years or so, however, the world has witnessed a relatively new phenomenon in economic history: persistent and seemingly self-sustaining growth in per-capita real income over the long haul in most of the so-called "developed economies" following the technological shock produced by the 'industrial revolution'. Periodic and occasionally large business-cycle disturbances notwithstanding, this phenomenon is still continuing, although at a different pace in different countries. Furthermore, over the last century or so, the world has also experienced episodes of economic takeoffs by less developed countries from relatively stagnant, low income levels into regimes of self-sustaining growth (e.g., the Asian Tigers), as well as episodes in which a relatively poor economy has overtaken a much wealthier one (e.g., the US versus Europe). If "exogenous", i.e., accidental, technological discoveries are the key to this mystery, what accounts for the smooth and continuous, but also variable, productivity growth in different countries, especially when technological discoveries originating in one country can be rapidly imitated and adopted by any other country?

The answer offered by much of the recently developed "endogenous growth" literature (see Lucas, 1988, and the articles in Ehrlich, 1990) rests on identifying "technology" as "human capital", and modeling perpetual technological advances as the outcome of investment in human capital treated as an endogenous variable (i.e., an object of individual choice) within a dynamic, general equilibrium framework. In essence, human capital is a stock of "productive knowledge", having two inherent dimensions: "embodied" and "disembodied". The first is knowledge embodied in workers. It augments the productivity of labor and physical capital inputs at a point in time. The second is creative knowledge which flows out of ideas originating with scholars, scientists, inventors and entrepreneurs. This "disembodied" knowledge is manifested in papers, books, patents, and algorithms, and winds up as process and product innovations at the firm and industry level. It is typically acquired through higher education and produced in tertiary institutions of teaching and research. While these types of human capital are distinct, they are also intertwined, as dissemination of knowledge and innovation, or "technology transfer", can hardly occur without the input of embodied knowledge. In this view, technology, as popularly understood - inventions, innovations, scientific and engineering discoveries - does not "fall from heaven": it stems from decisions made by families, firms, and governments to invest in different forms of formal schooling, job training, and research and development, making human capital the relevant **"engine, or facilitator, of growth".** Knowledge can accumulate continuously if the levels of **investment** in education made by current generations are high enough to insure that future generations wind up with superior productive knowledge.

But how does one measure this complex concept called “human capital”? Modern human capital theory identifies it as a function of schooling and job experience, which are imperfectly measured, however, because quantity of schooling may often be a poor measure of educational quality. Indeed, the hypothesis that investment in human capital serves as an engine of growth is yet to be verified through systematic econometric studies (but see section 6.C for some empirical insights). We here examine the hypothesis using mainly a historical case study: explaining the dynamic growth paths of the US and Europe by comparing the growth patterns of corresponding, albeit imperfect, human capital proxies: the **schooling attainments** of the US relative to Europe over the last century. Our dual hypotheses are: a. the economic overtaking of Europe by the US beginning in the late 19th century, and its continuing dominance through the 20th century, owe largely to the faster and more wide-spread growth of schooling attainments, especially at the secondary and tertiary levels; and b. these differential schooling attainments, wether domestically produced or imported, are ultimately attributable to the higher reward the US economy has offered to human capital attainments due to accommodating political and institutional factors. To flash out these arguments we begin by surveying historical evidence on the evolution of the different schooling attainment levels in the US relative to Europe over the 20th century.

2. Evidence on educational attainments: Does the thesis have legs to stand on?

The following is a summary of illustrative data on comparative educational attainments and educational spending by selected categories involving the US and other European or OECD countries, as reported in authoritative publications. Since year-to-year reports do not always involve the same categories, occasionally alternative years of data have been selected.

2A. Data on Educational attainments in the US v. OECD countries over the last century.

Average years of Formal Educational Experience of the Population Aged 15-64 in 1913and 1989 (Maddison’s data), and of the population aged 25-64 in 2003(OECD data). **(Table 1)**

Highlights: According to Maddison (1991), in 1913 average schooling years in the US was 6.93, behind Germany (6.94) and the UK (7.28). Japan had the lowest attainment (5.10). However, even at that point in time, the US already had the highest average higher education attainments in years in 1913 (0.2), followed by Netherlands (0.11), and France (0.10). In 1989, in contrast, Maddison’s data indicate that the US already emerged as the leader in educational attainments at all schooling levels. Average schooling years in the US shot up to 13.39, ahead of Japan (11.66), France (11.61) and the UK (11.28). Germany slipped to last place at 9.58. The average number of higher-education years attained in the US was 1.67, ahead of France (1.32), with other countries substantially lower. Note that Japan, which was at the last place in average schooling attainments in 1913, rose to second place in 1989.[2]

In 2003, OECD data suggest that the US still leads the world in average schooling attainments in years at all levels (13.8), and in higher education (1.71), but other countries are clearly catching up. The Netherlands (1.60) is second in AHY, followed closely by a rapidly developing Germany (1.59), and Germany reaches top rank in average secondary schooling attainments.

2.B. Recent evidence from OECD's *Education at a Glance,* 1998 and 2003

a. Educational attainments

Percentage of the population that has attained at least tertiary education Type-A by age group 1998 and 2003 **(Table 2)**

Highlights: In 1998, the percentage of the population 25-64 years of age educated in Tertiary type-A programs, defined as regular 4-year colleges or universities and advanced research programs, is the highest among all OECD countries (26.6%), followed by Norway (23.7%), while the average for all OECD countries is scarcely above half of the US. A striking pattern of the educational gap is that it is higher among older age cohorts. In the age group 55-64, for example, the corresponding US percentage is 22%, relative to just 9% for the OECD average. By 2003 Norway catches up with the US in the age group 25-64 at 29% for both, but the average for all OECD countries is still substantially below the US (16%). In the age groups 45-64, however, the US maintains a decisive advantage of a 2 to 1 ratio or over in 2003 as well.

Tertiary type B programs, in contrast, which are more popular in some OECD countries (e.g., Canada, Japan, New Zealand, Sweden) relate to vocational, rather than academic institutions. But even in total tertiary educational attainments, the US is second only to Canada in the age group 25-64 and is leading in the age group 55-64 in 2003. (These data are not included in Table 2, but the source for both is the same.)

Distribution of the population that has attained at least upper secondary education, by age group (1998) **(Table 3)**

Highlights: The US is leading in the age group 25-64 (86%), relative to an OECD mean of 61%, but much more so in the age group 55-64 (80%), where the second highest is Germany (76%). The gap narrows at younger age groups. In the age group 25-34, the US is in 6th place (88%), behind Japan, the Czech Republic, Norway, and Korea, and tied with Germany. These data clearly indicate that a number of European countries have caught up with the US in terms of secondary schooling in more recent years. But the US again shows overwhelming leadership in terms of the proportion of the population that has attained at least tertiary education:

Expected years of tertiary education for all 17-year-olds (1998) **(Table 4)**

Highlights: This table demonstrated more vividly that while the US is still in a dominant position in terms of the expected number of years of tertiary-type A education: 2.7 years for both part time and full time workers. Finland (2.9) and Norway (2.7) have already caught up with the US, but France at 1.9 and the UK at 1.7 have not done so.

In assessing the data regarding educational attainments, it is important to note that the US advantage is showing up most strongly in the older age categories. The advantage is narrowing at the younger cohorts, which indicates an underlying dynamic trend: Europe is gradually closing the educational gap. But the US still holds a commanding lead in the category of those who hold **at least** tertiary type-A education, especially at older age cohorts.

b. Expenditures on Education (all figures are in US dollars converted using PPP)

Expenditure on educational institutions as a percentage of GDP for all levels of education by source of funds (1990, 1995, and 2002). **(Table 5)**

Highlights: here the US (7.2%) is among the top countries in terms of total expenditure from both public and private sources for education institutions, being surpassed only by Iceland (7.4%), with Denmark and Korea (both 7.1%) following the US. But these numbers are somewhat misleading because they do not account for the differences in the composition of student populations in different countries. The more relevant data are total expenditure per student, and these are much higher in the US relative to other OECD countries (see below).

Annual expenditures on educational institutions per student (US dollars converted using PPP) by levels of education based on full-time equivalents (2002). **(Table 6)**

Highlights: US expenditure per student on all levels of secondary education in 2002 was $9098, while the average among OECD countries was $6992, but at this point the US already ranks behind Switzerland ($11900), and Norway ($10154) (Luxembourg at $15195, is not a comparable country). In the case of tertiary educational expenditures (both type A and B), however, the US ($20545) is second only to Switzerland ($23714), and only Sweden ($15715) and Denmark ($15183) have spending levels above $15000.

Expenditure per student (private and public) relative to GDP per capita by level of education based on full-time equivalents (2002). **(Table 7)**

Highlights: The US ratio here (25) is just about equal to the average in OECD countries in the case of all secondary expenditures (26), but at 57, it is still substantially above the average in OECD countries (43) in the case of all tertiary expenditures. To the extent that education can be considered consumption good, this ranking indicates only that higher education in the US is now a necessity rather than a luxury good (with income elasticity of demand falling short of unity). But these ratios may largely reflect differences in the weight of other types of spending on, say, private consumption or public defense, across different countries.

3. How the US schooling advantage emerged – Major Sources and trends

a. *The secondary schooling advantage*. Claudia Goldin (see, e.g., 2003) argues that what has been mainly responsible for the US advance over Europe is the massive "high school movement of 1910-1940". Her thesis is that, although advances in higher education have been important, the mass secondary education system, which first emerged in the US, set the stage for the subsequent transition to the mass higher education movement. In 1910, school enrollment rates for 5 to 19 year olds were fairly similar among the world's economic leaders (the ratio of enrollments relative to the US set at 1 was: .93 in France, .96 in Germany, and .82 in the UK). But by 1930, the US was 3 to 4 decades ahead of Britain and France, and the high-school gap remained large until the 1950s. The median 18-year old person was already a high- school graduate in the early 1940s. This had a knock- on effect on the massive development of higher education institutions after WWII: when President Franklin Roosevelt signed the GI Bill in 1944, the average GI could attend college because (s)he had already graduated from high school.

b. *The Morrill Acts and the Land Grant institutions of higher learning.* What is being overlooked by this explanation, however, is that the US already held the lead in tertiary enrollment in 1913, as Maddison's data show. What may have been responsible for this historical development are the Morrill Acts (Land Grant Creation) of 1862-1890, and related accommodating factors which made higher education in the US accessible to larger segments of the population relative to Europe. John Morrill was a Congressman from Vermont who managed to convince Congress and President Lincoln to launch a system of public higher education, to be financed through land grants from the Federal government to the States. Under the terms of the Morrill acts, later supplemented by the Hatch Act of 1887, the second Morrill Act of 1890, and the Smith-Lever Act of 1912, public lands, or funds in lieu of public lands, were granted to the States for the establishment and support of land-grant colleges and universities, and well as research stations that focused on agricultural and mechanical-art studies and research. I am not aware of any systematic analysis of the role the Morrill Acts had in the evolution of the higher education system in the US, but some important facts allude to their significance. There were 68 land-grant public institutions and universities located in the 50 States and Puerto Rico in 1961. Although at that point, these institutions already accounted for less than 5% of all 4-year institutions of higher learning, these institutions, varying greatly in size from the University of California to Delaware State College, accounted for 48% of total organized research expenditures, 40% of the doctorates conferred, 33% of the current-fund income for educational and general purposes, and 28% of the value of plant assets in the US in 1961.[3]

c. *The GI Bill of 1944.* The public education system, bolstered by the Land Grant movement, received a huge impetus by the Servicemen's Readjustment Act, popularly known as the GI Bill, signed by President Roosevelt in June 1944. The act mandated the Federal Government to subsidize tuition, fees, books, and educational materials for veterans meeting educational admission requirements, and to contribute to the living expenses they would incur while attending college or other approved institutions of their free choosing. The GI Bill created a massive higher education movement. Within the following 7 years, approximately 8 million veterans received educational benefits. Of that number, approximately 2,300,000 attended colleges and universities. The High School Movement of 1910-1940 played a critical role in facilitating this development since almost half of the soldiers returning home from WWII had a High School Diploma and were thus eligible to enroll in colleges and universities. The US lead in higher education was enhanced not just by the GI Bill, but also by Federal Pell Grants and the legislation of tuition assistance supports in many states. Again, Europe was lagging behind the US in this regard over much of the second half of the 20th century. The British Education Act of 1955, for example, just guaranteed all youth a publicly funded elementary and secondary schooling.

d. *Immigration and the brain drain*. Another key factor which accounts for a good part of the US schooling advantage is immigration of human capital into the US. In an open economy human capital is not necessarily just home grown – it can be imported through immigration of skilled and highly educated labor. It is beyond the scope of this essay to assess systematically the brain drain into the US, but there is general agreement for the proposition that the US became a magnate for skilled labor and scientists, first from Europe and later from Asia as well, following the economic advances of the US in the 20th century, especially after World War II. Dramatic support for this conjecture is provided in a 2005 study by the Committee on Science, Engineering, and Public Policy, showing that the share of all the science and engineering (S&E) doctorates awarded to international students rose from 23% in 1966 to 39% in 2000, the share of temporary residence among S&E post doctoral scholars increased from 37% in 1982 to 59% in 2002, and more than one-third of US Nobel Laureates to date are foreign born.

A number of caveats are relevant, however, for a more complete assessment of the US Schooling advantage over Europe in the 20th century:

i. The higher education gap, and more so the gap in secondary educational attainments, are now closing, as evidenced by Tables 3-5. They may have reached a peak sometime after WWII, but have continuously declined since then.

ii. The schooling attainments data apply unequivocally to tertiary type-A institutions (regular 4 year colleges/universities), but not as much to tertiary type-B, which are more vocational in nature, which remained more popular in Europe. Also, the numbers do not include post-formal training and apprenticeships, which are more prevalent in Europe.

iii. Finally, the numbers relate to educational attainments and expenditures, which are "input" measures into effective human capital formation and technological advance. The picture seems far more mixed concerning some "output" measures of educational achievements, as reflected by math test scores. Evidence indicates that the distribution of US combined mathematics literacy scores of 15-year-old students is, in fact, below that of the average of OECD countries (see **Table 8**). No such comparative test scores are available, however, at higher schooling levels.

4. Whence the divergence? – Contributing factors

(a). *Educational templates*: Goldin (2001) and Goldin and Katz (1999) emphasize the implicit choice between **general** training (formal schooling) and **specific** training (apprenticeship, on-the-job training options). General training is more expensive, but it produces more transferable and flexible skills across geographical areas, occupations and industries. The focus on general training in the US is attributable to the US developing into a larger open-trade area relative to European countries. Its labor force in the early 20th century was more mobile and responsive to technological changes in manufacturing, telecommunications, large-scale farming and retailing.

(b). *Economic development.* The growth of the industrial and transportation sectors of the economy, and the expanding size of the US domestic market, raised the rate of return to education, secondary and higher education specifically. The intellectual high school movements which started in New England spread quickly to the rich agricultural areas in central and western states, where rates of return to schooling were as high for blue collar workers and farmers as for white collar workers. The high school movement spread also because of the decentralized educational system in the US due to the fiscal independence of school boards.

(c). *Wealth effects*: By the early 20th century, the US already had the highest income per capita, enabling families to more easily finance the higher education of offspring of both genders.

(d). *Institutional policies related to education*: The US educational system has been more democratic, secular, and gender neutral. In contrast, the educational systems in Germany, France, and other European countries were more rigid and elitist over much of the 20th century. Differences in institutional restrictions are manifested especially in the context of tertiary education. In the US, publicly subsidized higher education started with the Merrill Acts, becoming massive in 1944, while in Europe this process began later – in some countries not until the 1960s and 70s. In France, e.g., the number of college students started increasing considerably only during the 1980s because of the knock-on effect of expanding secondary education: a political decision was made to increase to 80% the percentage of age cohorts that would reach the level of the *baccalauriat*, and admissions to the first year of university studies was guaranteed to anyone with a high school diploma, regardless of type. Thus, although European tertiary institutions have become virtually tuition-free in recent decades, **access** to these colleges and universities remained much more restricted until recently. The US, in contrast, has practiced virtually universal admission to higher education, albeit with differences between community colleges and public and private colleges and universities. As noted in section 2, however, that the gap in higher education enrollments between the US and Europe is fast closing.[4]

(e). *The Political-Economic Systems*: Last, but not least, the US has had a more democratic political system; e.g., suffrage was extended to all (white) US males early in the 19th century, but much later in almost all European countries. It has also had a freer, decentralized economy, where individuals, families, and firms can make resource allocation decisions in largely free markets, bolstered by the rule of law and protection of property rights, including intellectual property. The US has also had less regulated labor markets, and greater openness to external trade and immigration relative to Europe. These factors ultimately produced a relatively high rate of return to human capital investments for the domestic population, and a larger premium on completed education for skilled immigrants.

The preceding analysis traces the gap in educational attainments favoring the US in the 20th century to the interplay of two main forces: 1. the feedback effects on private demand for education generated by the new industrial economy, economic growth, and personal wealth; 2. the impact of the more open economy and society in the US on the returns to human capital formation, whether domestically produced or imported, and thereby on economic growth.

By items (a)-(c) above, economic affluence leads to greater demand for education as consumption, or to greater ability to finance private educational investments by overcoming inherent imperfections in the capital market. Items (d)-(e) above trace the growth in educational attainments to institutional, political, and economic policies which lower the costs, or raise the potential returns, to investment in especially higher education, thus enabling individuals and firms to capture more fully any external effects generated by education. These factors also encourage immigration of workers with superior education or entrepreneurial ability. Put differently, the democratic capitalism exercised in the US has contributed to a higher rate of return to individual investment in human capital generally, and tertiary education in particular.

While the two groups of factors represent apparent opposite directions of causality regarding the association between human capital formation and economic growth, they are, in fact, complementary. Greater investment in human capital as a proportion of total production capacity raises productivity growth, while the demand for human capital investments is partly a by-product of economic growth, and this needs to be accounted for in regression analyses aiming to explain productivity growth as a function of educational spending. But this would be a partial-equilibrium view of economic development. The endogenous growth, general equilibrium model discussed below sees both human capital formation and productivity growth as endogenous outcomes of underlying institutional, legal, and political/economic factors. Moreover, institutional factors, such as greater public willingness to augment private investment in education within a competitive market system, are also affected by the schooling level of the electorate. In this view, the critical causal factors can be traced especially to those summarized in item (e).

5. Linking human capital formation with economic growth:

A. The endogenous growth hypothesis: human capital as the engine of growth.

The literature on endogenous growth attempts to go beyond the neo-classical model of economic growth in two important ways: a. explaining growth as a result of factors endogenous to the economy, rather than exogenous, unpredictable technological inventions; b. identifying "technology" as human capital, or **knowledge**. By this view, knowledge breeds greater knowledge. Some new knowledge translates into higher productivity of existing resources (embodied human capital), and some is manifested through innovations, patents, books and manuscripts, and specialized capital goods that account for what is commonly perceived of as technical innovations ("disembodied human capital"). Human capital is ultimately the source of both types of "technology", and can therefore be considered the "engine of growth" (see Lucas, 1988, Becker et al., 1990, and Ehrlich and Lui, 1991).

The reason persistent growth is enabled by human capital formation is that knowledge is **the only asset that is not subject to diminishing returns,** as Frank Knight argued. The idea can be formalized in a simple way by specifying a law of human capital accumulation as follows:

(2) $H_{t+1} = A(H^e + H_t)h_t$

Here H_t and H_{t+1} represent the human capital stocks of a representative agent in generations t and t+1, A represents the technology of learning and human capital transfer, $(H^e + H_t)$ denotes production capacity (H^e representing fixed personal or family endowments and H_t acquired knowledge at t), which is transformed to real income, or output, at a constant, competitive wage rate w=1; and h_t represents the fraction of production capacity spent by members of generation t on the human capital formation of members of generation t+1. While the level of human capital attained by the next generation, H_{t+1}, could in principle be subject to diminishing returns in the rate of investment by the current generation, h_t, it is specified as a linear function of the human capital attained by the current generation by the argument that attained knowledge enhances the productivity of both investment in new knowledge and the intergenerational knowledge transfer.

Human capital can thus grow from one generation to the other essentially because the level of productive knowledge attained by a current generation serves as an input into the generation of knowledge in the succeeding generation. But whether the latter exceeds the former (or $H_{t+1}>H_t$) and to what extent, critically depends on whether investment in human capital exceeds a threshold level: note that if investment, h_t, is not sufficiently high, the productive knowledge attained by generation t+1 will be stuck at the same level of generation t, H_t, producing a stagnant equilibrium level of output. In a decentralized market economy and a democratic political system, investment in human capital is affected directly by individuals and families, as well as indirectly by the level of public spending they demand from their local and federal government.

Of course, the production of human capital is a necessary, but not a sufficient condition for expansion in productive capacity. Implicit in this analysis is the assumption that human capital accumulation translates to expansion in output desired by its users (Y) through the aggregate production function summarized in section 1 and the accommodating role of efficient markets. The endogenous growth paradigm indicates that in a steady state of continuous growth, physical capital accumulation, including natural resources and land, would adjust to the pace of human capital accumulation, making the latter the economy's engine of growth. At a given population level, continuous human capital formation will lead to continuous expansion in real output per-capita (y). Human capital (H) thus replaces the concept of "technology" (T) in equation (1).

The model outlined in the preceding discussion is a closed economy model. In an open economy, expansion of output is also conditional on the ability of the economy to retain the human capital it produces. The US was not the first to take off: the Industrial revolution began in Europe. But the emergence of the US as economic superpower can be attributed to the ability of the US market to provide a high reward for human capital investments, and thus to both retain domestically-produced human capital and attract human capital produced abroad.

B. The special role of higher education in economic growth.

The previous analysis also rests on the simplifying assumption that workers are homogenous. In reality, people are heterogeneous in terms of both innate ability and family endowments they possess. A more complete view of endogenous growth and development, based on human capital as engine of growth, must recognize differences among individuals and families in terms of their capacity to both acquire and implement knowledge. This is the framework used in my current joint work on income growth and income inequality (Ehrlich and Kim, 2004) which is used to explain the dynamic pattern of both income growth and income distribution over different stages of economic development.

The story is simple: human capital, as measured by average educational attainments, has a direct effect on the skill and productivity of the existing labor force, but also an indirect effect on the emergence of new ideas i.e., technological innovations and productivity growth. Those who are in a position to acquire more human capital, especially higher education, because of personal ability or family endowments allowing them to more economically finance higher education, are likely to be the "first movers" when it comes to create new knowledge, or implement advances in knowledge triggered by technological shocks. Both schools and the labor market also allow for the **socialization of knowledge**, whereby the achievements of workers with superior knowledge can spill over to, and be shared by, other workers. These "spillover effects" tie population groups of different human capital attainments together over the development process as well as in a regime of persistent growth, and ultimately produce stable income distributions. The existence of spillover effects and imperfections in the capital market also justify government's subsidization of education, and especially higher education, in order to maximize social income and welfare.

C. The role of underlying factors

The endogenous growth models described above are **general equilibrium** models. In such models, both human capital accumulation and income growth are "endogenous" choice variables: they attain self-sustaining growth as a consequence of individual choices about optimal investments individuals make in themselves and their offspring, motivated by a desire to maximize the return they obtain on these investments. Individual welfare maximization in a decentralized market system thus leads to continuous, self-sustaining growth for the average person in the economy – a dynamic restatement of Adam Smith's basic proposition.

But this also means that human capital accumulation and income growth are two sides of the same coin: while the production functions (1) and (2) represent a causal relation flowing from per-capita human capital formation (H) to per-capita income (y), this is a secondary causality. The primary one relates to the causal effects of underlying "parameters" which influence both variables; most importantly, factors enhancing the incentives individuals and families have to invest in their own, and their offspring's, knowledge, as well as the ability of the domestic economy to effectively utilize the human capital it generates or imports in domestic production.

Obvious parameters affecting both output and knowledge accumulation are knowledge production and transfer technologies (A and B(T) in equations 2 and 1), population longevity (see Ehrlich and Lui, 1991), which enable those investing in learning and training to recoup the benefits of their investments over a longer life-time horizon. Equally important, however, are institutional and public policy factors affecting **market** conditions that assure a competitive return to investors in both human and physical capital in labor and product markets. These include a legal system protecting property rights, including intellectual property, and a free-enterprise system where wages and rates of return on investment are determined by competitive market forces rather than bureaucratic intervention. They also include accommodating public policies which help overcome capital market constraints in education financing and internalize spillover effects generated by basic science. These conditions, as well as government regulations and tax policies, can thus greatly affect human and physical capital accumulation, hence output growth, by the way they enhance or discourage the incentive to invest.

Under a heavily regulated system, let alone a command economy, the bureaucracy rather than free markets determines the allocation and remuneration of resources, including education. The Soviet Union invested broadly in education that assured military might, not necessarily economic might, and fostered investment in “political capital”, promising bureaucratic power to apparatchiks, rather than in market-driven productive human capital (see Ehrlich and Lui, 1999.) A free-market system is better geared to reward human capital of the productive type through the market mechanism, and is thus more likely to produce self-generating growth.

Free trade and an open economy create greater opportunities for human capital accumulation, but also greater challenges. Greater opportunities, because investment in “disembodied knowledge” such as new production processes or new products is subject to scale economies that make their returns higher in a larger markets, which are facilitated by free trade. Greater challenges, because opportunities to migrate from one region or country to another mean that investment in human capital made in one place may actually wind up benefiting another. Public investment in human capital in Peru, or in Ireland before 1986, for example, did not bring about an economic takeoff and self-sustaining growth partly because graduates of institutions of higher learning sought employment in the US market rather than in their own countries. But this does not refute the thesis that investment in human capital is the key to economic growth. It simply reflects the fact that investment that is not backed up by a market system that assures an adequate reward to knowledge cannot be expected to yield its full economic benefits.

A final underlying factor is the role of externalities inherent in both the production and transfer of human capital. Private human capital, unlike physical capital, cannot serve as collateral in financial markets, which limits borrowing opportunities. This justifies a public role in the financing of education at all levels, but especially for higher education where investment is substantial, which enhances accessibility to such educational opportunities according to talent, rather than social class and privilege. Moreover, since higher education can generate spillover effects benefiting less educated workers, subsidizing it becomes an especially important role of government. That the US was a leader in opening up mass high school and higher-education systems has been a significant factor explaining its emergence as an economic superpower.

6. Evidence linking education and productivity growth:

A. Evidence from growth accounting

Estimates of the role of schooling in explaining per-worker income variations or growth rely on a "growth accounting methodology", following the works of Denison (1974) and Solow (1957). The technique ascribes changes in the aggregate economy (GDP per-capita) to variations in aggregate measures of capital utilization and labor employment, with the labor employment index weighted by measures of the education attainments of workers. Claudia Goldin and others estimate that over the 20th century (actually since 1915) the expansion in the educational index has accounted for close to a quarter of the 1.62 percent per-year increase in US labor productivity. Hall and Jones (1999) estimate that in 1988, educational attainments account for over 20 percent of the international variation in labor productivity across different countries.

These growth-accounting studies are limited in a few respects. They are based on levels of per-capita income comparisons rather than long-term rates of growth of per-capita, or per-worker income, and they overlook the fact that international data represent countries in different development stages. Common to all studies using the growth accounting methodology is that they report a substantial "unexplained" residual variation, known as the "Solow residual". It is generally attributed to "technological growth."

However, much of this residual technological growth component may be ascribed to the **indirect** role of education in inducing technological advancements, as technology is a derivative of special knowledge, or specific human capital. Indeed, this is the crux of the "endogenous growth" literature that identifies human capital as the engine of growth, and ascribes its formation to internal forces operating within a free-market system.

B. Evidence from rates of return to education

That education is the critical factor explaining differences in earnings across individuals at a point in time has been well established by human capital theory and related empirical work. The human-capital-earnings-generating function links the logarithm of individual earnings to the number of years of schooling and a quadratic specification of the number of years of job-market experience. This specification allows the measurement of the "rate of return to human capital" as the regression coefficient associated with the number of years of schooling. **Table 9**, based on a study by Heckman et al. (2003), provides evidence that the rate of return to schooling at all levels has been stable at upward of 10% in 6 decennial years, but has approached 13% in 1990. More important, by estimating separate regressions for white and black males, this study shows that over the period 1940-1990, rates of return to blacks, initially lower than those of whites, have more than caught up with the latter in 1990, indicating that the US labor markets have become more competitive over time, and better able to reward human capital regardless of race.

The Mincer linear regression model does not allow for separate estimation of rates of returns by alternative levels of schooling. By relaxing various linearity restrictions implicit in the Mincer model, however, Heckman et al. (2003) have estimated rates of return for primary, secondary and tertiary levels of schooling as well. Their results indicate that the rates of return are considerably higher for those actually completing High School and College education relative to other levels of schooling[5]. Other studies indicate that that the rate of return to especially college education rises at times of rapid technological innovation, essentially because people with higher skills adapt more quickly to changes in technology.

These studies focus on returns to education captured in market earnings. New work in economics indicates that this may greatly understate the full individual returns to education, which are derived from various non-market activities as well, such as improved health, longevity, and implicit individual assessments of their own life-saving values. Ehrlich and Yin (2005), e.g., estimate that both age-specific life expectancies and implicit private values of life-saving are substantially higher for those with tertiary, relative to high-school education.

C. Linking investment in schooling and per-capita income growth

Empirical studies linking educational attainments and economic growth have not produced uniform conclusions, partly because of disagreements about the quality of available schooling data. Barro and Lee's (1993) study, for example, indicates some positive but weak correlation between the overall schooling data they assembled and growth rates. Following Ehrlich and

Kim 2005, we here attempt to develop a different perspective on the link between human capital formation and growth by stressing the correspondence between **investment** in human capital, rather than the **level** of human capital attainments, and long-term growth rates of per-capita income. By our theoretical analysis, the long-term rates of investment in human capital, which are endogenous outcomes of underlying demographic, institutional and public policy variables, are the critical determinant of long-term growth rates of both per-worker human capital stocks and per-capita real output in a self-sustaining growth-equilibrium regime. While data on investment in education are not readily available, they can be inferred from time-series evidence on the rate of growth of educational attainments in different countries. We thus expect a close link between equilibrium values of average **growth rates** of educational attainments per-worker (H) and per capita GDP (GDPn) over relatively lengthy periods of time in countries experiencing persistent growth. To test this hypothesis, we first estimate expected growth rates of per-capita GDP, [1+g(GDPn)*], and schooling attainments, [1+g(H)*], based on underlying country-specific factors through a regression model described below, and then compute their association using the following log-linear regression specification:

(3) $\text{Log}[1+g(GDPn)]^* = \alpha + \beta \log[1+g(H)]^*$.

Specifically, we use data on the average schooling years attained by the population aged 15-65 from Barro and Lee (2003) and Summers and Heston estimates of real GDPn as proxies for our endogenous variables, along with data on explanatory variables listed below, to construct a panel data set from 57 developing and developed countries over a period of 31 years (1960-1991). We first run fixed-effects regressions relating each of our two endogenous variables to a set of underlying country-specific factors. These include demographic variables (population longevity measures), public policy variables (the share of government spending in GDP and a measure of the social security tax rate), as well as chronological time and the interaction terms of these explanatory variables with time. (For an explanation of the role of these explanatory variables see Ehrlich and Kim, 2005.) The fixed-effects specification also accounts for the role of idiosyncratic institutional factors that are unchanging over the sample period. This method allows us to generate **multiple** predicted values of g(GDPn)* and g(H)*, in each country over our sample period. We can then estimate equation (3) using an OLS regression model. Variant 1 of the model imposes a common intercept term (α) representing the same technology linking human capital formation to output growth in all countries, whereas variant 2 allows for variation in the latter, using a fixed-effects regression specification.[6]

The idea behind this experiment follows the basic thesis underlying our endogenous growth model. If human capital is the engine of growth, the equilibrium rates of growth of human capital and real income should be endogenous outcomes of the economy's institutional and demographic factors, including the degree of government intervention in private economic activity. If each of these two variables is predicted separately from these underlying country-specific "parameters", they should be closely related within countries. The results are presented in **Figure 3** and **Table 10**. Figure 3 shows the scatter of estimated expected growth rates of per-capita GDP and average schooling attainments within countries. The line going through this scatter represents the estimated regression line of variant 1 of equation (3). Table 10 shows also the estimated results of variant (2) of equation (3), which cannot be depicted graphically. The results in Table 10 indicate the existence of a statistically significant correlation between the predicted **growth rates** of per-capita schooling attainments and real income within countries in our panel. These results are experimental and preliminary, however. Better measures of human capital formation and more elaborate sensitivity analyses are required to confirm their validity.

EPILOGUE: Looking back and looking ahead

Although the evidence assembled in this paper concerning the long-term growth dynamics of per-capita GDP and schooling attainments is largely "circumstantial", it appear to be remarkably consistent with the view that human capital formation has been the "secret weapon" through which the US has been able to facilitate its robust long-term rate of persistent, self-sustaining growth in productivity and per-capital income. Moreover, it supports the hypothesis that the documented educational gap between the US and Europe in terms of average, high school, and especially higher education attainments is a major factor explaining why the US has overtaken Europe as an economic superpower in the 20th century. Can the US maintain its lead in the 21st century?

Since schooling gaps are closing between the US and Europe, there is reason to believe that Europe could catch up with, and might even surpass, the US in human capital formation and in per-capita income growth as well. But differences in the economic systems between the EU and the US still militate in favor of the US, where the private sector constitutes a larger share of the economy, and where human capital attainments are well rewarded by relatively freer labor and product markets.

Looking back, it is ultimately the efficiency of the free-market economy in the US which has provided a relatively high rate of return to investment in education - higher education in particular - and enabled efficient accumulation of human capital, whether domestically produced or imported. The democratic political system in the US has also augmented the process of human capital formation through prudent government subsidization of education generally, and higher education in particular, much ahead of similar efforts by Europe. These accommodating factors have been a major determinant of the ability of the US to attract human capital from other countries as well. Looking ahead, one may conclude that continued emphasis on education - higher education in particular - and support of an economic climate that encourages human capital formation and technological innovation, could sustain the US lead for years to come.

The US still enjoys a significant advantage in terms of the quality of its higher education system relative to Europe and other countries. At the same time, there are strong indications of the failure of the public elementary system in the US to produce competitive educational outcomes relative to other countries. Recognition of current shortcomings in the public education system in the US, along with the challenge to compete with educational systems in other countries, may improve human capital formation in the US at all levels. Whether or not the US lead is maintained, world welfare would be best served when **all** countries adopt competitive economic and educational policies yielding continuous human capital formation, per-capita income growth, and equitable income distributions.

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Footnotes

[1] These statistics are taken from Maddison (2003). All figures are converted to 1990 US dollars using the Geary Khamis Purchasing-Power-Parity (PPP) method. Very similar graphs pertain also to other major European countries. For example the growth rates of GDP and GDP per capita (in parentheses) over the period 1870-2001 were 2.207 (1.859) for France, 2.362 (1.780) for Germany, and 2.528 (1.953) for Italy. The US numbers over this same period were 3.411(1.872). The US overtook each of these countries in both GDP and GDP per-capita over the period 1840-1880.

[2] Early comparative educational data are difficult to collect. Some economic historians believe, however, that the US relative advantage in education was showing up even before 1913, which would even more strongly support the basic thesis of this paper.

[3] See Statistics of Land-Grant Colleges and Universities [LGCU], Year ended June 1961, US Department of Health Education and Welfare, Office of Education. In June 2005, the LGCU national association had 214 members. This includes 76 land-grant universities (36% of the membership), of which 18 are the historically black public institutions created by the Second Morrill Act of 1890, and 27 public higher education systems (12% of the membership). In addition, tribal colleges became land-grant institutions in 1994 and 33 are represented in NASULGC through the membership of the American Indian Higher Education Consortium (AIHEC).

[4] For a survey of European school systems, see section B (Structures and Schools) of *Eurodice*, (2000) "Key data on education in Europe -1999/2000 edition," *Eurodice*, Brussels, Eurostat.

[5] International comparisons using Mincer's model or related techniques are hampered by absence of comparable data. Existing evidence suggests, however, that estimated rates of return in the US tend to be high relative to those in other highly developed countries (See, e.g., Psacharopulous and Patrinos, 2002). Less developed countries may show unusually high rates of return to schooling during a takeoff period from stagnation to continuous, self-sustaining growth regimes.

[6] The analysis involves the following steps. In step 1 we run fixed-effects regressions of log(GDPn) or log(H) as a dependent variable on a set of regressors as follows: t, t*log(Pi1), t*log(Pi2), t*log(G), t*log(PEN), log(Pi1), log(Pi2), log(G), log(PEN), where t is chronological time in years , PEN is a measure of the social security tax rate, Pi1 and Pi2 are probabilities of survival of children to adulthood and of adults to old age, respectively, and G is the share of government spending in GDP. (For detail see Ehrlich and Kim, 2005.) In step 2 we compute multiple predicted country-specific growth rates of GDP and H over the entire sample period, g(GDPn)* and g(H)*, based on the estimated regression coefficients involving t and the interaction terms of the basic explanatory variables with t from step 1. This produces a large scatter of observations on 1+g(GDPn)* and 1+g(H)* allowing a relatively precise estimation of equation (3). In step 3 we then estimate variants 1 and 2 of equation (3) via OLS and fixed-effects regressions. Since the countries in our panel are in varying development stages, in additional regressions which we skip here for simplicity, we also allow the intercept terms in variants 1 and 2 to drift downward over time, which our model predicts to occur over the development process. These regressions produce very similar results to those reported in table 10, and have even higher explanatory power.

Table A: **Comparison of GDP Per-Capita for the top 25 countries (US dollars converted using Purchasing Power Parity)**

Country	Per Capita GDP	Estimate Year	Country	Per Capita GDP	Estimate Year
Luxembourg	58900	2004	Austria	31300	2004
Jersey	40000	2003	Belgium	30600	2004
United States	40100	2004	United Kingdom	29600	2004
Norway	40000	2004	Netherlands	29500	2004
Bermuda	36000	2003	Japan	29400	2004
San Marino	34600	2001	Finland	29000	2004
Hong Kong	34200	2004	Aruba	28000	2002
Switzerland	33800	2004	Germany	28700	2004
Cayman Islands	32300	2004	France	28700	2004
Denmark	32200	2004	Sweden	28400	2004
Ireland	31900	2004	Monaco	27000	2000
Iceland	31900	2004	Singapore	27800	2004
Canada	31500	2004			

Sources: http://www.cia.gov/cia/publications/factbook
http://www.worldfactsandfigures.com/gdp_country_desc.php

Table 1: ***Average years of Formal Educational Experience of the Population Aged 15-64 in 1913, 1989, and 2003****

1913

Country	Total (Rank)	Primary (Rank)	Secondary (Rank)	Higher (Rank)
France	6.18 (4)	4.31 (5)	1.77 (4)	0.10 (3)
Germany	6.94 (2)	3.50 (6)	3.35 (1)	0.09 (4)
Japan	5.10 (6)	4.50 (4)	0.56 (6)	0.04 (6)
Netherlands	6.05 (5)	5.30 (1)	0.64 (5)	0.11 (2)
United Kingdom	7.28 (1)	5.30 (1)	1.90 (2)	0.08 (5)
United States	6.93 (3)	4.90 (3)	1.83 (3)	0.20 (1)

1989

Country	Total (Rank)	Primary (Rank)	Secondary (Rank)	Higher (Rank)
France	11.61 (3)	5.00 (5)	5.29 (2)	1.32 (2)
Germany	9.58 (6)	4.00 (6)	5.20 (3)	0.38 (6)
Japan	11.66 (2)	6.00 (1)	4.95 (4)	0.71 (3)
Netherlands	10.51 (5)	6.00 (1)	3.82 (6)	0.69 (4)
United Kingdom	11.28 (4)	6.00 (1)	4.75 (5)	0.53 (5)
United States	13.39 (1)	6.00 (1)	5.72 (1)	1.67 (1)

2003*

Country	Total (Rank)	Primary (Rank)	Secondary (Rank)	Higher (Rank)
France	11.50 (6)	5.03 (6)	5.11 (4)	1.36 (4)
Germany	13.40 (2)	6.09 (5)	5.72 (1)	1.59 (3)
Japan	12.40 (5)	6.11 (3)	5.00 (5)	1.29 (5)
Netherlands	12.90 (3)	6.38 (1)	4.92 (6)	1.60 (2)
United Kingdom	12.70 (4)	6.11 (3)	5.43 (3)	1.16 (6)
United States	13.80 (1)	6.38 (1)	5.71 (2)	1.71 (1)

* Note: data for 2003 relate to population aged 25-64

Sources: Maddison (1991, p.64) for 1913, 1989

http://www.oecd.org/dataoecd/22/35/35282639.xls (Table A1.4) for 2003

Table 2: ***Percentage of the population that has attained at least tertiary education Type-A by age group (1998 and 2003)***

Country	1998					2003				
	25-64	25-34	35-44	45-54	55-64	25-64	25-34	35-44	45-54	55-64
Australia	17	19	18	16	10	20	25	21	20	14
Austria	6	7	8	5	4	7	8	8	7	5
Belgium	12	16	13	10	6	13	18	14	11	8
Canada	19	23	18	18	13	22	28	22	20	18
Czech Republic	10	10	12	10	8	12	12	14	11	10
Finland	13	14	15	13	8	16	23	17	14	12
France	11	15	10	10	6	14	22	13	11	10
Germany	14	14	16	15	10	14	14	15	15	12
Greece	11	15	14	10	6	13	17	15	12	7
Hungary	13	14	14	14	10	15	17	16	15	14
Iceland[1]	16	19	18	15	9	20	23	22	19	12
Ireland	11	16	11	7	5	16	23	16	13	9
Italy [1]	9	9	11	9	5	10	12	11	10	7
Japan	18	23	23	15	9	21	26	25	20	12
Korea	17	23	19	11	8	22	30	26	14	9
Luxembourg	na	Na	Na	na	na	6	7	7	6	4
Mexico	12	15	14	10	5	14	16	15	12	7
Netherlands[1]	24	27	26	23	17	22	25	23	21	17
New Zealand	13	16	13	12	7	16	21	17	15	10
Norway	24	27	25	22	17	29	37	30	25	20
Poland	11	12	10	11	10	14	20	13	11	11
Portugal	7	8	7	5	4	8	13	9	6	3
Slovak Republic	na	Na	Na	na	na	11	13	11	12	8
Spain	14	21	16	11	6	18	26	19	14	9
Sweden	13	10	14	15	11	18	24	17	17	16
Switzerland	14	16	15	13	11	18	20	19	16	15
Turkey	6	7	7	6	3	10	11	8	9	7
United Kingdom	15	17	17	15	11	19	24	19	18	14
United States	27	27	26	29	22	29	30	29	30	27
Country Mean	14	16	15	13	9	16	20	17	15	12

Note: Denmark is omitted in this table because the reported annual data for tertiary type-A attainments in Denmark are incompatible between 1998 and 2003. But the overall country mean includes Denmark.

Source: Education at a Glance 2000, p.36 (Table A2.2b)
http://www.oecd.org/dataoecd/22/35/35282639.xls (Table A.1.3a)

Table 3: ***Distribution of the population that has attained at least upper secondary education, by age group (1998 and 2003)***

Country	1998					2003				
	25-64	25-34	35-44	45-54	55-64	25-64	25-34	35-44	45-54	55-64
Australia	56	64	58	52	44	62	75	64	58	47
Austria	73	84	78	68	56	79	85	83	75	69
Belgium	57	73	61	51	34	62	78	68	55	43
Canada	80	87	83	77	65	84	90	86	83	71
Czech Republic	85	92	88	84	74	86	92	90	84	77
Denmark	78	85	80	78	67	81	86	82	80	74
Finland	68	84	78	62	41	76	89	85	73	55
France	61	75	63	56	41	65	80	69	59	48
Germany	84	88	87	84	76	83	85	86	84	78
Greece	44	66	52	36	22	51	72	60	44	28
Hungary	63	77	73	65	31	74	83	81	75	53
Iceland[3]	55	61	58	55	40	59	64	62	58	48
Ireland	51	67	56	41	31	62	78	67	52	38
Italy[3]	41	55	50	35	19	44	60	50	39	24
Japan	80	93	91	77	57	84	94	94	82	65
Korea	65	92	70	45	27	73	97	83	55	32
Luxembourg	na	Na	Na	na	na	59	68	61	54	50
Mexico	21	26	23	16	9	21	25	24	18	12
Netherlands[3]	64	74	68	59	50	66	76	71	62	53
New Zealand	73	79	77	69	58	78	84	81	76	64
Norway	83	93	88	78	65	87	95	92	85	76
Poland	54	62	59	53	37	48	57	49	46	40
Portugal	20	29	20	14	12	23	37	22	16	10
Slovak Republic	na	Na	Na	na	na	87	94	91	84	70
Spain	33	53	38	23	12	43	60	48	33	19
Sweden	76	87	80	73	60	82	91	88	80	69
Switzerland	81	88	83	80	71	70	76	72	68	61
Turkey	18	24	19	13	7	26	33	25	21	16
United Kingdom[2]	60	63	62	58	53	65	71	65	64	57
United States	86	88	88	87	80	88	87	88	89	85
Country Mean	61	72	65	57	44	66	75	70	62	51

Source: Education at a Glance 2000, p.35 Table A2.2
http://www.oecd.org/dataoecd/22/35/35282639.xls (Table A.1.2a)

Table 4: ***Expected years of tertiary education for all 17-year-olds (1998)***

Country	Full and Part Time	Rank	Full Time Only	Rank
Australia	2.3	5	1.4	16
Austria	1.8	14	1.8	8
Belgium	1.3	21	1.2	20
Canada	1.9	10	1.4	16
Czech Republic	0.9	24	0.8	24
Denmark	1.3	21	1.3	19
Finland	2.9	1	2.9	1
France	1.9	11	1.9	5
Germany	1.7	15	1.7	11
Greece	1.7	15	1.7	11
Hungary	1.6	19	0.9	23
Iceland	1.6	19	1.6	14
Ireland	na	~	na	~
Italy	2.2	7	2.2	4
Japan	na	~	na	~
Korea	1.9	11	1.9	5
Luxembourg	na	~	na	~
Mexico	0.8	25	0.8	24
Netherlands	2.2	7	1.9	5
New Zealand	2.1	9	1.5	15
Norway	2.7	2	2.4	2
Poland	1.9	11	1.0	22
Portugal	1.7	15	1.7	11
Spain	2.5	4	2.3	3
Sweden	2.3	5	1.8	8
Switzerland	1.1	23	1.1	21
Turkey	0.8	26	0.8	24
United Kingdom	1.7	15	1.4	16
United States	2.7	2	1.8	8
OECD Average	1.8		1.6	

Source: Education at a Glance 2000, p. 158 Table C3.2

Table 5: ***Expenditure on educational institutions as a percentage of GDP for all levels of education by source of funds (1990, 1995, and 2002)***

	2002			1995			1990		
Country	Public1	Private2	Total	Public1	Private2	Total	Public1	Private2	Total
Australia	4.4	1.5	6.0	4.5	1.2	5.7	4.2	0.8	5.0
Austria	5.4	0.3	5.7	5.9	0.3	6.1	na	Na	Na
Belgium	6.1	0.3	6.4	na	na	Na	na	Na	Na
Canada	na	na	na	6.2	0.8	7.0	na	Na	Na
Czech Republic	4.2	0.2	4.4	4.7	0.7	5.4	na	Na	na
Denmark3	6.8	0.3	7.1	6.1	0.2	6.3	na	Na	na
Finland	5.9	0.1	6.0	6.2	x	6.3	na	Na	na
France	5.7	0.4	6.1	5.9	0.4	6.3	5.1	0.5	5.7
Germany	4.4	0.9	5.3	4.5	0.9	5.4	na	na	na
Greece3	3.9	0.2	4.1	3.1	n	3.2	na	na	na
Hungary	5.0	0.6	5.6	4.9	0.6	5.5	na	na	na
Iceland3	6.8	0.6	7.4	na	na	Na	na	na	na
Ireland	4.1	0.3	4.4	4.7	0.5	5.3	na	na	na
Italy	4.6	0.3	4.9	4.7	na	Na	na	na	na
Japan	3.5	1.2	4.7	3.5	1.1	4.7	na	na	na
Korea	4.2	2.9	7.1	na	na	Na	na	na	na
Luxembourg	na	na	na	na	na	Na	na	na	na
Mexico	5.1	1.1	6.3	4.6	1.0	5.6	na	na	na
Netherlands	4.6	0.5	5.1	4.5	0.4	4.9	na	na	na
New Zealand	5.6	1.2	6.8	4.8	na	Na	na	na	na
Norway	6.7	0.3	6.9	6.8	0.4	7.1	8.1	na	na
Poland3	5.5	0.7	6.1	5.7	na	Na	na	na	na
Portugal3	5.7	0.1	5.8	5.3	n	5.3	na	na	na
Slovak Republic	4.0	0.2	4.2	4.6	0.1	4.7	4.8	0.3	5.1
Spain	4.3	0.5	4.9	4.5	0.9	5.4	4.4	0.7	5.1
Sweden	6.7	0.2	6.9	6.1	0.1	6.2	5.1	n	5.1
Switzerland	5.7	0.5	6.2	5.4	na	Na	na	na	na
Turkey3	3.4	0.4	3.8	2.3	na	2.3	2.8	na	2.8
United Kingdom	5.0	0.9	5.9	4.8	0.7	5.5	4.2	0.1	4.3
United States	5.3	1.9	7.2	5.0	2.2	7.2	4.9	2.2	7.1
Country mean	5.1	0.7	5.8	~	~	~	~	~	~
OECD total	4.9	1.2	6.1	~	~	~	~	~	~

Source: http://www.oecd.org/dataoecd/2/11/35286380.xls (Table B2.1a)

Table 6: ***Annual expenditures on educational institutions per student (US dollars converted using PPP) by levels of education based on full-time equivalents (2002)***

Country	Primary	All secondary	Tertiary-type A	All tertiary
Australia	5169	7375	13410	12416
Austria	7015	8887	12701	12448
Belgium	5665	8272	Na	12019
Canada	na	na	Na	na
Czech Republic	2077	3628	6671	6236
Denmark	7727	8003	Na	15183
Finland	5087	7121	11833	11768
France	5033	8472	9132	9276
Germany	4537	7025	11860	10999
Greece	3803	4058	5646	4731
Hungary1	3016	3184	8187	8205
Iceland	7171	7229	8232	8251
Ireland	4180	5725	Na	9809
Italy1	7231	7568	8649	8636
Japan	6117	6952	11984	11716
Korea	3553	5882	7630	6047
Luxembourg	10611	15195	Na	na
Mexico	1467	1768	Na	6074
Netherlands	5558	6823	13163	13101
New Zealand	4536	5698	Na	na
Norway	7508	10154	Na	13739
Poland	2585	na	Na	4834
Portugal1	4940	6921	Na	6960
Slovak Republic	1471	2193	4756	4756
Spain	4592	6010	8074	8020
Sweden	7143	7400	Na	15715
Switzerland1	7776	11900	25524	23714
Turkey1	na	na	Na	na
United Kingdom	5150	6505	Na	11822
United States	8049	9098	Na	20545
Country Mean	5313	7002	~	10655
OECD Mean	5273	6992	~	13343

Source: http://www.oecd.org/dataoecd/2/12/35286348.xls (Table B1.1)

Table 7: ***Expenditure per student (public and private) relative to GDP per capita by level of education based on full-time equivalents (2002)***

Country	All secondary education	All tertiary education
Australia	27	45
Austria	30	41
Belgium	29	42
Canada	na	na
Czech Republic	22	38
Denmark	27	51
Finland	26	42
France	31	34
Germany	26	41
Greece	21	25
Hungary	22	57
Iceland	25	29
Ireland	18	30
Italy	29	33
Japan	26	43
Korea	32	33
Luxembourg	29	na
Mexico	19	65
Netherlands	23	44
New Zealand	26	na
Norway	28	37
Poland	na	43
Portugal	37	37
Slovak Republic	17	38
Spain	26	35
Sweden	26	56
Switzerland	37	73
Turkey	na	na
United Kingdom	23	41
United States	25	57
Country Mean	26	43

Source: http://www.oecd.org/dataoecd/2/12/35286348.xls (Table B1.2)

Table 8: ***Average combined mathematics literacy scores of 15-year-old students by percentiles (2003)***

Country	5th	10th	25th	75th	90th	95th	90th–0th difference
Australia	364	399	460	592	645	676	246
Austria	353	384	439	571	626	658	242
Belgium	334	381	456	611	664	693	284
Canada	386	419	474	593	644	673	225
Czech Republic	358	392	449	584	641	672	249
Denmark	361	396	453	578	632	662	236
Finland	406	438	488	603	652	680	214
France	352	389	449	575	628	656	239
Germany	324	363	432	578	632	662	269
Greece	288	324	382	508	566	598	242
Hungary	335	370	426	556	611	644	241
Iceland	362	396	454	578	629	658	233
Ireland	360	393	445	562	614	641	221
Italy	307	342	400	530	589	623	247
Japan	361	402	467	605	660	690	258
Korea	388	423	479	606	659	690	236
Luxembourg	338	373	430	557	611	641	239
Mexico	247	276	327	444	497	527	221
Netherlands	385	415	471	608	657	684	241
New Zealand	359	394	455	593	650	682	256
Norway	343	376	433	560	614	645	238
Poland	343	376	428	553	607	640	231
Portugal	321	352	406	526	580	610	228
Slovak Republic	342	379	436	565	619	648	241
Spain	335	369	426	546	597	626	229
Sweden	353	387	446	576	631	662	243
Switzerland	359	396	461	595	652	684	256
Turkey	270	300	351	485	560	614	260
United States	323	357	418	550	607	638	251
OECD Average	332	369	432	570	628	660	259

Source: http://nces.ed.gov/programs/coe/2006/section2/table.asp?tableID=464

Table 9: ***Estimated Coefficient from Mincer Log Earnings Regression for Men***

		Whites		Blacks	
		Coefficient	Std. Error	Coefficient	Std. Error
1940	Intercept	4.4771	0.0096	4.6711	0.0298
	Education	0.1250	0.0007	0.0871	0.0022
	Experience	0.0904	0.0005	0.0646	0.0018
	Experience-Squared	-0.0013	0.0000	-0.0009	0.0000
1950	Intercept	5.3120	0.0132	5.0716	0.0409
	Education	0.1058	0.0009	0.0998	0.0030
	Experience	0.1074	0.0006	0.0933	0.0023
	Experience-Squared	-0.0017	0.0000	-0.0014	0.0000
1960	Intercept	5.6478	0.0066	5.4107	0.0220
	Education	0.1152	0.0005	0.1034	0.0016
	Experience	0.1156	0.0003	0.1035	0.0011
	Experience-Squared	-0.0018	0.0000	-0.0016	0.0000
1970	Intercept	5.9113	0.0045	5.8938	0.0155
	Education	0.1179	0.0003	0.1100	0.0012
	Experience	0.1323	0.0002	0.1074	0.0007
	Experience-Squared	-0.0022	0.0000	-0.0016	0.0000
1980	Intercept	6.8913	0.0030	6.4448	0.0120
	Education	0.1023	0.0002	0.1176	0.0009
	Experience	0.1255	0.0001	0.1075	0.0005
	Experience-Squared	-0.0022	00.000	-0.0016	0.0000
1990	Intercept	6.8912	0.0034	6.3474	0.0144
	Education	0.1292	0.0002	0.1524	0.0011
	Experience	0.1301	0.0001	0.1109	0.0006
	Experience-Squared	-0.0023	0.0000	-0.0017	0.0000

Source: Heckman et al. (2003)

Table 10: ***Correlating Predicted Growth Rates in Per Capita GDP and Average School Years of the Adult Population (based on Ehrlich and Kim, 2005)***

	Intercept (α)	Slope(β)	t-value (β)	Adjusted R^2
Variant 1 *	0.00567	1.67458	21.23	0.3036
Variant 2 **	**	1.25854	11.40	0.3682

Number of observations = 1,032.

* OLS regression estimates of equation (3)
** OLS fixed-effects regression estimates of equation (3) allowing for country-specific intercepts, not reported in this table.

Econometric procedure: see text and footnote 6.

Figure 1: ***GDP Comparison UK and USA***

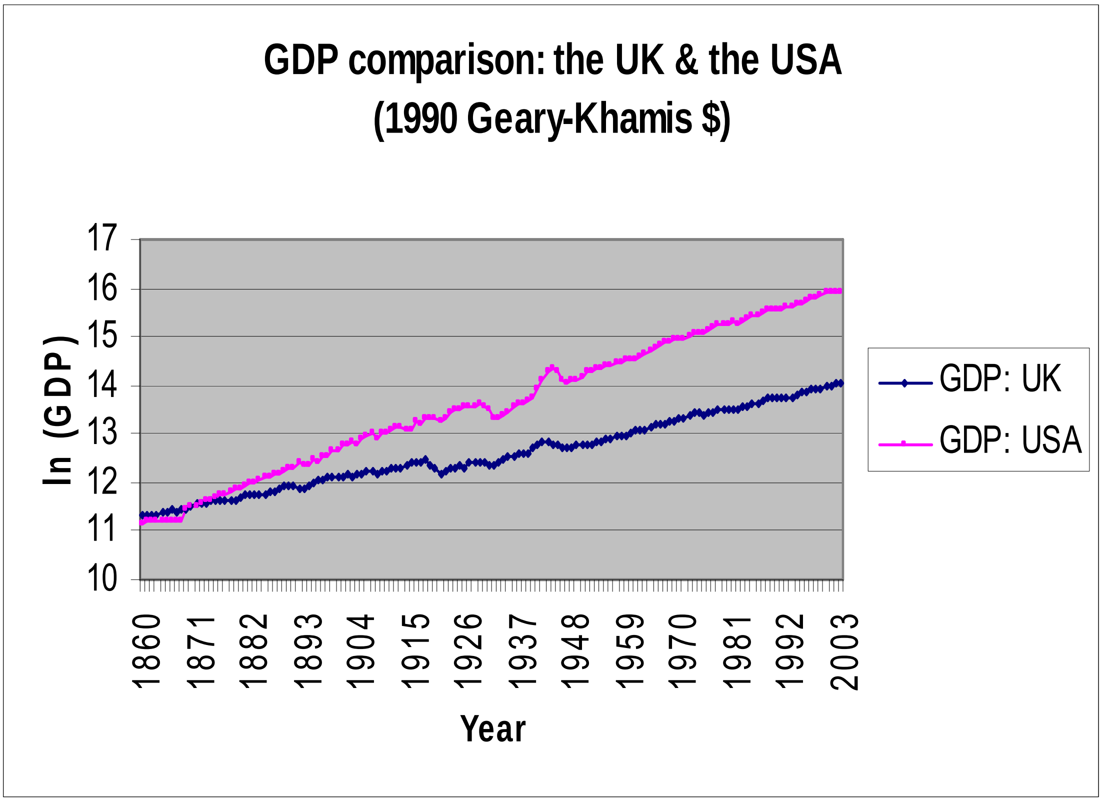


Figure 2: ***Per-Capita GDP comparison UK and USA***

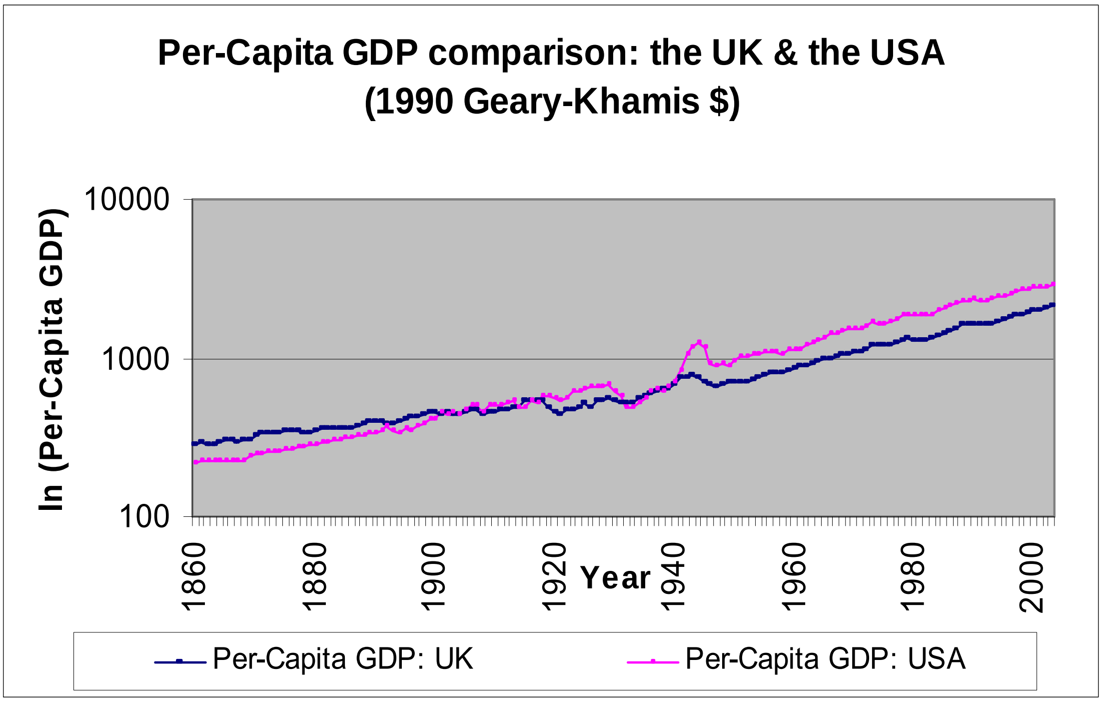
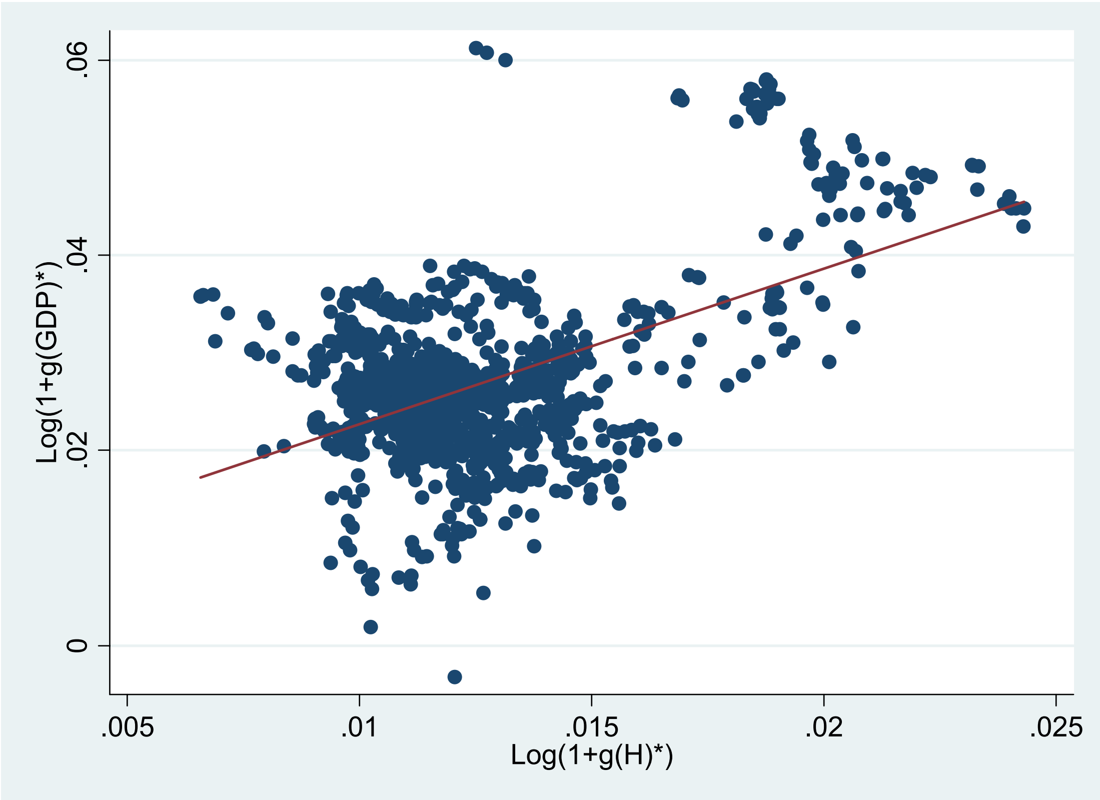


Figure 3: ***Correlating Predicted Growth Rates in Per Capita GDP and Average School Years of the Adult Population (based on Ehrlich and Kim, 2005)***



Note: The regression line in this scatter is based on Variant 1 of Equation 3.