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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. By human capital is meant an intangible asset, best thought of as a stock of embodied and disembodied knowledge comprising education, information, entrepreneurship, and productive and innovative skills, that are formed through investments in schooling, job training, and health, as well as through research and development projects and informal knowledge transfers. The conjecture is that the ascendancy of the US as an economic superpower in the 20th century owes in large measure to its faster human capital formation relative to the UK and "old Europe." Whether the thesis has legs to stand on is assessed through both stylized facts and some complementary empirical tests indicating that the US led other major developed countries in schooling attainments per adult population, beginning in the latter part of the 19th century and over the 20 century, especially at the secondary and tertiary levels. While human capital is viewed as a facilitator of, and a necessary condition for, long-term economic growth, the paper argues that it is not a sufficient condition. The underlying factors driving the US ascendancy are linked to the superior rates of return which the legal and political-economic system in the US has thus far offered as rewards for individual investments in human capital and their resulting innovative and entrepreneurial accomplishments, both home-produced and imported. This approach is compared to some alternative hypotheses about the underlying factors determining the prospects of long-term success or failure in fostering a persistent, self-sustaining economic growth and development.

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# Contents

# 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." This powerful concept is wrapped up in three layers of mystery. First, unlike physical capital, human capital is not a tangible asset. How, then, can we account for it empirically? Second, what explains its continuous formation over time? Third, how is such formation transformed into growth in real output and personal income?

One of the objectives of this essay is to unwrap this apparent mystery through an exposition of a general-equilibrium paradigm of economic development where human capital, or knowledge, 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 paradigm 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 such as market imperfections that affect adversely the accessibility and financing costs of schooling for those with borrowing constraints, or informal knowledge-spillover effects emanating from workers and entrepreneurs with superior education and skill, which enhance the productivity of others with whom they interact. The way these externalities are internalized may vary across different economies by the political and legal framework governing the economy, and as a consequence of accommodating economic and educational public policies, especially insofar as higher education is concerned. Such factors ultimately account for 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 U.S. as the world economic superpower, *overtaking* the U.K., and Europe in general. The U.S. was a relatively poor country over much of the nineteenth century. In the last few decades of that century, and especially during the twentieth century, however, the U.S. has *overtaken* the U.K. and other major European countries, and then developed considerable advantage over these 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 U.S. has developed a considerable gap over Europe in the schooling attainments of its labor force, especially at the higher education level. The gap remained significant through the entire twentieth century, although it narrowed in the latter part of it, and is continuing to narrow 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 U.S. foray into tertiary education beginning with the first Morrill Act of 1862, and continuing especially with the massive higher education movement following World War II. A basic argument of this paper is that the U.S. lead in knowledge formation, imperfectly measured by higher educational attainments, has been a major, and perhaps *the* major instrument through which the U.S. overtook Europe as the economic superpower in the twentieth 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 U.S. maintains a considerably larger level of per-capita income relative to practically all top twenty-five countries in the world, including even small tax-heaven countries (see Appendix A, Table A). In the early 1800s, however, the U.S. had levels of GDP and GDP per capita considerably below that of the U.K. and it was not until 1872 for GDP and 1905 for GDP per capita when the U.S. has overtaken the U.K. Figures 1 and 2 (see Appendix B) illustrate the comparisons poignantly. Abstracting from year-to-year and cyclical fluctuations, both the U.S. and U.K. graphs relating the logarithm of GDP or GDP per capita to chronological time appear over the long haul to resemble the shape of an upward-sloping straight line. The slope of each line represents the long-term annual growth rate of GDP or GDP per capita. The fundamental difference is that the slopes are higher for the U.S. relative to the U.K. In other words, the U.S. has overtaken the U.K. because its long-term growth rates have been higher: Over the 138-year period 1871–2008 (starting at the point of overtaking) the U.S. versus U.K. GDP growth rates have been 3.31% versus 1.93% per annum while the corresponding per-capita GDP growth rates were 1.8% versus 1.5%.[1] In recent decades, these gaps have narrowed. For example, over

[1] These statistics are taken from Maddison [2008]. All figures are converted to 1990 U.S. dollars using the Geary Khamis Purchasing-Power-Parity (PPP) method. Similar graphs apply to other major European countries as well. For example the growth rates of GDP and GDP per capita (in parentheses) over the period 1850–2008 – starting

the period 1961–2008, the comparative growth rates of GDP in the U.S. versus the U.K. were 3.19% versus 2.42%, while those for per-capita GDP were 2.2% versus 2.1%, respectively.[2] My basic thesis is that differences in long-term per-capita income growth stem primarily not from differences in physical stocks, including land or other natural resources, but from differences in the rates of growth of human capital. Both human capital formation and its impact on growth, however, are ultimately attributable to underlying institutional and policy factors which *reward* knowledge formation within an economy. In what follows I examine whether this hypothesis has a leg to stand on.

## 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 two-part question relates to determinants of the long-term *rate of growth*, as distinct from the *level*, of per-capita real income or GDP, taking the latter to represent a scalar measure of personal economic welfare.

A significant advance in the modern economic treatment of the problem came about with the neoclassical 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 persistent growth in per-capita income over time, which is a more relevant measure of private economic welfare than aggregate

when the U.S. overtook other major European countries in per-capita GDP – were: 3.42 (1.8) for the U.S.; 1.98 (1.5) for the U.K.; 2.03 (1.7) for France; 2.26 (1.7) for Germany; 2.25 (1.6) for Italy; 2.35 (1.8) for Spain.

[2] The shorter-term trends have been uneven for other major European countries. Over the period 1961–2003, e.g., the per-capita GDP growth rate in France and Italy were 0.21% and 0.40% higher than in the U.S., respectively, while in Germany it was 0.14% lower. However, over the period 1976–2003, the U.S.'s per-capita GDP growth was 0.28% higher than France's, 0.47% higher than Germany's, and 0.06% higher than Italy's.

income, strictly to exogenous technological shocks. This inference can be conveniently illustrated via the following "neoclassical" 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 conventional 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 neoclassical growth model suggests that the steady-state level of *per-capita* real income ($y$) is given by:

$$y^* \equiv B(T)f(k^*), \tag{1}$$

where $k^* \equiv (K/L)^*$ is the "golden rule," or equilibrium capital to labor ratio.

Growth in the equilibrium per-capita income level $y^*$ can thus occur by this analysis 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 labor and physical capital resources available to the economy at a point it time. In principle, therefore, the economic and regulatory policies that facilitate the operational efficiency of the market economy within which economic resources are utilized are also subsumed by this factor – a point that 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 two hundred 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 U.S. versus Europe). If "exogenous" factors, such as 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 continuous and self-sustaining technological advances as the outcome of persistent investment in human capital treated as a decision variable, subject to individual and social choice, within a dynamic, general equilibrium framework. The concept of human capital as an intangible asset is perhaps best defined as a stock of embodied and disembodied knowledge, comprising education, information, health, entrepreneurship, and productive and innovative skills, that is formed through investments in schooling, job training, and health, as well as through research and development projects, and informal knowledge transfers (see [Ehrlich, Murphy, 2007]). By this definition human capital has two inherent dimensions: "embodied" and "disembodied." The first is knowledge embodied in workers, or skill, which augments the productivity of labor and physical capital inputs at a point in time. The second is creative knowledge that flows from the minds of scholars, scientists, inventors, and entrepreneurs and increases their capacity to accumulate new knowledge. This "disembodied" knowledge is manifested in papers, books, patents, and algorithms, and winds up as *technological advances* – product and process innovations – at the firm and industry levels. It is thus more likely to be acquired and produced in tertiary institutions of teaching and research. While these types of human capital are distinct, they are also complementary, as creative knowledge feeds on previously accumulated embodied knowledge and facilitates the acquisition of new knowledge.

In this view, technology as popularly understood – inventions, innovations, scientific discoveries – does not "fall from heaven": it stems from decisions made by families, firms, and governments to invest in schooling, job training, and research and development, making human capital the relevant "engine," or facilitator, of growth. The fuel that feeds this engine are the rewards or *rates of return* offered by efficient markets and government policies to investments in knowledge formation, or human capital. Skill and creative knowledge can accumulate continuously in a given economy only if the underlying reward system in that economy supports a sufficient investment in skills and creative knowledge beyond a critical level.

But how does one measure human capital empirically? The empirical literature associated with this concept identifies it typically as a function of years of schooling and job experience. These measures must be supplemented, however, by corresponding measures of educational quality. Also missing are supplementary education and research efforts at the firm level, which become more important at advanced stages of development, and informal knowledge transfers. Indeed, the hypothesis that investment in schooling serves as an engine of long-term growth is yet to be verified through systematic econometric studies (but see Section 6 for some empirical insights). Nevertheless, I here venture to apply this hypothesis using as a case study the comparative long-term real income growth and educational attainment paths of the U.S. versus the U.K. and other major European countries over the last century. My dual hypotheses are: first, the economic overtaking of Europe by the U.S. beginning in the late nineteenth century, and its continuing dominance through the twentieth century, owe largely to the faster and more widespread schooling attainments, especially at the upper-secondary and the tertiary levels; and second, these differential schooling attainments, whether domestically produced or imported, are ultimately attributable to the higher reward the U.S. economy has offered to human capital attainments owing to accommodating political and institutional factors. To flash out these arguments I begin by surveying some historical evidence on the evolution of different schooling attainments in the U.S. relative to Europe over the twentieth century.

## 2. Evidence on educational attainments: Does the thesis have a leg to stand on?

The following is a summary of illustrative data on comparative educational attainments and educational spending by selected categories involving the U.S. 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.

### 2.1. Data on schooling attainments in the U.S. versus OECD countries over the last century

Highlights of Table 1 (see Appendix A) include Maddison's finding (1991) that in 1913 average schooling years in the U.S. (6.93) was behind Germany (6.94) and the U.K. (7.28). Japan had the lowest attainment (5.10). Even at that point, however, the U.S. 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 U.S. became the leader in schooling attainments at all levels. Average schooling years in the U.S. shot up to 13.39, ahead of Japan (11.66), France (11.61), and the U.K. (11.28). Germany slipped to last place at 9.58. The average number of higher-education years attained in the U.S. 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.[3] Unfortunately, no comparable data were available for the same population groups and countries in more recent years, but the following tables allow for such international comparisons using alternative educational attainment measures.

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

### 2.2.1. Schooling attainments

Table 2 (see Appendix A) shows that in 1998, the U.S.'s percentage of the population 25–64 years of age educated in tertiary type-A programs, defined as regular four-year colleges or universities and advanced research programs, reaches 26.6%, followed by Norway's 23.7%. In this year, the U.S. figure is decisively above Europe's five major economies: U.K., Germany, France, Italy, and Spain (E-5), while the average for all OECD countries is scarcely above half of the U.S. 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 U.S. percentage is 22%, relative to just 9% for the OECD average. By 2003 Norway catches up with the U.S. in the age group 25–64 at 29%, but the average for all OECD countries is still substantially below the U.S. (16%). In the age groups 45–54 and 55–64, however, the U.S. 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

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

tertiary educational attainments, the U.S. 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.)

Highlights of Table 3 (see Appendix A) include that in 1998 and 2003, the U.S. is leading in the age group 25–64 (86%, 88%), relative to the OECD means (61%, 66%) but much more so in the age group 55–64 (80%, 85%), where the second highest are Germany and Japan (76%, 78%). The gap narrows at younger age groups. In the age group 25–34 in 2003, the U.S. is in eighth place behind, Korea, Norway, Japan, the Czech and Slovak Republics, Sweden, Finland, and Canada, but above all the E-5, including Germany. These data indicate that a number of OECD countries have caught up with the U.S. in terms of secondary schooling in more recent years. But the U.S. again shows overwhelming leadership in terms of the proportion of the population that has attained at least tertiary education.

Table 4 (see Appendix A) demonstrates more vividly that while the U.S. 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 U.S., but France at 1.9 and the U.K. at 1.7 have not done so.

The attainments data tell a dynamic story: the U.S. advantage is highest in the older age categories. The gap is narrowing at the younger ages as well as over time, which indicates that Europe is closing the educational gap. But the U.S. still holds a commanding lead in the category of those who hold *at least* tertiary type-A education, especially at older age cohorts.

### 2.2.2. Expenditures on education

Comparative schooling attainments, as illustrated by Tables 1–4 are but one dimension of an effective measure of human capital. As important is the quality of the education experience. A possible measure of quality typically used by economists is educational *spending*, to which I turn next.

At 7.2% of GDP in 2002, the U.S. ranks 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 U.S. (Table 5, see Appendix A). But these numbers are not fully revealing because they do not account for the differences in the magnitude and composition of student populations across countries. More relevant are data on total spending per student, and these are much higher in the U.S. relative to other OECD countries (see below).

The U.S. expenditure per student on all levels of secondary education in 2002 was $9098, while the average among OECD countries was $6992 (Table 6, see Appendix A), but at this point the U.S. already ranks behind Switzerland ($11,900), and Norway ($10,154) (Luxembourg at $15,195, is not a comparable country). In the case of tertiary educational expenditures (both type A and B), however, the U.S. ($20,545) is second only to Switzerland ($23,714), and only Sweden ($15,715) and Denmark ($15,183) have spending levels above $15,000.

The U.S. 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 (Table 7, see Appendix A). To the extent that education can be considered a consumption good, this ranking indicates only that higher education in the U.S. 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 U.S. schooling advantage emerged: Major sources and trends

(a) *The secondary schooling advantage*. Claudia Goldin (see, e.g., [Goldin, 2001]) argues that what has been mainly responsible for the U.S. 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 U.S., set the stage for the subsequent transition to the mass higher education movement. In 1910, school enrollment rates for five-to nineteen-year-olds were fairly similar among the world's economic leaders (the ratio of enrollments relative to the U.S. set at 1 was: 0.93 in France, 0.96 in Germany, and 0.82 in the U.K.). But by 1930, the U.S. was three to four decades ahead of Britain and France, and the high school gap remained large until the 1950s. The median eighteen-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 World War II: 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 the previous explanation, however, is that the U.S. 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 and 1890, and related accommodating factors which made higher education in the U.S. 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 original Morrill Act, later supplemented by the Hatch Act of 1887, the second Morrill Act of 1890, and the Smith-Lever Act of 1914, 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, as 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 U.S., but some important facts allude to their significance. There were sixty-eight land-grant public institutions and universities located in the fifty states and Puerto Rico in 1961. Although at that point in time – following the explosion in tertiary institutions after World War II – these institutions, varying greatly in size from the University of California to Delaware State College, accounted for just less than 5% of all four-year institutions of higher learning, they still 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 U.S.[4]

[4] See Statistics of Land-Grant Colleges and Universities [LGCU], Year ended June 1961, U.S. Department of Health Education and Welfare, Office of Education. In June 2005, the LGCU national association had 214 members. This includes seventy-six land-grant universities (36% of the membership), of which eighteen are the historically black public institutions created by the Second Morrill Act of 1890, and twenty-seven public higher education systems (12% of the membership). In addition, tribal colleges became land-grant institutions in 1994 and 33 are represented in the National Association of State Universities and Land-Grant Colleges) through the membership of the American Indian Higher Education Consortium.

(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 seven years, approximately eight million veterans received educational benefits. Of that number, approximately 2.3 million 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 World War II had a high school diploma and were thus eligible to enroll in colleges and universities. The U.S. 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 U.S. in this regard over much of the second half of the twentieth 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 U.S. schooling advantage is immigration of human capital into the U.S. In an open economy human capital is not necessarily just homegrown – 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 U.S., but there is general agreement for the proposition that the U.S. became a magnet for skilled labor and scientists, first from Europe and later from Asia as well, following the economic advances of the U.S. in the twentieth 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 doctorates awarded to international students rose from 23% in 1966 to 39% in 2000, the share of temporary residence among science and engineering post-doctoral scholars increased from 37% in 1982 to 59% in 2002, and more than one-third of U.S. Nobel Laureates to date are foreign born.

A number of *caveats* need to be recognized, however, for a more complete assessment of the U.S. schooling advantage:

(i) The U.S. advantage at the tertiary level applies unequivocally to type-A institutions (regular four-year colleges/universities), but not as much to tertiary type-B, which are more vocational in nature. The latter has remained more popular in Europe. Also, the numbers do not include post formal training and apprenticeships, which are more prevalent in Europe.

(ii) However, schooling attainments, measured as the number of years of schooling or the percentage of the population with tertiary education, have institutional upper limits, for instance, a PhD degree, thus becoming a less effective measure of knowledge formation in highly developed economies. It is thus critical to take into account another dimension of educational attainments, which is more open-ended – schooling quality as captured by level of spending per student. In this regard, the educational gap between the US and the major European countries remains significant, as illustrated by Tables 5–7. Furthermore, investments in knowledge at the firm level via general on-the-job training and specific research and development programs are becoming a more important means of knowledge formation in the more developed economies. The U.S. may still hold a sizeable advantage over Europe in this supplementary human capital measure as well.

(iii) Both schooling lengths and expenditure levels are in essence "inputs" into effective human capital formation. The picture is far more mixed concerning "output" or quality measures, such as math test scores. Evidence indicates that the distribution of U.S. combined mathematics literacy scores of fifteen-year-old students is, in fact, below that of the average of OECD countries and in the mid-range of the E-5 countries (see Appendix A, Table 8). In contrast, at the tertiary level, U.S. academic institutions are generally ranked higher than Europe's and attract more international students and faculty.

## 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 U.S. is attributable to the U.S. developing into a larger open-trade area relative to European countries. Its labor force in the early twentieth 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 U.S. 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 gained momentum also because of the decentralized educational system in the U.S. owing to the fiscal independence of local school boards.

(c) *Feedback* w*ealth effects*. By the early twentieth century, the U.S. already had the highest income per capita, enabling families to more easily finance the higher education of offspring.

(d) *Educational policies*. The U.S. 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 twentieth century. Differences in institutional restrictions are manifested especially in the context of tertiary education. In the U.S., publicly subsidized higher education started with the Morrill Acts, becoming massive in 1944, while in Europe this process began later – in some countries not until the 1960s and 70s. In France, for example, 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. 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 U.S., 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 U.S. and Europe is fast closing.[5]

(e) *The political-economic systems*. Last, but not least, the U.S. has had a more democratic political system; e.g., suffrage was extended to all (white) U.S. males early in the nineteenth century, but much later in almost all European countries. It has also had a freer and more 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 U.S. has also had less regulated labor markets, and greater openness to external trade and immigration relative to Europe. These factors helped produce 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 U.S. in the twentieth century to the interplay of two main forces: first, the feedback effects on private demand for education generated by the new industrial economy, economic growth, and personal wealth; second, the impact of the more open economy and society in the U.S. 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 that 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 U.S. has 0 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 apparently 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 invest-

[5] For a survey of European school systems, see Section B (Structures and Schools) of [Eurodice, 2000].

ments 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 legal and political factors. Moreover, prudent political and economic policies 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

## 5.1. The endogenous growth hypothesis: Human capital as the engine of growth

The literature on endogenous growth attempts to go beyond the neoclassical model of economic growth in two important ways: (a) explaining persistent 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, manuscripts, and specialized capital goods that account for what is commonly perceived of as technological 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; Ehrlich, Lui, 1991]).

The reason persistent growth is enabled by human capital formation is that knowledge is *the only instrument of production that is not subject to diminishing returns*, as John Maurice Clark [1923] argued. The idea can be formalized in a simple way by specifying a law of human capital accumulation as follows:

$$H_{t+1} = A\,(H^e + H_t)\,ht \qquad (2)$$

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 per-capita real income, or output $y = (H^e + H_t)$, at an implicit constant competitive rental rate (normalized at 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, captured by $h_t$, it is specified as a linear function of the human capital attained by the current generation, $H_t$. The implicit argument is that attained knowledge and skill by any given generation enhances both the creation of new knowledge and the productivity of intergenerational knowledge transfer to the overlapping future generation, thus escaping diminishing returns.

Human capital can thus grow perpetually 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: by equation (2) if investment, $h_t$, is not sufficiently high, the knowledge attained by generation $t + 1$ will be stuck at the 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 accumulated human capital contributes to expansion in desired output ($Y$) through the aggregate production function introduced in section 1 and the accommodating role of efficient markets, which assure the allocation of skill and creative knowledge to their most productive uses. The endogenous growth paradigm indicates that in a steady state of continuous growth, physical capital accumulation, including natural resources and productive 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 U.S. was not the first to take off: the industrial revolution began in Europe. But the emergence of the U.S. as an economic superpower can be attributed to the ability of the U.S. 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.

## 5.2. 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, Kim, 2007] 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 schooling 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, that is, 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.

## 5.3. 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" that 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.

Basic parameters affecting both output and knowledge accumulation are knowledge production and transfer technologies – A and B ($T$) in equations 2 and 1 – and population longevity (see [Ehrlich, Lui, 1991]), which enable those investing in learning and training to recoup the benefits of their investments over a longer lifetime horizon. Equally important, however, are "institutional" factors, such as the "rule of law," a legal system which protects intellectual and property rights, 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 educational policies that help overcome capital market constraints in education financing and internalize spillover effects generated by basic science. These accommodating factors, including government regulations and tax policies, can greatly affect output growth by the way they enhance or discourage the incentives to invest in human capital. For example, 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 heavily in basic sciences used largely to promote military might, not necessarily economic might. Its *command* *economy* system also fostered investment in "political capital" promising bureaucratic power to apparatchiks, rather than in market-driven productive human capital (see [Ehrlich, 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, which make their returns higher in a larger market open to 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 U.S. 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 higher education, where investment is substantial, which enhances accessibility to such educational opportunities according to talent rather than social class and borrowing constraints. Moreover, since higher education can generate spillover effects on the productivity of less educated workers that are not fully internalized through a private reward system, subsidizing it becomes an especially important role of government. That the U.S. was a leader in opening up massive 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

## 6.1. 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 twentieth 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 U.S. 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.

Studies using the growth accounting methodology invariably find a substantial unexplained residual variation in productivity, known as the "Solow residual." It is generally attributed to "technological growth." However, much of this residual variation 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.

## 6.2. 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 formulated by Jacob Mincer 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 (see Appendix A), based on a study by Heckman, Lochner, and Todd [2003], indicates that the real rate of return to schooling thus measured has been stable at upward of 10% in six 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 U.S. labor markets have become more competitive over time, and better able to reward human capital regardless of race.

The Mincerian 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, Lochner, and Todd [2003] have also 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.[6] Other studies indicate that that the rate of return to especially college education shoots upward 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 nonmarket activities as well, such as improved health, longevity, and implicit individual assessments of their own life-saving values. Ehrlich and Yin [2005], for example, 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.

## 6.3. 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 [2007], we here attempt to offer a different

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[6] International comparisons using Mincer's model or related techniques are hampered by the absence of comparable data. Existing evidence suggests, however, that estimated rates of return in the U.S. tend to be high relative to those in other highly developed countries (see, e.g., [Psacharopulous, 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.

perspective on the link between education and growth by stressing the correspondence between *investments* in education, rather than the *level* of educational attainments, and long-term growth rates of per-capita income. By our theoretical analysis, the steady state rates of investment in human capital, which are endogenous outcomes of underlying demographic, institutional and public policy variables, are the critical determinant of corresponding long-term growth rates of both per-worker human capital stocks and per-capita real output in a growth-equilibrium regime. While reported data on educational outlays are incomplete, investment levels can be imputed from time-series evidence on relatively long-term rates of growth of schooling attainments in different countries. We thus expect a systematic link between equilibrium values of average growth rates of schooling attainments per worker ($H$) and per-capita GDP (GDPPC) 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, $[1 + g(\text{GDPPC})^*]$, and schooling attainments, $[1 + g(H)^*]$, which are predicted from underlying country-specific factors through a regression model described below, and then compute their association using the following log-linear regression specification:

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

Specifically, we use Barro and Lee [2003] data on average schooling years attained by the population aged 15–65, and Summers and Heston estimates of real GDPPC as proxies for our endogenous variables, along with data on explanatory variables listed below, to construct a panel of fifty-seven developing and developed countries over an intermediate-length period of thirty-one 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, Kim, 2007].) 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 $g(\text{GDPPC})^*$ 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 ($\alpha$) 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.[7]

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 the two endogenous variables of the model – human capital attainments $g(H)$ and real income $g(\text{GDPPC})$ – should be outcomes of the economy's institutional and demographic factors, including the degree of government intervention in private economic activity. If these two variables are predicted separately from these underlying country-specific "parameters," they should be closely related within countries. The results are presented in Figure 3 (Appendix B) and Table 10 (Aappendix A). Figure 3 shows the noisy 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. More complete measures of human capital formation and productivity growth over longer periods, and more elaborate sensitivity analyses, would be required to confirm the findings.

[7] The analysis involves the following steps. In step 1 we run fixed-effects regressions of log(GDPPC) or $\log(H)$ as a dependent variable on a set of regressors as follows: $t$, $t$*log($Pi$1), $t$*log($Pi$2), $t$*log($G$), $t$*log(PEN), log($Pi$1), log($Pi$2), log($G$), log(PEN), where $t$ is chronological time in years, PEN is a measure of the social security tax rate, $Pi$1 and $Pi$2 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, Kim, 2007].) In step 2 we compute multiple predicted country-specific growth rates of GDP and $H$ over the entire sample period, $g(\text{GDPPC})^*$ 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 $1 + g(\text{GDPPC})^*$ and $1 + g(H)^*$ allowing a meaningful 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.

## 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, even though imperfectly measured by schooling, has been the "secret weapon" through which the U.S. has been able to achieve 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 U.S. and Europe in terms of average high school, and especially higher education attainments, is a major factor explaining why the U.S. has overtaken Europe as an economic superpower in the twentieth century. Can the U.S. maintain its lead in the twenty-first century?

Table 11 (see Appendix A) summarizes the evidence on schooling attainments shown in Tables 2 and 3 for the 5 major European countries (E-5: Germany, U.K., France, Italy, Spain) expressed as percentages of the U.S.'s attainments over the period 1998–2003, which may serve as a rough indicator of the trends over the last few decades as well. Even over this short period we see evidence of closing educational gaps, primarily for upper high-school attainments, where the simple average level of schooling attainment for the age group 25–64 in the E-5 rose from 64.9% to 68.2% of that of the U.S. The gaps are closing even faster at the tertiary type-A level, where the corresponding simple average level of schooling attainments rose from 46.7% to 51.7%. Of all E-5 countries, the U.K. has converged most closely to the U.S.'s schooling attainments at the tertiary level, rising from 55.6% in 1998 to 65.5% in 2003.

However, as argued earlier, schooling attainments are subject to institutional upper limits (say, Ph.D. education), thus becoming a less effective indicator of human capital formation at more advanced development levels, where spending on educational quality and knowledge generated within firms may be more important supplementary measures of effective human capital. The US may still maintain a significant lead over much of Europe in these measures. Indeed, corresponding trends in long-term GDP and per-capita GDP (GDPPC) growth rates present a more mixed picture. Figure 4 shows how *percentage differences in long-term real GDPPC growth rates* between the U.S., U.K., and the E-5 (based on the Maddison 2003 data) have evolved over the last 150 years, as we gradually shift the starting reference period from 1850–2003 (the longest time period) to 1991–2003 (the shortest and recent time period). The long-term percentage differences indicate a consistent U.S. advantage, although they also exhibit quite a bit of noise and sensitivity to influential intermediate-term sub-periods. For example, over the Great Depression, the U.S. absolute GDPPC gap over the E-5 was declining significantly along with the U.S.'s long-term growth rate advantage before rising again during recovery. Over World War II and its aftermath, in contrast, the U.S. absolute gap over the E-5 was first rising because of the collapse of the E-5 economies, but was then falling because of the exceptionally high GDPPC growth rates in the E-5 over the following 2–3 decades of European recovery. More recently, however, the U.S. GDPPC growth rate advantage over the E-5 has trended back toward its 1850–2003 level.

One exception seems to be the U.K., where the U.S.'s long-term GDPPC growth-rate gap has been falling more steadily since the early 1930s, and again from the early 1960s when the U.K. has also made significant progress in relative educational attainments. In Germany, in contrast, the U.S.'s GDPPC growth-rate advantage has intensified since 1967, while its educational advantage over Germany has been increasing in more recent years. Thus even this, more recent evidence points to a positive correlation between relative growth rates of tertiary schooling attainments and per-capita GDP, at least in these two countries.[8]

Clearly, there are other forces in play which explain the evolution of comparative growth rates of the U.S. and the E-5 over the twentieth century, such as changes in labor market, welfare, free-trade, and immigration policies, but the U.S. advantage in human capital formation, as judged by schooling attainments especially at the tertiary level, seems to provide a powerful explanation for its long-term growth rate advantage over Europe.

Is the U.S. losing this advantage? The closing schooling gaps might indicate that Europe could catch up with, and even surpass this indicator of U.S.'s human capital formation and ensuing per-capita income growth. However, as figure 5 shows, the *absolute* historic gap between the U.S. and the E-5 in per-capita GDP levels is still far from closing, and it will continue to grow in absolute terms even if the respective growth rates converge. More important, future developments depend on the com-

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[8] Spain constitutes another example: while the U.S.'s long-term growth rate of GDPPC 1850–2003 slightly exceeds that of Spain, from 1877 Spain is reported to have had a higher growth rate, which expanded during World War II. Spain's advantage is still holding in recent years as well, but it also shows the highest percentage increase in higher-education attainments among the E-5, according to Table 12.

parative trends in the underlying causal factors which produced the U.S. long-term advantage in the first place.

Looking back, it is ultimately the relative efficiency of the free-market and open-economy system in the U.S. and the relatively higher *reward* it provided to skill and creative knowledge, which induced a higher rate of growth and efficient utilization of various components of human capital, whether domestically produced or imported. The democratic political system in the U.S. 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 U.S. to attract, and put to effective use, human capital from other countries as well.

Looking ahead, therefore, one may conclude that continued support of an efficient economic environment that assures a competitive reward to investment in human capital and encourages its persistent formation and utilization could sustain the U.S. lead for years to come. The U.S. still enjoys a significant advantage in terms of the quality of its higher education system and innovative activities relative to Europe and other countries. At the same time, there are strong indications of the failure of the public elementary system in the U.S. to produce competitive educational outcomes relative to other countries. Recognition of current shortcomings in the public education system in the U.S., along with the challenge to compete with educational systems in other countries, may improve human capital formation in the U.S. at all levels. Whether or not the U.S. lead is maintained is ultimately a secondary issue. World welfare would be best served if *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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# Appendix A: Tables

**Table A.** Comparison of real GDP per capita for the top 26 countries (U.S. dollars converted using purchasing power parity)*

| Country | Per Capita GDP | Estimate Year | Country | Per Capita GDP | Estimate Year |
|---|---|---|---|---|---|
| Singapore | 62400 | 2013 | Denmark | 37800 | 2013 |
| Norway | 55400 | 2013 | Belgium | 37800 | 2013 |
| United States | 52800 | 2013 | United Kingdom | 37300 | 2013 |
| Hong Kong | 52700 | 2013 | Japan | 37100 | 2013 |
| Switzerland | 46000 | 2013 | Finland | 35900 | 2013 |
| Canada | 43100 | 2013 | France | 35700 | 2013 |
| Australia | 43000 | 2013 | Israel | 34900 | 2013 |
| Austria | 42600 | 2013 | Korea, South | 33200 | 2013 |
| Netherlands | 41400 | 2013 | Saudi Arabia | 31300 | 2013 |
| Ireland | 41300 | 2013 | Spain | 30100 | 2013 |
| Sweden | 40900 | 2013 | UAE | 29900 | 2013 |
| Taiwan | 39600 | 2013 | Italy | 29600 | 2013 |
| Germany | 39500 | 2013 | Czech Republic | 27200 | 2013 |

*Table excludes countries with populations less than 5 million in 2013.

*Sources*: Central Intelligence Agency, The Word Factbook. <http://www.cia.gov/library/publication/the-world-factbook>

**Table 1.** Average years of formal educational experience of the population aged 15–64 in 1913 and 1989

| Country | Total (Rank) | Primary (Rank) | Secondary (Rank) | Higher (Rank) |
|---|---|---|---|---|
| **1913** | | | | |
| 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** | | | | |
| 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) |

*Source*: Data from Maddison [1991, p. 64].

**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 | 16 | 19 | 18 | 15 | 9 | 20 | 23 | 22 | 19 | 12 |
| Ireland | 11 | 16 | 11 | 7 | 5 | 16 | 23 | 16 | 13 | 9 |
| Italy | 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 | N/A | N/A | N/A | N/A | N/A | 6 | 7 | 7 | 6 | 4 |
| Mexico | 12 | 15 | 14 | 10 | 5 | 14 | 16 | 15 | 12 | 7 |
| Netherlands | 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 | N/A | N/A | N/A | N/A | N/A | 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:* [OECD, Education at a Glance, 2000, p. 36, Table A2.2b; OECD, Education at a Glance, 2005, Indicator A1: Educational attainment of the adult population <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 | 55 | 61 | 58 | 55 | 40 | 59 | 64 | 62 | 58 | 48 |
| Ireland | 51 | 67 | 56 | 41 | 31 | 62 | 78 | 67 | 52 | 38 |
| Italy | 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 | N/A | N/A | N/A | N/A | N/A | 59 | 68 | 61 | 54 | 50 |
| Mexico | 21 | 26 | 23 | 16 | 9 | 21 | 25 | 24 | 18 | 12 |
| Netherlands | 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 | N/A | N/A | N/A | N/A | N/A | 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 | 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*: [OECD, Education at a Glance, 2000, p. 35, Table A2.2; OECD, Education at a Glance, 2005, Indicator A1: Educational attainment of the adult population <http://www.oecd.org/dataoecd/22/35/35282639.xls>, Table A.1.2a].

**Table 2a and 3a.** Percentage of the population that has attained at least tertiary Type-A and Upper Secondary Education by age group (1998 and 2011)

| Country | 1998 | | | | | 2011 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** |
| | **At Least Tertiary Education Type-A** | | | | | | | | | |
| France | 11 | 15 | 10 | 10 | 6 | 18 | 27 | 21 | 13 | 12 |
| Germany | 14 | 14 | 16 | 15 | 10 | 16 | 18 | 18 | 15 | 15 |
| Italy | 9 | 9 | 11 | 9 | 5 | 15 | 21 | 16 | 11 | 11 |
| Norway | 24 | 27 | 25 | 22 | 17 | 36 | 46 | 39 | 31 | 26 |
| Spain | 14 | 21 | 16 | 11 | 6 | 22 | 27 | 25 | 20 | 15 |
| United Kingdom | 15 | 17 | 17 | 15 | 11 | 30 | 39 | 32 | 24 | 22 |
| United States | 27 | 27 | 26 | 29 | 22 | 32 | 33 | 34 | 30 | 31 |
| 29 OECD Countries Mean | 14 | 16 | 15 | 13 | 9 | 23 | 30 | 25 | 19 | 17 |
| | **At Least Upper Secondary Education** | | | | | | | | | |
| France | 61 | 75 | 63 | 56 | 41 | 72 | 83 | 78 | 68 | 58 |
| Germany | 84 | 88 | 87 | 84 | 76 | 86 | 87 | 87 | 87 | 84 |
| Italy | 41 | 55 | 50 | 35 | 19 | 56 | 71 | 60 | 52 | 40 |
| Japan* | 80 | 93 | 91 | 77 | 57 | 84 | 94 | 94 | 82 | 65 |
| Spain | 33 | 53 | 38 | 23 | 12 | 54 | 65 | 61 | 50 | 34 |
| United Kingdom | 60 | 63 | 62 | 58 | 53 | 77 | 84 | 80 | 75 | 67 |
| United States | 86 | 88 | 88 | 87 | 80 | 89 | 89 | 89 | 89 | 90 |
| 29 OECD Countries Mean | 61 | 72 | 65 | 57 | 44 | 75 | 82 | 78 | 73 | 64 |

* Data from Japan correspond to 2003.

*Source*: [OECD, Education at a Glance, 2000, p. 36, Table A2.2b, p. 35, Table A2.2, <http://www.oecd.org/dataoecd/22/35/35282639.xls>, Table A.1.3a, A.1.2a; Education at a Glance, 2013 <http://dx.doi.org/10.1787/888932847982>, Table T_A1.2a].

**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 | N/A | ~ | N/A | ~ |
| Italy | 2.2 | 7 | 2.2 | 4 |
| Japan | N/A | ~ | N/A | ~ |
| Korea | 1.9 | 11 | 1.9 | 5 |
| Luxembourg | N/A | ~ | N/A | ~ |
| 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:* [OECD, 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)

| Country | 2002 | | | 1995 | | | 1990 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Public** | **Private** | **Total** | **Public** | **Private** | **Total** | **Public** | **Private** | **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 | N/A | N/A | N/A |
| Belgium | 6.1 | 0.3 | 6.4 | N/A | N/A | N/A | N/A | N/A | N/A |
| Canada | N/A | N/A | N/A | 6.2 | 0.8 | 7.0 | N/A | N/A | N/A |
| Czech Republic | 4.2 | 0.2 | 4.4 | 4.7 | 0.7 | 5.4 | N/A | N/A | N/A |
| Denmark | 6.8 | 0.3 | 7.1 | 6.1 | 0.2 | 6.3 | N/A | N/A | N/A |
| Finland | 5.9 | 0.1 | 6.0 | 6.2 | *x* | 6.3 | N/A | N/A | N/A |
| 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 | N/A | N/A | N/A |
| Greece | 3.9 | 0.2 | 4.1 | 3.1 | *n* | 3.2 | N/A | N/A | N/A |
| Hungary | 5.0 | 0.6 | 5.6 | 4.9 | 0.6 | 5.5 | N/A | N/A | N/A |
| Iceland | 6.8 | 0.6 | 7.4 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ireland | 4.1 | 0.3 | 4.4 | 4.7 | 0.5 | 5.3 | N/A | N/A | N/A |
| Italy | 4.6 | 0.3 | 4.9 | 4.7 | N/A | N/A | N/A | N/A | N/A |
| Japan | 3.5 | 1.2 | 4.7 | 3.5 | 1.1 | 4.7 | N/A | N/A | N/A |
| Korea | 4.2 | 2.9 | 7.1 | N/A | N/A | N/A | N/A | N/A | N/A |
| Luxembourg | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Mexico | 5.1 | 1.1 | 6.3 | 4.6 | 1.0 | 5.6 | N/A | N/A | N/A |
| Netherlands | 4.6 | 0.5 | 5.1 | 4.5 | 0.4 | 4.9 | N/A | N/A | N/A |
| New Zealand | 5.6 | 1.2 | 6.8 | 4.8 | N/A | N/A | N/A | N/A | N/A |
| Norway | 6.7 | 0.3 | 6.9 | 6.8 | 0.4 | 7.1 | 8.1 | N/A | N/A |
| Poland | 5.5 | 0.7 | 6.1 | 5.7 | N/A | N/A | N/A | N/A | N/A |
| Portugal | 5.7 | 0.1 | 5.8 | 5.3 | *n* | 5.3 | N/A | N/A | N/A |
| 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/A | 5.1 |
| Switzerland | 5.7 | 0.5 | 6.2 | 5.4 | N/A | N/A | N/A | N/A | N/A |
| Turkey | 3.4 | 0.4 | 3.8 | 2.3 | N/A | 2.3 | 2.8 | N/A | 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*: [OECD, Education at a Glance, 2005, Indicator B2: Expenditure on educational institutions relative to Gross Domestic Product <http://www.oecd.org/dataoecd/2/11/35286380.xls>, Table B2.1a].

**Table 5a.** Expenditure on educational institutions as a percentage of GDP for all levels of education by source of funds (2010)

| Country | All secondary education | All tertiary education |
|---|---|---|
| Australia | 25 | 37 |
| Austria | 31 | 37 |
| Belgium | 29 | 40 |
| Canada | N/A | 56 |
| Czech Republic | 26 | 30 |
| Denmark | 29 | 47 |
| Finland | 25 | 46 |
| France | 32 | 44 |
| Germany | N/A | N/A |
| Greece | N/A | N/A |
| Hungary | 22 | 42 |
| Iceland | 22 | 25 |
| Ireland | 28 | 39 |
| Italy | 27 | 30 |
| Japan | 28 | 45 |
| Korea | 28 | 35 |
| Luxembourg | 21 | *m* |
| Mexico | 17 | 52 |
| Netherlands | 28 | 41 |
| New Zealand | 28 | 35 |
| Norway | 31 | 41 |
| Poland | 27 | 44 |
| Portugal | 35 | 41 |
| Slovak Republic | 21 | 30 |
| Spain | 30 | 42 |
| Sweden | 26 | 50 |
| Switzerland | 31 | 45 |
| Turkey | 16 | N/A |
| United Kingdom | 30 | 45 |
| United States | 27 | 55 |
| Country Mean | 27 | 41 |

*Source*: [OECD, Education at a Glance, 2013, Indicator B2: Expenditure on educational institutions relative to Gross Domestic Product].

**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 | N/A | 12019 |
| Canada | N/A | N/A | N/A | N/A |
| Czech Republic | 2077 | 3628 | 6671 | 6236 |
| Denmark | 7727 | 8003 | N/A | 15183 |
| Finland | 5087 | 7121 | 11833 | 11768 |
| France | 5033 | 8472 | 9132 | 9276 |
| Germany | 4537 | 7025 | 11860 | 10999 |
| Greece | 3803 | 4058 | 5646 | 4731 |
| Hungary | 3016 | 3184 | 8187 | 8205 |
| Iceland | 7171 | 7229 | 8232 | 8251 |
| Ireland | 4180 | 5725 | N/A | 9809 |
| Italy | 7231 | 7568 | 8649 | 8636 |
| Japan | 6117 | 6952 | 11984 | 11716 |
| Korea | 3553 | 5882 | 7630 | 6047 |
| Luxembourg | 10611 | 15195 | N/A | N/A |
| Mexico | 1467 | 1768 | N/A | 6074 |
| Netherlands | 5558 | 6823 | 13163 | 13101 |
| New Zealand | 4536 | 5698 | N/A | N/A |
| Norway | 7508 | 10154 | N/A | 13739 |
| Poland | 2585 | N/A | N/A | 4834 |
| Portugal | 4940 | 6921 | N/A | 6960 |
| Slovak Republic | 1471 | 2193 | 4756 | 4756 |
| Spain | 4592 | 6010 | 8074 | 8020 |
| Sweden | 7143 | 7400 | N/A | 15715 |
| Switzerland | 7776 | 11900 | 25524 | 23714 |
| Turkey | N/A | N/A | N/A | N/A |
| United Kingdom | 5150 | 6505 | N/A | 11822 |
| United States | 8049 | 9098 | N/A | 20545 |
| Country Mean | 5313 | 7002 | ~ | 10655 |
| OECD Mean | 5273 | 6992 | ~ | 13343 |

*Source:* [OECD, Education at Glance, 2005, Indicator B1: Educational expenditure per student, <http://www.oecd.org/dataoecd/2/12/35286348.xls>, Table B1.1].

**Table 6a.** Annual expenditures on educational institutions per student (US dollars converted using PPP) by levels of education based on full-time equivalents (2010)

| Country | Primary | All secondary | Tertiary type A | All tertiary |
|---|---|---|---|---|
| United States | 11,193 | 12,464 | NA | 25,576 |
| United Kingdom | 9,369 | 10,452 | NA | 15,862 |
| France | 6,622 | 10,877 | 15,997 | 15,067 |
| Germany | NA | NA | NA | NA |
| Italy | 8,296 | 8,607 | 9,576 | 9,580 |
| Spain | 7,291 | 9,608 | 14,072 | 13,373 |
| Austria | 10,244 | 12,551 | 15,101 | 15,007 |
| Belgium | 8,852 | 11,004 | NA | 15,179 |
| Denmark | 10,935 | 11,747 | NA | 18,977 |
| Finland | 7,624 | 9,162 | 16,714 | 16,714 |
| Netherlands | 7,954 | 11,838 | 17,172 | 17,161 |
| Norway | 12,255 | 13,852 | NA | 18,512 |
| Sweden | 9,987 | 10,185 | 20,750 | 19,562 |
| Switzerland | 11,513 | 14,972 | 23,457 | 21,893 |
| Japan | 8,353 | 9,957 | 17,544 | 16,015 |
| Korea | 6,601 | 8,060 | 11,271 | 9,972 |
| OECD Mean | 7,974 | 9,014 | ~ | 13,528 |

*Source:* [OECD, Education at a Glance, 2013 <http://dx.doi.org/10.1787/888932849350>, Table B1.1a].

**Table 7.** Expenditures per student (public and private) as a percentage of 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 | N/A | N/A |
| 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 | N/A |
| Mexico | 19 | 65 |
| Netherlands | 23 | 44 |
| New Zealand | 26 | N/A |
| Norway | 28 | 37 |
| Poland | N/A | 43 |
| Portugal | 37 | 37 |
| Slovak Republic | 17 | 38 |
| Spain | 26 | 35 |
| Sweden | 26 | 56 |
| Switzerland | 37 | 73 |
| Turkey | N/A | N/A |
| United Kingdom | 23 | 41 |
| United States | 25 | 57 |
| Country Mean | 26 | 43 |

*Source:* [OECD, Education at Glance, 2005, Indicator B1: Educational expenditure per student, <http://www.oecd.org/dataoecd/2/12/35286348.xls>, Table B1.2].

**Table 7a.** Expenditures per student (public and private) as a percentage of GDP per capita by level of education based on full-time equivalents (2010)

| | All secondary education | All tertiary education |
|---|---|---|
| Australia | 25 | 37 |
| Austria | 31 | 37 |
| Belgium | 29 | 40 |
| Canada | N/A | 56 |
| Czech Republic | 26 | 30 |
| Denmark | 29 | 47 |
| Finland | 25 | 46 |
| France | 32 | 44 |
| Germany | N/A | N/A |
| Greece | N/A | N/A |
| Hungary | 22 | 42 |
| Iceland | 22 | 25 |
| Ireland | 28 | 39 |
| Italy | 27 | 30 |
| Japan | 28 | 45 |
| Korea | 28 | 35 |
| Luxembourg | 21 | *m* |
| Mexico | 17 | 52 |
| Netherlands | 28 | 41 |
| New Zealand | 28 | 35 |
| Norway | 31 | 41 |
| Poland | 27 | 44 |
| Portugal | 35 | 41 |
| Slovak Republic | 21 | 30 |
| Spain | 30 | 42 |
| Sweden | 26 | 50 |
| Switzerland | 31 | 45 |
| Turkey | 16 | N/A |
| United Kingdom | 30 | 45 |
| United States | 27 | 55 |
| Country Mean | 27 | 41 |

*Source:* [OECD, Education at Glance, 2013, Indicator B1: Educational expenditure per student, <http://www.oecd-ilibrary.org/education/education-at-a-glance-2013_eag-2013-en>, Table B1.4].

**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:* U.S. Department of Education, Institute for Education Sciences, National Center for Education Statistics, "International Comparisons of Mathematics Literacy." <http://nces.ed.gov/programs/coe/2006/section2/table.asp?tableID=464>

**Table 8a.** Cut scores of 15-year-old students on PISA mathematics literacy scale at selected percentiles and percentile (2012)

| Country | Percentile | | | | | |
|---|---|---|---|---|---|---|
| | 10th | 25th | 50th | 75th | 90th | 90th to 10th |
| United States | 368 | 418 | 477 | 543 | 600 | 233 |
| France | 365 | 429 | 497 | 565 | 621 | 256 |
| Germany | 385 | 447 | 516 | 583 | 637 | 252 |
| Italy | 366 | 421 | 485 | 550 | 607 | 241 |
| Spain | 370 | 424 | 486 | 546 | 597 | 228 |
| Austria | 384 | 440 | 506 | 572 | 624 | 240 |
| Belgium | 378 | 444 | 518 | 589 | 646 | 268 |
| Denmark | 393 | 444 | 501 | 556 | 607 | 214 |
| Finland | 409 | 463 | 520 | 577 | 629 | 219 |
| Netherlands | 397 | 457 | 529 | 591 | 638 | 242 |
| Norway | 373 | 428 | 490 | 552 | 604 | 231 |
| Sweden | 360 | 415 | 478 | 543 | 596 | 236 |
| Switzerland | 408 | 466 | 534 | 597 | 651 | 243 |
| Japan | 415 | 473 | 538 | 603 | 657 | 242 |
| Korea, Republic of | 425 | 486 | 557 | 624 | 679 | 254 |
| OECD average | 375 | 430 | 494 | 558 | 614 | 239 |
| *Shanghai-China* | *475* | *546* | *622* | *685* | *737* | *262* |
| *Singapore* | *432* | *501* | *579* | *650* | *707* | *275* |
| *Hong Kong-China* | *430* | *499* | *569* | *629* | *679* | *249* |

*Source:* The National Center for Education Statistics (NCES). <http://nces.ed.gov/surveys/pisa/pisa2012/pisa2012highlights_3b.asp>

*Note*: This table shows the threshold (or cut) scores for the following: (a) 10th percentile- the bottom 10 percent of students; (b) 25th percentile- the bottom 25 percent of students; (c) 50th percentile- the median (half the students scored below the cut score and half scored above it); (d) 75th percentile- the top 25 percent of students; (e) 90th percentile- the top 10 percent of students. The percentile ranges are specific to each education system's distribution of scores, enabling users to compare cut scores across education systems. Education systems are ordered by cut score gap. The OECD average is the average of the national averages of the OECD member countries, with each country weighted equally. Scores are reported on a scale from 0 to 1,000. Standard error is noted by s.e. Italics indicate non-OECD countries and education systems. Results for Connecticut, Florida, and Massachusetts are for public school students only [Organization for Economic Cooperation and Development (OECD), Program for International Student Assessment (PISA), 2012].

**Table 9.** Estimated Coefficients from Mincer Log-Earnings Regressions for Males

| | | 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, Lochner, Todd, 2003].

**Table 10.** Correlating Predicted Growth Rates in Per Capita GDP and Average School Years of the Adult Population (based on [Ehrlich, Kim, 2007])

| | **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.

**Table 11.** Relative percentage differences in educational attainments (U.S. = 100) by level and age group (1998 and 2003)

**Attaining at least tertiary education Type-A:**

| | **1998** | | | | | **2003** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Country** | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** |
| US | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| France | 40.7 | 55.6 | 38.5 | 34.5 | 27.3 | 48.3 | 73.3 | 44.8 | 36.7 | 37.0 |
| Germany | 51.9 | 51.9 | 61.5 | 51.7 | 45.5 | 48.3 | 46.7 | 51.7 | 50.0 | 44.4 |
| Italy | 33.3 | 33.3 | 42.3 | 31.0 | 22.7 | 34.5 | 40.0 | 37.9 | 33.3 | 25.9 |
| Spain | 51.9 | 77.8 | 61.5 | 37.9 | 27.3 | 62.1 | 86.7 | 65.5 | 46.7 | 33.3 |
| United Kingdom | 55.6 | 63.0 | 65.4 | 51.7 | 50.0 | 65.5 | 80.0 | 65.5 | 60.0 | 51.9 |
| E4* | 44.4 | 54.6 | 51.0 | 38.8 | 30.7 | 48.3 | 61.7 | 50.0 | 41.7 | 35.2 |
| E5** | 46.7 | 56.3 | 53.8 | 41.4 | 34.5 | 51.7 | 65.3 | 53.1 | 45.3 | 38.5 |
| E11*** | 52.2 | 57.9 | 59.4 | 47.0 | 43.8 | 56.4 | 68.8 | 58.3 | 50.0 | 45.8 |

**Attaining at least upper secondary education:**

| | **1998** | | | | | **2003** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** | **25–64** | **25–34** | **35–44** | **45–54** | **55–64** |
| United States | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| France | 70.9 | 85.2 | 71.6 | 64.4 | 51.3 | 73.9 | 92.0 | 78.4 | 66.3 | 56.5 |
| Germany | 97.7 | 100.0 | 98.9 | 96.6 | 95.0 | 94.3 | 97.7 | 97.7 | 94.4 | 91.8 |
| Italy | 47.7 | 62.5 | 56.8 | 40.2 | 23.8 | 50.0 | 69.0 | 56.8 | 43.8 | 28.2 |
| Spain | 38.4 | 60.2 | 43.2 | 26.4 | 15.0 | 48.9 | 69.0 | 54.5 | 37.1 | 22.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| United Kingdom | 69.8 | 71.6 | 70.5 | 66.7 | 66.3 | 73.9 | 81.6 | 73.9 | 71.9 | 67.1 |
| E4* | 63.7 | 77.0 | 67.6 | 56.9 | 46.3 | 66.8 | 81.9 | 71.9 | 60.4 | 49.7 |
| E5** | 64.9 | 75.9 | 68.2 | 58.9 | 50.3 | 68.2 | 81.8 | 72.3 | 62.7 | 53.2 |
| E12**** | 80.0 | 89.9 | 83.1 | 74.9 | 65.9 | 81.4 | 93.1 | 86.3 | 77.2 | 69.3 |

*E4: Simple average of the normalized data for France, Germany, Italy, and Spain.

**E5: Simple average of the normalized data for France, Germany, Italy, Spain and United Kingdom.

*** E11: Simple average of the normalized data for Austria, Belgium, Finland, France, Germany, Italy, Netherland, Norway, Sweden, Switzerland, and the United Kingdom.

**** E12: Simple average of the normalized data for E11 countries and Denmark.

# Appendix B: Figures

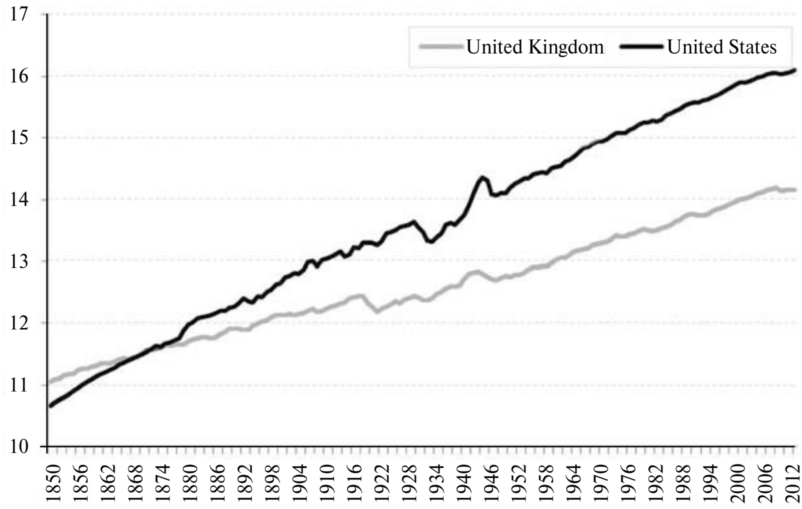


**Fig. 1.** Comparison of U.S. and U.K. Real GDP in Log Terms (1850–2012)

*Note:* GDP data are in real (PPP) 1990 Geary-Khamis million dollars. Data for 1851–1859 and 1861–1869 are imputed. For 2009–2012, GDP is computed using real GDP growth rate estimates from the IMF.

*Source:* Data from Angus Maddison, University of Groningen. <http://www.ggdc.net/maddison/maddison-project/home.htm>

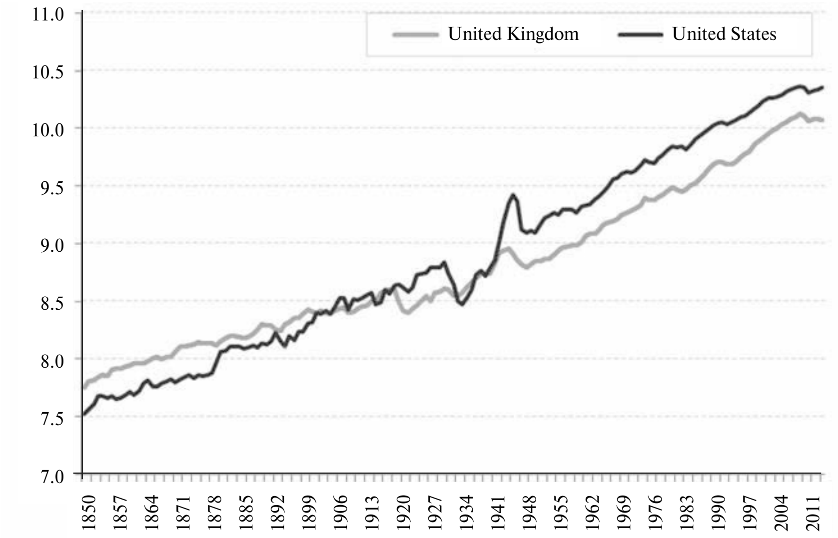


**Fig. 2.** Comparison of U.S. and U.K. Real GDP per capita in log terms (1850–2012)

*Note:* GDP data are in real (PPP) 1990 Geary-Khamis million dollars. For 2011–2012, GDP per capita is computed using GDP per capita growth rate estimates from the IMF.

*Source:* Angus Maddison, University of Groningen. <http://www.ggdc.net/maddison/maddison-project/home.htm>

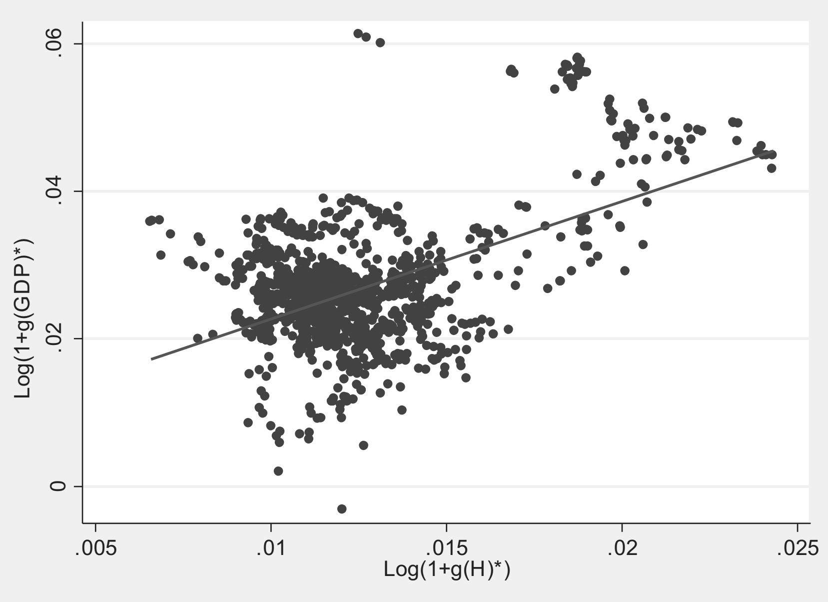


**Fig. 3.** Correlating predicted growth rates in per-capita GDP and average school years of the adult population (based on [Ehrlich, Kim, 2007])

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

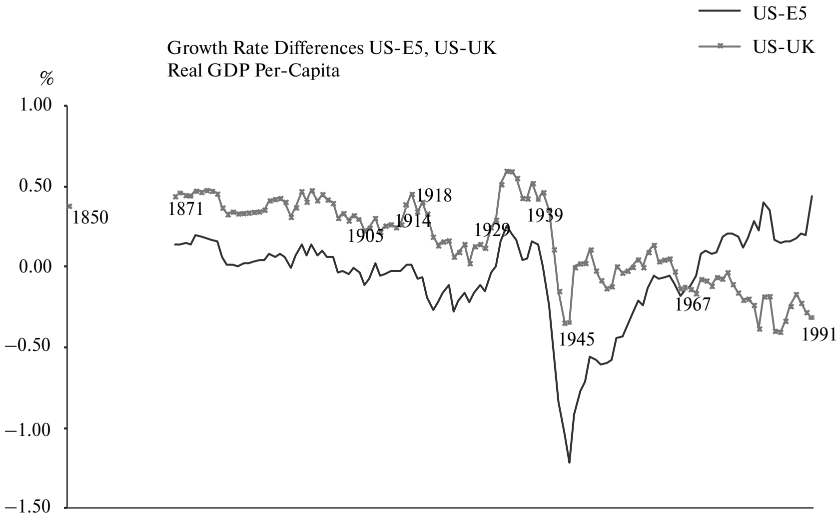


**Fig. 4.** Deviations in long-term per-capita GDP growth rates per annum over the period 1850–2003 between the U.S. and E-5, and U.S. and U.K.

*Note:* Chart shows Percentage differences measured at progressively later starting dates from 1850–2003 up to 1991–2003. GDP data are in real (PPP) 1990 Geary-Khamis dollars.

* E5 includes: France, Germany, Italy, Spain, and United Kingdom

*Source:* Data from Maddison [2003].

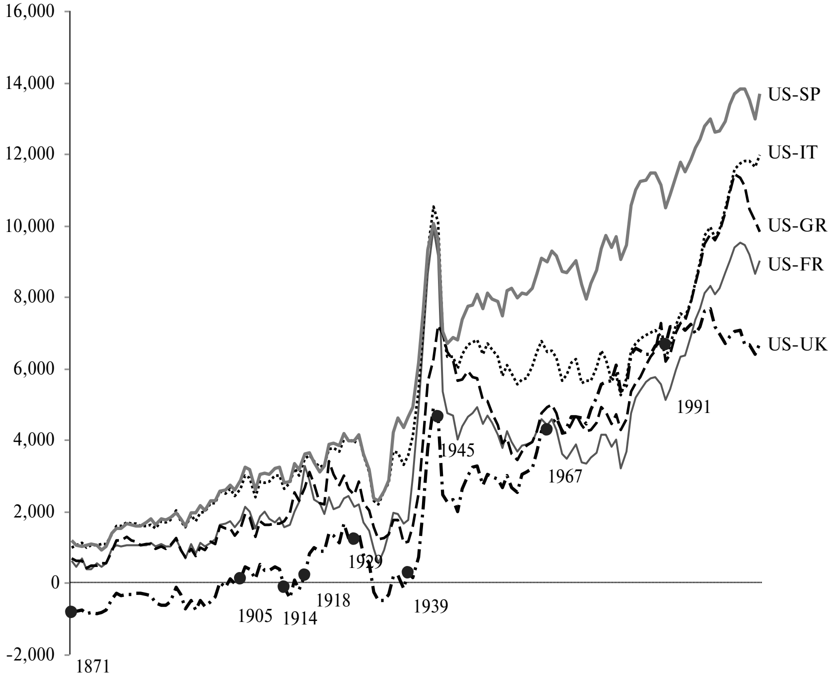


**Fig. 5.** Annual per-capita GDP absolute differences between the U.S. and major European countries (1871–2010)

*Note:* GDP data are in real (PPP) 1990 Geary-Khamis million dollars.

*Source:* Angus Maddison, University of Groningen. <http://www.ggdc.net/maddison/maddison-project/home.htm>

*Scientific publication*

Isaac Ehrlich

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