Convergence and Deferred Catch-up
Productivity Leadership and the Waning of American Exceptionalism

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There are two lines of agency visibly at work shaping the habits of thought of [a] people in the complex movements of readjustment and rehabilitation [required by industrialization]. These are the received scheme of use and wont and the new state of the industrial arts; and it is not difficult to see that it is the latter that makes for readjustment; nor should it be any more difficult to see that the readjustment is necessarily made under the surveillance of the received scheme of use and wont.

Thorstein Veblen, 1915

The comparative productivity experience of nations is commonly viewed as a race. But there is a difference between a runners' race and a productivity race between nations. In a track race, if one runner gets off to a fast start, there is no reason why, on that account alone, her rivals should then be able to run faster than she. A productivity race is different: under certain conditions, being behind gives a productivity laggard the ability to grow faster than the early leader. That is the main contention of the "convergence hypothesis." The most striking example of the convergence to which this hypothesis refers was the experience since World War II, when America's large lead eroded and the productivity levels of the other technologically advanced countries converged.

The convergence hypothesis stands on four sturdy pillars -- which in turn float on one large assumption. The assumption is that the countries in the productivity race differ only in their initial levels of productivity but are otherwise similar. The four legs are the four advantages in growth potential that a laggard nation enjoys just because it is behind. These are the pillars:

First, when a leader's capital stock is replaced or expands, the improvement in technology embodied in the new plant and equipment is limited by such advances in the efficiency of capital goods as may have been made during the life of a representative asset. In a laggard country, however, the tangible capital is likely to be technologically obsolete. After all, that is one reason the laggard is behind. When such equipment is replaced, the new equipment can embody state-of-the-art technology; so, on that account, the laggard can realize larger improvements in the average efficiency of its productive facilities than are available to the leader. An analogous argument applies to a laggard's potential advance in disembodied technology, that is, in the forms of industrial organization; routines of purchasing, production and merchandising; and managerial practice generally.

Second, laggard countries tend to suffer from low levels of capital per worker. That condition, especially in view of the chance to modernize capital stock, tends to make marginal returns to capital high and so to encourage rapid rates of capital accumulation.

Third, laggard countries often maintain relatively large numbers of redundant workers in farming and petty trade; so productivity growth can occur by shifting labor from farms to nonfarm jobs and from self-employment and family shops to larger-scale enterprises, even allowing for the cost of the additional capital that might be needed to maintain productivity levels in the new jobs.

Fourth, the relatively rapid growth from the first three sources makes for rapid growth in aggregate output and, therefore, in the scale of markets. This encourages the sort of technical progress which is dependent on larger-scale production.

These, then, are the components of the convergence hypothesis in its elemental form.[1] And if national characteristics were, indeed, to conform to the underlying assumption of similarity, we would expect that any national differences in productivity levels which might appear would be eliminated sooner or later, because of the growth advantages inherent in being behind.

The assumption of similarity calls for some explanation here. By it we mean that, there are no *persistent* differences in national characteristics that would inhibit a laggard country from exploiting the advantages that being behind would otherwise present. In actual experience, productivity differences among countries stem from both persistent and transient causes. Persistent causes include poverty of natural resources; small scale of domestic markets, coupled with barriers to foreign trade; forms of economic organization or systems of taxation that reduce the rewards for effort, enterprise or investment; or deeper elements of national culture that limit the responses of people to economic opportunities. Transient causes are occurrences like natural or military disasters, or dysfunctional forms of economic organization and public policy that may have ruled in the past but that have been effectively reformed.[2] The strength of the long-run tendency to convergence depends on a balance of forces: on the one side, the advantages in growth potential that are inherent in being behind, and on the other side, the limitations inherent in those persistent causes of backwardness that may originally have caused a country to become a productivity laggard. Therefore, in the limiting case envisaged by the model of unconditional convergence, where differences in productivity levels arise solely from transient "shocks", productivity growth rates in any period would be found to vary inversely with their respective initial levels, so that laggards would tend to catch up with the leaders and differences in levels eventually would be eliminated. For a quarter-century following World War II, as was noted, the growth record of the presently advanced countries was strikingly consistent with this simple formulation of convergence hypothesis. But not all of the historical experience of economic growth, even for this same group of countries, fits the hypothesis. From 1870 to about 1950, America not only maintained, but actually widened its lead over other countries in terms of real GDP per capita and labor productivity. Britain, the world's first industrial nation, had held the lead during the century before that, and the Netherlands did so at a still earlier time when it was a great mercantile power.

The insistent question, therefore, is how to reconcile the convergence hypothesis with the experience of persistent leadership. This involves asking what differences among countries impose limitations on the abilities of laggard countries to profit from the advantages of being backward. We must then ask how and why these limitations changed so as to become less constraining and thus led to the great boom in catch-up and convergence that has marked the era since World War II.[3]

To sharpen the focus of this inquiry, we confine ourselves to a comparison between the United States and a group of presently advanced capitalist countries since 1870. The group consists of 16 presently industrialized countries of Western Europe and North America together with Japan and Australia. (The list of countries appears in Table 1, below.) They are the countries for which Angus Maddison (1991, p. 196) has compiled estimates of manhour productivity rendered comparable over time by standard methods of price deflation and across countries by the purchasing-power-parity ratios prepared by Eurostat and the OECD. The next section reviews the broad features of the growth experience of these countries from 1870 to 1990. This is followed by a section in which we identify the kinds of factors other than a low productivity level that may give one or more countries an advantage in growth and, by the same token, operate as limitations on the ability of others to catch up. We then go on to sketch the particular forces that, during the last 120 years, first supported a strong American advantage and inhibited the forces of convergence, and later undermined the basis of that leadership advantage and lent impetus to the catch-up movement among the other industrially developed economies.

The nub of our argument is that in the closing decades of the 19th century the U.S. economy had moved into the position of global productivity leadership, which was to hold for a remarkably long period thereafter, through a fortunate concordance between America’s own exceptional economic and social characteristics, and the nature of the dominant path of technological progress and labor productivity advances. During the late 19th and early 20th centuries, that path was natural resource-intensive, tangible-capital-using and scale-dependent in its elaboration of mass-production and high-throughput technologies and modes of business organization. Although this trajectory can be traced to back to technological and industrial initiatives in both Britain and the USA earlier in the 19th century, it found fullest development in the environment provided by the North American continent. And so, during the course of the nineteenth century, it came to provide the USA with a strong productivity leadership advantage. This was so because the historical circumstances of contemporaneously developing economies, particularly those conditions affecting what we refer to as "technological congruence" and their "social capability", imposed limitations on the abilities of the productivity laggards of western Europe and Japan derive a strong potential for rapid growth simply on the basis of being behind the USA.

Yet America’s distinctive advantages did not retain their initially great importance throughout the first half of the present century. The advantage conferred by the USA’s rapid development of its rich endowment of mineral resources gradually dissipated, and some of the peculiar benefits that its industries derived from the larger scale and greater homogeneity of its domestic markets were eroded, partly by the growth of both domestic and foreign markets elsewhere, and partly by a gradual shift of the nature and direction of technological progress. In its global impacts the course of innovation became less biased towards the evermore intense application of tangible capital and natural resource inputs and, instead, came to favor greater emphasis on intangible capital formation through investments in education and R&D. For these and still other reasons, we contend that the waning of American exceptionalism, and the changing trajectory in the development of internationally available technology had the effect of reducing the *comparative* handicaps under which other countries seeking rapid productivity increases formerly were obliged to operate.

With the erosion of these American advantages, the ground was prepared for other countries with broadly similar economic and social institutions to participate in the interconnected processes of "catch-up investment" and "productivity convergence." As we shall see, however, the realization by the laggards among the industrialized countries of that potentiality for differentially faster productivity growth, after having been deferred by the circumstances of the Great Depression of the 1930s and World War II, was fostered by a number of special conditions that obtained internationally during the postwar decades.

The Comparative Productivity Record

In 1870, levels of aggregate labor productivity in the United States and the United Kingdom were apparently quite similar. Maddison's estimates (1991, Table 3.4) put the UK ahead by 4 percent, but given the uncertainties of such calculations, so small a difference can hardly be thought significant. The statistics, however, speak much more clearly about two other matters. First, both the UK and the United States enjoyed large leads over the other countries that had begun to industrialize by 1870. Secondly, between 1870 and 1913, the United States established a large lead over the UK (28 percent) and increased its already large lead over the generality of the other industrializing countries (see Table 1A).

Over the course of this long period of general peace and development, there is no sign of a catch-up with the new front-runner by the laggard countries. Among the 15 advanced countries other than the USA, only America's northern neighbor, Canada, improved its relative productivity position, and only one European country, Germany, was able to maintain its 1870 relative level -- which was but half as high as that of the leader. The average level of the 15 countries other than the United States fell from 62 percent of the American level in 1870 to 54 percent in 1913.[4]

On the other hand, virtually all the countries of Western Europe were closing the proportionate gaps that separated them from Britain, the former productivity leader.[5] This would seem to be quite consistent with the view that, in the spread of industrialization during the later-nineteenth century, the successful western European "followers" were looking toward

Britain, rather than the United States, as the technological and economic leader that it was most relevant for them to attempt to emulate.[6] If that view is correct, it suggests another way to frame the central question we are addressing in the present essay: Why did not the industrial latecomers of the European continent follow the lead of America, whose economy was giving visible indications of forging ahead of Britain?

Between 1913 and 1938, the laggard countries held back by world War I and by the financial disturbances of the Twenties, fell back still further. And World War II, which was a great stimulus to U.S. growth as its economy returned to high levels of capacity utilization, was a severe setback to the relative positions of the European countries and Japan. By 1950, after recovery from the most severe after-effects of the wartime destruction and dislocation, the average relative productivity levels of the other countries had sunk from 54 to 43 percent of the American level.[7]

There then followed the great "catch-up boom" from 1950 to the present.[8] The movement proceeded in two stages. During the first, from 1950 to 1973, the pace of catch-up was relatively fast: the laggards rose toward the American level at a rate of 1.8 percent a year, so that their average relative level, which was 43 in 1950, reached 66 in 1973. During this stage, the catch-up was achieved in spite of rapid American productivity growth which was at least as fast, and may have been even faster than in any previous period of comparable duration (Maddison, 1991, Table 3.3). Since 1973, catch-up has been distinctly slower -- only 1.3 percent a year -- in spite of the severe slowdown in the USA. Growth rates in Europe and Japan fell even more (in percentage points) than in this country.

There was no general catch-up to the United States before 1950, but it is worth recording that from 1870 to 1938, there was a substantial decline in the dispersion of productivity levels among the laggards, as can be seen from the figures for the western European countries in Table 1B.

Although for the full sample of 16 countries the trend rate of convergence was a weak 0.42 percent per annum, the corresponding downward drift of the coefficient of variation among the western European countries including the UK proceeded at an average rate of 1.11 percent per annum over this 68 year period.[9] Thus, over this long period before World War II there was "convergence among the followers", without the occurrence of "catch-up" vis-a-vis the newly emerged productivity leader.

During the wartime decade of the 1940s, however, the international dispersion of productivity levels increased markedly; in 1950 the coefficient of variation was larger than its 1938 value by almost two-thirds. Thereafter, from 1950 to 1973 the great "postwar catch-up and convergence movement" proceeded very systematically: the inverse rank-order correlation between countries' initial levels of productivity in 1950 and their subsequent growth rates between 1950 and 1973 was almost perfect -- the lower was a country's productivity level in 1950, the higher was its subsequent rate of growth.[10] In company with this, the process of convergence resumed at a pace that was historically unprecedented; the coefficient of variation declined at an average annual rate almost ten times as fast as its pre-World War II trend. Eventually, in the period after 1973, when the postwar growth boom passed into history and the rate of catch-up vis-a-vis the United States had slowed down appreciably, convergence also became substantially slower.

The general features of the postwar experience of the advanced capitalist economies is consistent with the predictions of a simple convergence hypothesis. Between 1950 and 1973, the gaps separating the productivity levels in the laggard countries from that in the USA were rapidly reduced, and the dispersion of relative levels within this group of economies declined swiftly. There was catch-up as well as convergence. Since 1973, with productivity gaps reduced, the rate of catch-up slowed down and the process of convergence weakened. So far, so good.

But why was there no general catch-up (and only modest convergence) throughout the eight decades from 1870-1950? For the period from 1913 to 1950, one may well think (correctly, in our view) that the forces making for catch-up and convergence were overwhelmed by two general wars, by the territorial, political and financial disturbances that followed, and by the variant impacts of the Great Depression on different countries.[11] Still, what circumstances inhibited catch-up vis-a-vis the United States for more than four decades of peaceful development between 1870 and 1913? And what occurred to release the forces of convergence and catch-up after the Second World War? The next section outlines a framework for study and discussion of these questions.

The Elements of Catch-up Potential and Its Realization

The conditions that govern the abilities of countries to achieve relatively rapid rates of productivity growth may be grouped into two broad classes: those that govern the potential of different countries to raise their productivity levels, and those that influence their abilities to realize that potential.

The convergence hypothesis tells us that one element governing countries' relative growth potentials is the size of the productivity differentials that separate them from the leader. Manifestly, however, the record of growth does not conform consistently to the predictions of the unconditional convergence hypothesis. The assumption that countries are "otherwise similar" is not fulfilled. There are often persistent conditions that have restricted countries' past growth and that continue to limit their ability to make the technological and organizational leaps that the convergence hypothesis envisages. We divide constraints on the potentials of countries into two categories.

One consists of the limitations of "technological congruence." Such limitations arise because the frontiers of technology do not advance evenly in all dimensions; that is, with equi-proportional impact on the productivities of labor, capital and natural resource endowments, and with equal effect on the demands for the several factors of production and on the effectiveness of different scales of output. They advance, rather, in an unbalanced, biased fashion, reflecting the direct influence of past science and technology on the evolution of practical knowledge and the complex adaptation of that evolution to factor availabilities, as well as to the scale of markets, consumer demands and technical capabilities of those relatively advanced countries operating at or near the frontiers of technology.[12]

It can easily occur that the resource availabilities, factor supplies, technical capabilities, market scales and consumer demands in laggard countries may not conform well to those required by the technologies and organizational arrangements that have emerged in the leading country or countries. Although technological choices do adapt to changes in the economic environment, there are strong forces making for persistence in the effects of past choices and for path-dependence in the evolution of technological and organizational systems. These may render it extremely difficult, if not prohibitively costly for firms, industries and economies to switch quickly from an already established regime, with its associated trajectory of technical development, to exploit a quite distinct technological regime that had emerged elsewhere, under a different constellation of economic and social conditions.[13] The laggards, therefore, face varying degrees of difficulty in adopting and adapting the current practice of those who hold the productivity lead.

The second class of constraints on the potential productivity of countries concern a more vaguely defined set of matters that has been labelled "social capability." This term was coined by Kazushi Ohkawa and Henry Rosovsky (1972). It covers countries' levels of general education and technical competence; the commercial, industrial and financial institutions that bear on their abilities to finance and operate modern, large-scale business; and the political and social characteristics that influence the risks, the incentives and the personal rewards of economic activity, including those rewards in social esteem that go beyond money and wealth.

An illustration may suggest the importance of the social and political constraints to which we refer. The 1989 level of value added per manhour in Japanese manufacturing was 80 percent of the corresponding U.S., according to the careful comparison carried out by Van Ark and Pilat (1993). For the same year, Maddison's (1992, Table 13) estimates show the overall level of productivity in Japan was only 65 percent of the American. This difference may reflect many causes, but one important cause is surely the resistance of Japanese politics and society to the substitution of large-scale, corporate farming and retailing and of foreign goods for the traditional very small-scale family farms and shops of that country. The productivity gap is especially pronounced in those industries where these influences have been especially strong: Wolff (1994) finds that in 1988 Japanese productivity in agriculture was just 18 percent of the U.S. level; the food, beverage, and tobacco industry's productivity was 35 percent of the American level, and for textiles the figure was 57 percent.

Over time there is a two-way interaction between the evolution of a nation's social capabilities and the articulation of societal conditions required for mastery of production technologies at or close to the prevailing "best practice" frontier. In the short-run, a country's ability to exploit the opportunities afforded by currently prevailing best practice techniques will remain limited by its current social capabilities. Over the longer-term, however, social capabilities tend to undergo transformations that render them more complementary to the more salient among the emerging technological trajectories. Levels of general and technical education are raised. Curricula and training facilities change. New concepts of business management, including methods of managing personnel and organizing work, supplant traditional approaches. Corporate and financial institutions are established and people learn their modes of action. Legal codes and even the very concepts of property can be modified. Moreover, experience gained in the practical implementation of a production technique enhances the technical and managerial competencies that serve it, and thus supports further advances along the same path. Such mutually reinforcing interactions impart "positive feedback" to the dynamics of technological evolution. They may for a time solidify a leader’s position or, in the case of followers, serve to counter the tendency for their relative growth rates to decline as catch-up proceeds.

On the other hand, the adjustments and adaptations of existing cultural attitudes, social norms, organizational forms and institutional rules and procedures is neither necessarily automatic nor smooth. Lack of plasticity in such social structures may retard and even block an otherwise technologically progressive economy’s passage to the full exploitation of a particular emergent technology (for example, Freeman and Perez, 1988; Perez and Soete, 1988; David, 1991b). New technologies may give rise to novel forms of productive assets and business activities that find themselves trammelled by features of an inherited jurisprudential and regulatory system that had never contemplated even the possibility of their existence.[14] For laggards, the constraints imposed by entrenched social structures may long circumscribe the opportunities for any sustained catch-up movement.

To summarize our general proposition: countries’ *effective* potentials for rapid productivity growth by catch-up are not determined solely by the gaps in levels of technology, capital intensity and efficient allocation that separate them from the productivity leaders. They are restricted also by their access to primary materials and more generally because their market scales, relative factor supplies and income constrained patterns of demand make their technical capabilities and their product structures incongruent in some degree with those that characterize countries that operate at or near the technological frontiers. And they are limited, finally, by those institutional characteristics that restrict their abilities to finance, organize and operate the kinds of enterprises that are required to exploit the technologies on the frontiers of science and engineering.

Taken together, the foregoing elements determine a country's effective potential for productivity growth. Yet another, distinct group of factors governs the ability of countries to realize their respective potentials. One set of issues here involves the extent to which followers can gain access to complete and reliable information about more advanced methods, appraise them, and acquire the artifacts and rights needed to implement that knowledge for commercial purposes. A second set of issues arise because long-term, aggregate productivity growth almost always entails changes in industrial and occupational structure. As a result, the determinants of resource mobility, particularly labor mobility are also important. And finally, macroeconomic conditions govern the intensity of use of resources and the financing of investment and, thereby affect the choices between present and future that control the R&D and investment horizons of businesses. By influencing the volume of gross investment expenditures, they also govern the pace and extent to which technological knowledge becomes embodied in tangible production facilities and the people who work with them.

We are now ready to put this analytical schema into use in a specific historical context: how the U.S. attained and sustained its productivity lead from 1870 to 1950, and then what changed during these years that released the catch-up and convergence boom of the postwar period.

Bases of the Postwar Potential for Catch-up and Convergence

The dramatic postwar record of western Europe and Japan creates a presumption that they began the period with a strong potential for rapid growth by exploiting American methods of production and organization. The productivity gaps separating the laggard countries from the United States were then larger than they had been in the record since 1870. However, the gains in prospect could only be realized if Europe and Japan could do what they had not been able to do before: take full advantage of America's relatively advanced methods. The insistent question, therefore, is why Europe, itself an old center of technological progress, had proved unable even to keep pace with the USA during the three-quarters of a century following 1870.[15] The answer we propose is that the difficulty lay in the failures of technological congruence and social capability, and that it was the gradual elimination or weakening of these obstacles that opened the way after the war to the strong catch-up and convergence of the postwar years.

Technological Congruence: Primary Materials

The American advantage stemmed first from America's more abundant and cheap supplies of primary materials.[16] Such supplies had a more important bearing on a country's growth potential in the 19th and early 20th centuries than they have had since that time. This is true because food then constituted larger shares of consumer expenditure and GDP, and resources devoted to agriculture were a larger share of total factor input than they have that time. Moreover, America possessed abundant virgin forests and brushlands. In the era before the Age of Wood that preceded the Age of Iron, this profusion of forest resources generated strong incentives to improve methods of production that facilitated their exploitation, to use them extravagantly in the manufacture of finished products (like sawn lumber and musket-stocks), and to lower the costs of goods complementary to wood (such as iron nails, to take an humble example).[17]

Beyond that stage, the industrial technology that emerged during the 19th and early 20th centuries, when America rose to productivity leadership and forged farther ahead, was based on minerals: on coal for steam power, on coal and iron ore for steel and on copper and other non-ferrous metal for still other purposes. American enterprise, reprising its previous performance in rising to "industrial woodworking leadership" by combining technological borrowing from abroad with the induced contributions of indigenous inventors, now embarked upon the exploration of another technological trajectory -- one that was premised upon, and in turn fostered the rapid (and in some respects environmentally profligate) exploitation of the country's vast mineral deposits. In this technology, the costs of coal as a source of steam power, of coal and iron ore for steel-making, and of copper and still other non-ferrous metals, bulked larger in the total costs of finished goods than subsequently came to be true. Cheap supplies of these primary materials thus underlay America's growing comparative advantage as an exporter of natural resource-intensive manufactures during the period 1880-1929 (Wright, 1990, Table 6 especially).

By the eve of the First World War, America had attained world leadership in the production of nearly every major industrial mineral of that era. But this position had been attained only in part because of the nation's abundant natural endowment. Perhaps even more crucial were the nation's successes in rapidly uncovering the existence of its rich sub-surface mineral reserves, in devising new methods of refining and processing that were adapted to their sometimes peculiar chemical characteristics, and in building an efficient network of transportation by water and rail that reached throughout its very large territory. Government policies and agencies played an active part in all those accomplishments, especially in subsidizing the extension of the railroads network into the American West, and by organizing and funding geological surveys and promoting the beginnings of systematic scientific research on subjects immediately relevant to the mineral industries. So did the newly formed faculties of engineering at the nation's institutions of higher education, both those at the older privately founded universities (like Columbia University's famous School of Mines), and the state colleges of more recent establishment under the terms of the 1862 Morrill Act (David and Wright, 1992). The peculiarities of the law of mining in the USA heightened the private, commercial incentives for investments in exploration and development. The federal government claimed no ultimate title to the nation's minerals, not even to those in the public domain. It offered free access to prospectors, and no fees or royalties were assessed against the minerals removed.

Finally, the incentives for minerals exploration and development stemmed even more largely from the demand that appeared as American manufacturing shifted towards the production of minerals-based capital and consumer goods. There was, therefore, a fruitful interaction between the development of primary materials supply, the advance of American technology, and the growth of manufacturing, construction and transportation (Rosenberg (1980); Wright (1990); David and Wright (1992)).

The minerals-based, resource-intensive technology proved to be the dominant path of technical progress in all the presently advanced countries, but America gained substantial advantages in whole-heartedly embarking upon that path by undertaking infrastructural investments to explore, develop and reduce the costs of access to her mineral resource deposits. Europe as a whole possessed known reserves of a number of the key minerals, such as iron ore, that in 1910 were as large as those identified in North America at the time, and the current rates of production of iron ore, coal and bauxite in Europe as a whole exceeded that of the USA in 1913.[18] But when it came to petroleum, copper, phosphate, gold and other minerals, America was out-producing the whole of Europe -- even with Russia included, and there was no nation in Europe , to say nothing of Japan, which approached the USA in the variety and richness of the mineral resources that actually had been developed, rather than remaining in "reserve" status.

Out of 14 important industrial minerals, America in 1913 accounted for the largest shares of world output in the cases of all but two -- and for those two it was the runner-up. Given the still high transportation costs of the time and the relative importance of materials in the total costs of finished goods, this translated into a significant cost disadvantage for Europe and Japan vis-a-vis the United States in the production of finished manufactures.[19]

With the passing of time, however, the importance of these inter-country differences declined -- for at least six reasons:[20]

First, technological progress reduced the unit labor input requirements in the mining, gas and oil industries both absolutely and relatively. In the United States, for which the quantitative evidence is most readily available, unit factor costs of minerals production fell relative to unit factor costs in the rest of the economy. Table 2 illustrates these points, with Frame A focusing on absolute costs, and Frame B on relative costs. Compared to the non-extractive (or non-primary production) sector of the domestic economy, the unit costs of labor and capital in minerals decreased by 10 percent between the late 19th century and 1919, and then dropped by another 50 percent during the period from 1919-1957. Over the same long period, factor productivity in agriculture was merely keeping pace with that in the non-extractive activities as a whole, whereas in the forestry sector relative unit factor costs appear to have risen at an accelerated rate after 1919 (as shown in Frame B).

Second, mineral resources were discovered and developed in many parts of the world where their existence had remained unknown at the end of the 19th century, so costs of materials at points of origin and use outside the United States would have tended to fall. Furthermore, technological advance increased the commercial value of mineral resource deposits that previously were neglected, and added new metals and synthetic materials to the available range of primary materials and agricultural products.

Third, petroleum came to be of increasing importance as a source of power for industry and transportation, and also as feedstock for the chemicals industry.

Fourth, transportation costs both by land and sea declined markedly, which reduced the cost advantages enjoyed by exporters of primary products in the further processing of such materials.

Fifth, crude materials came to be processed more elaborately and, on this account, primary products became a smaller fraction of the final cost of finished goods. The consumption of primary materials has declined per unit of final output, which had a similar effect. This is illustrated dramatically by a comparison of energy consumed in generating electric power with the electricity applied in industry and households. While electricity used per dollar of GNP more than quintupled between 1920 and 1970, energy consumed per dollar of GNP declined by a third (Table 2, Frame C).

Sixth, and finally, services in which the materials component is small have become more important, compared with foods and manufactures in which the materials component is larger.

For all of these reasons, differences in developed natural resource endowments have counted for less in recent decades than they had done earlier. One recent example of these changes deserves special notice. When the postwar period opened, it was widely expected that the well-worked, high-cost coal deposits of Europe and the more general lack of energy sources in Japan would pose serious obstacles to development for both. However, the rapid exploitation of cheap Middle Eastern petroleum and the development of low-cost transport by supertanker changed the picture. Energy problems became much less severe in Europe and Japan, which reduced what had been an important relative advantage of the United States.

Technological Congruence: Capital-Using and Scale-Intensive Technology

The technology that emerged in the 19th and that persisted into the early 20th century was not only resource-intensive, it was tangible capital-using and scale-dependent. Exploiting the technical advances of the time demanded heavier use of machinery per worker, especially power-driven machinery in ever more specialized forms. But it required operation on an ever-larger scale the use of such structures and equipment economical. Furthermore, it required steam-powered transport by rail and ship, itself a capital-intensive and scale-intensive activity, to assemble materials and to distribute the growing output to wider markets.[21] The importance of tangible capital supported by operation on a large scale was the message of all the early economists, beginning with Adam Smith and running through Bohm-Bawerk and Sidgwick to Taussig and Allyn Young. It is also a view supported by the economic history of technology and by statistical studies of American growth in the 19th and early 20th century.[22]

Tangible capital-using and scale-dependent methods again offered a technological path along which the American economy was drawn more strongly, and which the producers in the USA could follow more easily than their European counterparts during the late 19th and early 20th centuries. We have seen how a rich natural endowment had supported American development of the minerals-based technology of the later 19th century. In a similar way, the early sparse settlement of America's virgin lands and its abundant forest resources made American wages relatively high and local labor supplies inelastic. And high wages in turn encouraged the development of the era's capital-intensive mechanical technologies. The heavy use of power-driven capital equipment was further supported by the relatively large, rich, and homogeneous domestic market open to American firms.

By 1870, the United States already had a larger aggregate domestic economy than any of its advanced competitors. Moreover, extensive investments in railroads and other transportation infrastructure were helping to realize its potential as an integrated transcontinental product market. Boosted by its comparatively rapid population growth (which was sustained by a tide of international migration), the U.S. growth rate of real GDP between 1870 and 1913 outstripped all other industrializing countries. By 1913, therefore, the size of the American economy was over two and one-half times that of the U.K. or Germany, and over four times as large as France (Maddison, 1992, Table 3). America's per capita GDP also topped the other industrial nations in 1913, exceeding that of the UK by 20 percent, France by 77 percent, and Germany by 86 percent (Maddison, 1992, Table 1.1). These differences indicate the advantage that the United States enjoyed in markets for automobiles and for the other new, relatively expensive durable goods, to which the techniques of a scale-dependent, capital-using technology (like mass production) especially applied.

The American domestic market was both large and well-unified by an extensive transportation network. And it was unified in other ways that Europe at the time could not match. The rapid settlement of the country from a common cultural base in the Northeastern and Middle Atlantic seaboard closely circumscribed any regional differences in language, legal systems, local legislation and popular tastes. In fact, Americans sought consumer goods of unpretentious and functional design in preference to products that tried to emulate the more differentiated, elaborate and custom-finished look of the old European luxury crafts. This taste structure, which was commented on repeatedly at international expositions where American manufactures were displayed alongside the top quality wares of the Europeans, owed much to the spirit of democratic egalitarianism that prevailed over large sections of American society, and to the young nation's freedom from a heritage of feudal and aristocratic traditions and aesthetic values. It fostered the entrepreneurial strategy of catering to and actively creating large markets for the standardized products of large-scale production (Rosenberg, 1980; Hounshell, 1984).

The American development of mass production methods was also encouraged by the country's higher and more widely diffused incomes which supported an ample domestic market for the new metals-based durable goods. By contrast, Europe's lower and less equally distributed incomes initially restricted the market for such goods to its well-to-do classes, for whom standardized commodities had less appeal in any event, and thereby delayed the full application of American mass production methods.

Finally, American land abundance and the level, unobstructed terrain of the Midwest and trans-Mississippi prairies were especially well-suited to the extensive cultivation of grain and livestock under climatic and topographical conditions very favorable to the mechanization of field operations. None of these developments could be replicated on anything approaching the same comparative scale within European agriculture at the time. In this way, the "Westward Movement" helped perpetuate conditions of relative labor-scarcity, which in turn favored the substitution of machinery (and horsepower) for human effort, and further stimulated technological innovations localized at the capital-intensive end of the spectrum of farming techniques (David, 1975, chs. 4-5; Parker, 1972). In this way the recurring shifts of the farming frontier onto virgin soil contributed doubly to boosting nineteenth century agricultural productivity growth in the still largely agrarian American economy.[23]

The effect of the American advantage in scale, buttressed by high wages relative to the cost of finance, is reflected in comparisons of U.S. capital-labor ratios with those in three large European countries and Japan. Table 3 offers some illustrative figures. In 1870, Britain may still have used more capital per worker than the United States. But by 1913, both the British and German ratios had sunk to about 60 percent of the U.S. figure.[24] European (and Japanese) capital intensity, held back by wars and their aftermath, did not begin to catch up to the United States until after World War II, in conjunction with the postwar catch-up boom.

Again, however, these American advantages gradually waned in importance. As aggregate output expanded in Europe, the markets for more industries and products approached the scale required for most efficient production, with plants embodying technologies that had been developed to suit American conditions. Furthermore, the decline in transportation costs and the more liberal regime of international trade and finance that emerged between 1880 and 1913 encouraged producers to use international markets to achieve the scale required. From 1870 to 1913, the average growth rate of exports in continental Europe was 43 percent greater than GDP growth (Maddison, 1991, Tables 3.2, 3.15). Of course, there was a still greater expansion of trade during the 1950s and 1960s, when the growth of European exports exceeded the growth of their collective GDP (both in constant prices) by 89 percent. In this era, rising per capita incomes also helped assure that scale requirements in the newer mass-production industries producing consumer and producer durables would be satisfied for a widening range of commodities. As larger domestic and foreign markets appeared, laggard countries could begin to switch in a thorough-going way to exploit the capital-using and scale-dependent techniques already explored by the United States. This was a path toward catch-up that would prove to be especially important after World War II, even though it had begun to be followed by some large industrial enterprises in Europe and Japan during the interwar period (see Denison (1967: Ch. 17); Denison and Chung (1976: Ch. 10)).

Still another significant cause of the decline in American advantage was a gradual alteration in the nature of technological progress itself. Towards the end of the nineteenth century the former bias in the direction of tangible reproducible capital-using, scale-dependent innovations became less pronounced. New, capital-augmenting techniques (like the assembly line, and automatic railroad signalling, track-switching and car-coupling devices) were found to increase the throughput rates achievable with fixed production facilities. Even more portentous for the coming century, the growth of the scientific knowledge base relevant to industry encouraged shifts in the direction of innovation that began to favor investment in *intangible* assets (both human and non-human) rather than the further accumulation of conventional, tangible capital goods such as structures and equipment. In other words, the effect of this alteration of the bias of scientific, technological and organizational innovation, taken by itself, was that of raising the rate of return on intangible capital formation activities -- most notably, education and organized R&D -- in relation to the rate of return on investments in conventional tangible assets.

This view of the changing general thrust of technological progress at the beginning of the 20th century finds strong support in the quantitative and qualitative evidence from the American experience (Abramovitz and David (1973a,1973b); Kendrick (1976); David (1977); Abramovitz (1993)). We believe it applies equally to developments affecting Europe and Japan. One sees this shift reflected, first, in the trend of the share of tangible capital in the factor distribution of GDP. The latter had risen markedly in the middle of the 19th century, but then leveled off and declined just as markedly between the early 1900s and the mid-1950s. A second indication is found in the stability of rates of return to education in the face of huge increases during the present century in the proportions of the workforce who had comparatively extended periods of formal schooling. In the absence of some other influence (such as the hypothesized bias of technological change) acting upon the relative productivity and earnings of the more educated, the rising level of educational attainment among the labor force would have driven down the real rate of return on investment in education.

A third indication is to be seen in the rapid rise in organized research and development activities, whether measured as a fraction of corporate revenues or of aggregate output. Overall, according to estimates made by Kendrick (1994: Table 1B) "nonhuman tangible" capital formation -- consisting of structures and equipment, utilized land, and civilian and military inventories -- represented a secularly decreasing proportion of total real gross investment; the nonhuman tangibles' share declined from 64.9 percent in 1929 to 47.3 percent in 1990.[25] The share of investment devoted to intangible assets such education, R&D, health and others, rose by a corresponding amount. Kendrick (1994: Table 2) also presents parallel figures showing the growing importance of intangible assets in the total real gross capital stock.

A final manifestation of the rising importance of intangible investment in education is the growth of the number of jobs requiring long years of schooling in relation to the jobs requiring less formal instruction -- a trend that was firmly established in the USA during 1900-1960, and that has continued unabated during the past three decades (see Abramovitz (1993), Katz and Murphy (1992)). The global dimensions of this trend bears on our contention that there has been an erosion of the part of the American growth advantage which depended upon close congruence between the scale requirements of a tangible capital-using technology and the size of the USA's domestic market. While western Europe and Japan had lower levels of tangible capital throughout the first half of the twentieth century, they were able quite early to reach levels and trends of schooling more nearly approaching those in the United States, as shown in our Table 4. Although the European levels fell back somewhat from their relative position as of 1913 -- largely because of the more widespread continuation into higher education in the United States -- the significance of that limited reversal remains doubtful and uncertain in view of the roughness of the estimates and the differences in the "quality" and intensity of the school year among our small sample of countries. We conclude that the political and social conditions in most of Western Europe and Japan were substantially congruent with the new human capital-using bias of technological progress, just as they were in America.[26] Consequently, as intangible capital became more important, America's special advantage waned.

The United States led Europe -- with Germany a possible exception -- in the late-nineteenth century development of organized industrial R&D (Mowery and Rosenberg, 1989). Its lead continued to widen until sometime in the 1950s, but thereafter the differential vis-a-vis the R&D efforts of other economically advanced nations began to disappear, and, in recent decades the gap in the area of civilian and non-military related R&D has been essentially closed. Nelson and Wright (1992) attribute the continuing American technological leadership through the period of the 1950s and 1960s to the country's heavy investments in higher education and R&D. There is a distinction, of course, between seizing leadership in technology and managing to catch up in the level of labor productivity. The laggard countries achieved their postwar labor productivity catch-up during 1950-1973 mainly by exploiting the production techniques explored by American firms both in earlier times and contemporaneously. European and Japanese capabilities for assessing, acquiring and adapting existing technology, moreover, were becoming stronger as their R&D investment accumulated. As they approached American levels of efficiency in some lines of production, however, the emphasis of their own innovative efforts gradually shifted towards the exploration of other technological trajectories. For example, Broadberry (1993) has suggested that western European industrial firms have been able to reassert a degree of localized technological leadership during the 1970s and 1980s -- especially in the development of alternatives to Fordist, fixed transfer line, mass production methods -- because they had an advantage in marrying modern information technologies with the small-scale craft organization of production that was traditional in many of their branches of industry.

The Interdependence of Technological Congruence and Technological Progress

The preceding account has often referred to the technology with which American conditions were especially congruent as one that had "emerged" in the nineteenth century. This wording could suggest that we regard the path of 19th-century technological progress as exogenously determined. American superiority in making use of the opportunities presented by practical knowledge would then appear as just a happy accident, a fortunate concordance of American conditions with the character or biases of an autonomous path of progress. Was that really so?

It probably was, in some part. The inventions that opened the era of modern industrialization were mechanical inventions, and they drew upon the history of European experiments with labor-saving contrivances that stretched back to medieval times (White, 1968; Mokyr, 1990). That these inventions came first may have been accidental, but some opinion holds otherwise -- supposing that the reason they appeared earlier was that they were more readily grasped by people whose everyday observations and experiences had implanted in them intuitions about the laws of mechanics (Parker, 1984, v. I, ch. 8). Systematic invention based on electricity, chemistry, solid state physics and molecular biology, which required more fundamental and obscure scientific knowledge, had to wait. Meanwhile, the progress of mechanical applications put pressure on the older sources of fuel and primary materials: timber, coal, iron ore and the other metals. In an era of incomplete geographical exploration and high transport costs, America's natural resource endowment and its early development gave this country an advantage in exploiting the new opportunities.

At the same time, the water-powered and steam-powered mechanical inventions of the time were embodied in tangible and specialized capital equipment and driven by large factory-sited, central sources of power, transmitted by elaborate and expensive systems of belts. All of this was economical only if operated on a sufficiently large scale. So America's superior market scale gave it another substantial advantage in exploiting the potential of the 19th century's path of mechanical progress.

But did the 19th century path of technological progress that favored American productivity growth just "emerge"? Or alternatively, was it the product of a process of exploration, of learning and testing that was itself shaped by the exceptional, American conditions of resource abundance, high wages and large market size? After all, when businessmen, craftsmen and engineers look to reduce costs, they do not search with equal vigor through every possible combination of materials, labor, capital and scale. Rather, they concentrate on that segment of the spectrum of combinations which has already begun to reveal its economic opportunities and engineering challenges.[27] In America in the nineteenth and early twentieth century, conditions pointed this search process towards methods that spared the use of expensive labor by accepting intensive use of cheap materials or land, by equipping workers with better tools, and by organizing production on a large scale to spread the overhead of intensive capital use. Many familiar stories of American economic development are consistent with this hypothesis: the country's "wasteful" use of timber, its extensive land cultivation practices (including monoculture) which left soil exhaustion and erosion in the farmers' wake, and its innovative development of machine-made, "interchangeable" parts and later of mass production by assembly-line methods.

The logic of these endogenous mechanisms of technological change suggests that they may not only give direction to the search for progress, but also, in some circumstances, speed up the rate of advance. Insofar as the pace of learning depends on the cumulation of experience, it is influenced by the pace at which engineers and businessmen come into contact with new methods of production and with the capital goods in which they are embodied. Thus, the pace of technical advance may depend on the portion of production activities that involves constructing and installing new capital equipment and related structures, as well as on the growth rate of the cumulative gross stocks that constitute the setting for learning-by-doing and learning-by-using capital-embodied technologies.[28] Therefore, if American scale induced larger demand for tangible capital, it would also have supported a rate of technological progress faster than that being endogenously generated in Europe.

Moreover, American scale would have worked to speed up the pace of progress in still another way. The very process of conceiving, designing, testing and developing new methods and the equipment through which they work is itself an investment, the cost of which is less burdensome when spread over a larger output. It is ideas such as these that are embedded in the "new" growth theories that Paul Romer (1990) and others have put forward recently.

Manifestly, the two views we have sketched are not mutually exclusive. The path of advance that became dominant in the last century did not become established simply because Americans chose to use it. When Adam Smith wrote in 1776 that the division of labor opened the way to the substitution of tools for labor, and when he proposed his famous dictum that the division of labor is limited by the extent of the market, he did not have before him the American developments that would so thoroughly exploit these principles. The exceptional circumstances of the former colonists, whose Declaration of Independence had coincided with the publication of *The Wealth of Nations,* were propitious in that they so well satisfied the conditions for economic progress envisaged by its author. Thus, the technological investments undertaken by American inventors and entrepreneurs, and the direction in which American business firms pointed their efforts to raise efficiency, lay more directly on the dominant path of nineteenth century technical progress than was true in the case of Europe; and the results of those investments were embodied in forms of machinery, and in a scale of production operations that firms in Europe could not immediately imitate or readily adapt to their own circumstances.

Social Capability

Social capability has to do with those attributes, qualities and characteristics of people and economic organization that originate in social and political institutions and that influence the responses of people to economic opportunity.[29] It includes a society's culture and the priority it assigns to economic attainment. It covers the economic constitutions under which people live, particularly the rights, limitations and obligations involved with property, and all the incentives and inhibitions that these may create for effort, investment, enterprise and innovation. It involves those long-term policies that govern particular forms of organization or activity, such as limited liability corporations and financial institutions, and the policies that may support or restrict such organizations. And it covers the policies that provide for the public provision of social services and those that support the accumulation of capital by investments in infrastructure and by public education or research. With all that in mind, we can do no more than suggest how the shifting state of social capability may have worked to inhibit and then release the forces of catch-up and convergence in the group of presently advanced countries.

One thing is clear enough at the outset. The differences in social capability within the group of presently advanced market economies are less important than they are between this group and the less developed countries of the present time or those of a century ago. Even in the later 19th century, all of the presently advanced group had certain broadly similar features. All had substantially independent national governments at least as early as 1871.[30] Broadly speaking, all the countries except Japan share much of the older culture of Western Europe. Most important, all the countries, again excepting Japan, have lived during the entire period under basically stable economic constitutions that provide for a system operated mainly by business enterprises coordinated by markets for goods, labor, capital and land. In Japan, although a middle class of merchants had arisen even under the Shogunate, the country retained much of its older feudal character until the Meiji Restoration of 1868. Thereafter, however, it was rapidly transformed and by the turn of the century had established its own form of private enterprise, market economy (Rosovsky, 1961; Ohkawa and Rosovsky, 1972).

Beyond their economic constitutions, however, certain noteworthy differences worked to impair the ability of European countries to catch up to the United States during the late 19th and early 20th century. Nineteenth century America presented a contrast with Western Europe in its social structure, its people's outlook and their standards of behavior. In America, plentiful land offered a widespread opportunity to achieve a satisfactory income by the standards of the time. It fostered a relatively equal distribution of income and wealth and an egalitarian spirit. America's Puritan strain in religion tolerated and even encouraged the pursuit of wealth. The older European class structure and feeling did not survive America's wider dispersion of property and opportunity. Americans judged each other more largely on merit, and, lacking other signs of merit, wealth became the main badge of distinction. America's social and economic circumstances encouraged effort, saving and enterprise, and gave trade and the commercial life in general a status as high or higher than that of other occupations (de Tocqueville, 1840, II: First Book, ch. V, VIII, Second Book, ch. XVIII, XIX; Parker, 1991, 24-5, 123, 242, 245-49.)

While the social background of economic life in the countries of 19th century Europe was of course not uniform there were certain commonalities in their divergence from America conditions of the time. In all the European countries, a traditional class structure -- which separated a nobility and gentry from the peasantry, the tradesmen and an expanding middle class -- survived into the 19th century. Social distinction rested more on birth and the class status it conveyed than on wealth. Insofar as social distinction did turn on wealth, inherited wealth and income counted for more than earned income or the wealth gained by commerce, and landed wealth stood higher than financial wealth and still higher than industrial or commercial. The middle class who aspired to membership in the gentry or nobility bought rural seats and adopted upper-class standards of conspicuous consumption. Class lines were not impassible, but they were hard to cross. Wealth alone was not enough, whereas a step up in the status hierarchy could be gained through the adroit deployment of sufficient wealth in service to the crown or the nobility, or in contracting a socially advantageous marriage, or in purchasing a military or civil commission that entitled one to enter an occupation suitable to a gentleman. In short, the social order of western Europe diluted the characteristic American preoccupation with material success.[31]

These differences in the bases of social distinction -- and therefore in the priority assigned to economic attainment -- influenced many kinds of behavior that matter for productivity growth. They shaped the occupational choices of both the European gentry and bourgeoisie. When family income was adequate, sons were pointed towards the occupations that the upper classes regarded as gentlemanly or honorific: the military, the civil service, the church and, well behind, the professions. Even in the sphere of business, finance held pride of place, all to the detriment of commerce and industry (Landes, 1949, 54-7; Wiener, 1962).

In Europe, a related tradition from pre-industrial times influenced education in a way that reinforced these pre-existing patterns of occupational choice. The curricula in the secondary schools continued to emphasize the time-honored subjects of the classics and mathematics; the faculties of Europe's ancient and most prestigious universities dwelt upon these and also theology, law and medicine. Throughout Europe, university curricula emphasized what was regarded as proper for gentlemen destined for the clergy, the civil service and the liberal professions (de Tocqueville (1840:II,First Bk., Ch.X); Wiener (1962)). Although training in engineering did win a place for itself both in France and Germany early in the 19th century, its character in both countries was theoretical, concerned with preparing an elite cadre of engineer-candidates to serve the State in administrative and regulatory capacities. In contrast, by the late 19th century, engineering schools in America clearly had evolved a more practical, commercial and industrial bent.[32]

In a notable series of articles, David Landes (1949, 1951, 1954) and John Sawyer (1951, 1954) argued that the French outlook and social structure, as these had survived from pre-industrial times and then developed after the Revolution, gave the French family a more important role in the new industrial era than was true in America. Together with other factors, mainly the smaller size of the French domestic market, this emphasis on family business restricted the size of French firms. Family-owned businesses assured their family's continuing control by pursuing financial self-sufficiency, which led to a notably cautious policy and resistance to profit-seeking by expansion that might require external finance (Landes, 1949: p.53). This delayed the adoption of the corporate form of organization. Where technology demanded a larger scale than family funds could satisfy, as in steel, the preferred business form for the maintenance of family control was, according to Landes (1951:p.37, n. 10) the *commandite par actions*, "a form of sleeping partnership" in which ownership is represented by negotiable shares, but in which "[the] active partners are in sole charge of operations." *The Kommanditgesellschaft auf Aktien*, a similar arrangement, was popular in Germany. Alfred Chandler's great business history (1990: Pt. III) contends that the expansion of British firms and their development of managerial and merchandising capabilities were, likewise, limited by the desire of British entrepreneurs to keep control within their families.

Survivals of the pre-industrial social structure of France limited the scale of firms in other ways, as well. One that we already have noted was an aristocratic taste for quality and individuality in consumer goods, a penchant that may also account for the excessive degree of "finish" and durability that some observers have seen in European tools and machinery. This pursuit of quality and distinction inhibited the development of mass production, and supported the extreme fragmentation of retail trade in which tiny boutiques and specialty food stores offered limited lines of merchandise in an individual ambience. Similarly, a business ethos that can be traced back to the medieval guilds discouraged aggressive innovation and price competition, in favor of maintaining a high standard of quality in traditional product lines.

The French social structure and the outlook it inspired was doubtless different in its elements and strength from those in other European countries. Yet something of the same character does seem to have been at work throughout western Europe. For example, in M. J. Wiener's (1962) picture of English society, there is the same middle class yearning to rise on the social ladder to the rungs occupied by the gentry and nobility. There is the same drain of talent from industry and trade into more honorific occupations in the Civil Service, the military, clergy and the law. There is the same pre-modern cast of secondary and higher education, an emphasis on the classical and theoretical as opposed to the practical. Britain was a laggard in the development of curricula in engineering and business, although this probably owes something to a peculiarly British distrust of the educated specialist and a preference in practical life for learning on the job. In addition, class feeling also delayed the spread of mass education at the primary level during the 19th century. As one of us (Abramovitz, 1989: p. 59) has written:

> The upper class who controlled British politics in the nineteenth century were slow to be persuaded that mass education was needed and that state support was justified. The Church of England resisted the state schools that would be non-denominational. Moreover, when a State system was at last established, British working class feeling gave less than ardent support for its extension. Many workers resisted the view that schooling, at any rate schooling beyond the elementary grades, would be an advantage to their own class-bound children. The net result was that ... the school system expanded more slowly than in the United States and more slowly also than in some continental countries (for example, Prussia).

Alexander Gerschenkron (1962, p. 64) drew a corresponding parallel between France and Germany:

> ... most of the factors mentioned by Landes [for France] find their counterpart in the German economy. The strength of preindustrial social values was, if anything, greater in Germany than in France. The family firm remained strong, and the lower entrepreneurial echelons, whose numbers bulked large, behaved in a way which was hardly different from that in France. The pronouncement made at the turn of the century, that modern economic development had transformed the top structure of the German economy while everything beneath it still remained medieval, was, of course, a deliberate exaggeration. But there was some meaning in that exaggeration. Such as it was, it applied to France as much as to Germany.

Evidently, the persistence of pre-industrial social values was widespread in Europe, and its connections with occupational choice, the character of education, the size of firms, the resistance to standardization and the preference for quality over price suggest that these survivals had, indeed, inhibited European industrial development in the 19th century and for some time thereafter.

This conclusion has been disputed. Gerschenkron's (1954, 1962: 63-4) main contention, for example, was that the influence of preindustrial values on the economic development of France was overdrawn by Landes and Sawyer. Instead, he argued for the importance of differences in natural resource endowment, income levels and domestic market scale -- in short, to differences we have referred to as "technological congruence." Landes (1954) and Sawyer (1954), for their part, were careful not to make social structure and outlook the sole or even prime cause of the different pace of French and American development in the nineteenth century. In the face of Gerschenkron's criticism, however, they both strongly rejected his implied conclusion that these social factors were matters of negligible importance. And there the matter rests. Since it is extremely difficult to reduce the notion of "social capabilities" to a meaningful scalar magnitude, such considerations, typically, are omitted from formal economic models, and assertions as to their effects remain largely untested econometrically, despite the recent wave of interest in international comparative studies such as those surveyed by Fagerberg (1994). Unsatisfactory as this may be, we believe that such factors made some significant contribution to the U.S. preeminence in the late 19th and early 20th century. Thus, it would be still more unsatisfactory to leave them wholly out of consideration.

Neither social structure nor outlook, however, remained frozen in their 19th century forms. As economic development proceeded, the social status and political power of European business rose. The occupational targets of middle class youth gradually shifted. Business and the pursuit of wealth as a road to social distinction (as well as material satisfaction) became more appealing. Entrepreneurs became more familiar with public corporations, more receptive to outside capital as a vehicle for expansion, and more experienced in the organization, finance and administration of large-scale business. The small, specialized retail shop retained much of its old importance into the 1930s. But after World War II, the big, fixed-price chain stores expanded beyond the beach-head that companies like Woolworth and Marks and Spencer previously had established in Britain. The American-style supermarket, aided by the automobile and the home refrigerator, began to transform European retail food distribution.

The timing of this change around World War II is not accidental; the war itself had a profound impact on social structure and outlook. In the aftermath of the War, great steps were taken to democratize education. State-supported secondary schooling and universities were rapidly expanded, literally hundreds of new university campuses were constructed and staffed, and public support for the maintenance of university students was initiated. For virtually all the new students, careers in industry, trade, and banking and finance became the mecca, not the traditional honorific occupations. In France, even the *polytechniciens* joined industrial firms. Curricula were modified to fit the more practical concerns of this much-expanded student population. Schools of engineering and business administration were founded or enlarged. Even Britain, the perennial laggard in educational reform, responded by opening its new system of comprehensive secondary schools and its new red brick universities and polytechnical colleges.

The most important change of outlook was in the public attitude towards economic growth itself. In the first half of the century, and particularly in the interwar years, the major concerns had been income distribution, trade protection and unemployment. After the war, it was growth that gripped people's imagination, and growth became the premier goal of public policy. Throughout Europe and in Japan, programs of public investment were undertaken to modernize and expand the infrastructure of roads, harbors, railroads, electric power and communications. The demand for output and employment was supported by monetary and fiscal policy. The supply of labor was enlarged by opening borders to immigrants and guest workers. Productivity growth was pursued by enlarging mass and technical education, by encouraging R&D, and by state support for large-scale firms in newer lines of industry. The expansion of international trade was promoted by successive GATT rounds, and by the organization of the Common Market and EFTA.

We hold, therefore, that many features of European (and Japanese) social structure and outlook had tended to delay catch-up in the nineteenth century. But these inhibitions weakened in the early 20th century, and, in the new social and political milieu of postwar reconstruction, crumbled altogether. The traditional upper classes lost their hold on the outlook and aspirations of the growing middle class. The same forces tended to strengthen the political power of business corporations and trade unions, and to shift the directions of public policy accordingly toward institutional reforms and expansionary macroeconomic measures on which both interests could find agreement. In the aftermath of World War II, these developments joined to reinforce the vigorous catch-up process that had been released by the new concordance between the requirements of the forms of technology and organization that had appeared in America and the economic characteristics that now obtained in western Europe and Japan.

Conditions Promoting the Realization of Potential

The postwar period opened with a strong potential for European catch-up. But the actual realization of a strong potential depends on a variety of background conditions that, in the shorter term, govern the responses of businessmen, labor and governments to the opportunities before them. This background may be favorable or unfavorable, and it may persist for an extended span of years. Between 1914 and 1950 -- counting the difficult years of initial recovery from World War II -- these short-term factors doomed the possibility of realizing what might by then have already been a strong potential for rapid growth by catch-up. During the quarter-century following the second world war, however, the reverse was true. A full exposition of this subject would be a long story. Here, we can do no more than notice some of the important components.

New conditions favored the diffusion of technology. Transport, communications and travel became faster and cheaper. Multinational corporate operations expanded, creating new channels for the international transfer of technology, management practices, and modes of conducting R&D. Further, heavier investment in R&D was encouraged by a closer connection between basic science and technological applications, while the open, international character of much of the basic science research community fostered the rapid dissemination of information about new and more powerful research techniques and instruments that were equally applicable for the purposes pursued in corporate R&D laboratories.

Industry was able to satisfy a growing demand for labor without creating the tight labor markets that might otherwise have driven wages up unduly and promoted price inflation. Some key factors here were that unions had been weakened by war;, unprecedentedly rapid labor productivity growth in agriculture was freeing up workers from that sector, and Europe’s borders were opened wider to immigrants and guest workers. U.S. immigration restrictions themselves helped to create more flexible labor-market conditions in Europe (Kindleberger, 1967; Abramovitz, 1979).

Governmental policies at both the national and international levels favored investment, trade and the spread of technology. The dollar-exchange standard established at Bretton Woods, together with U.S. monetary and fiscal policy and U.S. capital exports, overcame the initial concentration of gold and other monetary reserves in this country. They sustained a chronic American balance-of-payments deficit that redistributed reserves and ensured an adequate growth of money supply throughout the industrialized world.

These and other matters that bear on the factors supporting "realization" in the post World War II era deserve more ample description and discussion, which one of us sought to provide on an earlier occasion (Abramovitz, 1979). We must confine this paper largely to the elements of a changing potential for rapid growth by productivity catch-up. Nonetheless, it is important to remember that the rapid and systematic productivity convergence of the postwar years rested on a fortunate historical conjuncture of strong potential for catching-up with the emergence of international and domestic economic conditions that supported its rapid realization.

Many of the elements forming that conjuncture have now weakened or disappeared; most plainly the large productivity gaps that had separated laggards from the leader have now become very much smaller. The break-up of that favorable constellation of forces has slowed both the rate of catch-up and convergence within the group of advanced countries. The passing of the postwar conjuncture of potential and realization was in large measure the result of developments inherent in the catch-up process itself (Abramovitz, 1994).

Summing Up: Bases of Productivity Leadership and Limits of the Potential for Catch-up:

America's position of productivity leadership was gained, and maintained for a remarkably long period, by a fortunate concordance between America's own exceptional economic and social characteristics and the nature of the path of technological progress that emerged and was developed in that region during the course of the 19th century. It was a concordance that other countries were not at first able to replicate or match by other means. So their potential ability to catch-up or even to keep abreast of American productivity growth was limited.

The 19th and early 20th century path of technological progress was minerals-intensive, tangible-capital-using and scale-dependent. America's superior concordance with the nature of this path rested on three elements. One was its superior endowment of natural resources and their early development. A second was its superior market scale. These were the elements of America's technological congruence and so the basis for a more far-reaching exploitation and development of the possibilities of tangible capital - using innovation, including mass production, than the natural-resources and scale of European economies could afford in the same period. America's third advantage lay in the sphere of social capability. Its egalitarian and secular outlook made wealth and economic attainment the basis of social distinction, made business a respected occupation and directed education and science to material ends. In Europe, by contrast, the social outlook was still colored by an aristocratic residue. Talent sought the older honorific occupations, schooling prepared gentlemen for them, and scientific effort was more largely bent towards learning for its own sake. A quest for family status and a reluctance to extend trust and financial control beyond the circle of kinship combined to restrict the size and scope of business enterprises. The persistence of a guild-like ethos, aristocratic standards of taste and inequality of incomes were still further European obstacles to the standardization of products and the substitution of power and machinery for labor in American-style mass-production factories.

In time, however, the sources of America's exceptional productivity advantage eroded. The region's early superiority in providing cheap access to industrial raw materials and sources of power waned, and the importance of abundant natural resources for production decreased. America's advantage in exploiting the dominant tangible capital-using but scale-dependent character of 19th century technological advance was also undercut. The domestic markets of the laggard countries grew larger. Cheaper transport and more liberal commercial policies opened wider markets, at least until 1913 and again, of course, in the post World War II period itself. Per capita incomes rose in Europe and Japan and began to provide larger markets for automobiles and the other consumer durables that were especially suitable for mass production. Businessmen in Europe and Japan gradually gained in experience with the organization, finance and operation of large corporations. The bias of technological progress began to shift from its older scale-dependent, tangible capital-using bias to a newer intangible capital-using bias less dependent on scale. Capitalist development gradually weakened the hold of aristocratic values in Europe; the outlook and institutions of European society came to resemble America's more closely.

The post World War II conjuncture of forces supporting catch-up has now largely done its work. It has brought the labor productivity levels of the advanced, capitalist countries within sight of substantial equality. The significant lags that remain among the advanced economies in course of catching-up are no longer to be found in a marked persistence of backward technology embodied in obsolescent equipment and organizations.[33] Rather, they lie in the remaining differences between American, European and Japanese capital-labor ratios, and in the sphere of politics and social sentiments that protect unduly low-productivity agricultural sectors and traditional forms of organization both in farming and retail trade. The great opportunities for rapid growth by modernization now belong to the nations of Eastern Europe, South and Southeast Asia and Latin America. Although it is correct to say that the argument presented here is immediately germane only to the experiences of the group of presently-advanced countries during a particular historical epoch, the classes of conditions that figure importantly in the story told here, nevertheless, may have a considerably wider applicability. The work of Barro (1991), DeLong and Summers (1991), Mankiw, Romer and Weil (1992), and still others, while confined to the post World War II era, has considered a much wider cultural, political and economic spectrum than the subset of industrially advanced market economies.[34] The findings of these studies seem to reflect the operation of mechanisms both of "local convergence" among the advanced economies and of "global divergence" between the advanced economies (joined by the few newly industrializing economies) and the remaining low income countries.[35] Throughout the world, deep-rooted political obstacles and the constraints imposed social capability, or, to use Veblen's (1915) words, by "the received scheme of use and wont," remain to be overcome.

Among the presently advanced capitalist nations, the question is whether substantial equality in productivity levels will long persist. Will a new bend in the path of technical advance again create a condition of superior technological congruence and social capability for one country? Or will conditions that support the diffusion and application of technical knowledge become even more favorable? And technology continue to pose demands for "readjustment and rehabilitation" that many countries can meet? For the foreseeable future, convergent tendencies appear to be dominant. But the full potential of the still-emergent Age of Information and

Communication is yet to be revealed. The industrialization of the huge populations of South and Southeast Asia may change the worlds of industry and commerce in ways that are now still hidden.

Our treatment of the problems of technological congruence and social capability has been highly general and suggestive. Although it may help us understand the path that we have already traveled, it is still unable to reveal what lies along the road ahead. When examined more deeply and in greater detail, however, these concepts may yet supply insights into the likely shape of the future, and so a means of preparing for it more effectively.

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Table 1A. Mean of the Labor Productivity Levels in 15 Advanced Countries Relative to the USA and in 9 Countries in Western Europe Relative to the UK and Measures of the Rates of Catch-Up

	15 Advanced Countries*				**Western Europe (9 countries)***		
	Mean level USA=100	**Rate of catch-up[a] (% per ann.)**			**Mean level (UK=100)**	**Rate of catch-up[a] (% per ann.)**	
1870	62	1873-13	-0.35	1870	57	1870-13	+0.35
1913	54	1913-38	-0.30	1913	66	1913-38	+0.80
1938	50	1938-50	-1.15	1938	81	1938-50	-0.67
1950	43	*1950-73*	*+1.82*	1950	74	*1950-73*	*+1.34*
1960	49	1950-60	+1.28	1960	88	1950-60	+1.66
1973	66	1960-73	+2.24	1973	101	1960-73	+1.09
1987	79	1973-87	+1.31	1987	103	1973-87	+0.10

*Western Europe includes Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, UK. The 16 Advanced Countries include Western Europe plus Australia, Austria, Canada, Finland, Japan, USA.

The rate of catch-up is the change per annum in the log of the mean level of productivity relative to the USA (or the UK) times 100.

Source: Maddison, 1991, Table C-11.

Table 1B. Measures of the Dispersion of Labor Productivity Levels in 16 Advanced Countries and in Western Europe and Rates of Convergence[a]

	16 Advanced Countries*				Western Europe (10 countries)*		
	Dispersion ($\sigma/\bar{x}$)	**Rate of convergence (% per ann.)**			**Dispersion ($\sigma/\bar{x}$)**	**Rate of convergence (% per ann.)**	
1870	.44	1870-13	0.36	1870	.31	1870-1913	0.75
1913	.37	1913-38	0.46	1913	.22	1913-38	1.73
1938	.33	1938-50	-2.10	1938	.14	1938-50	-2.56
1950	.43	*1950-73*	*4.00*	1950	.20	*1950-73*	*4.51*
1960	.34	1950-60	2.24	1960	.12	1950-60	4.78
1973	.17	1960-73	5.35	1973	.07	1960-73	4.30
1987	.13	1973-87	1.74	1987	.10	1973-87	2.88

*For the list of countries, see Table 1A

[a]Dispersion is measured by the coefficient of variation ($\sigma/\bar{x}$). The rate of convergence is the negative of the change per annum in the log of $\sigma/\bar{x}$ times 100. Rates of convergence were calculated from unrounded numbers and, therefore, are not precisely consistent with the rounded measures of dispersion shown above.

Source: Maddison, 1991, Table C-11.

Table 2 Indicators of Productivity Growth in the Production and Use of Primary Products

A.Relatives of output per worker in 1939 (1902=100)[a]

Mining including gas and oil	280
Gas and oil	444[b]
Mining excl. gas and oil	178
Agriculture	164
Manufacturing	194

[a] Comparisons are for 5-year averages centered on 1902 and 1939.

[b] Based on growth rate from 1902 to 1937.

Source: Barger and Schurr (1944), Table 12.

B. Unit Costs (Labor and Capital) of Gross Product Originating in Primary Products Sectors *Relative* to Unit Costs of Gross Domestic Non-Primary Product[a] in the U.S.A.

	Minerals	Agriculture	Forestry[b]
1870-1900 (average)	155	97	36
1900	155	94	47
1919	139	97	55
1937	78	91	100
1957	69	97	130

[a] GDP less products of Minerals industries, Agriculture, Forest Products and Fishing.

[b] Estimates for sawn logs only; 1937 interpolated from 1930 and 1940 figures.

Source: Barnett and Morse (1963), Tables 6,7 and 8.

C. Energy and Electricity Consumption per dollar of GDP in 1929 prices (1920 = 100)

	Energy Consumption in BTU equivalents per dollar:		Electricity Consumption
	Total[a]	in Electricity Generation	in kwh's per dollar
1900[b]	86	77	20
1920	100	100	100
1950	64	97	268
1970	63	n.a.	556

[a] Mineral fuels, hydropower and wood for fuel.

[b] Electricity consumption estimates for 1902.

Sources: 1900-1950 computed from data in Schurr and Netschert (1960), Tables 52, 58, and from Kendrick (1961), Table A-III, and estimated energy conversion estimates based on data in David (1991a) for 1902; extrapolations for 1950-1970 based on Darmstadter (1972) Appendix, Table 1.

Table 3 Comparative Levels of Capital-Labor Ratios, 1870-1979 (USA=100)

	Germany	**Italy**	**UK**	**Average of 3 European Countries**	**Japan**
1870	73		117	--	--
1880	73	26	106	68	12
1913	60	24	59	48	10
1938	42	32	43	39	13
1950	46	31	46	39	13
1970	71	48	53	57	29
1979	105	66	64	78	52

Note: Labor input measured by hours worked, capital by gross fixed non-residential capital stock (Germany by net capital stock; so the German relatives are somewhat understated).

Source: Wolff (1991): 565-79, Table 2

Table 4 Average Years of Formal Education of the Population Aged 15-64 in Four European Countries and Japan Compared with the USA 1913-1989

(USA=100)

	1913	1950	1973	1989
France	89	86	85	87
Germany	100	90	82	72
Netherlands	87	78	79	78
UK	105	99	91	84
Average of 4 European Countries	95	88	84	80
Japan	74	86	90	87

Source: 1913, 1950, 1973 from, Maddison (1987), Table A-12; 1989 from Maddison (1991), Table 3.8.

Endnotes

1. Whether the formulation offered here is more or less "elemental" than the neoclassical growth models patterned on Solow's (1956) seminal paper is a matter of taste. In Solow-style models, there exists a unique and globally stable growth path to which the level of labor productivity (and per capita output) will converge, and along which the rate of advance is fixed (exogenously) by the rate of technological progress. A large crop of mutant models of aggregate growth has flowered since the mid-1980s. These have diverged from the pure neoclassical strain of growth theory by rejecting, in one way or another, the assumption that all forms of capital accumulation eventually run into diminishing marginal returns. Consequently, they contest the Solow-model's global convergence implications. See Lucas (1988) and Romer (1986, 1990) for seminal contributions in this vein, and the useful recent surveys by van de Klundert and Smulders (1992), Verspagen (1992) and Amable (1994). Harris (1993) and Dosi and Fabiani (1994) essay thoroughly non-neoclassical approaches to modelling convergence and divergence phenomena.

2. It would be convenient to be able to treat recovery from the effects of war-related destruction and disruption on the productivity of surviving resources, as an unambiguous short-run, "rebound" process, in other words, as being clearly distinguishable from the phenomenon of long-run convergence. But, in actual experience, the two may be difficult to disentangle. Such is the case when reconstruction provides an opportunity for widespread introduction of structures and capital equipment, and organizational forms, that are of much more recent vintage than the economically obsolete facilities that had been destroyed. Dumke (1990), for example, argues that much of western Europe's "supergrowth" after 1948 is attributable to postwar reconstruction; using the ratio of 1948 GDP to 1938 GDP as a measure of the war-related supply shock a country had sustained, he finds from regression analysis that this variable continued to effect growth rates into the 1960s.

3. In the recent literature on the subject of convergence (discussed at greater length below) the term "catch-up" often has been used interchangeably with "convergence". An effort has been made here, to eschew that practice. "Catch-up" refers to the long-run process by which productivity laggards close the proportional gaps that separate them from the productivity leader (as reflected in the average measured presented here in Table 1A). "Convergence", in our usage, refers to a reduction of a measure of dispersion in the relative productivity levels of the array of countries under examination. Our idea of convergence is associated with the concept that Barro and Sala-i-Martin (1991, 1992) have labelled "σ-convergence". This refers to a narrowing of the dispersion within the international cross-section of productivity levels over time--as measured by the standard deviation of the logarithm of productivity, or, equivalently here, by the coefficient of variation of the productivity relatives (presented in Table 1B). Since it is "quasi-global" σ-convergence, measured for the entire group of advanced countries (including the United States), that we have in mind when speaking simply of "convergence", it is entirely possible for this to occur in the absence of any general catch-up.

4. As the text below points out, however, the speed of convergence within the group of 16 countries including the USA in this period was very slow compared with its pace after 1950, but also compared with the speed of convergence among the western European countries. In a recent paper, Taylor and Williamson (1994) estimate that the large population movements during 1870-1913 should have tended to raise the relatively low levels of productivity in Europe and to reduce the relatively high levels in the emigrant receiving countries, among which the USA was the largest. If one accepts their calculations, the

widening relative gap in labor productivity between western European countries and the USA during this same period is even more remarkable: the fall in the ratio of the 9-country Western European mean level (see Notes to Table 1A) vis-a-vis the USA level of productivity was from .65 to .53, even more pronounced than the drop shown for the full 15-country sample.

5. In describing Britain as "the former productivity leader," we have abstracted from the anomalously high relative level of productivity recorded for Australia in the early twentieth century. Australia's lead at the time rested only on its huge supply of land relative to labor in an economy almost entirely devoted to agriculture and animal ranching.

6. Interestingly enough, Alexander Gerschenkron's classic paper "Economic Backwardness in Historical Perspective"-- first published in 1952 and reprinted in Gerschenkron (1962: Ch. 2)--took the proposition of British leadership as virtually self-evident, basing it on much less firm empirical foundations than subsequently have been put in place. It now appears that the erosion of British productivity leadership vis-a-vis the Continental followers was almost universal; over the 1870-1913 interval the UK was able to maintain parity in the growth of real GDP per manhour only against Belgium. See Maddison (1991), Table 3.4. It would be of interest to try to gauge the extent to which the intra-European convergence observed over the period 1870-1913 was promoted by differentially heavier overseas immigration from the continent as a whole (vis-a-vis the British Isles), and especially from the Continent's peripheral regions -- first Scandinavia, and subsequently southern and eastern Europe. Although Taylor and Williamson (1994) discuss the role of international labor migration in convergence phenomena, their work focuses attention on the potential for altering productivity relationships between sending and receiving regions, not on productivity relationships among the regions that differed in rates of net emigration.

7. The Western European productivity catch-up relative to the UK continued between 1913 and 1938 while losing ground to the USA. All the continental countries grew at a faster rate than Britain, and their average productivity level rose from 66 to 81 percent of the UK level. World War II, however, hit the continental countries harder than it did the UK. Only Sweden and Switzerland, the two neutrals, continued their relative rise and the West European average fell back to 74 percent of Britain's level. (Maddison, 1991, Table C.11)

8. In speaking of a "catch-up" movement, we are referring to the rise in the mean of the followers' productivity relatives vis-a-vis the productivity leader, which in this instance is the United States. Throughout the following text, as was forecast in endnote 3, a distinction is maintained between "catch-up" and "convergence". In the recent macroeconomics literature, reference is often made to a different concept of catch-up that was called "β-convergence" by Barro and Sala-i-Martin (1991, 1992), which is essentially the coefficient on a negative correlation between productivity growth rates and initial levels of productivity (often with additional explanatory variables inserted). However, this kind of catch-up can easily confuse short-run, disequilibrium processes (like recovering from war-related destruction) with long-term convergence. Just as our preferred measures of "catch-up" and of "convergence" can diverge in their movements, σ-convergence is not implied by β-convergence: even though the lower productivity member of a pair is experiencing faster growth, the size of the absolute gap between them (the dispersion) may nonetheless be widening.

9. In their study of convergence in real GDP per capita levels in Europe 1850-1990 based on an augmented and revised versions of Maddison's (1991) data, Prados de la Escosura, Sanchez and Oliva (1993: 11) present the standard deviation of the logs measure of dispersion for the eight countries of the

Western European core (Belgium, Denmark, France, Germany, Netherlands, Sweden and the UK). This shows the same trend rate of decline (1.1 percentage points per annum) over the interval 1860-1938, with a faster rate of convergence during 1860-1913 being interrupted by a sharp rise in the dispersion in the 1913-1920 interval.

10. The Spearman rank correlation coefficient was - 0.96, as calculated from the data in Maddison (1989). See also Baumol, Blackman and Wolff (1989: Ch. 5). Prados de la Escosura et al. (1993: Table 4) present regression results for the fit of the unconditional convergence specification to real GDP per capita for 16 European countries over the entire period 1950-1990: the estimated regression coefficient on the logarithm of past per capita GDP is highly significant and implies a β-convergence rate of 1.7 percent per annum. Such statistical results, however, are not unproblematic. Abramovitz (1986) pointed out that the measures of inverse rank correlation which he reported, and, by the same token, the (β-convergence) results from linear regression analysis of the sort presented by Baumol (1986), would tend to overstate the strength of the negative relationship. DeLong (1988) developed a related point of criticism, noting that inasmuch as the estimates of initial productivity levels were constructed by methods that involved extrapolating backward from later benchmark data, measurement errors in the growth rates would be (negatively) correlated with those in the initial productivity levels. Friedman (1992) presents a systematic treatment of the same classic problem of regression bias due to errors in variables. All the foregoing, it should be noted, do not question the validity of the regression specification of the relationship as being linear in the logarithms of the countries respective productivity levels, as does Verspagen (1991), for example, to cite a notable exception in the literature. Therefore, whether or not the use of β-convergence type measures results in the overstatement of the strength of the "true" convergence process post-1950 in comparison with that for the period pre-1938, or pre-1913, is not a matter that has been resolved.

11. Actually, the effects of World War I and the Great Depression do not appear to have been sufficient to do more than temporarily interrupt the slow secular reduction of the dispersion in productivity levels that was taking place *within* the core group of western European countries. For compelling evidence on this point, see the study of Prados de la Escosura, Sanchez and Oliva (1993) on the convergence in real GDP per capita levels in Europe from 1850-1990. Focussing just on the 1929-1938 interval, we calculate from Maddison's (1991) comparative GDP per manhour estimates that the coefficient of variation within the group of 10 Western European economies (Table 1A) declined by almost 40 percent of its 1929 magnitude. Yet, the same measure computed for the entire sample of 16 advanced countries declined by only some 10 percent. Thus, the Depression decade had more of an effect in deferring the convergence of the Western European group toward the higher productivity of the USA and other regions of recent settlement than it had in delaying the process at work within the West European "convergence club" itself.

12. See David (1975: Ch. 1) for an introduction to the theory of "localized" technological progress and its relationship to the global bias of factor-augmenting technical change, and a synthesis of some of the pertinent historical evidence. Related, more recent studies are noted below. Broadberry (1993) applies this general framework to interpret the historical evidence on manufacturing productivity leadership and technological leadership relationships between the United States and western Europe over the period from 1820 to 1987.

13. On hysteresis effects and path-dependence in technological, organizational and institutional evolution, see, for example, David (1975, 1985, 1988, 1993, 1994a, 1994b). The concepts of technological regimes, or "paradigms" and "trajectories" is discussed by Dosi (1982, 1988), extending the work of Nelson and Winter (1977) and Sahal (1981).

14. On the problem of adapting intellectual property institutions to changes in the methods of acquiring knowledge of new technologies, and the problems of accommodating the needs of new technology innovations (in computer software and biotechnology, for example) within the existing legal framework of intellectual property, see David (1994a) and references therein.

15. Maddison (1991, Table 1.1) finds that the U.S. productivity advantage may have started well before 1870, perhaps as far back as 1820. But his estimates for these early years are exceedingly rough, and other estimates, at least for the United States, indicate that the American advantage increased little if at all between 1820 and 1870. In any event, industrialization in Canada, Australia and Japan and several of the European countries had hardly begun before 1870. For that reason, it would be wrong to view all the countries that eventually came to be "industrially advanced" as having been similarly positioned throughout the pre-1870 era in regard to their respective effective potentials for catching up with the productivity leader.

16. With some amendment, much of this section and the next follows the argument and evidence of several earlier papers: Rosenberg (1980), Wright (1990), Nelson (1991), David and Wright (1992), Nelson and Wright (1992), and previous work published individually and jointly by the present writers.

17. As Rosenberg (1976, Ch. 2) has said, in describing America's rise to woodworking leadership during the period 1800-1850: "[I]t would be difficult to exaggerate the extent of early American dependence upon this natural resource: it was the major source of fuel, it was the primary building material, it was a critical source of chemical inputs (potash and pearlash), and it was an industrial raw material par excellence."

18. See David and Wright (1991), Tables 1,2, and Figure 2. The following statements in the text are based on the same source, Figures 3-5, and Wright (1990), Chart 5.

19. For example, Wright (1990: p. 622) cites Foreman-Peck (1982: p. 874) to the effect that as late as the 1920s, "Ford UK faced steel input prices that were higher by 50 percent than those paid by the parent company."

20. These follow and elaborate on the lines of argument in Schultz (1951) and Nelson and Wright (1992).

21. For a general discussion of the trend towards round-aboutness and increasing capital intensity in late-nineteenth century industrial technology, the interested reader might begin with Abramovitz and David (1973a), Rosenberg (1976), and Hounshell (1984). With regard to the manufacturing industries in the United States and Britain, see the careful quantitative comparisons in James and Skinner (1985) and Broadberry (1993).

22. Growth accounting studies for the U.S. domestic economy in the 19th century shows that tangible capital accumulation was then the major source by far of the growth of output per manhour and of its acceleration. See, for example, Abramovitz and David (1973a), David (1977), Abramovitz (1993). But statistical analysis also indicates that the importance of capital accumulation in that era rested on a tangible capital-using bias of technological progress. Although a series of studies report that the elasticity of substitution between tangible capital and labor is less than unity --- which by itself would have reduced the income share of capital, which was the faster growing factor -- capital's share of GDP in fact rose markedly in the United States during the 19th century and remained stable into the early years of the

present century. There is, therefore, a strong presumption that technological progress was tangible capital-using not only at the aggregate level of the domestic economy, but within the industrial and agricultural sectors as well. For quantitative evidence on the elasticity of substitution and the bias of factor-augmenting technical change at the aggregate and industry levels in the USA, see David and van de Klundert (1965), Abramovitz and David (1973b), David (1975, Chs. 1, 4), David (1977), Cain and Paterson (1981).

23. Parker (1991: pp. 325-329) addresses the deeper issue of the endogeneity of technical and spatial innovation in the American agrarian context. There were, he suggests, two-way causal influences running between the westward movement and regional agricultural specialization, on the one hand, and technological progress in the development and improvement of farm machinery, on the other hand. This interaction was especially notable in the case of the mechanization of reaping and threshing small grains (which accounted for virtually all of the nineteenth century American labor productivity growth in wheat and oats), and in the development of improved plows, seed drills, and row cultivators (which accounted for all the productivity growth in corn farming).

24. Edward Wolff's figures in Table 3, which refer to gross reproducible, fixed, non-residential capital stock per person employed go back to Maddison (1982). More recent estimates by Maddison, however, based on standardized assumptions regarding asset lives, revise his earlier estimates drastically. They put US stock at a level over twice as high as the UK as early as 1890 (Maddison, 1991, Table 3.9). And more recent, still unpublished, figures suggest that the USA may already have enjoyed a substantial lead even in 1870.

In manufacturing, however, the capital-labor ratio in the USA was already 94 per cent of the UK level in 1870, on the evidence of the official (Census) net stock figures. Stephen Broadberry's (1992) adjustments to standardize the service life assumptions underlying the American and British net capital stock figures--carried out by Broadberry for 1950 and later dates--would suggest that the corrected comparison for 1870 would show the capital-labor ratio in the USA to have already been at 150 per cent of the UK's level. One must bear in mind, however, that in 1870, at the end of the golden age of "High Farming" in Britain, heavy reproducible capital formation for drainage and other farm improvements had pushed Britain's agricultural capital-output ratio to a level well above that in the USA.

25. The technologically driven shift in the structure of relative asset demands, therefore, should be seen to be significant force that has operated to reduce the conventionally measured gross savings rate (both in real and nominal terms) in the American economy during the 20th century. The fact that despite the recurrent urging by economists over a number of decades (see, e.g., Abramovitz and David (1973a), David and Scadding, 1974; Eisner, 1989; Kendrick, 1976, 1994), the official national income accounts remain blind to the rising importance of intangible capital formation has been a factor contributing to the misplaced emphasis given forces impinging on the supply of savings in efforts to explain and find policy correctives for the U.S. economy's "declining savings rate" problem.

26. Inkles (1981: pp.20, 25) points out that while different countries followed distinctive historical paths towards the complete enrollment of all children in primary school, and eventually in secondary school,too, the industrialized nations arrived quite rapidly at substantially the same destination in this regard; and they emerged with the institutional and administrative structures of their educational systems that resembled one another in many broad features. After World War II all the leading nations of the West increased the proportion of GNP expended on public education, converging on the figure of 6 percent (direct costs) during the period 1955-75, but, the national patterns of allocation of educational

expenditures among the primary, secondary and tertiary levels remained quite variegated. See also Inkles and Sirowy (1983).

27. See David (1975, Ch.1) for the formulation and historical application of a model of "locally neutral stochastic learning" built on the Atkinson and Stiglitz (1969) concept of localized technical change, the literature of learning by doing following Arrow (1962), and Rosenberg's (1969) notion of "compulsive sequences" of innovation. Antonelli (1994) recently has expanded the concept of localized technological change and shown its applicability in numerous industrial contexts.

28. The dependence of the growth rate of efficiency on the growth of the gross stock of (cumulated) investment was hypothesized in Arrow's (1962) classic paper on learning-by-doing. See Rosenberg (1980) on learning-by-using in the case of complex production systems. The hypothesis that productivity growth is stimulated particularly by high investment rates in producer's equipment receives some empirical support from DeLong and Summers' (1991) study of international data for the post-World War II period.

29. "Social capability" is a subject that has drawn the attention of historians and economists for many years. De Tocqueville (Part 2, 1840) and Veblen (1915) are notable examples of older writings. There was a considerable addition to this literature in the years following World War II, and we depend on these writings in the pages that follow. We refer especially to the essays by Arthur H. Cole, Thomas C. Cochran and others in the collective volume prepared by the Harvard Entrepreneurial Research Center (1949), to the series of biographies of businessmen edited by Miller (1952); to the essays on France by Sawyer (1951, 1954); to those on France and Germany by Landes (1949, 1951, 1954) and Gerschenkron (1953, 1954, 1955), and also to Wiener's (1962) controversial work on the role of culture and class in Britain's relative decline. In more recent decades the subject has been largely neglected and is only now being taken up again by economic historians, as in Parker (1982, 1991) and Lazonick (1994). An even fuller view of social capability would include the growing literature of public choice, economic organization and institutions, not only in economics but also in political science and sociology.

30. Some qualifications are in order. Finland was acquired by Russia in 1809 but granted a constitution that gave the country a semi-independent status. Full independence was achieved only in 1917. Denmark has suffered several partitions of Schleswig-Holstein and their transfer between itself and Germany. The unifications of Germany and Italy were completed only in 1871. While Austria itself has survived to the present time, it lost its Empire by the Treaty of St. Germain in 1919. Norway did not become fully independent until 1905, but gained substantial control of its internal affairs some decades earlier.

31. See endnote 29 for citations to works supporting what may seem to be a sweeping judgement.

32. See Emmerson (1973) on the intellectual foundations and the contrasting social realities that formed the context for engineering schools in Europe and North America. Especially notable was the contrast with the French "grandes ecoles", which initially had a strong influence on American engineering education. Ferguson (1992: pp.72, 208-09) notes that when the U.S. Military Academy was reorganized in 1817, the practical military and civilian engineering curriculum adopted was the one in use at the Ecole Polytechnique in Paris during 1795-1804; the heavily scientific curriculum that had been introduced at the Ecole Polytechnique after 1815 was essentially ignored, and never was widely adopted by American engineering schools. David and Wright (1992) discuss differences between American and European educational institutions in the case of 19th century mining engineering. In the 20th century, the long delay

in the appearance in Europe of schools of "business administration" and "management" conducted at the university and post-graduate levels is also worth notice in this connection.

33. A recent study by Dougherty (1991), applying the refined Tornqvist index procedures developed and implemented by Dale Jorgenson, reaches the following values for relative multifactor productivity (output per combined unit of labor and capital relative to the USA= 100) in 1989: Canada , 101; Germany, 89; France, 112; UK, 102; Italy, 101.

34. A considerable body of empirical work on convergence also has been produced using the international database, constructed by Kravis, Summers and Heston (1982) and extended by Summers and Heston (1988), on GDP constant purchasing power equivalents for more than 100 countries in the period 1950-1985. See Fagerberg (1994) for a recent survey. Although the time period covered is briefer, this data offers the advantage of being about to study a larger and more diverse sample of contemporary countries, within which difference in the degree of technological congruence and in social capabilities are likely to be more pronounced.

35. See Baumol (1986) for the initial suggestion that the international data showed the existence of "convergence clubs" rather than global convergence, and the econometrically rigorous tests for "local" as distinct from global convergence presented by Durlauf and Johnson (1992).