Historical Origins of the New American Economy

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In recent years many American business and political leaders have expressed apprehension about potential loss of the country's technological leadership in the world, reviving a discussion that was last active during the 1980s and early 1990s. Evaluating these concerns is difficult without a clearer historical definition of American technology and its connection to economic performance. This paper surveys the historical and institutional record of U.S. technological development, with an eye towards assessing the current situation. The paper's analytical core is the distinction between the technology-generating sectors of the economy and the technology-using sectors, which it is argued have had quite different relationships to each other across major historical phases. In the process, the paper revisits the argument of Nelson and Wright (1992) that "the advanced nations of the world have come to share a common technology." That proposition was clearly deficient as a forecast of the subsequent decade, which featured the dot.com boom and the Internet revolution, developments that fostered distinctively American productivity growth. But it may prove accurate after all, as a diagnosis of the state of the world in the twenty-first century.

Origins (1789-1860)

The first American innovations in technology predate the Revolution, but the emergence of a stream of economically significant advances occurred during the first two generations of nationhood. To the extent that national policy may be said to have encouraged innovation during this era, this largely took the form of enabling institutional arrangements rather than active subsidy or support. Notable progressive features of the Constitution of 1789 (as embodied by the Hamiltonian program of the 1790s) include establishment of a unified national market for the free flow of goods and persons; a uniform national currency; a standard system of weights and measures; and creation of a domestic capital market in which federal securities were actively traded. The states gave up their power to coin money and restrict interstate trade; but their desire to foster development and increase land values led states to compete for migrants and capital by chartering banks, roads, bridges, canals and other improvements.

A somewhat more active role may be assigned to the national system of patents (authorized under the Constitution and enacted during the first session of Congress). This was a true institutional innovation, in that fees were reduced and procedures streamlined relative to the British system, in a conscious effort to encourage an indigenous class of inventors. As of the 1830s, patents were awarded on the basis of technological novelty (established by a board of technical review), and the disclosure requirement served to disseminate new technical information rapidly to the reading public. Augmented by a network of patent agents and other intermediaries, the system encouraged innovative efforts through a much broader segment of the population than in Britain or other European countries (Khan and Sokoloff 2001, Khan 2005).

American technology's first major splash onto world consciousness came at the 1851 Crystal Palace Exhibition in London, where such innovations as the McCormick reaper and the Colt six-shooter stole the show. British engineers coined the term "American System of Manufactures" to refer to a novel national approach, and economic historians have debated ever since how their technical descriptions should best be understood as economics. Summarizing a lengthy literature briefly, American manufacturing methods were a) capital-intensive (specifically, using dedicated special-purpose machinery); b) resource-using, including both material inputs and fuels; c) designed to produce standardized products for the middle-class American market; d) intensive in unskilled (though hard-working) labor as opposed to skilled craft labor. The process generating these features may best be characterized as an *adaptation of European inventions to American national conditions*.

Rather than emphasizing particular features of this emerging national technology, the more important point is that the scale and homogeneity of the U.S. economy was large enough to support an indigenous technological network or community.[1] Although the process was thoroughly decentralized and intensely competitive, one may still speak legitimately of a collectivity pursuing common objectives, in that they were responding to market signals in a problem-solving environment characterized by rapid learning and spillovers across industries (Thomson 1989). Nathan Rosenberg (1963) identifies the central locus of learning and diffusion as the machine-tools industry, in which specialized firms cultivated technical expertise and sought out every opportunity to expand the market for their talents. Such firms experienced high turnover among technical personnel, much like their Silicon Valley descendants more than a century later. Leading machine-tool firms like the Matteawan Manufacturing Company of Beacon, New York, trained several generations of expert machinists only to find that these “alumni” left to take management positions or to found their own firms in new locations. A study of the careers of ten leading machinists found that they had worked for an average of 5.5 employers in 4.2 industrial centers (Lozier 1986, pp. 33, 202).

World Leadership (1860-1910)

Roughly between 1890 and 1910, the US became the world’s leading economy, as indicated by GDP per capita, productivity, industrial output, or qualitative assessments of technology in such industries as steel, aluminum, office equipment (typewriters), communications (telephone), and photography. Development of a distinctive American technology was clearly vital for this economic performance. Nonetheless, for present purposes it is important to note that at this historical juncture the US was not the world leader in science, nor in many aspects of technology broadly construed.

The Civil War decade launched a number of institutions representing a greater federal role in technology. The Department of Agriculture, created in 1862, sponsored research and experimentation in plant and animal breeding, and disease and insect control; and disseminated information to farmers through publications, experiment stations, and county demonstration work. The Morrill Act of 1862 established “land-grant” colleges for training in engineering, agriculture, and military science. Several federally-sponsored mineral projects were consolidated in 1879 with the founding of the U.S. Geological Survey. But although these investments in technological knowledge and human capital had important payoffs in the twentieth century, their direct role in the U.S. ascendancy to world economic leadership was relatively limited.

Much technological progress in U.S. industry across the nineteenth century took the form of elaboration and extension of the mechanical and metalworking skills that began in the antebellum era. In textiles, the U.S. pioneered the development of ring-spinning technology, which emerged as the major alternative to the British mule. The ring was well-adapted to American conditions, in that it employed relatively unskilled labor and was better suited to longer-staple U.S. cottons used in long production runs of standardized yarns and cloth. But this was not merely a choice between existing techniques. The ring's competitive position was assured by the Spindle Revolution, which increased machine speed from 5,500 rpm in the 1850s to 7,500 rpm in the 1870s (the Sawyer spindle) and to 10,000 rpm by 1880 (the Rabbeth spindle). By 1910, the two largest textile industries in the world were at opposite ends of the spectrum in their commitment to their preferred spinning technology (Saxonhouse and Wright 2004).

Textile machinery had important technical linkages to many other machine tools such as steam engines, turbines, and locomotives. In his study of mechanical innovations in sewing and shoe machinery, Ross Thomson observes: "Established and potential inventors were integrated in a communications network that tied the diffusion and improvement of some machines to the birth of others…By the time Goodyear developed its system of machines, it could call on well-established solutions and professional inventors. Most of its crossover inventors adapted machines to the requirements of the Goodyear shoe" (1989, pp. 211-12). Even in a newer and more science-based technology like the telegraph, Israel (1992) shows that improvements grew largely out of a "shop culture" of practical experience, and many practitioners moved from the operating room into the manufacture of equipment.

Turn-of-the century American technology may be seen as a confluence between this stream of mechanical expertise and development of the nation's potential in minerals. The U.S. Geological Survey emerged as the leading scientific bureau of the time and the most productive governmental research agency of the nineteenth century (David and Wright 1997). The payoff to its early topographical and geographical work had a lasting impact on popular appreciation of the practical benefits of scientific research. Through its close ties to the mining industry in research priorities and publications, the Survey acquired a reputation as an ideal stepping-stone toward career success in that sector. Federal support for minerals was supplemented and in some respects surpassed by the activities of the states. Columbia College in the City of New York led in the training of mining engineers between 1864 and the mid-1890s, but by the turn of the century more than twenty schools in the country granted degrees in mining. This surge nicely illustrates the entrepreneurial character of American research universities, which have been eager to adapt their curricula to changing industrial demands, and their research priorities to state and regional economic development (Rosenberg and Nelson 1994).

The American Century (1910-1970)

The first US surge to world economic leadership might have been followed by a gradual convergence in productivity and income levels among the advanced nations of the world. Instead, while the western European economies were set back by two world wars and disrupted world trade and payments during the interwar period, the US enjoyed a second surge to a unique head-and-shoulders leadership position by 1950. One major component of this performance reflected a continuation of 19^{th} century strengths in natural resources and mass production industries. The most dramatic example was the automobile industry, a blend of mass production methods, cheap materials and fuels. Although large, gas-guzzling Americans cars were clearly designed for the domestic market, the combination of scale economies and technology was powerful enough to dominate world motor vehicle trade in the 1920s (Foreman-Peck 1982).

A more lasting basis for technological leadership was established in those industries that were able to marry mass-production methods to organized science-based research. The institutional bases for this new phase included corporate research laboratories, research universities, and the deployment of trained scientists and engineers to the development of new science-based technologies. All of these developments had roots in the pre-World War I era, but Figures 1 and 2 show that the major quantitative expansion of laboratory foundations and employment of scientists and engineers in manufacturing occurred during the 1920s and continued even through the Great Depression of the 1930s.

Examples of new science-based technologies include electricity and petrochemicals. The technological basis for electrification of power in manufacturing were largely complete by the 1890s, but rapid diffusion and associated productivity effects began only in the 1920s. Electrification was encouraged by infrastructure investments in generation and transmission capacity, and it was implemented by a manufacturing investment boom, which allowed new plants to be redesigned so as to take full advantage of electricity's potential for savings in fixed capital and streamlining the flow of materials through the plant (David and Wright 2003).

Petrochemicals built on longstanding American leadership in petroleum, but new technologies emerged from university-industry collaborations that should be viewed as institutional innovations. For example, working in close partnership with M.I.T., New Jersey Standard's research organization in Baton Rouge, Louisiana, produced such process important innovations as hydroforming, fluid flex coking, and fluid catalytic cracking. A closely related innovation was the new professional specialty known as chemical engineering, a distinctively American creation that has been likened to a "general purpose technology" (Rosenberg 1998).

Taken together, these analyses support the macroeconomic interpretation of a broad shift in the character of U.S. technology between the nineteenth and twentieth centuries, from techniques intensive in natural resources and tangible capital to those drawing more on intangible forms of capital, including investments in human capital (primarily education) and research and development (Abramovitz and David 2000).

A related feature of new twentieth-century American technologies is that they generated jobs that favored more educated workers, a pattern that Claudia Goldin and Lawrence Katz (1998) refer to as "Technology-Skill Complementarity". Goldin and Katz show that growing employment of high-school graduates was associated with new technologies such as electric motors, continuous process and batch methods. This complementarity was in contrast to that of the nineteenth-century "American system," in which capital combined with unskilled labor to displace skilled craft artisans. One reading of the shift holds that a bias toward skilled or educated workers was inherent in the increasing science-based origins of these technologies. An alternative maintains that the change was endogenous to advances in American education, an example of "directed technological change" (Acemoglu 1998). In comparison to the pre-World War I years, manufacturing workers of the 1920s were more mature, better-educated, more likely to be English-speaking and married, and more committed to industrial work as a career.

Although their technological sophistication was more advanced, one may still characterize American technology during this era as adaptive to distinctive national conditions. For example, Misa (1995) identifies producer-user interaction as the core element in the evolution of a distinctive American steel technology, taking up such examples as railroads, skyscrapers, factories, and automobiles. Similarly, technological advances in office services were complementary to American acceptance of high-volume, standardized forms of communication and marketing (Broadberry and Ghosal 2002).

The Postwar Golden Age (1945-1970s)

The institutional bases of the knowledge economy were extended and in major ways reformulated after World War II, through federal government initiatives on many fronts. The GI Bill and other supports for higher education generated an unprecedented increase in the supply of trained scientists and engineers. New programs of the National Science Foundation and the National Institutes of Health provided public funding for basic research across a broad spectrum of fields. Still greater research funding came from the Department of Defense and the Atomic Energy Commission – generally under a Cold War rationale, but within a broad consensus that such research was an important contributor to national economic growth. By the middle 1950s American research universities were unquestionably best in the world, and young students from all over the world began to come to the U.S. for their training.

During this same period, the United States enjoyed sustained productivity growth averaging nearly three percent per year, driving and enabling advances in real wages and living standards across most of the population. One should not assume, however, that there was a tight linkage between progress in scientific research and the productivity record. Sectoral studies suggest that rapid productivity gains were centered in transportation, energy, and trade, including such innovations as containerization and piggybacking in trucking, rail and ocean shipping. Private-sector progress in these areas was facilitated by such infrastructure investments as highways and pipelines. (Field 2007). One may conceptualize many of these developments as part of a broad trajectory of adaptation to the automobile, including demographic trends such as suburbanization and regional migration. Since diffusion-type phenomena like these have inherent limitations, it is possible that productivity growth rates would have gradually slowed under many different historical scenarios, and indeed Field argues that the deceleration began prior to 1973, the conventional date for the end of the era (p. 85). As it happened, productivity growth slowed precipitously in the 1970s, because of the energy crisis and subsequent macroeconomic turmoil of that decade (Nordhaus 2004).

Technology-Generating vs. Technology-Using Sectors: A Key Distinction

In an effort to find some order in these diverse historical patterns, I propose that we maintain a distinction between the "technology-generating" sectors and institutions of the economy, and their "technology-using" sectoral counterparts. Such a distinction is often implicit and sometimes explicit in the productivity literature, so perhaps it is not controversial. Yet it is frequently lost in policy discussions regarding the "competitiveness" of the U.S. economy as a whole.

The distinction is essential for a number of reasons. The two parts of the economy can be very different from each other in basic characteristics. Only by separating machine-tool industries from final-products manufacturing have economic historians been able to make sense of the nineteenth-century patterns. Machine-tools firms were flexible, entrepreneurial, diverse, as they had to be to accommodate their high-mobility, individualistic high-tech employees – much the way Silicon Valley folk are said to change jobs without changing their carpools. Yet this same cast of characters designed a manufacturing technology that featured massive amounts of fixed capital, high energy demands, and routinized semi-skilled jobs for a high-turnover work force: a system proverbially "designed by geniuses to be run by idiots."

A second international example illustrates the importance of distinguishing the two sectors. Between the 1840s and the 1920s, world trade in cotton spinning machines was dominated by a handful of British textile machinery companies; by 1913 these firms supplied 87 percent of world trade in spinning and preparatory machines. As previously noted, the British domestic cotton industry was largely committed to the mule. The outward-looking British textile machinery industry, however, began to produce ring spinning machines in the 1870s, under license from the American inventors. Within a few years, British companies were proudly promoting their own advanced versions of ring machines, which they marketed to emerging cotton industries all over the world. Because the British machinery makers responded to international rather than merely to domestic demands, progress in ring technology enhanced its skill-saving properties while extending the range of fiber lengths and yarn counts that rings could accommodate, thereby contributing to the demise of the historic Lancashire textile industry beginning in the 1920s (Saxonhouse and Wright 2004).

A second reason for separating technology-generating from technology-using is that there are often extended lags between initial technological breakthroughs and their ultimate diffusion and productivity impacts. Well-known historical examples include the mechanical reaper in the nineteenth century, and electrification in the twentieth. In a famous study, Paul David (1990) suggested an analogy between the delayed productivity effects of electrification and the slow-growth decade of the 1980s, when (as Solow remarked) computers were visible everywhere except in the productivity statistics.

Lags between invention and innovation seemed all-important just two decades ago, as part of the critique of American corporations that was widely accepted during the 1980s and early 1990s. Americans continued to excel in generating new technologies, it was said, but our corporations lagged (behind the Japanese especially) in bringing these inventions to commercial fruition. Shortcomings included: continued adherence to inherited mass-production methods, coupled with failure to appreciate the importance of product quality; decision-making on the basis of narrow return-on-investment criteria, associated with an absence of long-term followthrough; control by lawyers and financial types, who lacked and undervalued engineering expertise; and a failure to invest in labor force quality.[2] These performance problems were either swept away or superseded by the US-led IT/dot.com productivity boom of the late 1990s. But the diagnosis may well have contained much validity in its time. Evidently, however, observers underestimated the flexibility and responsiveness of the IT-using sectors of the American economy in the wake of the internet revolution of the 1990s.

The Nelson-Wright Diagnosis

In 1992, Richard Nelson and Gavin Wright presented an argument that the U.S. had lost or at least was in the process of losing the technological leadership that it had long enjoyed over other advanced countries in the world. Our analysis was not based on putative failings of American corporate leadership, either cultural or structural. Rather, we argued that postwar American leadership had two main components: longstanding expertise in mass-production technology, and newer postwar first-mover leadership in science- and research-based technologies. The first of these rested on historical circumstances that had now passed: abundant natural resources and a uniquely large and attractive domestic market. By the 1960s, the U.S. was a net importer of virtually every economically important mineral, buying at world market prices and leveling the international playing field. While the American domestic market was as large and attractive as ever, liberalization of world trade and reductions in transportation costs meant that producers in all advanced countries had nearly the same market access formerly available only to American firms. Our point was not that the long history of U.S. economic leadership rested on narrow market advantages. It was that Americans had developed a distinctive *technological* lead under favorable conditions that could not easily be replicated elsewhere. In the postwar era this uniqueness no longer prevailed, and mass production methods rapidly spread around the world.

This adjustment was not particularly painful at the time, because leadership in mass production was replaced by leadership in high-tech industries like electronics, chemicals, aerospace, telecommunications and semiconductors. This new advantage was buttressed by all of the infrastructural supports discussed in the previous section, which continually replenished and extended U.S. technological capabilities. Furthermore, the U.S. high-tech lead seemed destined to continue, because markets for high-tech products were largest and most robust in the United States, in that these new products were designed for use by technologically sophisticated firms or affluent, discriminating consumers – elaborated in "product cycle" models that were popular in that era.

The problem was, as we saw it in 1992, that the newer technologies, having been codified and formalized in explicit technical formulas and models, were far more mobile internationally than mass-production technologies had been. To the extent that U.S. leadership was reinforced by differences in income levels, these gaps were rapidly closing in the postwar world. To the extent that leadership reflected larger investments in training scientists and engineers, or in organized research, these structures also proved readily replicable elsewhere. Thus we presented tables and graphs similar to Figure 3, suggesting that by many indicators of technological standing, the leadership position that loomed large as late as 1965 had greatly diminished by 1990. Our conclusion was not that the country was in economic decline, but that "the advanced countries of the world have come to share a common technology" (Nelson and Wright 1992, p. 1962).

What Went Wrong (Right)?

The Nelson-Wright diagnosis was logical and seemed to fit the facts reasonably well in the early 1990s. But as a forecast, it was not very accurate. Along with many others, we did not foresee the explosive impact of the Internet, and we most certainly did not foresee the unique affinity this new technology would have for the American economy and society. Beginning in 1995, U.S. productivity came out of its quarter-century doldrums and averaged between 2 and 2.5 percent per annum for the next decade. After some early debate and uncertainty, virtually all analysts concluded that the acceleration was primarily associated with direct and indirect effects of new IT technologies (for examples, Oliner and Sichel 2000, Stiroh 2001). Furthermore, both IT diffusion and productivity acceleration were primarily U.S. phenomena, prompting a revival of self-criticism in Europe about complacency and rigidities (Crafts 2004). By the end of the century, the locational pattern of high-tech manufacturing was again polarized in favor of the U.S., reversing decades of apparent equilibration and convergence (Figure 4).

What happened? The graphs in Figure 4 aggregate five manufacturing industries deemed as "high-tech" by the National Science Board (aerospace; computers and office machinery; communications equipment, pharmaceuticals; and medical, precision, and optical instruments), and as such, they conflate technology-generating and technology-using in proportions that would be difficult to disentangle. But there is little doubt that both elements contributed to the *fin de siecle* restoration of American technological exceptionalism. David Mowery and Timothy Simcoe (2002) argue that the Internet grew out of historically recognizable dimensions of the U.S. "national innovation system." Originating in a Defense Department project in the 1960s, what became the Internet was carried forward in the 1970s and 1980s by a diverse network of computer scientists and engineers. University associations were important, partially accounting for the "unsponsored" character of the technology during key periods of its development. American antitrust policy weakened the ability of incumbent firms (IBM and ATT) to control the technology, leaving the door open to new entrants such as Cisco and Dell, who took advantage of the country's well-developed capital markets. Network effects and standards were critical for early diffusion. Although the key protocols were not invented in the U.S., twenty years of federal and private-sector investments in R&D and infrastructure supported their rapid domestic adoption and development. The entry of AT&T World Net in 1995 established a branded, reliable nationwide Internet access service, but other ISPs soon followed. By 1998, more than 92 percent of the U.S. population had access by a short local phone call to seven or more ISPs, and the transition to commercial uses proceeded rapidly (Greenstein 2000, pp. 159-166).

The productivity effects of IT, however, did not simply walk through the door in exchange for a firm's user ID and password. Firm-level studies all show that major gains in productivity required restructuring of systems and personnel practices, steps for which IT was necessary but by no means sufficient (e.g., Sadun and Reenen 2005). On this dimension too, U.S. firms took the lead in innovative uses of IT, demonstrating a responsiveness often attributed to the country's free-wheeling managerial culture as well as the relative freedom from regulations and controls of various kinds, from marketing rules to personnel practices. Often called "co-invention," these complementary developments frequently involved close, productive interactions between IT suppliers and users. According to David Mowery: "U.S. competitive resurgence in industries such as computers and semiconductors relied on close proximity of U.S. producers and demanding, innovative users in a large domestic market" (1999, p. 4).

Particularly important in the 1990s were innovations in retail and wholesale trade, sectors previously thought to be inherently limited in their productivity potential (Triplett and Bosworth 2003). McKinsey (2001) concluded that the bulk of productivity acceleration in these sectors was attributable to managerial innovation at one firm, Wal-Mart. IT was important, but the McKinsey report stresses that it was only one of many management tools, a "necessary but not sufficient enabler of productivity gains."

Where Do We Stand?

Thus, during the decade bracketing the second and third millennia, the economic standing of the United States in the world seemed to have returned to that of a generation before: The country enjoyed economic leadership; this leadership was technologically based; and technology generation and usage complemented each other at the national level. The question before us is: Is this configuration sustainable? With all due recognition to the hazards of prediction, my assessment is no, it is not.

This judgment is not based on perceived shortcomings in the U.S. economy, either in technology generation or in usage. Nor does it derive from a perception that the American system can be readily transferred abroad, to countries with very different traditions and institutions. My appraisal reflects instead the observation that both the *sources* and the *content* of new technologies are rapidly internationalizing. This trend has many dimensions: increasing diversity in the geographic origins of innovation; rising two-way trade in high-technology products; high and rising shares of the foreign-born among U.S. science and engineering students, employees, and entrepreneurs; the increasing tendency towards two-way migration flows of high-tech personnel; and rapid globalization of internet usage. Among many possible indicators: Figure 5 displays the rapid rise in the share of U.S. patent applications submitted by foreigners, especially after 1995; Figure 6 shows the striking increase in the share of scientific and technical articles that are internationally co-authored – not just in the U.S. but in Europe and Asia as well.

Some analysts suggest that the U.S. can still retain its position of technological leadership in the face of these developments, because the country's centers of university-industry interface are uniquely attractive from a global perspective. Thus, Arora and Gambardella (2005) argue that the rise of software centers in such countries as India, Ireland and Israel represents a new international division of labor: the 3Is specialize in service and production for export, while the U.S. retains its "special comparative advantage" in "the development of new commercial applications or solutions" (p. 17).

There are many indications, however, that the asymmetrical character of high-tech interactions is changing fast. The two-way character of knowledge and personnel flows is the central theme of AnaLee Saxenian's new book, *The New Argonauts* (2006), confirmed by accounts of jockeying by "Nerd Birds" for seats on such flights as "The

Bangalore Express" between Silicon Valley and new technology centers in India (*San Jose Mercury News*, February 7, 2007). To the extent that software development entails adaptation to national idiosyncracies of various kinds, the sheer size of the emerging markets in India and China imply that technology-generating firms will direct their innovative energies towards satisfying these demands. As of 2007, there were twice as many Internet users in Asia than in North America, and that gap should widen in the future because penetration rates in Asia were still far behind, 12 percent compared to 70 percent (Internet World Stats, www.internetworldstats.com/stats.htm, accessed 6 November 2007). Consistent with this logic, high-tech companies such as Cisco and Microsoft have announced opening of major R&D facilities outside of the United States (Freeman 2006, p. 131).

Richard Freeman (2006) views the emerging geographic reconfiguration with some alarm, noting that populous low income countries such as China and India can deploy large numbers of scientists and engineers at low salaries, even though these high-tech workers are a small proportion of their work forces. He predicts a long and painful adjustment process as the U.S. relinquishes its position of superiority in science and technology and loses its "monopoly rents from being the lead country" (p. 148).

The argument presented here is more limited but perhaps more precise. Both technology-generating and technology-using sectors of the U.S. economy have unique strengths from a global perspective, and so long as these strengths are nourished and replenished over time, there seems little reason for deep pessimism about their futures. Loss of global market *share* may be inevitable, but this is more a matter of psychological and political adjustment than painful economic contraction. What we are indeed losing, however, is the uniquely privileged *access* to advanced technologies on the part of American firms that arose historically because of their proximity to its sources and implicit or explicit biases toward the country-of-origin in its detailed design. Twenty-first century technologies, whether or not they are "made in America," are no longer intended or designed primarily for the American market, and this trend towards internationalization seems irreversible. An analogy might be to the historical U.S. position as world leader in virtually every major industrial mineral at the time of World War I, a status that in its day was an important contributor to U.S. leadership in manufacturing. Loss of national leadership in minerals was not really a net blow to the country's manufacturing sector – imported minerals were cheaper after all. But it was a loss of American uniqueness in international context, and this change called for adjustments in both perception and behavior on the part of American business. This is roughly what we should expect for high-tech industry in the future.[3]

To be clear on what is *not* being argued, there is no suggestion here that the productivity performance of firms in technologically advanced countries of the world is or will soon be identical. To the contrary: countries of comparable development level display persistent differences in such dimensions as regulation, labor markets, education, politics, and norms of behavior. Some of these differences seem to be directly related to the use of IT. In a series of comparative studies, Bloom, Sadun and Van Reenen find that American managers consistently outperform those of other nationalities, and their advantage is associated with greater and more effective use of information technology (Bloom, Sadun, and Van Reenen 2007; Bloom and Van Reenen 2007). The authors rate managers on a range of managerial "best practices," including the use of promotion and pay incentives, lean manufacturing techniques, performance management and effective targets. They find that U.S. firms are on average significantly better managed than European firms, a difference they attribute to lower levels of prevailing regulation.

The authors do not, however, attribute the performance of American managers to greater technological sophistication, nor to their proximity to the firms from which the technology originated. Indeed, one of the striking findings is the superior performance of American managers *of multinational firms producing abroad*. Thus their skill in deploying new technology does not seem closely tied to production within the country. Although the interpretation of this finding undoubtedly requires further consideration, it is consistent with the thesis of this paper that the factors governing performance of technology-using sectors of the economy are largely separable from those governing the success of the technology-generating sectors. This trend towards separation was clearly visible in the 1980s and early 1990s; after a brief decade of interruption, the same trend is once again emerging for all to see.

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Figure 1. Laboratory Foundations in US Manufacturing

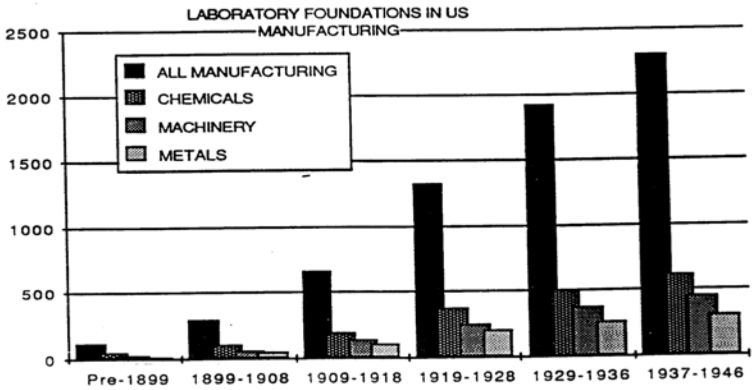


FIGURE 1 LABORATORY FOUNDATIONS IN US MANUFACTURING

SOURCE: Mowery and Rosenberg (1989), Table 4.1

Figure 2. Scientific Personnel/ 1000 Wage Earners

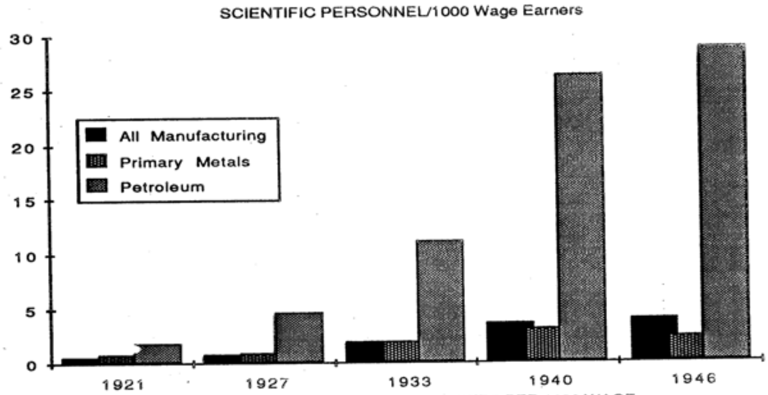


FIGURE 5. SCIENTISTS AND ENGINEERS PER 1000 WAGE EARNERS

SOURCE: Mowery and Rosenberg (1989), Tables 4.2, 4.3, 4.4, 4.5, 4.6

Figure 3. Scientists & Engineers in R&D/ 10,000 Workers

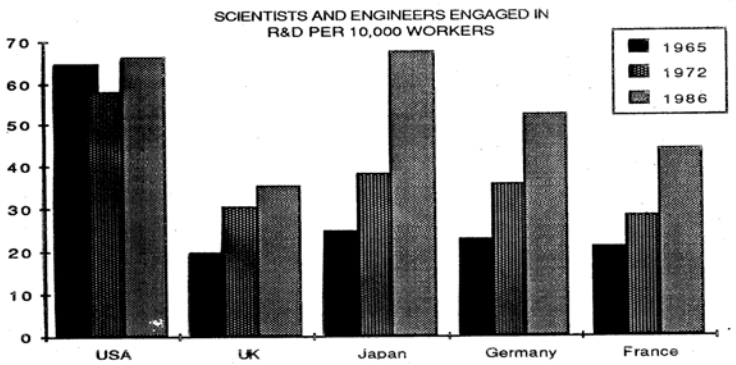


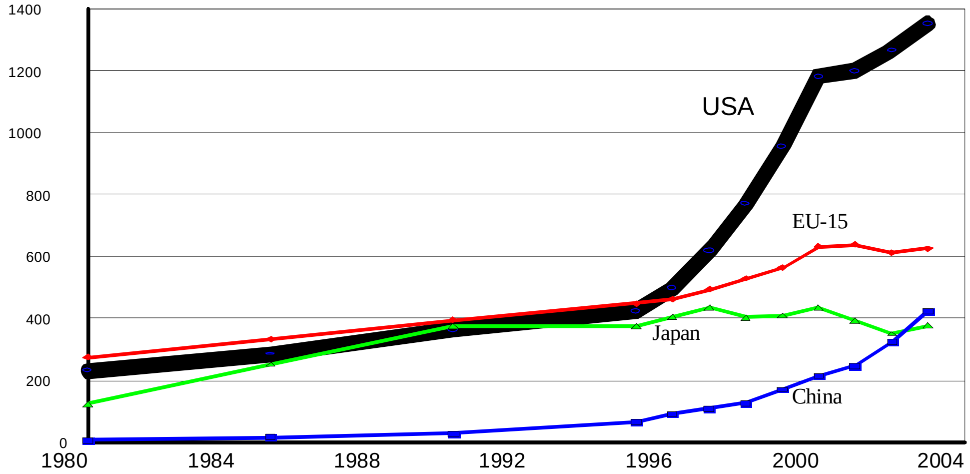
FIGURE 8. SCIENTISTS AND ENGINEERS ENGAGED IN R&D PER 10,000 WORKERS

SOURCE: National Science Board, Science and Technology Indicators (1989), Appendix Table 3-19.

Figure 4

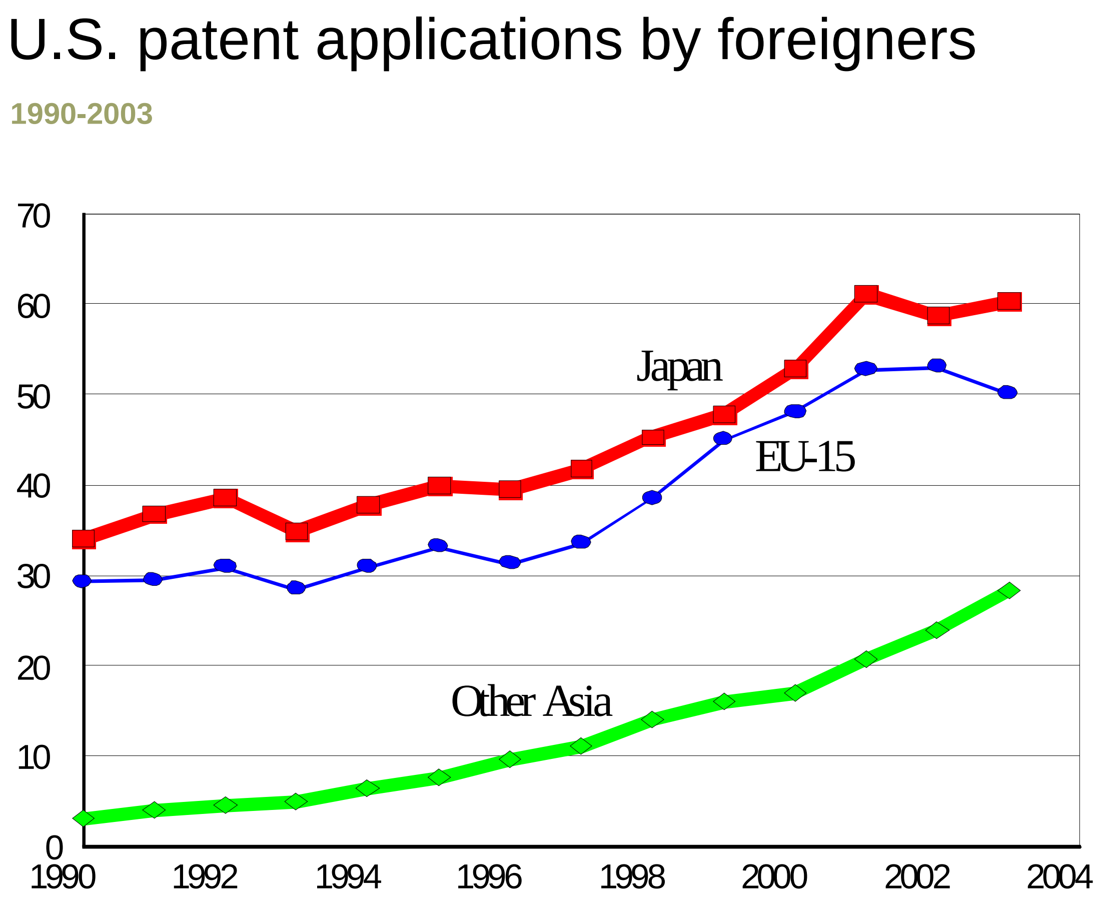
Location of High-Tech Manufacturing

1980-2003



Source: NSB, *Science & Engineering Indicators Appendix Table 6-2*

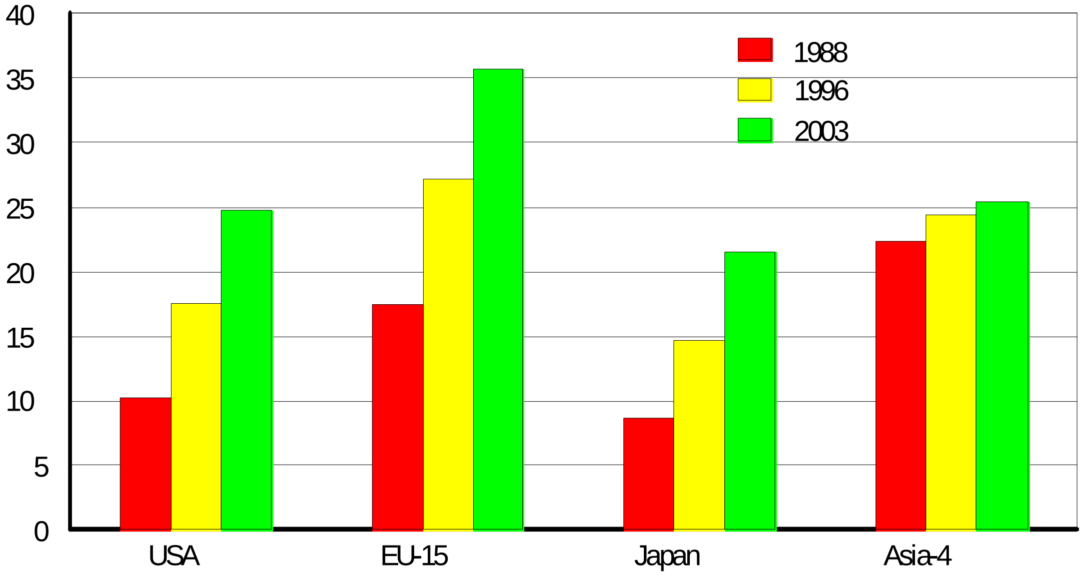
Figure 5



Source: NSB, *Science and Engineering Indicators*, Appendix Table 6-13.

Figure 6

Share of scientific and technological articles internationally coauthored, 1988-2003



Source: NSB, *Science and Engineering Indicators*, Appendix Table 5-53.

Notes

[1] This paragraph draws upon Wright (1999), pp. 299-303. Meyer (2006) elaborates similar themes.
[2] For examples of this indictment, see Dertouzos et al 1989, and Baldwin and Clark 1994.
[3] This discussion focuses exclusively on Information Technology, the cluster of advances associated with the US-led productivity surge after 1995. Geographic dimensions of biotechnology may be quite different. Knowledge creation in biotechnology is closely associated with university research, and the U.S. is the clear leader in developing commercial applications from that research (Gittelman 2006, Zucker, Darby and Brewer 1998). It is not yet clear, however, that productivity-enhancing innovations will emerge from this branch of science, though it must be acknowledged that some of the uncertainty is related to the difficulty of measuring the value of outputs in this field.