Organizational Learning and International Competition:
The Skill-Base Hypothesis

by

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## The Skill-Base Hypothesis

Since the 1970s a persistent feature of the U.S. economy has been increasing income inequality, to the point where the United States now has the most unequal distribution of income among the advanced industrial economies. Sustainable prosperity – the spreading of the benefits of economic growth to more and more people over a prolonged period of time -- appears to have become an elusive objective. At the same time, in the late 1990s, after more than two decades of intense competitive challenges, the United States retains international leadership in a range of science-based industries such as computer electronics and pharmaceuticals as well as in service sectors related to such things as finance and food. The U.S. economy appears capable of innovation, but incapable of sustainable prosperity.

Are innovation and equality inherently in opposition to one another? In a previous report to the Levy Institute, co-authored with Mary O'Sullivan, we hypothesized that the coexistence of innovation and inequality in the U.S. economy in the 1980s and 1990s reflects a systematic bias of major U.S. corporations against making innovative investments in broad and deep skill bases.[1] Rather, these corporations, which exercise inordinate control over the allocation of resources and returns in the economy, are choosing to invest, and are best able to innovate, in the production of goods and services that use narrow and concentrated skill bases to develop and utilize technology.

Why are "skill bases" important to the economy? They form the foundation on which people engage in collective and cumulative – or organizational – learning, which is in turn central to the process of economic development. Case-study evidence suggests that the manufacturing industries in which the U.S. economy has been most severely challenged by high-wage foreign competition – industries such as automobiles, consumer electronics, machine tools, and commodity semiconductors – are those in which innovation and sustained competitive advantage demand investments in broader and deeper skill bases. If the "skill-base hypothesis" is valid, then it may well be that innovation and equality can go hand in hand.[2] From a policy perspective, the relevant issue is how business enterprises can be induced to make innovative investments in broad and deep skill bases.

The skill-base hypothesis adds an important dimension to American debates on the relation between investments in "technology" and sustainable prosperity. On one side have been those who stress the weakened innovative capabilities of the U.S. economy in international competition.[3] They have called for the U.S. government and businesses to allocate more resources to education, training, research, and cooperative investment projects that can support the United States in making a competitive response. These arguments assume, often more implicitly than explicitly, that these innovative responses will promote sustainable prosperity in the United States.

On the other side have been those who argue that income inequality cannot be blamed on

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[1] William Lazonick and Mary O'Sullivan, "Corporate Governance and Corporate Employment: Is Prosperity Sustainable in the United States?," Report to the Jerome Levy Economics Institute, December 1996.

[2] Ibid.

[3] Stephen Cohen and John Zysman, Manufacturing Matters, Basic Books, 1987; Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, and the MIT Commission on Industrial Productivity, Made in America: Regaining the Productive Edge, MIT Press, 1989; Laura D'Andrea Tyson, Who's Bashing Whom?: Trade Conflict in High-Technology Industries, Institute for International Economics, 1992.

international competition but rather on the employment impacts of "new technology"[4]. The volume of world trade, they argue, is not large enough to have a significant impact on the distribution of income in the United States. If the United States has problems keeping people employed at high wages, it is because, for a given level of investment, technologies of the computer age do not create the same quantity and quality of employment opportunities for Americans as did the technologies of the past. Income inequality has grown, they argue, because new technologies displace employment opportunities that used to be well paid. Pay attention to raising the levels of both investment and relevant skill in the U.S. economy, and the income distribution will improve.

The skill-base hypothesis views both international competition and technological change as important determinants of the distribution of income. But the hypothesis is embedded in a theory of innovation and economic development in which the impacts of international competition and technology on income distribution depend on corporate investment strategies. Across U.S. industrial corporations, these strategies, and the investment in skill bases that they entail, are in turn influenced by American institutions of corporate governance and corporate employment.[5] The rise of powerful international competition based on investments in broader and deeper skill bases may lead U.S. corporations to seek to remain innovative by investing in technologies that only require investments in narrow and concentrated skill bases.

Powerful support for the skill-base hypothesis can be found in the experience of Japanese-U.S. industrial competition over the past few decades. Japan has taken on and surpassed the United States in many industries in which it was the previous world leader. The foundations of Japanese success in international competition, I shall argue, were investments in broad and deep skill bases to generate organizational learning. The problems of both innovation and equality in the United States in the 1980s and 1990s have not been inherent in technology. Rather the problems derive from corporate strategies to develop and utilize technology.

U.S. corporations, I contend, have been investing in narrow and concentrated skill bases in a world of international competition in which innovation has increasingly come from investing in broad and deep skill bases. If the skill-base hypothesis is correct, the problem of reversing the trend toward income inequality in the United States goes much deeper than growth policies or industrial policies. It requires transformation of the way industrial corporations are governed and the way people are employed

## Organizational Integration

Almost all of the major industrial corporations in the U.S. economy in the post-World War II era made investments in managerial learning from the early decades of the twentieth century, if not before. Many of the productive and competitive advantages of these investments in managerial organization still accrued to these corporations decades after the particular individuals involved in these collective learning processes had left the corporate scene.

In comparative international perspective, U.S. industrial corporations were not unique in building their managerial organizations into formidable sources of sustained competitive

[4] See Paul Krugman and Robert Lawrence, "Trade, Jobs, and Wages," Scientific American, April 1994.
[5] Lazonick and O'Sullivan, "Corporate Governance and Corporate Employment."

advantage. What made U.S. industrial corporations unique among their counterparts in the advanced economies was their dedication to a strategy of taking skills, and hence the possibilities for craft learning -- much less corporate learning -- off the shop floor.[6] This process of transforming skilled craft work into "semi-skilled" operative work was a prolonged one, constrained as it was by the development of new technology through managerial learning. But, as reflected in the distinction between "salaried" and "hourly" personnel, the strategy of relying exclusively on the managerial organization for the development of new productive capabilities has been, throughout the twentieth century, a distinctive characteristic of U.S. industrial development.

The American corporate strategy of confining organizational learning to those employed within the managerial structure enabled the United States to become the world's leading industrial power during the first half of the twentieth century.[7] On the basis of this leadership, U.S. industrial corporations were able to provide high pay and stable employment to not only managerial employees but also shop-floor workers, whether they be skilled or semi-skilled.

Over the past few decades, however, powerful international competitors have arisen who have developed productive capabilities by integrating managers and workers into their organizational learning processes. The *hierarchical segmentation* between managers and workers that the American "managerial revolution" entailed became a major institutional barrier to making the types of investments in organizational learning required to sustain prosperity in the U.S. economy. In an era of intense international competition in which sustained competitive advantage went to those enterprises and nations that made investments in, and integrated, the organizational learning of both managerial and shop-floor personnel, the investment strategies of most U.S. industrial corporations that focused only on managerial learning fell short.

The competitive problem that has faced U.S. industrial corporations is that, over time for a particular product, the innovation process, of which the organizational learning process is its social substance, has become increasingly *collective* and *cumulative*. Organizational learning has become increasingly collective because innovation -- the generation of higher quality, lower cost products -- depends on the integration of an ever-increasing array of specific productive capabilities based on intimate knowledge of particular organizations, technologies, and markets. Organizational learning has become increasingly cumulative because the collective learning that an organization has accumulated in the past increasingly forms an indispensable foundation for the augmentation of organizational learning in the present and future.

The increasingly collective and cumulative character of organizational learning means that, for a particular product, an innovative investment strategy is one that entails investments in *broader and deeper skill bases* -- divisions of labor that extend further down the organizational hierarchy and involve more functional specialties. The investments in skill bases are not simply investments in the learning of large numbers of individuals performing a wide variety of functions. For these investments in broader and deeper skill bases to generate higher quality, lower cost products requires *organizational integration*, a set of social relations that provides participants in a complex division of labor with the incentives to

[6] William Lazonick and Mary O'Sullivan, "Big Business and Skill Formation in the Wealthiest Nations: The Organizational Revolution in the Twentieth Century," in Alfred D. Chandler, Jr., Franco Amatori and Takashi Hikino, Big Business and the Wealth of Nations, Cambridge University Press, 1997; William Lazonick, Competitive Advantage on the Shop Floor, Harvard University Press, 1990.
[7] William Lazonick and Mary O'Sullivan, "Big Business and Skill Formation."

cooperate in contributing their skills and efforts toward the achievement of common goals.

At any point in time, the technological possibilities and organizational requirements of the innovation process vary markedly across industries in terms of the extent of the skill base in which the innovating enterprise must invest. In industries, such as pharmaceuticals, in which value-added comes mainly from research, design, and marketing, *narrow and concentrated skill bases* of scientists, engineers, and patent lawyers remain sufficient for generating higher quality, lower cost products. In such industries, U.S. industrial enterprises have been able to remain world leaders. But in industries, such as automobiles, where value-added comes mainly from manufacturing processes that combine a complex array of physically distinct components, international competitive challenges have been based on investments in broader and deeper skill bases. The investments in organizational learning occur not only within corporate management structures but also on the shop floor and in the vertical supply chain. In those industries in which international competition demands investments in such broad and deep skill bases, once-dominant U.S. industrial enterprises have lost substantial competitive advantage.

In the U.S. automobile industry, American-based companies have regained some of the markets they have lost -- or at least have stemmed the loss of market share. The skill-base hypothesis posits that they have done so by *investing in broader and deeper skill bases than was previously the case.*[8] In responding to these competitive challenges, moreover, the organizational problem that has faced U.S. industrial enterprises over the past few decades has gone beyond the hierarchical segmentation between managers and workers. Even within the managerial structure -- the traditional locus of organizational learning in U.S. enterprises – organizational integration appears to have given way to two types of segmentation which we call *functional* and *strategic.*

Compared with both the integrated organizational structures of foreign competitors and the integrated managerial structures that characterized the most successful U.S. companies in the past, organizational learning within the managerial structures of U.S. enterprises has been limited by the *functional segmentation* of different groups of technical specialists from one another. Specialists in marketing, development, production, and purchasing may be highly skilled in their particular functions, but relative to their counterparts abroad, in U.S. enterprises they tend to respond to incentives that lead them to learn in isolation from one another. Functional segmentation makes it difficult if not impossible for such isolated specialists to solve complex manufacturing problems that require collective and cumulative learning.

In addition, in comparative and historical perspective, a distinctive characteristic of U.S. industrial enterprises since the 1960s has been the *strategic segmentation* of those top managers who control enterprise resources from those lower down the managerial hierarchy on whom the enterprise has relied for organizational learning. In allocating vast amounts of resources, top managers of major U.S. industrial corporations have increasingly lost the incentive to remain cognizant of the problems and possibilities for organizational learning within the enterprises over which they exercise control. Within a particular enterprise, tendencies toward hierarchical, functional, and strategic segmentation may be mutually reinforcing, thus making it all the more difficult for an enterprise, or group of enterprises, to invest in organizational learning once they have embarked on the organizational-segmentation path.

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[8] I am currently engaged in a comparative study of organizational integration and competitive advantage in the automobile industry, supported by the Center for Global Partnership, in collaboration with the International Motor Vehicle Program.

The skill-base hypothesis seeks to test these propositions concerning the growing importance of hierarchical, functional, and strategic integration for attaining and sustaining competitive advantage, and the increasing tendency toward organizational segmentation along these three dimensions in U.S. industrial corporations in historical and comparative perspective. The skill-base hypothesis, and the theoretical perspective on innovation and economic development in which it is embedded, derives from our historical and comparative analyses of the role of organizational integration in shifts in international competitive advantage.[9] The empirical evidence required to test the hypothesis requires must be derived from in-depth analyses of the investment strategies, organizational structures, and competitive performance of particular companies based in different nations that have engaged in head-to-head competition in particular industries.

The purpose of this paper is to motivate such a research agenda by drawing on some of the findings of a now vast range of literature on the interaction of organization and technology in U.S.-Japanese industrial competition. This evidence, much of it deriving from the experiences of management consultants and case studies by business academics, provides substance to the skill-base hypothesis. In this paper, I shall focus on differences in hierarchical integration and organizational learning in Japanese and American enterprises. I shall argue that understanding hierarchical integration of technical specialists and production operatives forms an indispensable foundation for understanding the functional integration of technical specialists themselves – a subject that now dominates much of the management literature on technological competition. Absent from this paper will be a discussion of strategic integration and segmentation, a subject that, in relation to the skill-base hypothesis, has been treated at length elsewhere, and that provides the analytical interface between issues of corporate governance and organizational learning.[10] In what follows, therefore, I shall be concerned with the social structures that generate organizational learning rather than with the social structures that allocate resources to building different types of skill bases.

## Organizational Learning

If there is one nation that has challenged the United States for international industrial leadership in the last half of the twentieth century, that nation is Japan. In 1950 Japan's GDP per capita was only 20 percent of that of the United States; in 1992 90 percent.[11] The Japanese challenge had come, moreover, not in those industries in which American companies were weak or that they had neglected. On the contrary, the challenge came in

[9] William Lazonick, Business Organization and the Myth of the Market Economy, Cambridge University Press, 1991; Mary O'Sullivan, Innovation, Industrial Development and Corporate Governance, Ph.D. dissertation, Harvard University, June 1996; Lazonick and O'Sullivan, "Big Business and Skill Formation"; William Lazonick and Mary O'Sullivan, "Organization, Finance, and International Competition," Industrial and Corporate Change, 5, 1, 1996; Lazonick and O'Sullivan, "Corporate Governance and Corporate Employment."

[10] O'Sullivan, Innovation, Industrial Development and Corporate Governance; Mary O'Sullivan, Contests for Corporate Control, Oxford University Press, forthcoming; Lazonick and O'Sullivan, "Corporate Employment and Corporate Governance"; William Lazonick and Mary O'Sullivan, "Finance and Industrial Development: Part I, the United States and the United Kingdom," Financial History Review, 4, 1, 1997; and "Finance and Industrial Development, Part II, Japan and Germany," Financial History Review, 4, 2, 1997.

[11] Angus Maddison, "Explaining the Economic Performance of Nations, 1820-1989," in William J. Baumol, Richard R. Nelson, and Edward N. Wolff, eds. Convergence of Productivity: Cross-National Studies and Historical Evidence, Oxford University Press, 1994, 22.

industries such as automobiles, electronics, and machine tools in which the United States had attained a seemingly invincible position as the world's leading mass producer.

Since the 1980s much has been written about the institutional and organizational sources of Japanese competitive advantage. Social institutions such as lifetime employment and cross-shareholding and organizational practices such as total quality management and consensus decision-making have been critical elements of Japan's phenomenal rise from the ashes of defeat after World War II. But these institutions and organizations would not have generated the so-called Japanese economic miracle in the 1950s and 1960s had Japan not already possessed in the immediate aftermath of the war an accumulation of technological capabilities.

Japan had been accumulating capabilities in mechanical, electrical and chemical technologies since the late nineteenth century when the Japanese "managerial revolution" had begun. At the time of the Meiji Restoration in 1868, Japan had little in the way of modern industrial capabilities.[12] Under the slogan "Rich Nation, Strong Army", the Restoration government implemented a strategy for industrial development that was heavily dependent on borrowing knowledge, technologies, and even institutions from abroad.[13] In the first half of the 1870s, private and public interests set up institutions of higher education – most notably Keio University, the Institute of Technology (later part of Tokyo Imperial University), and the Commercial Law School (which became Hitotsubashi University) -- to supply key personnel to an innovative industrial economy.[14] By the 1880s Japan had a steady supply of both indigenous graduates and teachers.[15]

Large numbers of university graduates were lured into industry, with the *zaibatsu* (including their affiliated industrial enterprises) taking the lead.[16] From 1900 to 1920, for example, the employment of graduate engineers increased from 54 to 835 at Mitsui and from 52 to 818 at Mitsubishi.[17] These highly educated personnel were not only eagerly recruited but also well paid by the companies that employed them. In addition, companies often incurred the considerable expense of sending these employees abroad for varying lengths of time to acquire more industrial experience.[18]

During the interwar period the overall development strategy of the Japanese economy

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[12] See Tessa Morris-Suzuki, The Technological Transformation of Japan, Cambridge University Press, 1994.

[13] Richard Samuels, "Rich Nation, Strong Army": National Security and the Technological Transformation of Japan, Cornell University Press 1994; D. Eleanor Westney, Imitation and Innovation, Harvard University Press, 1987. On the development of a financial system for industrial development, see William Lazonick and Mary O'Sullivan, "Finance and Industrial Development: Part II".

[14] Johannes Hirschmeier and Tsunehiko Yui, The Development of Japanese Business, second edition, George Allen & Unwin, 1981,166; Janet Hunter, A Concise Dictionary of Modern Japan, University of California Press, 1984, 47; Etsuo Abe, "Shibusawa, Eiichi (1840-1931)," in Malcolm Warner, ed., International Encyclopedia of Business and Management, Routledge, 1996, 4451.

[15] Shin'ichi Yonekawa, "University Graduates in Japanese Enterprises before the Second World War," Business History 26, July 1984, pp. 193-218; Ryoichi Iwauchi, "The Growth of White-Collar Employment in Relation to the Educational System," and H. Uchida, "Comment", in Tsunehiko Yui and Keichiro Nakagawa, eds., Japanese Management in Historical Perspective, University of Tokyo Press, 1989, 83-108.

[16] Yonekawa, "University Graduates in Japanese Enterprises."

[17] Uchida, "Comment," 108.

[18] Iwauchi, "Growth of White-Collar Employment," 99; Hirschmeier and Yui, Development of Japanese Business, 154.

became increasingly dominated by the investment requirements of militarization and imperial expansion. Relying heavily on the *zaibatsu*, Japan devoted considerable resources to building capabilities in mechanical, electrical, and chemical engineering. In the immediate aftermath of World War II, as the Allied Occupation engaged in the dissolution of the once-powerful *zaibatsu*,[19] Japanese scientists and engineers organized to seek new ways to develop and utilize their capabilities.

In 1946 they formed the Japanese Union of Scientists and Engineers (JUSE), an association devoted to promoting the nation's technological development through education, standard setting, and the diffusion of information. Influenced by U.S. occupation officials versed in statistical quality control (SQC) techniques that the United States had used for military production during the war, JUSE focused on the application of quality control in an economy based on production for commercial markets. In 1949 JUSE established the Quality Control Research Group (QCRG), which included participants from academia, industry, and government.

The following year JUSE sponsored an eight-day seminar on SQC by Dr. W. Edwards Deming, a physicist who had been working for the U.S. government developing the sampling methods for SQC.[20] These techniques were used to monitor mass-produced output for systematic deviations from "quality" standards as a prelude to controlling (identifying and correcting) quality problems. Deming's lectures were well received as was the volume of these lectures that JUSE promptly published. The author donated the royalties from the book to JUSE, which in turn used the funds to establish the now-famous Deming Application Prize, awarded annually since 1951 to an industrial company for its achievements in the application of quality control (QC) methods.[21]

One of the key figures in applying QC methods to Japanese industry was Kaoru Ishikawa, an engineering professor at the University of Tokyo. Starting in 1949, under the auspices of QCRG, Ishikawa began teaching the QC Basic Course to industrial engineers, using translated British and American texts. "After conducting the first course," Ishikawa recalled,

> it became clear to us that physics, chemistry, and mathematics are universal and are applicable anywhere in the world. However, in the case of quality control, or in anything that has the term 'control' attached to it, human and social factors are strongly at work. No matter how good the American and British methods may be, they cannot be imported to Japan as they stand. To succeed, we had to create a Japanese method."[22]

Ishikawa, along with others, developed the Japanese method in the 1950s through their direct involvement with Japanese manufacturing companies, particularly in the fledgling automobile industry.[23]

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[19] T. Adams and Iwao Hoshii, A Financial History of the New Japan,Kodansha International, 1972, 23-25. See also T. Bisson, Zaibatsu Dissolution in Japan, University of California Press, 1951; Eleanor Hadley, Antitrust in Japan, Princeton University Press, 1970.

[20] Kaoru Ishikawa, What is Total Quality Control? The Japanese Way, Prentice-Hall, 1985, 16

[21] Izumi Nonaka, "The Development of Company-Wide Quality Control and Quality Circles at Toyota Motor Corporation and Nissan Motor Co. Ltd., in Haruhito Shiomi and Kazuo Wada, eds., Fordism Transformed: The Development of Production Methods in the Automobile Industry, Oxford University Press, 1995.

[22] Ishikawa, What is Total Quality Control?, 16-17

[23] Nonaka, "Development of Company-Wide Quality Control," 143. See also Shigeru Mizuno, Company-Wide Total Quality Control, Asian Productivity Organization, 1984.

What was different about Japanese conditions that made it necessary to "create a Japanese method"? And how by the 1970s and 1980s did the Japanese method that was created become the world's most powerful manufacturing approach for setting new standards of high quality and low cost? In particular, how did Japanese manufacturing for mass markets differ from the system that Americans had previously developed in the first half of the twentieth century when U.S. industry established itself as the world's leading mass producer?

The fundamental difference between the Japanese and American organization of mass production was on the shop floor. The American system of mass production that dominated the world economy by the mid-twentieth century was based on the production of long runs of identical units by expensive special-purpose machines tended by "semi-skilled" operatives.[24] The transformation of the high fixed costs of these mass-production technologies into low unit costs of final products required the cooperation of these shop-floor workers in the repetitive performance of narrow manual functions needed to maintain the flow of work-in-progress through the interlinked mechanical system.

The American machine operatives themselves were not involved in either monitoring the quality of work-in-progress or searching for solutions to quality problems in the manufacturing process. By design, they were excluded from the process of organizational learning that generated the American system of mass production.[25] Reflecting the American practice of confining organizational learning to the managerial structure, and developing technologies that displaced the need for skill on the shop floor, quality control had evolved in the United States as a strictly managerial function.

Leading American mass producers were willing and able to provide greater employment security and higher wages to shop-floor workers to ensure their cooperation in keeping pace with the expensive high-speed, special-purpose machinery. These companies, that is, established incentives to gain the cooperation of operatives in the *utilization* of technology. But the managers of these companies were unwilling to grant these operatives any role in the development of technology. Rather they confined such organizational learning to the managerial structure. Indeed in the American companies considerable managerial learning was devoted to organizing work and developing mass-production technologies.[26]

In the post-World War II Japanese automobile industry, companies like Toyota and Nissan did not have the luxury of long runs. Reflecting Japan's low level of GDP per capita, in 1950 the entire Japanese automobile industry produced 31,597 vehicles, which was about the volume that U.S. companies produced in one and a half days.[27] In that year, Nissan accounted for 39 percent of production and Toyota 37 percent, while for the industry as a whole 84 percent of the vehicles produced were trucks.[28] As production increased over the course of the 1950s, with cars becoming a larger proportion of the total, Nissan or Toyota had to produce an increasing variety of vehicles to survive. In responding to these demand-

[24] On the emergence of American mass production, see David Hounshell, From the American System to Mass Production, 1800-1932, Johns Hopkins University Press, 1984.

[25] On the historical origins of this hierarchical segmentation, see Lazonick, Competitive Advantage on the Shop Floor, ch. 7-9.

[26] Ibid.; William Lazonick, "Rethinking 'Taylorism': Organization of Innovation for the Twenty-First Century," INSEAD, photocopy, June 1997.

[27] Michael Cusumano, The Japanese Automobile Industry: Technology and Management at Nissan and Toyota, Harvard University Press, 1985, 75, 266,

[28] Cusumano, Japanese Automobile Industry, 75.

side conditions, therefore, these companies had no possibility of achieving low unit costs by simply adopting American mass-production methods.

On the supply-side, over the course of the twentieth century Japanese industry had developed capabilities that could now enable companies like Toyota and Nissan to develop and utilize technology in a profoundly different way. These companies could draw on a sizable supply of highly educated and experienced engineers. Many Toyota employees, for example, had accumulated relevant technological experience over the previous decades working for the enterprise group when it was Japan's leading producer of textile machinery.[29] In addition, the automobile industry was able to attract many engineers who had gained experience in Japan's aircraft industry before and during the war.[30]

Before the war, moreover, many Japanese companies had integrated foremen into the structure of managerial learning so that they could not only supervise but also train workers on the shop floor. Whereas in the United States, the foreman, as "the man in the middle", served as a buffer between the managerial organization and the shop floor, in Japan the foreman was an integrator of managerial and shop-floor learning. From the late nineteenth century, a prime objective of U.S. managerial learning had been to develop machine technologies that could dispense with the skills of craft workers on the shop floor. In contrast, with an accumulation of such craft skills lacking in Japan, the problem that had confronted technology-oriented managers from the Meiji era had been to develop skills on the shop floor as part of a coordinated strategy of organizational learning.

The rise of enterprise unions in the early 1950s both reflected and enhanced the social foundations for this hierarchical integration. During the last half of the 1940s, dire economic conditions and democratization initiatives gave rise to a militant labor movement of white-collar (technical and administrative) and blue-collar (operative) employees. The goal of the new industrial unions was to implement "production control": the takeover of idle factories so that workers could put them into operation and earn a living.[31] As an alternative to the "production control" strategy of militant unions, leading companies created enterprise unions of white-collar and blue-collar employees. In 1950 under economic conditions deliberately rendered more severe by the Occupation's anti-inflationary "Dodge line", companies such as Toyota, Toshiba, and Hitachi fired militant workers and offered enterprise unionism to the remaining employees. The post-Korean War recession of 1953 created another opportunity for more companies to expel the militants and introduce enterprise unionism. The continued and rapid expansion of the Japanese economy in the "high-growth era" ensured that enterprise unionism would become an entrenched Japanese institution.[32]

The prime achievement of enterprise unionism was "lifetime employment", a system that gave white-collar and blue-collar workers employment security to the retirement age of 55 or

[29] William Mass and Andrew Robertson, "Indigenous Innovation and Technology Transfer: Toyoda Enterprises and Platt Brothers," Business and Economic History, 2nd ser., 25, 2, 1996.

[30] See Kazuo Wada. "The Emergence of the 'Flow Production' Method in Japan," in Shiomi and Wada, Fordism Transformed.

[31] Joe Moore, Japanese Workers and the Struggle for Power, 1945-1947, University of Wisconsin Press, 1983; Andrew Gordon, The Evolution of Labor Relations in Japan: Heavy Industry, 1853-1955, Harvard University Press, 1985, 343; N. Hiwatari, "Japanese Corporate Governance Reexamined: The Origins and Institutional Foundations of Enterprise Unionism," paper prepared for the Conference on Employees and Corporate Governance, Columbia University Law School, November 22, 1996.

[32] Gordon, Evolution of Labor Relations in Japan ch. 10; Cusumano, The Japanese Automobile Industry; David Halberstam, The Reckoning, Morrow, 1986, Pt .3; Hiwatari, "Japanese Corporate Governance".

60. Foremen and supervisors were members of the union, as were all university-educated personnel for at least the first ten years of employment before they made the official transition into "management". Union officials, who were company employees, held regularly scheduled conferences with management at different levels of the enterprise to resolve issues concerning remuneration, work conditions, work organization, transfers, and production.[33]

These institutional conditions supported the integration of shop-floor workers into a company-wide process of organizational learning. Top managers had ultimate control over strategic investments, and technical specialists designed products and processes, typically on the basis of technology borrowed from abroad. But, given these managerial capabilities, the unique ability of Japanese companies to transform borrowed technology to generate new standards of quality and cost depended on the integration of shop-floor workers into the process of organizational learning.

Through their engagement in processes of cost reduction, Japanese shop-floor workers were continuously involved in a more general process of improvement of products and processes that, by the 1970s, enabled Japanese companies to emerge as world leaders in factory automation. This productive transformation became particularly important in international competition in the 1980s as Japanese wages approached the levels of the advanced industrial economies of North America and Western Europe. During the 1980s and 1990s, influenced as well by the impact of Japanese direct investment in North America and Western Europe, many Western companies have been trying, with varying degrees of success, to implement Japanese high-quality, low-cost mass-production methods.

Especially since the 1980s a huge English-language literature has emerged on Japanese manufacturing methods, much of it written by industrial engineers with considerable experience as employees of, or consultants to, manufacturing companies in Japan and the West. In addition, there is a growing body of academic research on the subject, although it tends to focus more on functional integration than on hierarchical integration. My purpose here is to summarize this body of evidence to make the case that, in comparison with the once-dominant American mass producers, a fundamental source of Japanese manufacturing success has been the hierarchical integration of shop-floor workers in the process of organizational learning. I shall also indicate how, within Japanese companies, hierarchical integration contributed to the generation of higher quality, lower cost products as part of a process of organizational learning that included integration across specialized functions.

In a comprehensive account of Japan's manufacturing challenge, Kiyoshi Suzaki, a former engineer at Toshiba who then turned to consulting in the United States, contrasts the operational and organizational characteristics of a "conventional" (traditional American) company and a "progressive" (innovative Japanese) company in the use of men, materials, and machines in the production process (see Table 1).[34] In the generation of higher quality, lower cost products, the integration of Japanese shop-floor workers into the process of organizational learning contributed to 1) the more complete *utilization of machines*, 2) superior *utilization of materials*, 3) improvements in *product quality*, and 4) *factory automation.* In summarizing the ways in which hierarchical integration contributed to these innovative outcomes in Japan, I shall indicate how and why Japanese practice differed from the hierarchical segmentation of shop-floor workers that was, and still largely remains, the

[33] See, for example, Koichi Shimokawa, The Japanese Automobile Industry: A Business History, Athlone, 1994.
[34] Kiyoshi Suzaki, The New Manufacturing Challenge, Free Press, 1987.

norm in American manufacturing.

**Table 1. Operational and Organizational Characteristics of American and Japanese Manufacturing**

| | **American company** | **Japanese company** |
|---|---|---|
| ***Operational characteristic*** | | |
| Lot size | Large | Small |
| Setup time | Long | Short |
| Machine trouble | High | Low |
| Inventory | Large | Small |
| Floor space | Large | Small |
| Transportation | Long | Short |
| Lead time | Long | Short |
| Defect Rate | High | Low |
| ***Organizational characteristic*** | | |
| Structure | Rigid | Flexible |
| Orientation | Local optimization | Total optimization |
| Communication | Long chain of command | Open |
| Agreement | Contract-based | Institution-based |
| Union focus | Job-based | Company-based |
| Skill base | Narrow | Broad |
| Education/training | Low quality | High quality |
| Training | Insignificant | Significant |
| Supplier relations | Short-term/ many competitors | Long-term/ selected few |

Source: Adapted from Kiyoshi Suzaki, The New Manufacturing Challenge, Free Press, 1987, 233.

- Utilization of Machines

In the decade after the war, the Japanese pioneered in cellular manufacturing – the placement of a series of vertically-related machines in a U-shape so that a worker, or team of workers, can operate different kinds of machines to produce a completed unit of output. Used particularly for the production of components, cellular manufacturing requires that workers perform a variety of tasks, and hence that they be multi-skilled.

The Japanese system differed from the linear production system used in the United States in which shop-floor workers specialized in particular tasks, passing the semi-finished unit from one specialized worker to the next. Historically, this fragmented division of labor resulted from the successful strategy of American managers in the late nineteenth century to develop and utilize mechanized technologies that could overcome their dependence on craft contractors who had previously controlled the organization of work.[35] To better supervise the "semi-skilled" workers who operated the new mechanized technologies, American managers then sought to confine adversarial shop-floor workers to narrow tasks. After the rise of industrial unionism in the 1930s, shop-floor workers used these narrow job definitions as a foundation for wage-setting, thus institutionalizing this form of job control in collective bargaining arrangements.

[35] David Montgomery, The Fall of the House of Labor, Cambridge University Press, 1987.

The prevalence of adversarial bargaining and job control only served to increase the resolve of most U.S. corporate managers to keep skill and initiative off the shop floor in the decades after World War II. Meanwhile, developing and utilizing the capabilities of the multi-skilled shop-floor worker in a myriad of ways, Japanese companies created new standards of quality and cost. This continuous improvement, which the Japanese called *kaizen*,[36] enabled Japanese companies to outcompete the Americans, even in their own home markets, even as Japanese wages rose and the yen strengthened in the 1980s and 1990s.

With the need to use mass-production equipment to produce a variety of products in the 1950s, Japanese companies placed considerable emphasis on reducing setup times. Long setups meant excessive downtime, which meant lost output. Once set in motion, the search for improvements often continued over years and even decades. For example, in 1945 the setup time for a 1000-ton press at Toyota was four hours; by 1971 it was down to three minutes. A ring-gear cutter at Mazda that took more than six hours to set up in 1976 could be set up in 10 minutes four years later.[37]

By the 1980s the extent of the market that Japanese manufacturers had captured meant that small-batch production was no longer the necessity it had been 30 years earlier. But the ability of these companies to do what the Japanese call "single-digit" (under ten minutes) setups enabled them to use the same production facilities to produce a wide variety of customized products. Single-digit setups had become a powerful source of international competitive advantage.

The reduction of setup times involved the redesign of fixtures, the standardization of components, and the reorganization of work. Shop-floor workers had to be willing and able to perform as much of the setup operations as possible for the next product batch while machines were producing the current product batch. The reorganization of work needed to reduce setups represented another productive activity that could take advantage of the incentive and ability of Japanese shop-floor workers to engage in a variety of tasks. The broader knowledge of the production process that these workers possessed was in turn used to find new ways to reduce setup times.

In the United States, in contrast, the problem of reducing setup times was neglected in part because of long runs and in part because of the unwillingness of American management to invest in shop-floor skills. In Japan a dynamic learning process was set in motion in which the learning of shop-floor workers was critical. In the United States, hierarchical segmentation meant that, when the production of long runs of identical output was no longer a viable competitive strategy, corporations had not developed the skill bases required for reducing setup times.

If shop-floor skills can prevent downtime through quick setups, they can do so as well through machine maintenance. Keeping machines trouble free requires the involvement of shop-floor workers in continuous inspection and daily maintenance as well as engineers to solve chronic problems and to train the shop-floor operatives. As Suzaki has put it,

> zero machine troubles can be achieved more effectively by involving operators in maintaining normal machine operating conditions, detecting abnormal machine conditions as early as possible, and developing countermeasures to regain normal machine conditions. This requires development of a close working

[36] Masaaki Imai, Kaizen: The Key to Japan's Competitive Success, Random House, 1986.
[37] Suzaki, New Manufacturing Challenge, 43.

> relationship among operators, maintenance crews, and other support people as well as skill development and training to increase the abilities of those involved.[38]

In American mass production, shop-floor workers have not only lacked the skills to maintain machines. They have also been denied the right to maintain machines by managers who feared that, far from reducing downtime by keeping machines trouble free, such shop-floor intervention would be used to slow the pace of work. Indeed one role of first-line supervisors employed on American mass-production lines has typically been to ensure that production workers do not interfere with machine operations on the assumption that such intervention will make the machines more trouble prone.

Cellular manufacturing, quick setups, and machine maintenance all contribute to higher levels of machine utilization and lower unit costs. But ultimately unit costs are dependent on how quickly products can be transformed from purchased inputs into salable outputs. That is, unit costs depend on cycle time.

As Jeffrey Funk (on the basis of his experience working at Mitsubishi Electric Corporation for a year) described it: "The reductions in cycle time were achieved through numerous engineer and operator activities." The engineers were primarily responsible for making system-wide improvements concerned with identifying and resolving production bottlenecks, and with developing "product families" of different types of chips that undergo the same processes, thus reducing setup times and eliminating mistakes. The operators were primarily responsible for identifying possibilities for localized improvements on the wafer and assembly lines. Each operator was in a working group that met once or twice a month, through which they made numerous suggestions for improvements, a high proportion of which were acted upon by engineers. Operators responsible for wafer furnaces contributed, for example, to improvements in the delivery, queuing, and loading systems, all of which reduced cycle time. At Mitsubishi Electric between 1985 and 1989, cycle time for semiconductor chips was reduced from 72 days to 33 days, even as the number of chip styles more than doubled to 700 and the number of package types assembled increased from 20 to 70.[39]

A comparison of the Mitsubishi wafer department with a U.S. factory using similar equipment found that the Japanese factory produced four times the number of wafers per direct worker, employed fewer support workers per direct worker, had a higher ratio of output to input in the wafer process, and had a cycle time that was one-fourth of that achieved by the U.S. factory. "These improvements," according to Funk,

> lead to shorter cycle time, higher yields, less wafer breakage, and higher production of wafers per direct worker. The multifunctional workers enable Mitsubishi to have fewer support staff. Since the direct workers perform many of the activities typically performed by support staff in a U.S. factory, the direct workers can determine which activities are most important and how to improve the efficiency of these activities.[40]

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[38] Suzaki, New Manufacturing Challenge, 123
[39] Jeffrey L. Funk, The Teamwork Advantage: An Inside Look at Japanese Product and Technology Development, Productivity Press, 1992, 197.
[40] Ibid., 198-204.

- *Utilization of Materials*

Perhaps the most famous Japanese management practice to emerge out of the "high growth era" was the just-in-time inventory system, (JIT). By delivering components to be assembled as they are needed, the carrying costs and storage costs of work-in-progress can be dramatically reduced. But JIT only works if the parts that are delivered just in time are of consistently high quality. JIT only yields lower unit costs when component suppliers, be they in-house or external subcontractors, have the incentive and ability to deliver such high-quality parts. It was to ensure the timely delivery of such high-quality components, for example, that in 1949 and 1950 the first step taken by Taichi Ohno in developing JIT at Toyota was to reorganize the machine shop into manufacturing cells that required multi-skilled operatives.[41]

In the Japanese assembly process, JIT demands high levels of initiative and skill from production workers. Using the *kanban* system, it is up to assembly workers to send empty containers with the order cards – or *kanban* – to the upstream component supplier to generate a flow of parts. The assembly worker, therefore, exercises considerable minute-to-minute control over the flow of work – a delegation of authority that American factory managers deemed to be out of the question in the post-World War II decades on the assumption that shop-floor workers would use such control to slow the speed of the line. To prevent a purported shortage of components from "creating" a bottleneck in the production process, American managers kept large buffers of in-process inventory along the line.

The Japanese assembly worker also has the right to stop the line when, because of part defects, machine breakdowns, or human incapacity, the flow of work cannot be maintained without sacrificing product quality. When a problem is discovered and a worker stops the line, a light goes on to indicate its location and others in the plant join the worker who stopped the line in finding a solution to the problem as quickly as possible. To participate in this process, therefore, shop-floor workers must develop the skills to identify problems that warrant a line stoppage, and they must contribute to fixing the problem. Without hierarchical integration, JIT and *kanban* cannot work.[42]

- Product quality

The willingness of Japanese companies to develop the skills of shop-floor workers led to a very different mode of implementing quality control in Japan than in the United States. Statistical quality control (SQC), as already mentioned, originated in the United States. In American manufacturing, however, SQC remained solely a function of management, with quality-control specialists inspecting finished products after they came off the line. Defective products had to be scrapped or reworked, often at considerable expense. Defects that could not be detected because they were built into the product would ultimately reveal themselves to customers in the form of unreliable performance, again at considerable expense to the manufacturing company, especially when higher quality competitors came on the market.

For American companies, from the 1970s the higher quality competitors were typically the Japanese. In Japan, the integration of shop-floor workers into the process of organizational

[41] Wada, "The 'Flow Production' Method in Japan," 22.
[42] Kuniyoshi Urabe, "Innovation and the Japanese Management System" in Kuniyoshi Urabe, John Child, and Tadao Kagono, eds., Innovation and Management: International Comparisons, Walter de Gruyter, 1988.

learning meant that product quality could be monitored while work was in progress in the production process, and thus that defects could be detected and corrected before they became built into the finished product. The result was less scrap, less rework, and more revenues from satisfied customers.

In the 1950s American managers could justify the exclusion of shop-floor workers from participation in quality control on the grounds that the SQC methods in use were too complicated for the blue-collar worker. Only more highly educated employees were deemed capable of applying these tools. Given the quality of education received by young Americans destined to be "semi-skilled" factory operatives, the managers of U.S. companies had a point. With mass education being controlled and funded by local school districts, most future blue-collar workers received schooling of a quality that was consistent with the minimal intellectual requirements of repetitive and monotonous factory jobs. This correspondence between schooling and prospective skill requirements in hierarchically segmented workplaces helps to explain why to this day the United States ranks among the lowest of the advanced economies in terms of the quality of mass education and among the highest in terms of the quality of higher education.

In Japan, even in the 1950s, blue-collar workers with manufacturing companies were high-school graduates. But as part of a national system of education of uniformly high standards, they received much the same quality education as those who would go on to university. Even then, the involvement of Japanese shop-floor workers in SQC was accomplished by making the methods more easily accessible and usable by blue-collar workers. As Kaoru Ishikawa, the pioneer in the implementation of SQC in Japan, put it: "We overeducated people by giving them sophisticated methods where, at that stage, simple methods would have sufficed."[43]

The reliance of Japanese companies on the skill and initiative of shop-floor workers for superior machine utilization and reductions in materials costs made these employees ideal monitors of product quality. Relying on this skill base, SQC became integral to the Japanese practice of building quality into the product rather than, as in the United States, using SQC to inspect completed products that had defects built in.

In the 1960s the involvement of shop-floor workers in improving machine utilization, materials costs, and product quality became institutionalized in quality control (QC) circles. In addition to initiatives undertaken by individual companies to apply QC methods in particular factories, a series of radio broadcasts by JUSE in the late 1950s had diffused an awareness of the potential of quality control. Then, in 1960, JUSE put out a publication, <u>A Text on Quality Control for the Foreman</u>, that became widely used by first-line supervisors in the workplace.[44] The success of this publication led to a monthly magazine, <u>Quality Control for the Foreman</u> (<u>FQC</u>). In the process of gathering information for the magazine, JUSE found that, in many factories, foremen and workers had formed themselves into small groups to discuss quality control and its application to specific problems. The editorial board of <u>FQC</u> (of which Ishikawa was the chairman), in issuing the following statement, effectively launched the QC circle movement:

> 1. Make the content [of FQC] easy for everyone to understand. Our task is to educate, train, and promote QC among supervisors and workers in the forefront of our work force. We want to help them enhance their ability to manage and to improve.

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[43] Ishikawa, <u>What Is Total Quality Control?</u>, 18
[44] Ibid., 21

> 2. Set the price low to ensure that the journal will be within the reach of everyone. We want as many foremen and line workers as possible to read it and benefit from it.
> 3. At shops and other workplaces, groups are to be organized with foremen as their leaders and include other workers as their members. These groups are to be named QC circles. QC circles are to use this journal as the text in their study and must endeavor to solve problems that they have at their place of work. QC circles are to become the core of quality control activities in their respective shops and workplaces.[45]

QC circles could be registered with, and announced in, FQC. Beginning in 1963 a national QC circle organization was created, complete with central headquarters, nine regional chapters, conferences, seminars, and overseas study teams. Twenty years later there were almost 175,000 QC circles registered with nearly 1.5 million members.[46]

QC circles became extremely effective in generating continuous improvements in the quality and cost of Japanese manufactured products. In participating in the continuous improvement of these production systems, shop-floor workers did not solve problems in isolation from the rest of the organization but rather as part of a broader and deeper process of organizational learning that integrated the work of engineers and operatives. The foreman as team leader served as the conduit of information up and down the hierarchical structure.

The QC circle movement, led by JUSE, helped to diffuse throughout Japanese industry the organizational and technological advances made at the leading companies. For example, in the mid-1960s there were frequent breakdowns of a newly installed automatic metal plating machine in the assembly division of Toyota's Motomachi Plant. The relevant QC circle systematically considered possible causes, and through testing came up with solutions. In reporting the work of this QC circle, FQC stated:

> The supervisor may understand the design of the machine and how to run it, but is probably unaware of its detailed tendencies or weaknesses. The people who know best about the condition of the machine are the workers, and quality circles provide an opportunity to get important information from them.[47]

In solving problems in machine utilization, QC circles found that the solutions invariably entailed improvements in product quality as well. As Izumi Nonaka has put it in his account of the history of quality control at Toyota and Nissan:

> Toyota production methods, such as just-in-time, kanban, and jidoka (automation) are well known, but it should be stressed that, in relation to quality control, if 100 per cent of the parts reaching a given process are not defect free, Toyota methods will not work smoothly. In other words, quality is the foundation of Toyota production methods. From about 1963, just-in-time and jidoka were adopted in all Toyota factories, and a close relationship between these methods and quality was immediately established.[48]

The QC circle movement focused Japanese workers on the goal of achieving "zero defects"

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[45] Ibid., 138

[46] Ibid.,, 138-139, See also Nonaka, "Development of Company-Wide Quality Control."

[47] Nonaka, "Development of Company-Wide Quality Control," 154.

[48] Ibid., 151

– detecting and eliminating defects as the product was being built rather than permit defects to be built into the product. In recounting why an incipient zero defect (ZD) movement (initiated by the U.S. Department of Defense for its contractors) failed in the United States in the mid-1960s, Ishikawa put the blame squarely on the failure of American companies to integrate shop-floor workers into the process, as was being done in Japan. "The ZD movement became a mere movement of will," Ishikawa observed, "a movement without tools. . . . It decreed that good products would follow if operation standards were closely followed." In the Japanese quality control movement, however, it was recognized that "operation standards are never perfect."

> What operations standards lack, experience covers. In our QC circles we insist that the circle examine all operation standards, observe how they work, and amend them. The circle follows the new standards, examines them again, and repeats the process of amendment, observance, etc. As this process is repeated there will be an improvement in technology itself.

Not so, however, in the United States, where management practice "has been strongly influenced by the so-called Taylor method." In the United States, according to Ishikawa,

> engineers create work standards and specifications. Workers merely follow. The trouble with this approach is that the workers are regarded as machines. Their humanity is ignored. [Yet] all responsibilities for mistakes and defects were borne by the workers. . . . No wonder the movement went astray.[49]

In the late 1960s and early 1970s, on the eve of the Japanese challenge to U.S. manufacturing, many American industrial managers began to worry not so much about the quality of the products they were generating as about the quality of shop-floor work itself. The alienated worker was fingered as the source of lagging productivity.[50] During the first half of the 1960s, the annual average rate of increase of manufacturing productivity in the United States had been 5.1 percent while that of manufacturing wages had been 3.9 percent. But in the second half of the 1960s, when the annual rate of increase of manufacturing productivity averaged a mere 0.6 percent, manufacturing wages rose at a rate of 5.9 percent.[51] Amidst an escalation of absenteeism and unauthorized work stoppages, the productivity problem sparked a search among U.S. manufacturing companies for new structures of work organization that would secure the cooperation of shop-floor workers in realigning the relation between work and pay.

Within the automobile industry, the United Auto Workers joined corporate management on a National Joint Committee to Improve the Quality of Worklife. The problem was to convince workers that programs of "job enrichment" and "job enlargement" were not merely new ways to speed up production and reduce employment. Unfortunately, during the 1970s, even many promising experiments at work reorganization that had already yielded significant productivity gains were cut short when middle managers and first-line supervisors realized that the ultimate success of the programs entailed a loss of their power in the traditional hierarchically segmented organization.[52] Indeed, in general, the more pervasive response

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[49] Ishikawa, New Manufacturing Challenge, 151-152

[50] See U.S. Department of Health, Education, and Welfare, Work in America, MIT Press, 1972; Richard E. Walton, "Work Innovations in the United States," Harvard Business Review, 57, July-August 1979.

[51] See Lazonick, Competitive Advantage on the Shop Floor, 280-284.

[52] See Richard E. Walton, "The Diffusion of New Work Structures: Why Success Didn't Take," Organizational Dynamics, 3, Winter 1975; Andrew Zimbalist, "The Limits of Work Humanization,"

to the productivity problem in American manufacturing in the 1970s was an increase in shop-floor supervision rather than the transformation of work organization. From 1950 to 1970, the number of foremen per 100 workers in American manufacturing increased from 3.4 to 4.8; by 1980 this ratio had shot up to 8.0.[53]

During the 1980s, in the face of intense and growing competition from the Japanese, many companies throughout the United States sought to introduce Japanese-style "quality programs" into their workplaces. In their comprehensive survey of available case studies of these "experiments in workplace innovation," Eileen Appelbaum and Rose Batt found that "U.S. companies have largely implemented innovations on a piecemeal basis and that most experiments do not add up to a coherent alternative to [traditional U.S.] mass production."[54] They contended that

> quality circles and other parallel structures [of work reorganization] were a 'fad' in the early 1980s and have since been discredited in most U.S. applications as either not sustainable or providing limited results. . . . The overwhelming majority of cases show that firms have introduced modest changes in work organization, human resource practices, or industrial relations – parallel structures such as quality circles involving only a few employees, a training program, or a new compensation system. We consider these to be marginal changes because they do not change the work system or power structure in a fundamental way.[55]

The fundamental problem, I would argue, was lack of resolve by those who governed these corporations to effect the organizational integration of "hourly" shop-floor workers and "salaried" managerial employees. What is more, it appears that hierarchical segmentation in U.S. industrial enterprises fostered functional segmentation. Distant from the realities of problem-solving in the actual production process, U.S. technical specialists sought to solve problems by using the tools of their own particular disciplines, putting up barriers to communicating even with other specialists within the managerial organization, and throwing partially solved problems "over the wall" into the domains of other functional specialists.[56] In Japan, by contrast, the hierarchical integration of technical specialists in a learning process

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Review of Radical Political Economics, 7, Summer 1975; Stephen A. Marglin, "Catching Flies With Honey: An Inquiry into Management Initiatives to Humanize Work," Economic Analysis and Workers' Management, 13, 1979.

[53] Nelson Lichtenstein, "'The Man in the Middle': A Social History of Automobile Industry Foremen," in Nelson Lichtenstein and Stephen Meyer, eds. On the Line: Essays in the History of Auto Work, University of Illinois Press, 1989.

[54] Eileen Appelbaum and Rosemary Batt, The New American Workplace: Transforming Work Systems in the United States, Cornell University Press, 1994, 10.

[55] Ibid., 70. See also Thomas Kochan, Harry Katz, and Nancy Mower, Worker Participation and American Unions: Threat or Opportunity?, W. E. Upjohn Institute for Employment Research, 1984; Edward E. Lawler III, Gerald Ledford, and Susan A Mohrman, Employee Involvement in America: A Study of Contemporary Practice, American Quality and Productivity Center, 1989; Robert E. Cole, Strategies for Learning: Small Group Activities in American, Japanese, and Swedish Industry, University of California Press, 1989.

[56] The problem of functional segmentation in U.S.-Japanese competition has in recent years become a prime focus of comparative studies carried out in American business schools. See for example Kim B. Clark and Takahiro Fujimoto, Product Development Performance, Harvard Business School Press, 1991; Funk, Teamwork Advantage; D. Eleanor Westney, "The Evolution of Japan's Industrial Research and Development," in Masahiko Aoki and Ronald Dore. eds., The Japanese Firm: The Sources of Competitive Strength, Oxford University Press, 1994; Daniel I. Okimoto and Yoshio Nishi, "R&D Organization in Japanese and American Semiconductor Firms." in Aoki and Dore, The Japanese Firm.

with production workers created lines of communication and incentives to solve problems in concert with other specialists. Relative to their competitors in the United States, the result of functional integration for Japanese manufacturers has been not only superior product quality but also more rapid new product development.

The different way in which quality control was implemented in Japan and the United States is a case in point. In Japan, QC was embedded in the whole structure of organizational learning. In Japan quality control is, as Izumi has put it, "the responsibility of all employees, including top and middle management as well as lower-level workers, from planning and design, to production, marketing, and sales. . . [in] contrast with the American reliance on specialist quality control inspectors."[57] Ishikawa has emphasized the functional segmentation of American QC inspectors:

> In the United States and Western Europe, great emphasis is placed on professionalism and specialization. Matters relating to QC therefore become the exclusive preserve of QC specialists. When questions are raised concerning QC, people belonging to other divisions will not answer, they will simply refer the questions to those who handle QC.
>
> In Western countries, when a QC specialist enters a company, he is immediately put in the QC division. Eventually he becomes head of a subsection, a section, then of the QC division. This system is effective in nurturing a specialist, but from the point of view of the entire business organization, is more likely to produce a person of very limited vision.
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> For better or for worse, in Japan little emphasis is placed on professionalism. When an engineer enters a company, he is rotated among different divisions, such as design, manufacturing, and QC. At times, some engineers are even placed in the marketing division. [58]

- Factory Automation

In the late 1970s, American manufacturers continued to attribute the mounting Japanese challenge to low wages and the persistent productivity problem at home to worker alienation. By the 1980s and 1990s, however, the innovative reality of the Japanese challenge became difficult to ignore, as the Japanese increased their shares of U.S. markets across a range of key industries, even as Japanese wage rates rapidly rose and the yen steadily strengthened.

Even then, there appeared to be a way out for U.S. manufacturers that did not require imitation of the Japanese by building broader and deeper skill bases. Since the 1950s American management had envisioned "the Factory of the Future" -- a completely automated production facility that would do away with the need to employ production workers altogether.[59] Yet, notwithstanding massive investments by U.S. corporations and the U.S. government in factory automation, attempts by American companies to create the

[57] Nonaka, "Development of Company-Wide Quality Control."
[58] Ishikawa, New Manufacturing Challenge, 23.
[59] See David F. Noble, Forces of Production: A Social History of Industrial Automation, Oxford University Press, 1984, ch. 4.

"factory of the future" failed.[60]

In sharp contrast, building on their investments in broad and deep skill bases, and decades of continuous improvement of production processes, Japanese companies succeeded. At the end of 1992, the Japanese had installed about 349,500 robots compared to 47,000 in the United States and 39,400 in Germany.[61] The Japanese also developed and utilized flexible manufacturing systems (FMS) -- computer-controlled configurations of semi-independent work stations connected by automated material handling systems -- in advance of, and on a scale that surpassed, other nations.[62] Japan's success in machine tools and factory automation reflected their leadership in the integration of mechanical and electronics technologies, or what since the mid-1970s the Japanese have called "mechatronics".[63]

For example, in his case study of the introduction of FMS at Hitachi Seiki, Ramchandran Jaikumar found that the first two attempts, undertaken between 1972 and 1980, had failed because of insufficient coordination across functions. In 1980, therefore, the company set up the Engineering Administration Department that "brought together a variety of different functions from machine design, software engineering, and tool design."[64] The new structure of organizational learning, which built on the lessons of the previous failures, led to success. The development teams on the two failed attempts had, according to Jaikumar,

> integrated the different components of their systems through machinery design rather than through general systems engineering concepts. They had viewed flexible manufacturing systems as technical problems to be solved with technical expertise. The difficulty of evaluating trade-offs whenever conflicts arose over design specifications or procedures convinced Hitachi Seiki that it was problems of coordination among people that was stymying systems development. The company realized that what was needed was to view FMS as a manufacturing problem to be solved with both manufacturing and technical expertise. Consequently the third phase of FMS development at Hitachi Seiki was a radical departure from the previous two.[65]

In his comparisons of Japanese and U.S. FMS in the first half of the 1980s, Jaikumar found that, even though the FMS installations in both countries contained similar machines doing similar kinds of work, the Japanese developed the systems in half the time, produced over nine times as many parts per system in average annual volumes that were about one-seventh of American practice, with much greater automation, and utilization rates.[66] "Differences in results," said Jaikumar, "derive mainly from the extent of the installed base of machinery, the technical literacy of the work force, and the competence of management. In each of these areas, Japan is far ahead of the United States."[67]

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[60] For an excellent case study, see Noble, Forces of Production; see also Robert J. Thomas, What Machines Can't Do: Politics and Technology in the Industrial Enterprise, University of California Press, 1994.

[61] Tsuneta Yano Memorial Society, ed., Nippon: A Charted Survey of Japan, 1993/94, Kokusei-sha, 1993, 191.

[62] Ramchandran Jaikumar. "Japanese Flexible Manufacturing Systems: Impact on the United States," Japan and the World Economy, 1 1989.

[63] See Fumio Kodama, Emerging Patterns of Innovation: Sources of Japan's Technological Edge, Harvard Business School Press, 1995,193; also V. Daniel Hunt, Mechatronics: Japan's Newest Threat, Chapman and Hall, 1988.

[64] Jaikumar, "Japanese Flexible Manufacturing Systems," 126.

[65] Ibid.

[66] Ibid., 129.

[67] Ibid.

More specifically, he described how the Japanese developed the reliability of FMS to achieve untended (automated) operations and system uptime levels of over 90 percent, in the process transforming not only shop-floor technology but also the job of a "shop-floor operator".

> The entire project team remains with the system long after installation, continually making changes. Learning occurs throughout and is translated into on-going process mastery and productivity enhancement. . . . Operators on the shop floor, highly skilled engineers with multifunctional responsibilities, make continual programming changes and are responsible for writing new programs for both parts and systems as a whole. Like designers, they work best in small teams. Most important, Japanese managers see FMS technology for what it is -- flexible -- and create operating objectives and protocols that capitalize on this special capability. Not bound by outdated mass-production assumptions, they view the challenge of flexible manufacturing as automating a job shop, not simply making a transfer line flexible. The difference in results is enormous.[68]

Ultimately, then, the development of automated systems -- including the integration of electronic, mechanical, and chemical processes that made these technologies "advanced" -- has not been the work of "blue-collar" employees, even as the Japanese have traditionally understood the term. Rather it has been the work of teams of highly educated and highly trained engineers who had mastered their technical specialties but who were also able and willing to integrate across specialties. As stated earlier, that the Japanese could even consider entry into complex manufacturing industries such as automobiles and consumer electronics after World War II was because of the learning that their scientists and engineers had accumulated in the decades before as well as during the war.

But the Japanese history of the hierarchical integration of traditional blue-collar workers into the development and utilization of manufacturing technology laid the basis for functional integration as technology became more and more complex. The accumulated learning of Japan's scientists and engineers after the war was in and of itself no match for that which the American's possessed. Yet, during the postwar decades Japanese scientists and engineers developed and utilized their collective capabilities in manufacturing as part of an organizational learning process that integrated the capabilities of shop-floor workers in making continuous improvements to the manufacturing process. In the 1980s and 1990s this history of hierarchical integration played a significant role in fostering the functional integration that has been key to Japan's success relative to the United States in factory automation.

The importance of taking organizational learning to the shop floor also applies in the semiconductor industry, the most complex and automated of manufacturing processes. As Okimoto and Nishi argue in their excellent comparative study of Japanese and U.S. semiconductor manufacturing:

> Perhaps the most striking feature of Japanese R&D in the semiconductor industry is the extraordinary degree of communication and 'body contact' that takes place at the various juncture and intersection points in the R&D processes – from basic research to advanced development, from advanced development to new product design, from new product design to new process technology, from new process

[68] Ibid., 130.

> technology to factory-site manufacturing, from manufacturing to marketing, and from marketing to servicing. Owing to pragmatic organizational innovations, Japanese semiconductor manufacturers have excelled – where many American and European manufacturers have faltered – at the seemingly simple but extremely difficult task of making smooth 'hand-offs' at each juncture along the long-interconnected R&D pipeline.[69]

The key links in this pipeline in Japanese semiconductor R&D are between divisional labs and factory engineering labs. Engineers from these labs, according to Okimoto and Nishi, "continually meet and interact in seeking to iron out problems that inevitably arise in mass-manufacturing new products."[70] Okimoto and Nishi continue, stressing the importance of the integration of R&D with manufacturing:

> The largest concentration [of engineers] is usually found at the FELs [factory engineering laboratories], located at factory sites where the messy problems of mass production have to be worked out. The majority of Japanese engineers have at least some exposure to manufacturing engineering as part of their job rotation and career training. Not only is there no stigma attached to manufacturing assignments; the ladder of promotion leading up to higher reaches of executive management – and beyond (including *amakudari*, or post-career executive entry into new companies) – pass through jobs that involve hands-on manufacturing experience. It is almost a requirement for upward career and post-career mobility.
>
> In the United States, by contrast, manufacturing engineers carry the stigma of being second-class citizens. To the manufacturing engineers falls the 'grubby' work of production – for which they receive lower pay and lower prestige compared with the 'glamorous' design jobs. In how many US semiconductor companies can it be said that the majority of engineers are engaged in manufacturing? Few, if any. And, looking at the large number of merchant semiconductor houses in Silicon Valley, we see that only a minority even possess manufacturing facilities, much less factory engineering laboratories.[71]

It would appear more generally that, by focusing the skills and efforts of engineers on continuous improvements in quality and cost in the production process, hierarchical integration provided a foundation for functional integration in Japanese manufacturing. If, in the first half of the 1980s, most Western analyses of the sources of Japanese competitive advantage focused on the integration of the shop-floor worker into the organizational learning process, over the last decade or so the emphasis has shifted to the role of "cross-functional management", "company-wide quality control," or "concurrent engineering" in generating higher quality, lower cost products. Much of the discussion of functional integration has been focused on its role in "new product development" in international comparative perspective.[72] But, I would argue, the key to understanding the influence of functional integration on innovation and international competitive advantage is the integration of product and process development, and the skill-base strategy that such

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[69] Daniel I. Okimoto and Yoshio Nishi, "R&D Organization in Japanese and American Semiconductor Firms," 193.
[70] Ibid., 195.
[71] Ibid.
[72] See for example Clark and Fujimoto, Product Development Performance. See also Ikujiro Nonaka and Hirotaka Takeuchi, The Knowledge-Creating Company, Oxford University Press, 1995.

integration entails. Such an understanding of organizational integration requires an analysis of functional integration in relation to the legacy of hierarchical integration or segmentation.

## A Research Agenda

If valid, the skill-base hypothesis can reconcile the fact that many U.S. industrial enterprises still remain innovators in international competition with the evidence on increasing income inequality in the United States. A systematic bias of U.S. industrial corporations to compete for product markets by investing in narrow and concentrated skill bases could provide a significant explanation for the income inequality trends over the last two decades or so. Testing the skill-base hypothesis may help provide answers to a number of related questions concerning the ways in which, in particular industries and activities, U.S. industrial corporations have responded to international competitive challenges.

- To what extent have U.S. companies exited from particular industries, and particular activities within a particular industry, in which they have been challenged by enterprises that have invested in broader and deeper skill bases as an alternative to transforming their strategies and structures to make the requisite investments in organizational learning?

- To what extent have the attempts of U.S. companies to respond to these competitive challenges been hampered by their failure to confront and transform sufficiently the strategic, functional, and hierarchical segmentation that they have inherited from the past?

- What can we learn about the incentive and ability of U.S. companies to make investments in broader and deeper skill bases by comparing strategy, organization, and performance of different companies in the same industry -- for example, Ford, GM, and Chrysler in automobiles -- that have sought to respond to the same international competitive challenges?

- What has been the importance of foreign direct investment -- for example, Japanese "transplants" in the United States -- as distinct from international trade in shaping the responses of U.S. companies to international competitive challenges?

- What has been distinctive about the investment strategies and organizational structures of U.S. companies that have become or remained leaders in international competition in the 1980s and 1990s? Did an historical legacy of investments in broader and deeper skill bases, and a relative absence of organizational segmentation, enable an older company like Motorola or 3M to continue to make such investments in the 1980s and 1990s, thus representing the exceptions that prove the rule in U.S. industry? Have newer companies such as Intel and Microsoft become world leaders through the organizational integration of narrow and concentrated skill bases?

Such questions indicate that testing the skill-base hypothesis and its immediate implications requires in-depth research of particular companies that compete in particular industries in different national economies in different, and typically over prolonged, periods of time. The more limited objective of this paper has been to elaborate the analytical framework for testing the skill-base hypothesis by synthesizing available evidence on differences in organizational learning in industries in which the United States and Japan compete head-to-head.

What are those industries, and how has competitive advantage been shifting between the United States and Japan? Tables 2a-c show the structure of bilateral Japanese-U.S. trade from 1979 to 1995.

### Table 2a. Japan-U.S. Bilateral Merchandise Trade, 1979, 1987, and 1995

**millions of U.S. dollars (current)**

| | 1979 | | 1987 | | 1995 | |
|---|---|---|---|---|---|---|
| | **Exports** | **Imports** | **Exports** | **Imports** | **Exports** | **Imports** |
| **TOTAL** | 26,403.5 | 20,430.8 | 83,579.9 | 31,490.5 | 120,858.9 | 75,408.1 |
| **Foodstuffs** | 189.0 | 4,422.9 | 404.1 | 6,778.9 | 303.4 | 15,951.4 |
| **Raw Materials** | 136.5 | 6,011.7 | 167.3 | 5,645.2 | 380.9 | 8,017.2 |
| **Light Goods** | 2,200.6 | 481.1 | 6,465.5 | 3,037.6 | 7,979.4 | 8,745.8 |
| **Chemical Goods** | 653.1 | 2,053.3 | 2,080.8 | 4,035.3 | 4,826.1 | 7,072.7 |
| **Metal Goods** | 3,939.6 | 1,660.7 | 4,101.8 | 901.0 | 4,045.1 | 2,190.4 |
| **Machinery** | 19,008.3 | 4,310.2 | 69,493.9 | 9,075.4 | 100,182.5 | 30,515.6 |
| Office Machines | 679.9 | 530.1 | 7,373.7.1 | 1,589.9 | 14,183.7 | 4,862.5 |
| Electrical Machinery | 4,393.3 | 1,349.9 | 17,050.1 | 3,008.9 | 29,384.8 | 12,746.4 |
| Transportation Equip. | 10,106.4 | 985.5 | 32,050.3 | 1,854.7 | 32,023.9 | 5,987.7 |
| Precision Instruments | 1,515.9 | 357.9 | 3,967.3 | 620.1 | 6,545.7 | 1,844.5 |
| **Reexports,unclassified** | 275.4 | 133.5 | 866.5 | 622.5 | 3,141.0 | 1,603.0 |

### Table 2b. Japan-U.S. Trade Growth, 1979-1995

**1979=100**

| | Japanese Exports to US | | | US Exports to Japan | | |
|---|---|---|---|---|---|---|
| | **1979** | **1987** | **1995** | **1979** | **1987** | **1995** |
| **TOTAL** | **100** | **317** | **458** | **100** | **154** | **369** |
| **Foodstuffs** | **100** | **214** | **161** | **100** | **153** | **361** |
| **Raw Materials** | **100** | **123** | **279** | **100** | **94** | **133** |
| **Light Goods** | **100** | **294** | **363** | **100** | **631** | **1818** |
| **Chemical Goods** | **100** | **319** | **739** | **100** | **197** | **344** |
| **Metal Goods** | **100** | **104** | **103** | **100** | **54** | **132** |
| **Machinery** | **100** | **366** | **527** | **100** | **211** | **708** |
| Office Machines | 100 | 1085 | 2086 | 100 | 300 | 917 |
| Electrical Machinery | 100 | 388 | 669 | 100 | 223 | 944 |
| Transportation Equip. | 100 | 317 | 317 | 100 | 188 | 608 |
| Precision Instruments | 100 | 262 | 432 | 100 | 173 | 515 |
| **Reexports, unclassified** | **100** | **315** | **1141** | **100** | **466** | **1201** |

**Table 2c. Proportionate Shares of Japan-US Bilateral Merchandise Trade, 1979, 1987, and 1995**

**Percent of Annual Bilateral Exports**

| | Japanese Exports to US | | | US Exports to Japan | | |
|---|---|---|---|---|---|---|
| | 1979 | 1987 | 1995 | 1979 | 1987 | 1995 |
| **TOTAL** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** |
| **Foodstuffs** | **0.7** | **0.5** | **0.3** | **21.6** | **21.5** | **21.2** |
| **Raw Materials** | **0.5** | **0.2** | **0.3** | **29.4** | **17.9** | **10.6** |
| **Light Goods** | **8.3** | **7.7** | **5.2** | **2.4** | **9.6** | **11.6** |
| **Chemical Goods** | **2.5** | **2.5** | **4.0** | **10.1** | **12.8** | **9.4** |
| **Metal Goods** | **14.9** | **4.9** | **3.3** | **8.1** | **2.9** | **2.9** |
| **Machinery** | **72.0** | **83.1** | **82.9** | **21.1** | **28.8** | **40.5** |
| Office Machines | 2.6 | 8.8 | 11.7 | 2.6 | 5.0 | 6.5 |
| Electrical Machinery | 16.6 | 20.4 | 24.3 | 6.6 | 9.6 | 16.9 |
| Transportation Equip. | 38.3 | 38.3 | 26.5 | 4.8 | 5.9 | 7.9 |
| Precision Instruments | 5.7 | 5.2 | 5.4 | 1.8 | 2.0 | 2.4 |
| **Reexports, unclassified** | **1.0** | **1.0** | **2.6** | **0.7** | **2.0** | **2.1** |

Source: Japan External Trade Oragnization, White Papers on International Trade, Japan, Trade Statistics, Ministry of International Trade and Industry, 1980, 1988, 1996.

As useful as these data are as points of departure, they have important limitations for defining the comparative case studies needed to test the skill-base hypothesis. The importance of foreign direct investment, cross-border outsourcing, and third-country exports means that trade data provide only a partial picture of shifts in head-to-head competitive advantage. Moreover, as we shall see for example in the case of "aircraft engines and parts", hidden within a narrowly defined industrial classification of traded goods, may be important international divisions of labor that reflect investments in different types of skill bases.

In 1995 Japan exported $120.9 billion of goods to the United States (27. 3 percent of all Japanese exports) and imported $75.4 billion from the United States (22.4 percent of all Japanese imports) for a merchandise trade surplus of $45.5 billion.[73] The United States is by far Japan's foremost trade partner for both exports and imports. Japan's next largest trade partners in 1995 were for exports South Korea (7.1 percent of Japan's total) and for imports China (10.7 percent of the total).[74]

Of Japan's exports to the United States in 1995, 82.9 percent fell under the broad category of "machinery". This category included, among the major classifications, office machines (11.7 percent of all goods exports), electrical machinery (24.3 percent), transportation equipment (26.5 percent, of which automobiles were 18.3 percent and automobile parts 6.5 percent), and precision instruments (5.4 percent) (see Table 2c). The remainder of Japanese exports to the United States consisted largely of chemical goods (4.0 percent), metal goods (3.3 percent), and light industrial products (6.6 percent).

[73] Nikkei Weekly, ed., Japan Economic Almanac 1997, Nihon Keizai Shimbun, 1997, 107.
[74] Ibid.

What did the United States export to Japan? Machinery accounted for 40.5 percent of U.S. exports, consisting mainly office machines (6.5 percent), electrical machinery (16.9 percent, of which semiconductors and integrated circuits were 7.1 percent), and transportation equipment (7.9 percent). The remainder of U.S. *manufactured* exports to the United States consisted mainly of an assortment of light products (11.6 percent, including textiles, paper products, records and tapes, and sporting goods) and chemical goods (9.4 percent). But all manufactured goods only accounted for less than two-thirds of U.S. exports to Japan. Over one-third of U.S. exports to Japan in 1995 were either foodstuffs (21.2 percent) or raw materials (10.6 percent). For Japan, foodstuffs and raw materials exports were only 0.6 percent of its total exports to the United States.

Note that, in the 1970s, as the Japanese challenge mounted, the United States was even more reliant than it would be in 1995, in relative terms at least, on exports of foodstuffs and raw materials to Japan. In 1979, 51.0 percent of U.S. exports to Japan took the form of these basic materials. In that year 75 percent of Japan's raw materials imports from the United States were soybeans (5.7 percent of total imports), wood (11.2 percent), and coal (5.0 percent). By 1995 Japan imported a somewhat larger quantity of soybeans (but the proportion of total imports fell to 1.5 percent), and absolutely smaller quantities of wood (4.2 percent) and coal (0.9 percent). Hence over the 16-year period, the relative importance of foodstuffs for U.S. exports to Japan was maintained, while the relative, and in some cases absolute, importance of raw materials declined.

The case of U.S. agriculture is a case in point of the need for in-depth industry-specific analyses of the sources of sustainable competitive advantage. Looking at the trade data, an economist might conclude that the importance of raw materials, and particularly foodstuffs, in U.S. exports to Japan is simply a matter of very different land-labor ratios in the two nation's factor endowments. To draw such a conclusion, as valid as it might appear on the surface, would, however, miss the critical importance of collective and cumulative learning on a national scale over the past century in making agriculture the one industrial sector in which the international competitive advantage of the United States is most sustainable. It would neglect a century-long history of organizational learning, akin to the managerial revolution that occurred within major U.S. industrial corporations, in which the U.S. Department of Agriculture created a national system of research and development that diffused new technology to millions of farmers through the state-based activities of land-grant colleges, experiment stations, and county agents. Indeed, the legacy of this massive investment in organizational learning is not only productive supremacy in agriculture but also the world's foremost structure of industrial research institutions embedded in the U.S. system of higher education.[75]

Note also that the relative importance of machinery exports from Japan increased substantially in the first eight-year period, while the relative importance of U.S. machinery exports increased from 1979 to 1995, with the major gains being made in the late 1980s and early 1990s. The United States made these gains despite the continuing decline of its machine tool industry in the face of relentless Japanese competition. By 1991, compared with the U.S. machine tool industry, the value of Japanese machine tool production was 356 percent and machine tool exports 443 percent.[76] In the 1990s, the Japanese have also

[75] Louis Ferleger and William Lazonick, "The Managerial Revolution and the Developmental State: The Case of U.S. Agriculture," Business and Economic History, 2nd ser., 22, 2, 1993; Louis Ferleger and William Lazonick, "Higher Education for an Innovative Economy: Land-Grant Colleges and the Managerial Revolution in America," Business and Economic History, 2nd ser., 23, 1, 1994.

[76] Yano Memorial Society, Nippon, 199.

successfully challenged the German machine tool manufacturers, surpassing them for the first time in 1992 in the value of production, and in 1993 in the value of exports. Capturing larger and larger shares of export markets through 1996, Japanese companies now completely dominate the mid-range and high-range markets for CNC (computer numerically controlled) machine tools. The low-end markets have been left mainly to Taiwanese companies, and the high-end niches in non-CNC machine tools remain in the hands of the Swiss, Germans and, to a more limited extent, the Americans.[77]

Between 1987 to 1995 the U.S. gains in machinery were mainly in integrated circuits (up 4.6 percent) and automobiles (up 3.9 percent), these two categories accounting for almost 75 percent of the increase in U.S. machinery exports as a proportion of total exports. Within the category of Japanese transportation equipment exports, in 1985 30.2 percent were automobiles (3,278,724 vehicles) and another 6.2 percent were auto parts; in 1995 these figures were 18.2 percent (2,066,255 vehicles) and 6.6 percent respectively. The decline in Japanese exports reflected the Japanese strategy of foreign direct investment in automobiles, either directly in the United States or in Southeast Asian countries such as Thailand and Indonesia that then exported automobiles or parts to the United States. In 1985 Japanese automobile companies produced 254,000 cars and 107,000 trucks in the USA; in 1995 1,942,000 cars and 414,000 trucks.[78] In 1987, the leading U.S. industry within the transportation equipment category was aircraft, which represented 5.0 percent of all exports. In 1995 aircraft had declined to 2.6 percent of U.S. exports to Japan, and had been surpassed by automobiles, which in were 4.2 percent of U.S. exports (294,874 vehicles), up from only 0.3 percent (88,395 vehicles) in 1987.

It was mainly Japanese companies operating in the United States that were doing the exporting. Of just over 100,00 automobiles exported from the United States to Japan in 1994, 53,500 were from Honda, USA and another 11,300 from Toyota USA, leaving about 35 percent of the exports to be shared between GM, Ford, and Chrysler (some of whose cars were produced through joint ventures with Japanese companies). The total number of cars exported to Japan by the three U.S. automakers was less than the number exported by Volkswagen/Audi and only about 60 percent of the combined sales of BMW and Mercedes Benz in Japan. Each of the U.S. companies was also outsold in Japan by Rover, Opel (owned by GM), and Volvo.[79]

The United States and Japan almost balance trade within the classification "aircraft engines and parts".[80] U.S. exports of internal combustion engines to Japan increased from 288 engines worth $0.8 billion in 1987 to 788 engines worth $0.9 billion in 1995. But, increasingly parts dominate the trade in aircraft engines, especially from Japan to the United States. The ability to integrate innovation in advanced materials with precision engineering has been key to Japan's growing success. Building on pioneering investments in the development of polyacryonitric carbon fiber by Toray Industries in the 1970s, three Japanese synthetic fiber producers now dominate 60 percent of the world market.[81] Finding a market at first as a light and durable material for sports equipment such as tennis rackets

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[77] Robert Forrant, "Good Jobs and the Cutting Edge: The U.S. Machine Tool Industry and Sustainable Prosperity," Report to the Jerome Levy Economics Institute, May 1997.
[78] Nikkei Weekly, Japan Economic Almanac 1996, 151.
[79] Ibid., 101, 103.
[80] Beth Almeida, "Are Good Jobs Flying Away?: U.S. Aircraft Engine Manufacturing and Sustainable Prosperity," Report to the Jerome Levy Economics Institute, May 1997.
[81] Japan Economic Almanac 1997, 210; Kodama, Emerging Patterns of Innovation, 59-60. See also Tsuneo Suzuki, "Toray Corporation: Seeking First-Mover Advantage," in Takeshi Yuzawa, ed. Japanese Business Success: The Evolution of A Strategy, Routledge, 1994.

and golf clubs, in the 1980s Japanese-made carbon fiber became a primary composite material used in both aircraft and engines. For example, Ishikawajima-Harima Heavy Industries -- one of the three major Japanese companies involved in jet engine manufacture -- currently produces carbon fiber blades for jet engines made by General Electric. Japan's competitive advantage in producing such parts that combine advances in chemical and mechanical engineering would seem to derive from its investments in broad and deep skill bases.

Organizational integration also appears important in explaining trade in semiconductors. In 1995, Japanese exports of integrated circuits accounted for 6.2 percent of all Japanese exports to the United States (up from 1.4 percent in 1987), and hence represented one-quarter of 1995 electrical machinery exports. This bilateral trade in integrated circuits reflects U.S. specialization in microprocessors and Japanese specialization in dynamic random access memories (DRAMs) -- an international division of labor built on investments in different skill bases in the two nations. Describing the "lagged parallel model" of new product development, pioneered at Toshiba and subsequently diffused to other Japanese enterprises as well as U.S.-based Texas Instruments, Okimoto and Nishi have pointed out that

> the lagged parallel project model is effective for work on only certain types of technology. It works for DRAMS, SRAM [sic], and other commodity chips, which share highly predictable linear trajectories of technological advancement. The model is not particularly well suited for products based on nonlinear, highly volatile technological trajectories, where the parameters of research for the next and successive product generations cannot be understood ahead of time. Thus it is not accidental that Japanese companies have dominated in commodity chips but have lagged behind U.S. companies in logic chips, microprocessors, and software for applications and operating systems. The latter may require a different, perhaps less structured, organizational approach.[82]

As for computers, American success in PCs and packaged, standardized software does not mean that the Japanese have not been successful competitors. U.S. government agencies, including the military, have been buying supercomputers from the Japanese. The success of a company like Toshiba in laptop computers reflects Japan's long-standing success at miniaturization, a technological advance that requires the integration of design and manufacturing. Japan also dominates international competition in liquid crystal displays (LCDs), a technology invented by RCA in 1967, but developed from the early 1970s most successfully by Sharp in a growing number of applications. By 1992, Sharp controlled 38 percent of the world's rapidly growing market for LCDs.[83]

In the United States, there is growing evidence that even in industries such as jet engines and medical equipment, the trend in the United States is out of manufacturing and even design, and into the low fixed cost and highly lucrative business of servicing high-technology equipment.[84] A recent hostile takeover attempt of Giddings & Lewis, the largest machine-tool maker in the United States, by another American company, Harnischfeger, had as it objective the shedding of the target's business of manufacturing machine tools for the

[82] Okimoto and Nishi, "R&D Organization in Japanese and American Semiconductor Firms," 197-198.
[83] Kodama, Emerging Patterns of Innovation , 56-58.
[84] Beth Almeida, "Are Good Jobs Flying Away?"; Chris Tilly, "The Diagnostic Medical Equipment Industry: What Prognosis for Good Jobs?" Report to the Jerome Levy Economics Institute, June 1997.

automotive industry so that the company could focus on servicing installed machinery.[85] In the end, a "white knight", the German company, Thyssen, acquired Giddings, promising to maintain its manufacturing business. But the fact is that considerable money can be made by taking a reputable manufacturing company and turning it into a servicing company.

Precisely because the United States has been a leader in industries such as jet engines, medical equipment, and machine tools, the nation has a huge accumulation of experienced technical specialists, many of whom no longer have as secure employment with equipment producers as they had in the past. Some of these people are finding continued employment servicing the equipment that the companies for which they worked used to both produce and service. In the past, they acquired these skills through organizational learning. But their utilization of these skills today confines them to narrow and concentrated functions that removes them even further from the processes of organizational learning that will drive innovation in the future.

In the absence of indigenous manufacturing capability and organizational learning in these industries, where will the next generation of American high-technology service specialists accumulate new state-of-the-art skills? The U.S. economy has a vast accumulation of high-technology skills that derives from the organizational learning that took place in managerial structures over the past century, and off of which it can live, and even innovate, for some time into the future. But, if instead of using this organizational learning to build broader and deeper skill basis, American businesses move toward relying on even narrower and more concentrated skill bases, the trends toward income inequality of the last two decades will continue. If I am right, addressing the problem of income inequality in the United States means paying serious attention to the comparative research agenda and the issues of corporate employment and corporate governance that the skill-base hypothesis implies.

[85] "Giddings Accepts Buyout Offer From Thyssen of $675 Million," Wall Street Journal, June 9, 1997.