THE MIT JAPAN PROGRAM

日本プログラム

Science, Technology, Management

科学・技術・経営

Indigenous Innovation and Industrialization: Foundations of Japanese Development and Advantage

William Lazonick and William Mass

MITJP 95-03

Center for International Studies
Massachusetts Institute of Technology

Indigenous Innovation and Industrialization: Foundations of Japanese Development and Advantage

William Lazonick and William Mass

MITJP 95-03

Distributed Courtesy of the
MIT Japan Program

Science • Technology • Management

Center for International Studies
Massachusetts Institute of Technology
Room E38-7th Floor
Cambridge, MA 02139

phone: 617-253-2839
fax: 617-258-7432

*****

About the MIT Japan Program
and its Working Paper Series

*****

The MIT Japan Program was founded in 1981 to create a new generation of technologically sophisticated "Japan-aware" scientists, engineers, and managers in the United States. The Program's corporate sponsors, as well as support from the government and from private foundations, have made it the largest, most comprehensive, and most widely emulated center of applied Japanese studies in the world.

The intellectual focus of the Program is to integrate the research methodologies of the social sciences, the humanities, and technology to approach issues confronting the United States and Japan in their relations involving science and technology. The Program is uniquely positioned to make use of MIT's extensive network of Japan-related resources, which include faculty, researchers, and library collections, as well as a Tokyo-based office. Through its three core activities, namely, education, research, and public awareness, the Program disseminates both to its sponsors and to the interested public its expertise on Japanese science and technology and on how that science and technology is managed.

The MIT Japan Program Working Paper Series provides an important means to achieving these ends.

*****

Indigenous Innovation and Industrialization: Foundations of Japanese Development and Advantage

William Lazonick and William Mass
University of Massachusetts Lowell

I. Indigenous Innovation

In the twentieth-century experience of economic growth, the case of Japan stands out. Here is an economy that, in terms of GNP per head, transformed itself from one of the poorer nations in the world at the beginning of the century into one of the richest by the 1980s.

Is the case of Japan unique? If so, its experience has little to teach us about the development paths, possibilities, and problems of other nations. Or have the driving forces of Japanese economic development during this century also been operative in the successful development of other leading industrial economies? If so, an understanding of the case of Japan in comparative perspective can contribute to the theoretical conceptualization of the process of economic development more generally.

Our main argument can be simply stated: a central determinant of Japan's phenomenal economic success during this century was indigenous innovation. The specific institutional structures that enabled Japan to engage in indigenous innovation are peculiar, if not unique, to that nation. But the organizational principles on which these institutions operated, as well as the centrality of indigenous innovation to the process of economic development, make the Japanese case relevant for understanding development and underdevelopment around the world.

What makes the Japanese case important is not just its own growth record but the fact that Japan achieved this growth by successfully challenging the industrial leadership of the most powerful economies in the world. Indeed, Japan challenged the existing leaders, not in the industries where they were weakest, but the ones in which they were strongest. Hence, in the 1920s and 1930s Japan took on Britain in textiles, in the 1970s and 1980s the United States in consumer electronics and mass-produced automobiles, and in the 1990s Germany in machine tools and luxury automobiles.

What is indigenous innovation? By innovation, we mean ways of transforming inputs into outputs that, given prevailing factor prices, result in products of higher quality and/or lower cost than had previously been available. By this definition, innovation provides the basis for increasing value to the consumer without reducing returns to the producer.

By indigenous innovation, we mean simply that new products and new processes that permit the delivery of higher quality at lower cost originate within a nation. Indigenous innovation permits a nation to experience economic development in terms of rising real per capita incomes.

To analyze the process of economic development invariably requires an understanding of the strategies and structures of the productive entities within a nation -- individuals, enterprises, industries, regions -- that participate in the innovation process. As an overriding political unit, however, the nation can play a critical role in providing coherence to these strategies and structures in ways that facilitate the innovation process.

Innovation is the source of sustainable competitive advantage -- that is, competitive advantage that does not depend on a lowering of the standards of living of those who participate in the process of delivering value to consumers. When the gains to innovation are shared between producers and consumers, standards of living rise because of both higher returns to the factors of production and lower expenditures per unit of value consumed. The result is economic development.

The innovation process requires the generation and the utilization of knowledge that becomes embodied in new products and new processes. The generation of knowledge and its embodiment in products and processes takes time and has costs but does not in and of itself yield returns to innovation [see Lazonick 1991:ch.3; Lazonick 1993]. For returns to innovation to occur, the new products and processes must be utilized sufficiently to yield costs per unit of consumable service that are lower than those previously attainable.

Indigenous innovation is by no means inconsistent with borrowing technology from abroad. The history of economic development shows that borrowing technology is central to indigenous innovation. The borrowing that results in indigenous innovation does not simply entail imported machines and foreign specialists. Rather what must be borrowed is existing knowledge on the basis of which indigenous entities (enterprises, industries, regions) can develop new knowledge that can in turn be embodied in innovations. Indigenous innovation builds on knowledge acquired abroad to develop unique productive capabilities at home.

An alternative to the indigenous innovation hypothesis is one that argues that nations gain global competitive advantage by combining imported machines and foreign specialists with the cheap labor of the indigenous labor force. Access to labor that will work long and hard hours for low wages, according to this hypothesis, enables a nation to capture markets in low value-added industries. The implicit developmental assumption is that, over time, competitive advantage based on cheap labor can be used to move into higher value-added industries that permit a higher standard of living in terms of remuneration and work conditions.

Japanese history does not support the cheap labor hypothesis [see Mass and Lazonick 1990]. Had low wages and high effort been the prime sources of Japanese competitive advantage, Japan would not have been the success story of twentieth-century economic development. It was indigenous innovation, not cheap labor or even cheap capital, that permitted Japan to transform itself from a low-wage economy in the early twentieth century to a high-wage economy by the 1970s.

II. The Analysis of Indigenous Innovation

Why was Japan able to engage in indigenous innovation? Were the conditions that made Japan an indigenous innovator peculiar to that nation? Or was Japan doing something in similar ways that successful industrializers such as Britain, United States, and Germany had done before? And what about much less successful industrializers such as India, China, and Brazil? Can an understanding of the Japanese experience reveal what has been lacking in less developed nations that has blocked indigenous innovation?

To study indigenous innovation, we require an analytical framework that can comprehend the key elements in the innovation process. In an informative book on technology transfer to Japan, Takeshi Hayashi [1990] distinguishes five factors -- what he calls the five Ms -- that promote indigenous innovation: management, manpower, machinery, materials, and markets. To these we would add a sixth M: money, which actually should come first on the list.

Money, or finance, plays a critical role in the innovation process because those who control money get to choose what type of strategy an enterprise will pursue. An innovative strategy inherently entails fixed costs because expenditures have to be made on "machinery" (that is, plant and equipment) and certain types of "manpower" (including those people who inhabit the managerial structure) with a time lag before the receipt of returns. These fixed costs are high because of not only the scale of investments but also the developmental period that (by definition) must occur before the investments that entail fixed costs can generate returns.

Those who control money may or may not make strategic decisions that entail innovation -- they may or may not act as entrepreneurs. Strategic decision-makers can, and often do, decide not to be innovative but to produce on the basis of resources that already exist within the company or that can be readily purchased on factor markets -- what we have labeled an adaptive strategy. A necessary condition for innovation is that those who control financial resources choose innovative investment strategies rather than adaptive investment strategies.

They must, moreover, keep financial resources committed to the innovative strategy until the products and processes are sufficiently developed and utilized so that they generate returns. A failure to generate returns at any point in time may be a manifestation, not of a failed strategy, but of the need to commit even more financial resources to an ongoing learning process. To keep money committed to the innovative investment strategy, those who control money must have intimate knowledge of the problems and possibilities of the investment strategy, or entrust their money to strategic managers who have such knowledge.

Management is required to plan and coordinate the development of the specialized division of labor and the integration of the specialized productive activities required for an innovation to emerge. The innovative efforts that count for economic development invariably involve continuous, cumulative, and collective learning. Continuous learning results in the improvement of skills. Without continuous learning, acquired capabilities atrophy. Cumulative learning permits the use of acquired technological capabilities as the foundations for acquiring new capabilities. Without cumulative learning, more complex

capabilities cannot build on fundamental capabilities already acquired. Collective learning enables the planned coordination of specialized divisions of labor to develop new technology and generate productivity. Without collective learning, planned coordination is an economic burden rather than an economic benefit. Management's role in an innovative enterprise is to ensure the continuity, cumulativity, and collectivity of the learning process.

Manpower -- or labor power to be gender neutral at the sacrifice of alliteration -- is the input into the innovation process that can potentially learn. But, because of the continuous, cumulative, and collective character of the learning process, individuals cannot just learn as they please. Central to the innovative strategy is investment in the capabilities of those people who comprise the specialized division of labor that management must plan and coordinate.

Strategic decision-makers ("money") do not invest in all of the people whom they employ, but only in those people whom they expect to participate in the collective learning process. Strategic decision-makers do not want to invest in people who will exit the enterprise with their human assets. Nor do they want to invest in people who will use their voice within the enterprise to subvert rather than support the process of innovation.

Machines combine with manpower to transform materials into products. Innovation in machinery is both skill-displacing and skill-augmenting. It is skill-displacing because certain productive capabilities that used to reside in manpower can now be more effectively performed by machines. It is skill-augmenting because innovation in machinery requires the application of new knowledge to develop the machinery and utilize it effectively in the production process. Machines can affect the productivity of a given product and the quality of the product produced. There is generally an intricate relation between innovation in materials and innovation in machines. Innovation in machines and materials both in turn depend on the complementary skills of manpower.

Materials are the substances that people as labor power transform into products. As such materials become embodied in work-in-process -- components, parts, and intermediate goods. An understanding of the character of these materials in their raw and semi-processed states is critical for the innovation process to take place. A key innovation may entail the creation of new materials through chemistry or the blend of materials that enter the production process. The quality of materials and semi-processed inventories will affect not only the quality of the product but also the ways in which machines and manpower are developed and utilized.

In particular, high-throughput production processes require "high-throughput" materials -- that is, materials that do not cause machine stoppages and costly downtime, At the same time, costs are also increased by the wastage of materials because of the application of inadequate skills and inferior machinery in the production process. The combination of manpower, machines, and materials constitutes the enterprise's technology.

Markets provide the opportunity for the enterprise to generate returns on the investments in organization ("management") and technology ("manpower", "machines", "materials"). The strategic role of "money" is to decide for which markets the enterprise should produce outputs as well as from which markets the enterprise should purchase inputs.

Identification of markets, actual or potential, that can be served by the enterprise's technological capabilities is critical to the strategic decision making process, while gaining access to new markets is central to the actual innovation process. Given strategic decisions to compete for markets through innovation, management's role is to ensure the transformation of inputs into outputs in ways that generate learning and productivity so that the resultant products are ones that buyers both want and can afford.

III. Japan versus United States

From the perspective of the American economy, the most formidable competitive challenges since the 1960s have come from the Japanese. These competitive challenges did not occur in those industries in which it was weakest but rather in industries devoted to the mass production of consumer durables -- specifically, consumer electronics and automobiles -- in which the United States led the world. To complement these strategies, the Japanese also developed a steel industry that far surpassed that of the United States in productivity. As a backward linkage from their sustained competitive advantage in consumer durables, moreover, the Japanese pursued effective innovative strategies in semiconductors and machine tools. An understanding of the sources of Japanese competitive advantage requires an analysis of how the Japanese organized the six Ms of enterprise to generate technological innovation and competitive advantage.

Money

Innovation requires financial commitment so that high fixed-cost investments in physical and human resources ("machines" and "manpower") can be transformed into high quality, low cost products. In Japan, before World War II, the prime source of financial commitment was the family firm. Continuous innovation came from owner-entrepreneurs who used their profits from one successful investment to fund the next investment. In mining, shipping, shipbuilding, and steel, the innovative family firm was typically a "house" of family members -- the famous zaibatsu -- which delegated operating control, and usually strategic decision-making as well, to professional managers. The zaibatsu, or their constituent companies, also provided funds to new ventures with varied success [Morikawa 1992].

After World War II, under the American occupation, the zaibatsu were dissolved, and shares were disbursed among companies, financial institutions, and individuals [Gerlach 1992; Miyajima 1994]. But, when the Americans left, a movement began among Japanese enterprises engaged in long-term investment strategies to ensure that ownership stakes in their companies rested in the hands of stable shareholders -- generally other companies and banks with whom they had long-term business relations -- who would provide financial commitment.

These stable shareholders did not, and still do not, sell their shares to public investors (who speculate on the Tokyo Stock Exchange). Nor do they demand high dividends. Stable shareholders instead ensure that company earnings remain under the control of the professional managers who run the enterprises, thus creating the financial commitment necessary for continuous innovation. It is through their business relations

rather than through their equity stakes that stable shareholders actually share in the gains of innovation.

In the United States, owner-entrepreneurs have played the same role as in Japan in pursuing innovative investment strategies. Contrary to American folklore, new ventures have never been financed by the stock market. Rather the stock market serves as a means for successful companies -- ones that through innovation have transformed themselves from new ventures into going concerns -- to permit the owner-entrepreneurs and their backers (venture capitalists) to monetize the productive assets that they have accumulated. This monetization occurs by the transfer of ownership rights from the original owner-entrepreneurs to portfolio investors willing to hold the shares of the companies that the entrepreneurs have built up [see Lazonick 1992; Lazonick 1994; Lazonick and O'Sullivan 1995a].

As a result of the creation of a national market in industrial securities around the turn of the century, shares in the major American industrial corporations became widely distributed among wealthholding households that would not and could not exercise strategic control over the corporations that they now owned. Rather, ownership of the company's assets was separated from control over strategic decision-making. The strategic decision-makers were professional managers, many of whom had the interest and ability to use the financial resources of their companies to engage in continuous innovation.

In Japan, strategic decision-making power in the pre-World War II zaibatsu was often, although not always, delegated to professional managers. Under these arrangements, enterprise earnings tended to be plowed back into new investments. The managers who controlled money understood the opportunities and requirements of innovative investment strategies. The dissolution of the zaibatsu only increased the incentive and ability of top managers in Japan to engage in innovation.

In the United States, by contrast, the widespread distribution of shareholders left professional managers in positions of strategic decision-making power by default rather than design. This separation of ownership from control persisted well into the post-World War decades. By virtue of professional careers spent primarily climbing up and around the managerial organization, these strategic decision-makers -- the controllers of money -- had an intimate knowledge of the other five Ms. Possession of this knowledge enabled these top managers to evaluate the prospects for success of innovative investment strategies, while their own individual goals, shaped as they were by their professional careers and membership in the organization, gave them a bias in favor of innovating rather than adapting.

Over the past two decades or so, however, the rise of the institutional portfolio investor in the United States has permitted the concentration of share ownership. These new shareholders have been willing and able to extract earnings from existing industrial corporations, but without ensuring that this money would end up under the control of new organizations that are able and willing to engage in continuous innovation. In many industrial corporations, even when strategic decision-makers are not threatened with a loss of control over the allocation of financial resources, their backgrounds and their own financial

portfolios lead them to favor immediate financial returns over the long-term requirements of innovation.

In sum, even though, from the late nineteenth century both Japan and United States experienced a managerial revolution that persists to the present, the systems of corporate governance in the two nations differ significantly. During the first half of this century, American top managers as strategic decision-makers controlled money, and invested in innovation. The fragmentation of shareholders rendered owners impotent in influencing the choice of corporate strategy.

Since the 1950s, Japanese managers as strategic decision-makers have controlled money, and have invested in innovation, not because owners have been rendered impotent but because ownership is in the hands of business organizations that have a common interest in innovation. This pressure to invest in innovation has been increased by the ability of enterprise unions to ensure that a large proportion of the labor force has permanent employment status, and hence has an interest in the long-term prosperity of the enterprise.

Meanwhile, American managers as strategic decision-makers have progressively lost control over money, and have become less able and willing to invest in innovation. Increasingly, financial interests that seek to extract the returns of past investments -- or, as some financial economists put it, to "disgorge the free cash flow" -- have gained influence and control over corporate strategy. At the same time, the declining power of the organized labor movement in the United States as well as erosion of employment security within managerial structures themselves have reduced the number and power of stakeholders in the enterprise who have an interest in an innovative investment strategy or the ability to carry one out. The result has been a mounting tendency in American corporations to choose adaptive strategies that live off resources accumulated in the past rather than invest in innovation for the sake of future prosperity.

Management

The shift in strategic decision-making from innovation to adaptation manifests the notion, prevalent in the United States but not in Japan, that the company is run for its owners. Yet, even in the United States during the period when share ownership was effectively separated from strategic control, companies were de facto, even if not de jure, run for the sake of their organizations -- which in the United States meant their managerial structures (or what John Kenneth Galbraith [1967] called the "technostructure").

Especially where complex technologies were the foundation of a corporation's competitive advantage and market dominance, a company required managerial structures to plan and coordinate the specialized divisions of labor of their enterprises [see Lazonick and Mass 1995]. These highly collectivized managerial structures could engage in continuous and cumulative learning. It was this collective -- or organizational -- capability embodied in cohesive managerial structures that made the United States a formidable industrial power.

The key to creating these organizational capabilities was the long-term attachment of managerial employees to the enterprise -- similar in practice to what the Japanese call "permanent employment". American companies recruited graduates of colleges or

professional schools to begin their careers as lower level specialists within the managerial structure. Subsequently, management development programs transferred the most promising specialists around the organization and promoted them up the managerial hierarchy.

By giving these employees a broader understanding of company operations and by placing them in positions of increasing authority and responsibility, the management development programs gradually transformed a portion of the specialists into generalists who could plan and coordinate the specialized divisions of labor under their control. After two or three decades with the company, a small number of these generalists would reach top management positions where they would assume control over strategic decision making.

This system of career-long employment and advancement not only transformed specialists into generalists but also worked as a powerful motivator for specialists and generalists alike to identify with the goals of the enterprise. Given the separation of ownership from control, it was this integration of highly skilled individuals into the organization as a collectivity that was the essence of the managerial revolution in the United States [Lazonick 1986].

As both cause and effect of the movement from innovative to adaptive investment strategies in the United States, organizational integration of the managerial structure has been breaking down. At the top, strategic managers, rewarded with exceedingly high pay and valuable stock options, have been under pressure to show high earnings and pay out high dividends in the short run at the expense of long-run investments in innovation. With the turn from innovation to adaptation, the long-term attachment of managerial personnel to the organization ceases to be conceived by strategic managers as a costly-to-replace organizational asset but simply as an immediate expense that drags down earnings. Short-term relations with consultants, contractors, and employees become viewed as essential to "flexibility". These relations may permit flexibility in maintaining high corporate earnings. They do not, however, provide flexibility for shifting from one innovation to the next as a continuous process.

From this perspective on the rise and decline of U.S. managerial capitalism, the formidable organizational capabilities that the Japanese have put in place reflect a more thoroughgoing elaboration of an earlier U.S. model rather than a wholly new departure in internal organization. The Japanese corporations have elaborated American managerial capitalism of an earlier era into a more collective capitalism by developing long-term relations with employees not only in the managerial structure but also on the shop floor. In terms of mode of payment (salaries and shares in the gains of innovation) and employment conditions (permanent tenure and skill development), shop-floor workers in major Japanese corporations are in much the same position as managerial employees in both Japanese and American enterprises. Similarly, the long-term relation of major Japanese corporations with their suppliers -- that is, with vertically related, but legally distinct, firms -- is today even stronger than the relation between American corporations and their managerial employees. Japanese enterprises are more organizationally integrated than American enterprises, and it is this superior organizational integration that is the key to Japanese industry's competitive success [see Lazonick and West 1995; Lazonick and O'Sullivan 1995b].

Organizationally integrated relations with shop-floor workers and suppliers permit Japanese managers to plan and coordinate specialized divisions of labor in ways that are unattainable for the managers of most American corporations, which at best have collective capabilities only within the managerial structure. As a result, Japanese managers can contemplate innovative investment strategies that are not realistic options for strategic decision-makers in U.S. enterprises even when their managerial organizations are integrated and intact. As an elaboration of the organizational principles of American managerial capitalism, Japanese collective capitalism creates very different possibilities for the development and utilization of manpower, materials and machines.

Manpower

In the United States, the ideology underlying corporate governance is that the enterprise is run for owners. This despite the fact that American capitalism became dominant in the world economy during the era when the separation of ownership from control characterized those very corporations that engaged in continuous innovation. The American ideology was, and remains, that the managers (in many cases tens of thousands of them) were but the agents of the owners (as "principles"), and that "hourly workers" were interchangeable units of a commodity called labor.

Consistent with the ideology of the "hourly worker", when owners were fragmented and managers had control, the innovative strategies of most major U.S. corporations entailed massive investments in the capabilities of employees within the managerial structure but did not include investing in the skills of shop-floor workers. Because of a historical legacy of conflict with craft labor over the utilization of new technology, American managers became obsessed with taking skills off the shop floor, vesting them instead in managerial employees and the machines that these managerial employees designed, installed, and repaired [see Lazonick 1990:chs.7-10].

This investment strategy worked in the first half of this century. In industries based on complex technology, the companies that made the innovative investments in organizational capabilities within the managerial structure gained sustained competitive advantage. Particularly in science-based electrical and chemical industries, critical organizational capabilities resided in the corporate laboratories put in place to engage in continuous innovation.

In the 1920s those companies that had emerged as dominant used their sustained competitive advantages to gain the cooperation of nonunionized shop-floor labor by offering them more employment security and higher wages than they could get elsewhere in the economy. During the Great Depression of the 1930s, the gains of the 1920s were used to keep managerial structures, and their capabilities for continuous innovation, intact. In the 1940s and 1950s, sustained competitive advantage was used, as in the 1920s, to gain the cooperation of shop-floor workers, but under the changed conditions of institutionalized collective bargaining with the new mass-production unions.

The American investment strategy began to break down when the Japanese built organizational capabilities not only within the managerial structure but also on the shop floor. In a nation that embarked on a mission of industrialization without a legacy of craft

skills, Japanese companies never had to confront craft unions over the utilization of new technology. In sharp contrast to American investment strategies that were bent on taking skills off the shop floor, a prime focus of the investment strategies of Japanese companies was to develop skills on the shop floor. For this reason, Japanese companies have always invested in the skills of those blue-collar workers who were committed to the paid labor force (that is, males).

To protect these investments in human assets, Japanese companies have extended to those shop-floor employees in whom they have invested permanent membership in the organization on a par with most managerial employees. In the post-World War II period, the rise of enterprise unions made this permanent membership explicit in the form of the widely recognized, even if noncontractual, practice of permanent employment. The other side of the same collective coin is the subordinate position of ownership rights to membership rights in the Japanese corporation [Dore 1993].

The Japanese company is run for its employees, not for its owners, because it is recognized that it is the employees as a collectivity who constitute the unique competitive assets that the company possesses. That these assets include the skills of shop-floor workers has permitted the Japanese to develop and utilize materials and machines in ways that are not compatible with the organizational capabilities of most American companies, even when the capabilities of their managerial structures have remained intact [Lazonick 1990:chs.9-10].

Machines

From the industrial revolution in the Lowell textile mills and the advent of the "American system of manufactures" in the Springfield Armory, Americans pioneered in mass production methods that embodied the strength and skill requirements of production in machines. The innovations in machinery displaced the skills of craft workers on the shop floor. At the same time, the integrated character of these innovations created demands for engineering skills that could be systematically applied in one factory after another and for managerial coordination to ensure high rates of utilization of the investments in expensive machines and highly trained personnel.

The American system of mass production evolved over decades not only within industrial sectors but also through the intersectoral transfer of mass-production technologies [see Hounshell 1984; Thomson 1989]. At every stage, the design of machinery reflected the managerial goal of taking skills off the shop floor. At the same time, ever more formidable organizational capabilities were put in place within the managerial structures of the major corporations to develop new technologies and ensure their utilization.

The Japanese confronted these capabilities head on. In the decades after World War I, they took on the once-dominant British economy in cotton textiles -- an industry in which Britain had continued to dominate global competition before the war [Lazonick and Mass 1993]. In the decades after World War II, they took on the United States, not, as we have already mentioned, in those industries in which the Americans were weakest but, on the contrary, in those industries -- steel, consumer electronics, and automobiles -- in which the United States had reigned supreme. Nor was it a "miracle" that Japan was able to challenge the United States in these industries after World War II. Japan had already

accomplished much the same feat in cotton textiles against the British before World War II, and had, in the process, built up technical capabilities that could be transferred to the higher value-added industries.

What had enabled the Japanese to challenge the British so successfully were their investments from the 1870s in engineering skills that could be embodied in new technologies on the shop floor. And what made the Japanese challenge to the United States so successful was the combination of investments in engineering skills (in which the Americans had invested as well) and complementary shop-floor skills.

Indeed, it is widely recognized that the ability of engineers to interact with shop-floor workers has been key to Japanese success in introducing and making effective use of flexible manufacturing systems in such industries as automobiles and consumer electronics [Hayes 1981; Jaikumar 1986; Cole 1989]. Such organizational integration of technical skills has also been key to the success of the Japanese in rapid product development [Clark and Fujimoto 1991]. In the United States, the failure to invest in the skills of shop-floor workers combined with the deeply entrenched segmentation between management (including engineers) and labor have posed formidable constraints on companies in utilizing advanced machine technologies.

Materials

The emphasis in the development of U.S. manufacturing methods has been on the attainment of high levels of throughput by integrating the strength and skill requirements of the production process into the capabilities of machines. The high-throughput potential of these machines cannot be realized, however, without materials of sufficient durability and flexibility to undergo processing at high speed without breaking. Hence the need for American mass producers to integrate the preparation of key materials into the planned coordination in order to ensure such consistently high quality.

Typically American companies have achieved such integration through in-house producers, leaving it to external suppliers to supply materials that can be produced subject to standard specifications and that do not require further transformation by high-throughput machinery. In the preparation of those materials that are integral to high-throughput methods, however, the lack of skills on the American shop-floor makes it difficult to control for quality, and hence large inventories are required to ensure that enough materials of sufficiently high quality are constantly available to avoid disruptions to the flow of work.

Any such disruptions are particularly serious in the American context, moreover, because shop-floor workers typically have neither the skills nor the prerogative to determine the source of quality problems. Even when materials consistently meet the quality test for high-throughput processing, this absence of shop-floor skills and initiative still often means that materials that are defective for delivering the services of the final product are not detected in the production process, but are built into the final product.

The Japanese have been much more adept than the Americans at materials innovation because of relations with workers and suppliers that integrate their activities into the learning process of the organization. This organizational integration enables the

Japanese to produce materials of more consistent quality, and hence enhances their ability to utilize high-throughput machinery with a minimum of materials wastage. As the Japanese have demonstrated in the implementation of just-in-time inventory systems, processed materials of consistent quality permit higher throughput without constant human interventions and without requiring large buffer inventories of these materials.

The engineering capabilities required to make the Japanese production system work rely on not only the analytical skills of professional engineers but also, as in the case of statistical quality control, the complementary, and organizationally integrated, analytical skills of both workers on the shop floor and suppliers in legally distinct firms. It is the inability to achieve this integration of skills extending down to the shop floor and across legally distinct firms that has constrained American managers to use higher quality (and hence more expensive) raw materials combined with large inventories of processed materials. It is this same lack of organizational integration that has inhibited the diffusion of computer programmable machinery in American industry in sharp contrast with its rapid diffusion in Japanese industry [Lazonick and West 1994].

Especially in the more capital-intensive industries where high throughput is more critical to low unit costs, the American system permitted competitive advantage during the first half of the century, despite the high wages of even unskilled American workers. Among manpower organized within the management structure, the Americans had developed the organizational capabilities to develop and utilize high-throughput machinery. American management then combined these high-throughput machines with abundant supplies of high-quality (but expensive) materials and unskilled immigrants, and then, increasingly, African-American labor.

Over the past few decades, however, the American system has been unable to sustain its competitive advantages of the past. Through indigenous innovation in the combination of manpower, machines, and materials, Japanese management generated a continuous, cumulative, and collective learning process that, as it developed, increasingly challenged the American system in terms of productivity and cost. To be sure, lower wages and interest rates in Japan helped their enterprises to capture markets even before they had achieved the high levels of productivity of the Americans. But, as recent years have shown, the continuous development of productive capabilities in Japan, compared with relatively stagnant productivity growth in the United States, has enabled the Japanese to gain competitive advantage over the Americans even with similar factor prices.

Markets

Well into the twentieth century, the United States used tariff protection to enable its domestic industries to substitute for cheaper foreign products. Throughout the twentieth century, Japan has done the same, although it has supplemented tariff protection with many other trade barriers ranging from restrictions on the size of retail outlets to content requirements to quotas. In the cases of both the United States and Japan, this import substitution strategy permitted enterprises and industries to engage in indigenous innovation, and thereby ultimately replace import substitution with export expansion.

Within the keiretsu structure, Japanese companies typically set up distinct enterprises to service markets in new industries [Fruin 1993]. Given that these new firms maintain

membership in the keiretsu structure, the Japanese can attain the same benefits of the multidivisional structure by sharing certain organizational capabilities -- for example, research or marketing facilities -- across firms.

Where the Japanese differ markedly from the Americans, however, is in pushing economies of scope down to the shop floor. The Japanese system of production, with its integration of engineering and shop-floor skills, has made it possible to use the same plant to manufacture products for a number of different market segments of an industry. Speedy ("single digit" for less than ten minutes) changeovers allow Japanese industrial plants to shift flexibly from one product variety to another. In some industries, such as automobiles, engineers have structured the production process so that, in conjunction with shop-floor skills, many different product varieties can be produced simultaneously on the same machines. American companies, with their traditional segmentation between management and workers, have been unable to generate such shop-floor economies of scope [Best 1990].

IV. Indigenous Innovation in Japanese Cotton Textiles

What are the implications of the analysis of the innovative enterprise in general and the Japanese case in particular for the developing economies? In our view, an enormous intellectual barrier to answering this question is the discipline of development economics itself. Most Western development economists have sought to devise policies for the economic development of the industrially backward economies without an adequate understanding of the historical forces, social and technological, that contributed to the success of the advanced industrial economies.

In historical perspective, the Japanese case reveals the importance of engaging in the process of indigenous innovation early and sustaining the indigenous innovation process over the long run. Indeed, before the Japanese economic "miracle" based on automobiles and consumer electronics in the post-World War II decades, the Japanese economy had undergone another "miracle" based on cotton textiles [Mass and Lazonick 1990; Lazonick and Mass 1993; Mass and Miyajima 1993]. The story of how, from the 1870s, the Japanese developed their cotton textile industry to make it a dominant global competitor by the 1930s reveals much about the institutional, organizational, and technological features of industrialization generated by indigenous innovation, and provides a contrast to the attempts by many developing economies to generate industrialization by means of import substitution.

The Meiji Restoration of 1868 brought into political power in Japan an elite bent on building the industrial capabilities of the economy. A key step in this direction was state investment in mass schooling and higher education. Of particular importance for technological development was the creation of engineering universities that provided the Japanese with the conceptual capability to learn about technological developments around the world.

From the 1870s major Osaka spinning companies employed these engineers, often sending them to study technology abroad, and then using them at home to modify and adjust imported machinery to make effective use of a materials strategy known as "cotton

blending". The engineering challenge was to achieve high levels of productivity while using less expensive cotton that, without engineering, would break more often in the spinning process and thus reduce throughput.

The Japanese strategy in the use of cotton (which could account for 80-90 percent of the value of spun yarn) differed markedly from the materials strategies adopted by spinning firms in Britain and the United States. In Britain, spinning mills bought their cotton from week to week in Liverpool, the site of the world's largest cotton exchange. Although the British often blended cotton of different staples and grades, the choice of blend depended on short-run fluctuations in the relative prices of staples and grades of cotton rather than long-run productivity considerations [Lazonick and Mass 1984]. To adjust to these constantly changing blends, the spinning mills relied on the skills and efforts of craft workers operating traditional spinning machines, rather than university-trained engineers. The cotton-cost cutting strategy of British cotton textile producers generated yarn that was too break-prone to be economical when used on the Draper automatic loom, thus resulting in a virtual neglect of the machine in Britain when it was rapidly diffusing in the United States.

In Japan, by contrast, the choice of cotton blend by a spinning mill reflected the enterprise's long-term technology strategy. Japanese mills typically purchased quantities of Indian and American cotton of consistent staple and grade to last at least six months, and rarely changed the cotton blend. Knowledgeable foreign visitors to Japanese spinning companies took note of the cotton-blending strategy and remarked that each mill had a specialized blending formula that it kept a well-guarded secret.

As in Japan, spinning mills in the United States sought to achieve high levels of productivity by holding large stocks of cotton of consistent staple and grade to be used on advanced technology to increase the rate of throughput in the production process. Unlike the Japanese, however, the Americans favored the use of unblended, high quality (and hence expensive) cotton. By minimizing yarn breakages in the spinning and weaving processes, the high-quality, unblended cotton substituted for expensive engineering and operative labor. Given the high cost of labor in the United States, the American strategy was one that embodied technological capabilities in the cotton input while minimizing the need for the employment of skilled labor on the shop floor. In contrast, the Japanese strategy substituted highly trained engineering labor for higher quality cotton.

The choice of materials strategy, therefore, generated a need for indigenous learning. This need was filled in Japan by the university-trained engineers in whom the major spinning companies invested to transform them into a textile technologists. A major element of the investment in these personnel was a six- to twelve-month stint studying technology abroad [see Hunter 1991].

But the developmental impact of the Japanese cotton-blending strategy went even further. In the 1890s the Americans generated a breakthrough weaving technology -- the Draper automatic loom -- that was designed for use with longer staple unblended American cotton [Mass 1989a and Mass 1989b]. Rather than adopt a machine technology that was unsuited to their production methods, the Japanese sought to develop their own automatic loom that could get high productivity using blended cotton [Mass and Miyajima 1992].

The automatic mechanism on the Draper loom changed the bobbin of weft yarn in the loom's shuttle, whereas the mechanism on the Toyoda automatic loom changed the whole weft shuttle with a fresh bobbin of yarn inside. Those who think that a machine is a machine might count the Toyoda automatic loom, diffusing rapidly as it did some three decades after the Draper automatic loom, not as an indigenous innovation, but at best a borrowed imitation. Such thinking is wrong. It took the founders of the Toyoda Automatic Loom works, Sakichi Toyoda and his son Kiichiro (a graduate of the Tokyo University Engineering School), over two decades of persistent experimentation to develop their version of the automatic loom. When the perfected Toyoda automatic loom became available, moreover, it was a phenomenal success. Why would such effort have been put into, and such results have been generated by, a machine that was simply an imitation of the thirty-year-old American innovation?

The Toyoda automatic loom was not a borrowed imitation. The Toyoda automatic loom was an indigenous innovation because it fit the investment strategies and organizational structures of Japanese cotton textile manufacturers in ways that the Draper automatic loom could not. The need for indigenous innovation in automatic weaving derived not only from the high price that the Draper Company exacted for its looms, but more fundamentally from the strategy of the major Japanese spinning mills of blending short-staple (and hence less expensive) Indian cotton with long-staple (and hence more expensive) American cotton in the spinning of yarn.

Why were Sakichi and Kiichiro Toyoda able to respond to this challenge? Given that the development of an automatic loom suitable for Japanese manufacturing conditions took over two decades, the Toyodas were obviously dedicated and persistent. But they had more going for them than perseverance. The financial resources and skills that Sakichi and Kiichiro Toyoda brought to their automatic loom enterprise came from previous, less complex, efforts at indigenous innovation in which Sakichi had been successful.

In the 1890s Toyoda was among the pioneers in the development of an inexpensive but productive wooden power loom that small weaving firms, producing for the home market, could use instead of either the low-productivity hand loom or the expensive power loom imported mainly from the British company, Platt Brothers. The Toyoda power looms diffused quickly to the decentralized weaving sector that was producing cotton cloth for the Japanese market. Sakichi Toyoda also produced iron power looms for the export-oriented "spinning" companies, and these machines too diffused quickly as these companies either integrated forward or replaced existing Platt Brothers power looms. Following disputes over continuing support for costly R&D, Sakichi left the loom manufacturing company that still bore the Toyoda name. He established textile manufacturing enterprises whose profits continued to be devoted to loom technology development.

In contrast to weaving machinery, in spinning machinery there was little import substitution in Japan until the 1930s, even though some companies, including Toyoda, attempted to develop an indigenous line of spinning machines. In continuing to import British textile machinery, however, the Japanese relied to an extraordinary degree on just one company, Platt Brothers. The relation between Platt Brothers and the major Japanese spinning companies was not an arm's-length market relation but an ongoing collaboration in engineering the type of textile machinery that the Japanese cotton spinning companies

required. In contrast, textile mills in other Asian and Latin American nations acquired machinery "off-the-shelf" from a variety of foreign companies, with price and current productivity performance rather than the potential for technological development and cost reductions as the main purchasing criteria.

The Toyoda automatic loom increased labor productivity in Japanese weaving operations by anywhere from 3 to 19 times depending on the cloth being woven and the machines previously used. The diffusion of the innovation was rapid: 17,000 machines installed by 1931 and 40,000 by 1936. Taking the lead in adopting the new technology were the major "spinning" companies that dominated the Japanese cotton textile industry and that had integrated spinning and weaving operations since the late nineteenth century. In addition, however, by the late 1930s some 30 percent of the industry's automatic looms were in specialized weaving mills that purchased their yarn from the integrated "spinning" companies and that sold their cloth for export through the powerful trading companies. In the export boom of the 1930s, the trading companies, large-scale spinning companies, machinery makers, trade associations, and federal and local governments all played roles in encouraging and enabling small-scale weaving firms to make investments in state-of-the-art technologies. Such integrated investment strategies across vertically specialized firms remained characteristic of the Japanese cotton textile industry during the post-World War II decades, and enabled the industry to remain competitive against low-wage Asian producers into the 1980s [Dore 1986].

The introduction of the Toyoda automatic loom was a critical factor -- although not the only factor -- in Japan's rise to international dominance of world cloth exports in the interwar period. In the China market, for example, Britain, Japan's main competitor, had supplied 53 percent of cotton cloth imports in 1913 compared with 20 percent for Japan. In 1921, each nation had a 43 percent share. In 1925, however, the British share fell to 24 percent while Japan's share climbed to 66 percent. In 1930, Britain's share was 13 percent and Japan's share was 72 percent. A shift in market shares, just as dramatic, occurred in India as well. Between 1914 and 1932, while Britain's share of Indian cloth imports declined from 97 percent to 50 percent, Japan's share rose from 0.1 percent to 45 percent.

But it was not just the Japanese cotton textile industry that benefited from indigenous innovation in textile machinery. By 1938 Japan had not only substituted its own weaving machinery for British imports at home but had also become (after Britain) the second largest exporter of textile machinery by volume in the world and (after Britain and Germany) the third largest by value. In addition, indigenous innovation in textile machinery provided Japanese industry with many of the capabilities needed to move into more complex technologies such as automobiles.

In one case the transition from textile machinery to automobiles was remarkably direct. In the 1930s the Toyoda Automatic Loom Company gave birth to the Toyota Motor Company, with the first Toyota car being produced at the automatic loom works. An automatic loom has over three thousand parts that have to be unified into one smoothly running machine, so prolonged experience in building these looms was invaluable for producing cars. For example, the assembly line for Toyoda automatic looms was the first in Japan to use a conveyor belt system as a test bed for automobile manufacturing. Continuity in finance was also important to continuity in innovation: the actual funds that

Toyoda allocated to its venture into automobiles came from the licensing of the Toyoda automatic loom to Platt Brothers, the company from which, going back to the emergence of the Japanese cotton textile industry in the late nineteenth century, the Japanese had purchased virtually all of their imported machines.

V. Indigenous Innovation and the Developing Economies

The Toyoda-Toyota story, which is the subject of an ongoing collaborative research project [Lazonick, Wada, Mass, and Miyajima 1993] is not an isolated instance of indigenous innovation in Japan. A recent book by Takeshi Hayashi [1990] summarizes the results of a major United Nations University project on technology transfer to Japan that included a number of historical studies of indigenous innovation in industries such as mining, rail transportation, iron and steel, and textiles in the late-nineteenth and early-twentieth centuries. Hiroyuki Odagiri and Akira Goto [1993] provide a century-long overview of "the Japanese system of innovation", with numerous examples of indigenous technological development. Yukiko Fukasaku [1992] has done an in-depth study of indigenous innovation, especially in engines and welding, at the Mitsubishi Nagasaki shipbuilding company from the 1880s to the 1930s. The detailed research by Michael Cusumano [1985] on Toyota and Nissan also shows how the Japanese used their organizational capabilities to transform borrowed technology. Leonard Lynn [1982] has offered his extremely well-researched case study of the Japanese adoption of the basic oxygen furnace as an example of (in Lynn's words) "a unique social capacity to adopt and improve foreign technology explains much of Japan's economic success." Richard Samuels [1994] has shown how "indigenization" was integral to the Japanese strategy linking economic development and national security.

More generally, in a recent article on technological accumulation and economic growth, Martin Bell and Keith Pavitt [1993] have highlighted the "misleading distinction between 'innovation' and 'diffusion'". They argue that "diffusion involves more than the acquisition of machinery or product designs, and the assimilation of related operating know how. It also involves continuing, often incremental, technical change by which the original innovations are (i) moulded to fit particular conditions of use in a widening range of specific situations, and (ii) further improved to attain performance standards beyond those originally achieved." What we have called indigenous innovation fits both these criteria.

As illustrated by the case of Japanese cotton textiles, a continuous, cumulative, and collective learning process that generates vertical and even intersectoral linkages characterizes industrialization based on indigenous innovation. Such dynamic learning processes and industrial linkages are absent from industrialization based simply on import substitution -- that is, technological diffusion without technological innovation. As Albert Hirschman [1971:93-94] put it several decades ago, import-substituting industrialization "brings in complex technology, but without the sustained technological experimentation and concomitant training in innovation which are characteristics of the pioneer industrial countries."

For the developing economies, the case of Japan shows that when import substitution is combined with a dynamic learning process, export expansion and sustained economic growth can be the results. Certainly, the case of Japanese textiles puts to rest the notion

that the way for a less developed economy to compete is through cheap wages. The challenge of economic development is to transform low wages into high wages through indigenous innovation. The productivity growth that results from the innovation process permits the innovating enterprises, regions, and economies to outcompete lower wage rivals while paying their workers higher and higher wages.

An understanding of indigenous innovation makes it clear that notions of technological and economic convergence through the international transfer of technology underestimate the problems of utilizing borrowed technology [for the convergence debate see Baumol, Nelson, and Wolff 1994]. Technology that is merely borrowed tends to be technology that cannot be utilized because the borrowers do not have in place the necessary organizational and institutional structures that can transform machines into productivity [see Lazonick and O'Sullivan 1995b]. Conversely, an economy that has put in place the organizations and institutions that permit a dynamic learning process to occur will, by virtue of the presence of those organizations and institutions, have the ability to develop and utilize the technologies that it has borrowed. It will, that is, have the social capability to engage in indigenous innovation.

The problem that confronts developing economies, therefore, is how to transform import substitution into indigenous innovation. The policy implications of the need to make this transformation are immense, and demand intelligent debate. The future progress of such debate requires a theory of economic development that is rooted in the innovative enterprise and organizational learning that has characterized the industrialization experiences of the most successful economies. Only then -- when those concerned with development policy have grasped the continuous, cumulative , and collective character of successful economic development -- can academics and policy makers begin to contemplate why continuous, cumulative, and collective development has for so long eluded so many nations of the world.

William Lazonick is University Professor and William Mass is Interim Dean of Graduate Programs at the College of Management, University of Massachusetts Lowell. Both are also co-directors of the UMass Lowell Center for Industrial Competitiveness.

The authors would like to thank anonymous reviewers from the Association of Japanese Business Studies for helpful suggestions.

REFERENCES:

Baumol, William J., Richard R. Nelson, and Edward N. Wolff, eds., Convergence of Productivity: Cross National Studies and Historical Evidence, Oxford University Press, 1994.

Bell, Martin, and Keith Pavitt, "Technological Accumulation and Industrial Growth: Contrasts Between Developed and Developing Countries," Industrial and Corporate Change, 2, 1993:157-210.

Best, Michael, The New Competition: Institutions of Industrial Restructuring, Harvard University Press, 1990.

Clark, Kim, and Takahiro Fujimoto, Product Development Performance, Harvard Business School Press, 1991.

Cole, Robert E., Strategies for Learning: Small-Group Activities in American, Japanese, and Swedish Industry, University of California Press, 1989.

Cusumano, Michael, The Japanese Automobile Industry, Harvard University Press, 1985

Dore, Ronald, Flexible Rigidities: Industrial Policy and Structural Adjustment in the Japanese Economy, 1970-1980, Stanford University Press, 1986.

Dore, Ronald, "What Makes the Japanese Different?" in Colin Crouch and David Marquand, eds., Ethics and Markets: Co-operation and Competition within Capitalist Economies, Blackwell, 1993.

Fruin, Mark, The Japanese Enterprise System, Oxford University Press, 1992.

Fukasaku, Yukiko, Technology and Industrial Development in Pre-War Japan: Mitsubishi Nagasaki Shipyard, 1884-1934, Routledge, 1992.

Galbraith, John Kenneth, The New Industrial State, Houghton Mifflin, 1967

Gerlach, Michael, Alliance Capitalism: The Social Organization of Japanese Business, University of California Press, 1992.

Hayashi, Takeshi, The Japanese Experience in Technology: From Transfer to Self-Reliance, United Nations University Press, 1990.

Hayes, Robert H., "Why Japanese Factories Work," Harvard Business Review, July-August 1981:

Hirschman, Albert O., A Bias for Hope: Essays on Development and Latin America, Yale University Press, 1971.

Hounshell, David, From the American System to Mass Production, 1800-1932, Johns Hopkins University Press, 1984

Hunter, Janet, "British Training for Japanese Engineers: The Case of Kikuchi Kyozo," in H. Cortazzi and G. Daniels, eds., Britain & Japan, 1859-1991, Routledge, 1991.

Jaikumar, Ramchandran, "Postindustrial Manufacturing," Harvard Business Review, November-December 1986.

Lazonick, William, "Strategy, Structure, and Management Development in the United States and Britain," in Kesaji Kobayashi and Hidemasa Morikawa, eds., Development of Managerial Enterprise, University of Tokyo Press, 1986.

Lazonick, William, Competitive Advantage on the Shop Floor, Harvard University Press, 1990.

Lazonick, William, Business Organization and the Myth of the Market Economy, Cambridge University Press, 1991.

Lazonick, William, "Controlling the Market for Corporate Control: the Historical Significance of Managerial Capitalism," Industrial and Corporate Change, 1, 1992.

Lazonick, William, "Learning and the Dynamics of International Competitive Advantage," in Ross Thomson, ed., Learning and Technological Change, Macmillan, 1993.

Lazonick, William, "Creating and Extracting Value: Corporate Investment Behavior and American Economic Performance," in Michael Bernstein and David Adler, eds., Understanding American Economic Decline, Cambridge University Press, 1994.

Lazonick, William, and William Mass, "The Performance of the British Cotton Industry, 1870-1913," Research in Economic History, 9, 1984.

Lazonick, William, and William Mass, "Indigenous Innovation and Economic Development: Is Japan a Special Case?" photocopy, Center for Industrial Competitiveness, University of Massachusetts Lowell, 1993.

Lazonick, William, and William Mass, eds., Organizational Capability and Competitive Advantage, Elgar, 1995.

Lazonick, William, and Mary O'Sullivan, "Financial Commitment and Economic Development," Center for Industrial Competitiveness, University of Massachusetts Lowell, photocopy, January 1995a.

Lazonick, William, and Mary O'Sullivan, "Organization, Finance, and International Competition," Industrial and Corporate Change, 1995b, forthcoming.

Lazonick, William, Kazuo Wada, William Mass, and Hideaki Miyajima, "Indigenous Innovation and Industrialization: Organizational Learning in Cross-National Perspective," research proposal submitted to the Joint Social Science Research Council and Japan Society for the Promotion of Science Collaborative Research Program, April 1993.

Lazonick, William, and Jonathan West, "Organizational Integration and Competitive Advantage: Explaining Strategy and Performance in American Industry," Industrial and Corporate Change, 4, 1, 1995, forthcoming.

Lynn, Leonard, How Japan Innovates, Westwood, 1982.

Mass, William, "Mechanical and Organizational Innovation: The Case of the Draper Loom," Business History Review, 63, Winter 1989a.

Mass, William, "Developing and Utilizing Technological Leadership: Industrial Research, Vertical Integration, and Business Strategy at the Draper Company, 1816-1930," Business and Economic History, second series, 18, 1989b.

Mass, William, and William Lazonick, "The British Cotton Industry and International Competitive Advantage: The State of the Debates," Business History, 32, October 1990.

Mass, William, and Hideaki Miyajima, "Technology Transfer and the First Japanese 'Economic Miracle': The Roots of Toyota," paper presented to the Business History Seminar, Harvard Business School, December 14, 1992.

Mass, William, and Hideaki Miyajima, "Technology Transfer, Diffusion, and Development: Fostering Private Capabilities and the Roots of the Japanese 'Economic Miracle,'" Business and Economic History, second series, 22, 1993.

Miyajima, Hideaki, "The Transformation of Zaibatsu to Postwar Corporate Groups -- From Hierarchically Integrated Groups to Horizontally Integrated Groups", Journal of the Japanese and International Economies, 8, 1994.

Morikawa. Hidemasa, Zaibatsu, University of Tokyo Press, 1992.

Odagiri, Hiroyuki, and Akira Goto, "The Japanese System of Innovation: Past, Present, and Future," in Richard R. Nelson, ed., National Innovation Systems: A Comparative Analysis, Oxford University Press, 1993.

Samuels, Richard J., "Rich Nation, Strong Army": National Security and the Technological Transformation of Japan, Cornell University Press, 1994.

Thomson, Ross, The Path to Mechanized Shoe Production in the United States, University of North Carolina Press, 1989.