THE 1996 NEWCOMEN PRIZE ESSAY

From Textiles to Automobiles: Mechanical and Organizational Innovation in the Toyoda Enterprises, 1895-1933

William Mass[1]
Center for Industrial Competitiveness
University of Massachusetts, Lowell

Andrew Robertson
Harvard University

The story of Sakichi Toyoda (1867-1930), the great industrial entrepreneur and national hero, is taught to every Japanese school child. Foreign tourists are told he was the Japanese Thomas Edison. As recently as 1985, the patent office listed Sakichi Toyoda as one of the ten most important inventors in Japanese history. The textile machinery company that he founded eventually gave birth to the Toyota Motor Corporation. Before the Japanese stock market bubble burst, the Toyota Motor Corporation committed 150 billion yen (roughly $150 million) for the recently completed Toyota Industrial Museum, a remarkably well-done pæan to a vision of social progress as technological progress. What is lacking is a sense of the critical and essential role of social organization, without which the determinants and consequences of technological development will be misunderstood. This paper explores both the organizational and the technological aspects of early Toyoda entrepreneurial history for insights into the foundations of Toyota's postwar performance and potential implications for economic development more generally.

[1] The authors would like to thank Qiwen Lu and Damian Kieran for their excellent research assistance. In addition, we would like to thank our colleagues Takeshi Abe, Eisuke Daito, Kazuo Wada, and particularly Hideaki Miyajima for helpful discussions and for their assistance in securing Japanese-language materials. All of them are exempt from any responsibility for our errors of omission and commission. The international collaboration that has supported this research has been funded by the Social Science Research Council and the National Science Foundation. Some of the research was conducted while William Mass was a Harvard Newcomen Fellow, and parts of this paper were presented to the Harvard Business History Seminar in a paper co-authored with Hideaki Miyajima. An earlier version of this paper was presented at the "Symposium on Industrial Development and International Competition" at the Suntory and Toyota International Centres for Economics and Related Disciplines, London School of Economics and Political Science, January 4-5, 1996. Finally, we want our readers to be aware that in this draft we have followed Western convention in placing Japanese surnames last in the text, but first in listing bibliographic references.

BUSINESS AND ECONOMIC HISTORY, Volume Twenty-five, no. 2, Winter 1996.
 ISSN 0849-6825.

In *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century*, Tessa Morris-Suzuki cited the surprising claim of a leading interwar Japanese technologist, the director of the pioneering RIKEN Institute Masatoshi Okochi that "Japanese researchers were skilled and original inventors, but that Japan's weakness lay in an inability to commercialize radically new ideas" [pp. 116-7]. Okochi's concern was that Japanese firms would more readily choose to refine imported technologies where a market was already developed, rather than to bear the greater uncertainty, associated risk, and heavy developmental costs of taking a more radical innovation from laboratory bench to full-scale production. Morris-Suzuki points to the exception that proves the rule, by discussing "the classic example of Japanese innovation": the Toyoda Loom Works established by Sakichi Toyoda in 1906, and his son Kiichiro, who, drawing on his university training, put in place systematic and costly large-scale research and extensive prototype and mill testing to refine his father's inventions.

In a recent paper on "The Learning Process and the Market: The Japanese Capital Goods Sector in the Early Twentieth Century," Tetsuro Nakaoka utilized the concept of appropriate technology to describe the possibilities early in the industrialization process for indigenously developed technological leaps. For instance, domestic capital goods producers can serve niche capital goods markets that supply machinery to local manufacturers producing traditional products. These sectors are poorly served by expensive and (for their purposes) inappropriately designed and specified capital goods produced in developed economies. The indigenous innovations reinforce and accelerate development, simultaneously altering previously existing conditions and opening new opportunities for "quantum leaps in technology" for indigenous capital goods producers.

Nakaoka notes, "One typical example of a manufacturer who made this leap successfully is the Toyoda Loom Works" [Nakaoka, 1994, p. 13]. Nakaoka cites three "quantum leaps" initiated by Sakichi in narrow loom, iron broad loom, and automatic loom invention, the latter refined by Kiichiro. Given the ongoing changes in economic conditions that accompany successful development, Nakaoka stressed the need for recurring or continuous technological leaps to sustain the development process. Each successive technological leap required upgraded and more expensive equipment and engineering know-how. Nakaoka identified insufficient capital resources as the most general impediment and barrier to sustained development. Deciding where and how best to deploy financial resources aimed at "quantum leaps" in technology requires deep knowledge of the adequacy of the platform from which one attempts to leap, the resources needed to help bridge the gap, and a strategy for their effective mobilization.

This paper describes how the Toyoda enterprises achieved international competitiveness in textile machinery production. It elaborates on and supplements the assessments of Morris-Suzuki and Nakaoka by addressing questions about the relation between Sakichi and Kiichiro's mechanical innovations and

the technology readily available from foreign machinery suppliers; the extent and character of indigenous Japanese innovations in textile technology; the relationship of strategic choices and innovations in both technology and organization; and the rise of Japanese industrial leadership as reflected in the negotiations over technology transfer and a proposed merger between Platt Bros. and two Toyoda enterprises. Collaborative research reported elsewhere addresses related questions about the role of industrial organization and national institutions in altering the strategic options available for Japanese textile and textile machinery enterprises [Lazonick and Mass, 1984, 1995; Mass and Lazonick, 1990; Mass and Miyajima, 1993].

The insights of Morris-Suzuki and Nakaoka highlight the unevenness and discontinuity of organizational development and technological achievment in the process of economic development. The most important and fundamental feature of Japan's interwar growth was the character of and relationship between development in both 1) export sectors, primarily light industries and especially cotton textiles, and 2) import substitution in heavy industries. As a case study, this paper strives to build an understanding of the uneven evolution of organizations and the "leaps" toward international technological competitiveness in cotton textile machinery, the key to long-term cotton textile export success, as part of a continuous and cumulative developmental process. We aim to present an integrated view of elements of continuity and discontinuity in the dynamics of Japanese technology transfer and development and in particular to illuminate the following phenomena:

- **Finance and Markets** – The critical access to finance and markets provided by Toyoda's sustained relationship with the leading general trading company Mitsui Bussan, and with individual Mitsui managers, was periodically strained as entrepreneurial initiatives required an independent development path.
- **Long-Term Relations to Key Technologists and Technicians** – There was a remarkable, and generally unknown (at least in the West), rivalry between the first and second enterprises established by Sakichi Toyoda (Toyoda Loom Works and the Toyoda Automatic Loom Works), wherein he sustained relationships of mutual support with key technologists from the company he formerly managed.
- **Product Development and Manufacturing** – Toyoda played a leading role in pioneering the introduction of the American system of interchangeable parts into Japanese manufacturing, essential to the commercial success of mechanical innovations.
- **Invention and Organized Industrial Research** – Organized industrial research played an early and leading role at Toyoda (and we reassess the character and relative importance of the accomplishments of Kiichiro relative to his father Sakichi). The central technical innovations, embodied in the Toyoda automatic loom, resulted in successful pioneering commercialization of automatic weaving machinery in competition with both imported technology and indigenous rivals because they were

appropriately designed to suit Japanese textile and machining capabilities, and they integrated design with the development of superior Toyoda manufacturing capabilities.

- **Social Organization and Individual Enterprise Development** – The breadth and depth of the Japanese efforts to develop indigenous textile technology prompted widespread competition and simultaneously promoted the development of human and technical resources that rivals sought to mobilize for their own purposes. At the same time Toyoda enterprises' strategy and structure led to their relative domination of their rivals.
- **Technology Transfer from Japan to Britain** – We describe the nature and sources of tension between Platt Bros. and the Toyoda Loom Works that reflected the factors undermining Platt Bros.' efforts to manufacture and sell automatic weaving technology developed and licensed from Toyoda.
- **The Rise of New Industrial Leaders** – Finally, the unexpected and ultimately failed initiatives by Mitsui Bussan to merge Platt Bros. with the Toyoda Loom Works and the Toyoda Automatic Loom Works reflected the changing relationships and their perception among all four parties as the Japanese industrial firms attained international competitiveness.
- **Technology Transfer across Industries** – The deep and long-lived roots of Toyoda's corporate culture supported its success in transferring existing capabilities into and building new capabilities for the emerging automobile industry, even in the face of promising returns to continued investment in areas of current strength.

An Introduction to the Early History of Toyoda Textile Enterprises

In 1885, Sakichi Toyoda participated in an evening study group where he learned of the newly enacted Patent Law and was said to have set his goal on invention as an avenue to contribute to national development. Having grown up in a traditional textile manufacturing region, Sakichi began his efforts at developing superior hand looms in 1887. Sakichi attended the Third National Industrial Exhibition in Tokyo in 1890 and visited the machinery pavilion every day for two weeks. During the following year he patented his first wooden hand loom invention. Sakichi's technical advance involved linking the flying shuttle to the movement of the reed when beating down the weft. This first invention allowed a productivity increase of 50 percent compared with other indigenous looms in use. But the wooden hand loom was not a commercial success; at about the same time a flying-shuttle attachment, called a "battan," was introduced from France which could be attached at much lower cost than a Toyoda hand loom and offered comparable efficiency [Kobayashi, 1995, p. 16].

Sakichi built four or five of his patented looms in a small weaving factory that he established in the Tokyo area. His endeavor coincided with a period of slack trade, however, and Sakichi had returned to his village by the end of 1893. As a means to generate the revenue necessary to finance

continued loom experimentation, Sakichi invented a yarn-reeling machine, a device for winding yarn. His reeler produced constant lengths of yarn twice as efficiently as conventional devices. He relocated the weaving factory and retail outlet, Toyoda Shoten, to Nagoya and opened the **Ito Retail Store** as a sales outlet for the reeler in 1895. Sakichi's second wife and his younger brother Heikichi managed the store and reeler sales [Toyoda, 1967, p. 28; hereafter when only page numbers are given in brackets, the source is Toyoda, 1967].

Sakichi invented his first successful narrow wooden power loom in 1896 and garnered much industry attention. Along with a reeling machine customer, Tohachi Ishikawa, Sakichi established the **Otokawa Weaving Company** as a partnership. Sakichi's capital contribution consisted of 60 Toyoda wooden power looms. By 1898 a weaver could operate two or three Toyoda steam-powered looms instead of a single conventional loom. Productivity in the modernized mill increased four-fold, cloth quality improved, and costs fell by over 50 percent. In order to advance his loom experimentation, Sakichi also established an independent pilot plant in Nagoya running 36 power looms as a basis for gaining manufacturing experience [p. 32].

In 1899 Kamenosuke Fugino, the Mitsui Bussan main branch manager for the Division of Cotton Yarn and Cloth, inspected the operating Toyoda power looms and evaluated the prospects for their mass production. Mitsui negotiated an exclusive ten-year contract with Sakichi for producing and selling power looms. The **Igeta Trading Company** was set up as the sales agent; its top managers came from the Nagoya branch of Mitsui Bussan, and Sakichi Toyoda became the chief engineer responsible for improving the power loom [pp. 34-40].

This first Toyoda power loom found initial sales success with small manufacturers weaving narrow cloth for such export markets as Korea, Manchuria, and Taiwan. Toyoda's looms were easier to maintain and much less expensive than those of the primary foreign competitors [p. 47; Toyota, 1988, p. 28]:

Table 1: Prices of Narrow Power Looms, 1899

Loom Manufacturer	Loom Price (in yen)
Hartmann, German	872
Diedrichs, French	389
Toyoda	93

The most important achievement of Sakichi's continued development efforts was a patented let-off device that maintained the warp at a constant tension as it was being fed off the warp beam. In addition, and for the first time, he turned his attention to the development of a loom that would automatically replenish the weft yarn when the yarn on a bobbin was exhausted. Again facing partners concerned about business solvency during cyclical downturns, Sakichi resigned from the Igeta Trading Company, disappointed by the lack of financial support for his continued loom development. Sakichi returned to the Toyoda Shoten and renamed it **Toyoda**

Trading Company (Toyoda Shokai) which absorbed the former Ito Trading Company. He opened an independent cloth mill running 138 power looms. His wife and his younger brother Sasuke managed the Toyoda Trading Company and the mill, so that Sakichi could once again turn to his loom experiments [p. 40; Toyota 1988, pp. 28-29].

Sakichi next invented an automatic shuttle-changing device that was attached to narrow power looms in 1903. Although the initial effort was not successful, Mitsui Bussan was interested in financing the establishment of the **Nagoya Weaving Company**, with 150 looms equipped with Sakichi's automatic attachments for further experimentation. Lacking the capacity for loom manufacturing, Sakichi contracted with Kimoto Iron Works, a firm with experience in manufacturing textile machine parts [Suzuki, 1994, p. 155].

Kanegafuchi Cotton Spinning Company (a forerunner of Kanebo, Ltd., one of the three dominant integrated spinning and weaving firms) was interested in developing Sakichi's automatic loom for the manufacture of broadcloth for export. Although still at an early stage of loom development, Sakichi agreed to allow the company to utilize his patented devices because Kanegafuchi promised to license and manufacture Sakichi's loom if it proved successful. Kanegafuchi re-equipped its power looms with automatic shuttle-changing mechanisms designed by Sakichi. The underlying business relationship was probably with Mitsui Bussan, which would normally have been responsible for marketing and selling the automatic looms. However, Mitsui was restricted in its public actions because of its role as the exclusive representative of Platt Bros. in Japan. (The pressures leading to change in the Mitsui-Platt relationship will be discussed in a later section.)

Kanegafuchi set up a mill experiment to compare the performance of 50 Toyoda Trading Company looms with 44 Platt Bros. power looms, ten U.S. Draper bobbin-changing automatic looms, and six Kip Baker looms (English looms with warp-stop motions). After a one-year trial, all the automatic looms proved to be unsatisfactory in operation, whereas the Platt Bros. power looms were a success. Sakichi and the Toyoda Trading Company suffered financial losses in providing material support for this experiment. Sakichi drew two lessons from this experience: First, he became fully cognizant of the extent of foreign competition he confronted as he vied to introduce an automatic loom into the Japanese market. Second, from then on, Sakichi supervised testing under mill conditions when developing all his mechanical innovations [pp. 41-43; Toyota, 1988, pp. 29-30; Suzuki, 1994, p. 155].

In reviewing the experience of producing cloth with Toyoda's narrow automatic looms, the head of Mitsui Bussan's Nagoya branch office Okano Teiji recounted the problems resulting from the poor quality of loom manufacturing and the complexity of the loom's mechanisms: "Because the techniques used in this machine's manufacture are not advanced, it does not operate as it should...(I)t is not a simple machine, it gives the workers many problems. Moreover, it requires a long time to gain the skill necessary to use it" [Suzuki, 1994: p. 156].

Recognizing the lengthy development period necessary to construct a competitive automatic loom, Sakichi turned his attention to raising the investment funds required for continued automatic loom experimentation. He renewed his focus on the development, manufacture, and sale of the power loom. By 1905 he had invented a higher performance iron and wood narrow loom, the Model 38 power loom (named for the 38th year of the Meiji period). In addition to its greater durability, at 85 yen the iron 38 loom was twice as expensive as the earlier all-wood frame model. A weaver could operate six or seven Model 38 looms compared to only two or three of the earlier models [Suzuki, 1994, p. 157].

The following year two new loom models were marketed: the Model 39 power loom, used for weaving coarse yarn, and a Model L, "simplified" light loom (kei-ban) for narrow, thin-weave cotton and jute fabrics. With the assistance of Mitsui Bussan's Osaka branch manager Kamenosuke Fugino, Sakichi secured a loan of 130,000 yen from Mitsui Bussan to finance expansion. In 1906 in an area within Nagoya, Sakichi established the **Shimazaki Factory**, consisting of both a weaving-machine factory with a production capacity of 150 power looms per month, and a pilot cloth factory. The sales record summarized below confirms the looms' commercial success as the Shimazaki Factory was operating near capacity [47-48; Toyota, 1988, p. 28].

Table 2: Sales Summary 1905–March, 1909

Loom Model	Sales
38	947
39	2,307
L (kei-ban)	4,201

Concerned about sustaining Toyoda Trading Company's strong financial foundation into the future, Sakichi began recruiting technically able employees. In 1903 he hired two engineering university graduates (Kogakshi), two graduates from a post-secondary technical education program (Kotokogyo), and seven or eight technical high school graduates [49]. Sakichi's recruitment of such highly educated employees was very exceptional among small proprietorships.

The success of Toyoda's power loom was evident as early as 1906, when Fugino visited Sakichi and his production facility and recommended that Toyoda convert to a joint-stock company. Sakichi, reportedly resistant at first to sharing control, but aware of the importance of his relationship to his creditors, agreed to incorporation to secure large-scale financing and cooperated in establishing the **Toyoda Loom Works** (Toyoda-shiki Shokki Kabushiki Kaisha). The president of the Toyoda Loom Works was Fusazo Taneguchi, who was also the president of the giant spinning firm the Osaka Spinning Company. Sakichi was the operating manager of the Toyoda Loom Works. Seishu Iwashita, an important arranger in the business world, was among the other top managers, and additional consultants included the renowned Takeo Yamanobe (most closely linked with the Osaka Spinning

Company) and Fugino of Mitsui Bussan. The Toyoda Trading Company ceased operation [pp. 50-51].

The capital investments in the Toyoda Loom Works were made by financial leaders in Tokyo, Osaka, and Nagoya [Izumi, 1980, p. 18]. Though Sakichi and Hachirojiro Mitsui, the president of Mitsui Bussan, were the largest shareholders with 5 percent each, there were 143 additional shareholders. Sakichi's managerial control was considerably diluted [Yamazaki, 1987, p. 47].

Toyoda sold more power looms than any of its domestic rivals, and the Toyoda Loom Works soon became dominant in the narrow-cloth power loom market segment, servicing small and medium-sized cloth mills selling to the domestic market. Its leading position emerged with its pioneering improvements in manufacturing methods, and the Toyoda Loom Works quickly turned to the challenge of broad loom production and the direct challenge of the dominant foreign loom suppliers.

Sakichi turned to the task of developing a wide loom suited for integrated mills producing broad cloth for export markets. He developed the H-model, an all-iron wide power loom in 1908. Sakichi realized the H-model loom had to be made of metal to be able to withstand the increased vibration resulting from the greater loom width. All previous attempts at manufacturing a workable wide power loom had failed, mainly because Japanese machining capabilities were inadequate for producing sufficiently accurate component parts [p. 52].

The Introduction of the American System and the Origins of Advanced Manufacturing in Japan

At the first general meeting of the Toyoda Loom Works in 1907, president Taniguchi explained:

> It is most regrettable that at the present time we still do not have sufficient equipment to completely manufacture this loom...The iron frame narrow looms installed at Nagoya Cloth were provided by Toyoda but were manufactured at the Osaka Kimoto Iron Works as our Shimazaki Factory is incomplete. The poor results stem from a failure in the manufacture of the loom. As a result of these failures and accidents, the Toyoda Loom and its associated patented equipment reached a stage in which it is unwanted. Not only Nagoya Cloth Company but at other companies using Toyoda's iron frame loom, the results are uniformly bad.

The problems at Kimoto Iron Works were not uncommon among manufacturers of iron power looms in other countries as well as in machine manufacturing elsewhere in Japan. The Kimoto Iron Works was not engaged in the manufacture of interchangeable parts. Almost no two machines used in the manufacturing process were alike. In large-scale operations looms inevitably broke down. Without interchangeability, each broken part required a new piece to be specially made [Suzuki, 1994, p. 161].

Sakichi's search for solutions and improvements led him to hire Charles A. Francis, an American teacher of mechanical engineering at the Tokyo Higher Technical School who had also been employed as an engineer for the Pratt and Whitney Company. From 1905 to 1907, Francis had provided guidance at a Japanese leading machine tool company, Igekai Ironworks, where he "trained workers in the basic techniques of machine manufacture," including "the use of indicators and gauges, the cutting of high precision gears and screws, and the adjustment of the main [lathe] spindle...[H]e introduced to the company batch production of standard models. He taught engineers about...the design of jigs and fixtures, and the layout of equipment on the production line," and advised managers on essential, high-quality machine tools to consider purchasing [Nakaoka, pp. 25-26, 1994]. However, the Igekai Ironworks lacked the resources to implement the full plan for reorganization and within a half a year Francis was dismissed [Suzuki, 1994, p. 162].

In confronting the difficulties with the manufacture of Toyoda looms at the Kimoto Iron Works foundry in particular, Francis redesigned 'tools, developed standardized specifications, thoroughly standardized the gauges, and drew up an overall plan for the factory. When the management at Toyoda Loom Works proved reluctant to pay Francis the full salary Sakichi had promised, Sakichi had them deduct the required amount (half of Francis' pay) from his own salary as chief engineer and executive director.

Before addressing manufacturing methods at the Kimoto Ironworks, Francis first designed and directed the construction of a machine tool manufacturing plant that produced lathes and other tools required in production in 1907. Other than a single tool installed by the Ikegai Ironworks, all the machinery installed in the factory was the most modern iron machinery from England, Germany, and the United States. With this equipment, the factory made the approximately 300 gauges required for loom production. With its own tool factory, Toyoda could establish a system of standards and begin manufacturing interchangeable parts. Workers were trained in accord with a new division of labor, ending the craft organization of manufacturing where skilled metal workers made, owned, and used their own tools. The commitment to establishing new technological capabilities was reflected in the decision to forgo paying out dividends to shareholders [p. 61; Suzuki, 1994, pp. 162-63].

The Toyoda Loom Works soon developed a series of new iron-frame models for both narrow looms (the K model in 1908 and the more successful L model in 1909) and broad looms (model H in 1908). These Toyoda iron-frame looms were mass produced at the factory that Francis designed, the first production system employing modern engineering technology in Japan [Toyowa, 1967, pp. 8-11].

Two new facilities were soon established. Because the pilot weaving plant at Shimazaki had been converted to a warehouse, Sakichi sought to establish a new experimental factory. He built another pilot weaving factory, the **Toyoda Kikui Weaving Factory**, as a shop independent of the Toyoda

Loom Works. Sakichi's brother, Sasuke, managed the new cloth mill test site [p. 52]. They initially subcontracted their iron work to Kimoto, but a new casting foundry was established in 1908. New and higher quality standards were necessary to achieve interchangeability, but the workers sought to meet quantity output goals. Conflicts also emerged among the managers responsible for meeting the new quality standards and for implementing new work organization and practices. Despite significant turnover of both managing engineers and workers, the Toyoda Loom Works soon developed a loyal group of engineers and workers who achieved interchangeability of parts and who differentiated their practices from the rest of the metal-working industry. At least in part because of these changes, Toyoda was able to double factory output between 1908 and 1910 without increasing its workforce [Suzuki, 1994, pp. 166-68].

Start-up production problems and difficulties in operating Toyoda looms under mill conditions prompted Mie Spinning (later merged into Toyo Spinning) to send a technical manager to inspect the operation of Toyoda's pilot factory in October 1909. Three Mie directors had been major stockholders from the start of the Toyoda Loom Works. Under the direction of an Imperial University-trained engineer, Aisaburo Mano, the Mie textile engineers and operatives with experience in operating imported looms (both automatic and non-automatic) made improvements in the new model Toyoda looms they tested. Toyoda's wide iron power looms were evaluated in comparison with Platt Bros. looms, and the results demonstrated no overall performance difference between them. In 1913 the price of the Toyoda broad loom was 160 yen, 20 percent less than the cost of a comparable imported loom. With orders for wide looms beginning to arrive from integrated spinning companies, a turning point had been reached in the international competitiveness of the Toyoda looms [p. 59; Suzuki, 1994, p. 165]. Not surprisingly, this early period of new product and process development was rife with customer complaints from both mills purchasing narrow looms and the growing number of mills ordering wide looms [Toyowa, 1967, pp. 10-12]. Continued difficulties in manufacturing exacerbated a developing rift between Sakichi and president Taneguchi.

By 1910 the high development costs and the investments required to scale up production showed promise of reaping substantial returns, but much of the period from 1907 leading up to World War I were years of relatively slow economic growth. Still, from the second half of 1910, Toyoda Loom Works began paying dividends to its stockholders. The rift emerging between Taneguchi and Sakichi deepened, as they disagreed about the appropriate scale of R&D expenditures. Extensive mechanical testing in particular required large capital investments. As a result, Sakichi resigned from the company that was built upon the commercialization of his inventions and that continued to carry his name after his departure [p. 62; Suzuki, 1994, p. 168]. Although Sakichi Toyoda ended his formal managing relationship with Toyoda Loom in 1910, he in fact continued as a director even after he established a rival company.

More important, Sakichi continued to provide guidance, especially during difficult times, to the Toyoda Loom managing engineers he had put in place in the casting facility.

The Toyoda Loom Works continued development of the iron broad loom and its production capacity. Aisaburo Mano of Toyo Spinning and Sakichi Toyoda provided crucial guidance – the former in product development and the latter in manufacturing – to ensure Toyoda Loom Works' success. Difficulties in coordinating large-scale testing of narrow looms at Nagoya Cloth Company prompted the amalgamation of the two companies in 1913 and the subsequent re-equipping of both facilities with wide looms. Assisted by Aisaburo Mano, now the manufacturing supervisor of Toyo Spinning, Toyoda Loom Works developed an English-style iron wide loom that was delivered to Toyo in 1914 and 1915. The success of this N-type of broad loom led to the virtual cessation of loom imports in Japan by 1920.

Mitsui Bussan's Fugino repeatedly urged that the Kimoto Ironworks be the next factory to introduce interchangeable parts technology, a goal that it fitfully attempted and eventually fully achieved under new management. The combination of Kimoto's ongoing financial difficulties, continuing supply problems confronting Toyoda Loom, and Toyoda's need for expanded production capacity led Mitsui Bussan to mediate the acquisition of Kimoto by the Toyoda Loom Works in 1916. The core group connected to Sakichi Toyoda, including the chief engineer (Fuguro Tsuchiya), the heads of design (Iwataro Okabe) and casting operations (Chotaro Kubota), and key technicians at Toyoda Loom were reassigned in similar capacities to the Kimoto Iron Works [Suzuki, 1949, p. 150; Suzuki, 1994, pp. 166-70; Toyowa, 1967].[2]

A survey of the installed stock of 49,354 looms in integrated spinning companies in 1920 identified 63 percent of foreign origin (two-thirds of which were from Platt Bros.), and out of the 36 percent of looms that were domestically produced, over 90 percent of these were made by the Toyoda Loom Works [Yanagihara, 1979, p. 43]. Table 3 provides evidence of the increased success of the Toyoda Loom Works after British imports were interrupted by World War I [Yanagihara, 1979, pp. 52-53]. International competitiveness was secured on the basis of loom models developed and of manufacturing capabilities attained after Sakichi's official departure, even as the company relied on his patented inventions and his unofficial guidance of key manufacturing personnel.

[2] One important consequence of the merger was the departure of Kimoto Iron Works' chief engineer Fuguro Sakamoto, and the launching of his career toward becoming the head of Enshu Loom, the chief rival of Toyoda Automatic Loom. The history of Enshu Loom will be briefly discussed below.

Table 3: Toyoda Loom Works, Loom Sales

Classification	Type	Year Developed	Construction	Total Number of Looms Sold
Narrow Width	A	1907	Wood-iron	1,846
Narrow Width	B	1907	Wood-iron	4,731
Narrow Width	K	1908	Iron	213
Narrow Width	I	1909	Wood-iron	6,088
Narrow Width	L	1909	Iron	15,247
Narrow Width	Y	1915	Iron	42,783
Total				70,908
Broad Width	G	1907	Wood-iron	180
Broad Width	H	1908	Iron	3,742
Broad Width	N	1914	Iron	87,114
Broad Width	S	1927	Iron	173
Broad Width	L.T	1932	Iron	901
Broad Width	M	1934	Iron	444
Total				92,554
Total as of October 1935				163,462

Learning from a Trip Abroad

On May 8, 1910 Sakichi along with his childhood friend and employee Akiji Nishikawa, a practical textile mill engineer, departed on a tour of textile districts in the United States and Europe. After arriving in New York, Sakichi was taken around to textile facilities surrounding Boston, New Bedford, Fall River, Providence, and Worcester by the New York-based machine branch manager of Mitsui Bussan. Sakichi gained confidence from evaluating the construction and operation of American looms in light of what he had learned from his own factory experiments and inventions. In comparison, the American looms' speed of revolution was slower, the vibration level was higher, the Draper bobbin-changing mechanism was too complicated, and the high rate of warp breakage resulted in an unsatisfactory number of cloth defects [pp. 63-64].

Believing that the invention of a competitive automatic loom had high worldwide value, Sakichi had Ishibara, a technical expert from Japan, join him. Sakichi and Ishibara proceeded to England, while Nishikawa and the Mitsui Bussan representative followed through on the U.S. patent application process. Sakichi recorded six U.S. patents during the years 1909–1914, including inventions related to a warp let-off and a circular loom (1909), an automatic shuttle-changing mechanism and a picker check (1910), a shuttle-changing loom (1912), and a protecting device for shuttle replenishing (1914) [Annual Reports of the Commissioner of Patents, 1909–1914].

Sakichi reportedly felt that his technical capabilities were superior to the U.S. loommakers as he left New York for England in October 1910. He

investigated spinning and weaving mills in Manchester and then visited mills on the Continent for another month before arriving back in Japan in January 1911 [p. 64].

In the widely circulated and prescient report of his British travels, Sakichi made a direct link between the development of the automatic loom and the Japanese ability to capture British export markets, a possibility requiring much additional industrial development and twenty years to accomplish (see Mass and Lazonick, 1990).

> On first seeing Manchester, I realized that making our industry the biggest would be a fairly easy task. In England, the average number of machines each female operator monitors is only 4.5. Moreover, there are no factories equipped with automatic looms. For this reason, I hold great hope for our industry. Additionally, the wages of British workers are over four times those of our workers. In Japan, the number of machines our workers on double width looms can operate is gradually increasing. For production costs of one pound, our output is slightly higher than that for Britain. If we manufacture our automatic loom, and the number of machines our workers operate rises to eight, it is estimated that our labor costs per pound, will drop to 23% of British costs. If we can do this, we will gradually overtake the British, culminating in certain victory [p. 64].

Ready and eager to renew his manufacturing and development efforts, Sakichi this time avoided challenges to his managerial control by securing personal sources of financing. He and his family relocated to a new textile mill in Nagoya, which expanded from 100 to 200 looms between 1911 and 1914. Sakichi's intense efforts in automatic loom development led him to focus on minimizing the extent of yarn breakage. For the first time, he decided to complement his research on improved loom operation with large-scale research into spinning technology.

In efforts to minimize reliance on outside capital, Sakichi established the **Toyoda Automatic Weaving Factory**, a privately financed and closely held cloth mill that manufactured cloth commercially and was simultaneously dedicated to loom experimentation. Although there were no dominant outside financial partners, the Mitsui Osaka branch manager Fugino Kamenosuke served on the executive board of the company. Sakichi's initial financing was, however, insufficient to realize his planned goal of equipping 200 looms with automatic shuttle-changing mechanisms. Instead only 100 wide power looms were purchased, and only eight of these were equipped with automatic shuttle-changing mechanisms at the start.

Needing the other 100 looms in order to maintain the combined commercial viability of his mill and loom experimentation, Sakichi secured additional financing in a remarkable manner. In October 1912, he renegotiated the terms of the original contract transferring his loom patent rights to the Toyoda Loom Works. According to the original contract, after a 10 percent profit was paid out as dividends to Toyoda Loom Works' shareholders, one-

third of the remaining profits were to be awarded to Sakichi. Willing to forgo his share of future earnings, Sakichi agreed to trade the remainder of his revenue claims for a lump-sum settlement of 80,000 yen. Sakichi was able to purchase the additional looms and thereby to sustain the momentum on his automatic loom experiments as well. Sakichi's commitment to securing the funds necessary to prevent the short-run diminution of his experiments proved extraordinarily costly in the long run. The magnitude of the future earnings he traded away was on a scale he could not possibly have foreseen. From 1914 to 1919 the Toyoda Loom Works earned 3 million yen that would have been turned over to Sakichi as royalty payments. However, Sakichi did sustain the viability of his mill concern during a period when he did not want to relinquish sole control of his enterprise [pp. 65-67].

As Table 3 shows, the Toyoda Loom Works developed increasingly popular iron wide looms as the World War I economic boom extended their market. The use of wide power looms at smaller-scale weaving mills began at this time as well. "The war stopped the flow of European and American cotton goods into Asia, and Japanese spinning and weaving manufacturers surged to fill the vacuum" [Hayashi, 1983, p. 13].

Meanwhile, the Toyoda Automatic Weaving Factory was manufacturing cloth, with a corner of the facility dedicated to loom experiments. Sakichi found that the purchased yarn was prone to frequent breakage, problematic for weaving with an automatic loom. He therefore decided to integrate his operations backward into spinning. To confront (and solve) the fundamental technical problems involved in automatic weaving, Sakichi needed to consolidate the complementary technical and organization linkages between weaving and spinning operations. He planned to begin an experimental spinning department at Nagoya in 1914 with only 6,000 ring spindles, a much smaller facility than the average mill of 50-60,000 spindles. At this point he deepened his alliance with Ichizo Kodama, the manager of Mitsui's Nagoya branch, who provided him assistance in establishing spinning operations [pp. 67-68].

Sakichi steadily expanded his integrated facilities in response to increased sales stimulated by the World War I economic boom. Sakichi's daughter Aiko married Kodama's younger brother Risaburo in 1915. At the time Risaburo was the branch general manager for C. Itoh & Co., a leading raw cotton trading company. The Toyoda-Kodama family alliance joined textile technological capabilities with marketing expertise in critically essential input and product markets: cotton and cloth. The alliance had dramatic consequences within the Toyoda family as well. Following Japanese custom, Sakichi adopted Risaburo, who thereby became his eldest son, supplanting his biological son Kiichiro as his primary heir [pp. 68-9].

One auto industry historian, Michael Cusumano, has cited the adoption of Risaburo as a primary reason for Sakichi's enduring commitment to business expansion into other major growth areas such as automobiles. Sakichi wanted to provide a corporate legacy large enough for both heirs and their

families. With a sufficiently large inheritance, Kiichiro could receive his due and family resentments that might otherwise thwart effective development of the productive potential of the alliance could be avoided [Cusumano, pp. 58-59].

The period from 1912 to 1915 proved to be a very productive period for automatic loom invention and patenting. Most important, Sakichi made notable advances in patenting an improved let-off device. But research and experimentation on automatic looms subsided as the Toyoda textile enterprises proved increasingly successful.

After four years of war-time growth, the Toyoda Automatic Weaving Factory was replaced by **Toyoda Cotton Spinning and Weaving Co., Ltd.**, in 1918. The new company was established with Sakichi as president and Risaburo as managing director. The company was capitalized at 3 million yen ($1.5 million). The newly incorporated entity had 34,000 ring spindles, 1,000 power looms (only eight of which were equipped with automatic shuttle-changing mechanisms), and 1,000 employees and principal shareholders (see Table 4) [pp. 70-1].

Table 4: Toyoda Cotton Spinning and Weaving Ownership, 1918

Stockholders	% shares
Sakichi Toyoda	48.0
Fujino Kamenosuke (Mitsui)	29.4
Risaburo Toyoda	10.0
Kodama Yoneko	9.0
Kiichiro Toyoda	.5
Kodama Ichizou	1.0
5 Other Toyoda Relatives	1.2
15 Unrelated Individuals	1.4
Total Shares	100,000

In October 1918 Sakichi traveled with Nishikawa to the Chinese mainland to investigate the prospects for establishing a new spinning and weaving enterprise there, a project that would take three more years to bring to fruition. His expressed reasons for seeking an offshore production site were two-fold: First, Sakichi felt that beyond business considerations, he would develop production abroad when other Japanese spinning companies would not, serving the national interest by improving relations with China. Second, Japanese living standards and wages were increasing, and Sakichi was aware that Japanese wage advantages could not continue indefinitely, so this move was also a strategic decision to produce in a lower-wage economy [p. 73].

Sakichi set up a personally controlled enterprise in China. After 1920 when Chinese tariffs were raised, other Japanese spinning companies began setting up Chinese subsidiaries. Sakichi responded by expanding his China operations and established the **Toyoda Spinning & Weaving Works** in Shanghai. Capitalized at 5 million Yo (approximately 5 million yen) Sakichi was president and Akiji Nishikawa was the general manager. This mill had 60,000 spindles and 400 looms. Sakichi moved his family to Shanghai to ensure that

the venture would be a success. Nishikawa was asked to manage the textile company operations [p. 78].

Joined by his son, Kiichiro, in 1920 and with his financial situation better than ever, Sakichi once again engaged in loom research and development on the scale from which he had pulled back in 1914. Soon after the Shanghai company was established, Sakichi devoted his energy to a circular weaving machine (an inventive effort that was never successful, although a prototype is the centerpiece in the main lobby of the newly opened Toyota Museum) and automatic loom invention. Sakichi traveled back and forth between Shanghai and Nagoya and oversaw the expansion of the Nagoya experimental facility from eight to 32 automatic shuttle changing looms [p. 81].

Kiichiro Assumes Hands-on Research Leadership

Kiichiro was a mechanical engineer trained at the University of Tokyo. He worked for his father upon graduating from college in 1920. Although his thesis dealt with pneumatic pumps, as a member of the company's technical staff he became a specialist in casting technology and machine-parts manufacturing for Toyoda Spinning and Weaving [Cusumano, 1985, p. 58]. Kiichiro played the central role in the intensified research activities, which rapidly achieved many improvements. A new automatic shuttle-changing mechanism was developed, different from the two central inventions that Sakichi had patented in 1903 and 1909.

In 1903 Sakichi had designed an automatic shuttle-change motion in which the shuttle change occurred below the "race" upon which the shuttle traveled from one side of the loom to the other. During the shuttle change the new shuttle was pushed from below the race, forcing the exhausted shuttle from the shuttle box at the end of the race. This approach was not successful. Sakichi developed an alternative design in 1909 in which a pushing rod horizontally moved the new shuttle into the shuttle box during the shuttle change.

One advantage of the second approach was the increased time allowed to execute the shuttle change. Most shuttle-change mechanisms were more complex, requiring the loom to stop operation, then start up again after the shuttle exchange occurred. Sakichi's simpler motion occurred more slowly than other non-stop shuttle exchangers and operated with precision even at high speed.

The fundamental invention developed by Kiichiro and patented in 1925, is described as follows: "[A] mechanism linking the front and rear panels of the shuttle box, ensures that as the new shuttle is pushed into the shuttle box, both the front and rear panels move simultaneously; because of this improvement this motion's shuttle changes became smoother and required less power. In Sakichi's 1909 invention, in which the front and back panels of the shuttle box opened independently at high speeds, delayed opening of the back panel caused mischanges to occur" [pp. 514-15].

Just as important for successful commercialization as the fundamental patented inventions, essential modifications were made on the other basic loom mechanisms such as the warp let-off device and the warp-stop motions.

Sakichi finally decided to operate his own automatic loom factory as a pilot plant, but the 32 experimental looms were insufficient for effective development of management practices and worker training. In addition, the warp preparation processes required further modification for automatic weaving, and Sakichi recognized that successful development would require a separate production facility. An automatic loom pilot plant was built in Kariya, Aichi Prefecture, in 1923. With potential capacity for 500 automatic looms, production was begun with two hundred looms purchased from the Toyoda Loom Works and newly equipped with automatic devices. The loom testing stimulated an increased rate of invention, as measured by an accelerating rate of patent applications. From 1903 through 1921 there had been five Toyoda shuttle-changing patents; nine additional patents in this key mechanism were developed between 1922 and 1929. Yarn was supplied by the Toyoda Spinning & Weaving factory. Early on, test results made apparent the limitations of yarn quality at the parent company. It became critically necessary to manage the spinning process itself, which required the establishment of a new, dedicated spinning department. The minimum efficient scale for a spinning factory was 20,000 ring spindles costing 2.5 million yen, a scale of operation that was reached at Kariya by 1926 [pp. 82-84].

Sakichi asked the Toyoda Loom Works to produce 1,000 power looms, on which he would attach his automatic mechanisms. However, a dispute erupted over the interpretation of the renegotiated terms of the 1912 agreement regarding who actually retained control over Sakichi's 1909 patent rights and their application to the shuttle-change mechanisms Sakichi intended to install. In effect, before cooperating with Sakichi's experiments, the Toyoda Loom Works wanted him formally to sign over to them the 1909 patent rights, a step Sakichi had not taken as part of the 1912 settlement. The disagreement and concern over distribution of potential returns from future development of the 1909 patents prompted Sakichi to improve the automatic loom and at the same time to strengthen his patent claims independent of the Toyoda Loom Works. Meanwhile, even as the dispute over patent rights intensified, the Toyoda Loom employees producing the looms to which the automatic shuttle-change mechanisms were attached worked directly under Sakichi [Suzuki, 1994, p. 170].

In October 1924, Sakichi dramatically gathered the employees of his company and asked them to put forth greater exertions to sustain operations profitably, while he would ensure that inventive efforts on the automatic loom would be intensified. The results were immediate and just as dramatic. In November and December there were ten new patents, including the most important single patent, which would govern the design for the shuttle-changing system as it was developed (Kiichiro's 1925 shuttle box). The automatic loom design was sufficiently perfected to allow preparations to begin for mass production [p. 84].

In this first phase, however, the factory was not adequate. Sakichi leased an iron factory in Hioki from his close friend, Nozue, and asked his long-time

associate Kubota to construct a foundry and casting facility in the Hioki foundry. During 1925 the automatic loom was redesigned for mass production and successfully tested in a pilot plant of 350 looms. In 1926 Sakichi established the **Toyoda Automatic Loom Works** in Kariya, next to the experimental spinning and weaving mill. Soon after its establishment, first Kuboto, then many other engineers and skilled technicians from Toyoda Loom Works transferred to the new company. This group, long attached to Sakichi, became the nucleus for building up production capabilities, particularly in casting, as required in the production of automatic looms, then of high-draft ring spinning frames, and eventually of automobiles [Suzuki, 1994, p. 170].

The Toyoda Automatic Loom Works was capitalized at 1 million yen ($460,000) and produced 1,203 automatic looms within the first year. Of these, 520 looms were placed in the Kariya experimental factory; 528 were placed in the main branch plant of Toyoda Spinning & Weaving; 124 automatic looms were placed in the Kikui Spinning & Weaving Company (a closely affiliated mill established in 1918); 24 in the Toyoda Kikui Weaving Factory; and the last seven, the only early loom models operated outside of Toyoda-controlled facilities, went to Kanebo.

The need for and actual testing of alterations in the yarn preparation and spinning processes became a matter of utmost importance for successful automatic weaving. The Toyoda approach entailed extensive testing on a large scale to gain an understanding of the links between materials processing and machinery design. Risaburo Toyoda reviewed this history in 1929 in a textile trade journal [Toyoda, R. 1929, p. 9-10):

> For example, insufficient attention is paid to preparatory processes. This is the primary enemy of automation. This is even the case in reformed factories in which automatic looms have been successfully adopted. Even there, one frequently hears complaints about bad yarn. At Toyoda Automatic Loom also, from the very beginning, we devoted the greatest care to this problem, spinning yarn from long fiber cotton. However, because of improvements in the above mentioned preparation process, it is possible now to use raw cotton hardly different from that used by the standard power looms...An important point in researching the problem of how to adapt the loom to Japanese conditions is that the general application of automatic looms to textile manufacture is still in its infancy...It is our company's greatest desire to produce a loom adapted to the current state of our cotton cloth industry, and in the future to accompany this development of more and more advanced cotton weaving technology with the production of these looms. For example, recently we have been testing a loom for extended periods of time and getting results of 220 picks per minute. Recently in England, whether an American bobbin changer or a shuttle changer could exceed 160-70 picks per minute provoked storms of controversy. However, in the operational experimentation carried out at our Kariya factory, because a small test sample is no good for

> ensuring the observation of each and every type of design flaw, two hundred to five hundred and thirty machines are used in testing. Initially, we assigned each operator six looms, but we have gradually increased this so that now each operator handles over fifty looms, with the expectation that this number will soon exceed sixty looms per operator.

The Toyoda Automatic Loom Works assumed pride of place as the central concern among the growing number of firms in the Toyoda group. Kiichiro became a managing director in charge of loom production. A foundry, an iron works, and a woodworking shop were built, and sales of the Toyoda G-type automatic loom began in 1927. The new automatic loom cost 3.3 times as much as the 200 yen prince of a conventional power loom. However, the differences in staffing requirements were dramatic. One expert described the typical comparison as the difference between a weaver who could operate 25 automatic looms and one operating only two to three power looms, yielding a commensurate nine- or ten-fold increase in productivity [Ishii, 1979]. The automatic loom was an immediate success in the marketplace. As Table 5 indicates sales were concentrated with the integrated spinning mills.

Table 5: Sales of Automatic Looms, Toyoda Automatic Loom Company (Hioki Factory in 1924 to mid-1931)

Total Domestic Market	13,143
Toyoda line	2,604 (19.8%)
Integrated	8,621 (65.6%)
Other	1,894 (14.4%)
School/Inspec.	24
Export	3,825
China inclu. Toyoda Boshoku, 428	3,143
Korea	444
India	225
Platt	1

Sakichi's options for raising the capital for the new company included participation by one or a combination of the following organizations: Mitsui Bussan, Toyoda Loom Works, and the Toyoda Spinning & Weaving Company. The issues included sharing financial risk, securing family and managerial autonomy, and avoiding potential patent conflicts between the Toyoda Loom Works and the Toyoda Spinning & Weaving Company. In August 1926 the Toyoda Loom Works sued to force a change in the name of record on the disputed 1909 patent. This action ended the possibility of cooperation between Sakichi and the company he originally had established. The patent suit was resolved after 18 months with the direct intervention of Aichi Prefecture's governor, but the terms of this resolution are not known. The shareholding interests in the Toyoda Automatic Loom Works are shown in Table 6 and the composition of the first customers is shown in Table 5 [84].

Table 6: Toyoda Automatic Loom Works, Ltd. Ownership, 1927

Stockholder (at time of establishment)	% of shares
Toyoda Spinning-Weaving Inc.	61.5
Sakichi Toyoda	5
Kiichiro Toyoda	5
Risaburo Toyoda	5
2 Other Toyoda Relatives	5
Ichizou Kodama	5
9 Others	13.5
Total Shares	20,000

The company president was Risaburo, and Kiichiro was the general manager. Sakichi was a counselor, as he returned to assuming primary responsibility in overseeing invention. He also renewed his effort to invent a circular loom. In addition to producing cotton spinning and weaving machines profitably, the expressly stated and primary purpose of the Toyoda Automatic Loom Works, Ltd., was to research and develop textile machinery.

Sakichi suffered a mild cerebral hemorrhage in 1927. For a time he appeared to be recovering, but acute pneumonia set in and he died on October 30, 1930. The Toyoda enterprises continued to expand, with the establishment of the Shonaigawa Dye Works in 1928 and Toyoda Oshikiri Spinning and Weaving Company and Chuo Spinning & Weaving in 1929.

Indigenous Development of Japanese Power Loom Manufacturing Capability: A "Social Phenomenon" and Competition

Although the Toyoda Loom Works was an early industry leader – it had many rivals – so many, in fact, that Tetsuro Nakaoka has referred to the activities of loom inventors and entrepreneurs during the late nineteenth to early twentieth century as a "sort of social phenomenon" widespread throughout the weaving regions [Nakaoka, 1982, p. 55]. In 1733, John Kay, a Lancashire weaver, invented the flying shuttle, called a batten, and doubled weaver productivity. Kay had modified the picker stick motion that threw the shuttle from one loom side to the other by attaching it to a handle at the top of the loom. The weaver simply pulled the handle with one hand to move the shuttle from side to side. Two weavers and a loom maker, sent by the Kyoto prefectural government to Lyon, France in 1873, spent a year studying Western weaving technology, and the most important expertise they brought back to Japan was their knowledge of the batten.

The batten spread gradually throughout the weaving districts and marked a turning point in the pace and extent of continued improvements to the traditional hand looms. The batten is significant for the evolution of weaving technology was its function as the pivotal link in the transition from hand to power looms. At various points in the decades surrounding the turn of the century, each weaving region had its own leading loom inventors. Shigejiro

Matsuda in Mie invented a pedal-operated hand loom in 1885, the first step toward the development of a practical power loom. Soon thereafter in Tochigi, Kozaburo Terasawa redesigned the pedal operated loom in a manner that closely prefigured the earliest power looms. These improved hand looms diffused widely in the 1890s. The transformation from pedal looms to power looms principally required new mechanical devices for the warp let-off motion that would control and maintain constant tension on the warp yarns, a cloth roll take-up motion, a power drive mechanism, and several parts modifications of lesser significance. These two inventors, along with others including Sakichi Toyoda, developed locally suited power looms that varied in the incorporation of the devices needed to transform increasingly complex hand looms into power looms.

Forming a de facto technological community, these inventors learned from each other and at the same time developed differentiated loom designs. Sakichi Toyoda's early efforts at Igeta Trading Company in Aichi have already been described. All of the earliest models and varieties of power looms were narrow looms constructed from wood except for the gears, pulleys, and a few other metal parts. Ishimatsu Kubota of Osaka produced the first Japanese iron loom in 1903. Masajiro Suzuki established a loom manufacturing business in Enshu and constructed an iron narrow power loom in 1908. Sakichi Toyoda made the transition first to mixed wood-iron and then to all-iron looms in the 1907–9 period. Michio Suzuki founded Suzuki Loom Works (the predecessor of Suzuki Automobile Industry) and developed a power loom in 1913.

The indigenous development of power loom manufacturing capability in its initial stages advanced productivity in the traditional sector of specialized weaving mills. Spun from domestically grown, short fiber cotton, Japanese yarn was coarse (defined as a yarn "count" below 20). Domestic consumers preferred narrow cloth, which was used for kimonos and appreciated for its suitability for dye absorption (especially indigo). In effect, domestic market standards created a barrier to finer, imported yarn and cloth. (Direct tariff protection was also in place.) As higher income consumers purchased imported cotton textiles, in part as a substitute for native silk products, the tastes of the broader consuming public changed. (For a history of the changing product quality choices in the Japanese textile market, see Nakaoka, 1982].

Changes in the quality of yarn supplied by the specialized spinners and woven by the specialized, traditional weavers necessarily changed in a complementary manner. Over time the specialized weavers learned to use yarn made by mixing silk and cotton fibers, or by mixing longer, imported cotton fiber with domestic cotton stock. Eventually the weavers became capable of fully incorporating the domestically spun yarn made from wholly imported raw cotton into their cloth. The specialized weavers maintained a competitive advantage in providing narrow cloth made from coarser yarn for domestic customers until the widespread adoption of Western dress after World War II. During this transition, the traditional Producing Center (Sanchi) weaving

sectors adapted to the changing fashion by increasingly adopting broader power looms (see Table 7 below).

The integrated spinning mills continued to buy the majority of their looms from foreign manufacturers until the successful domestic development of iron broad power looms during World War I. During the 1920s, the large integrated, export-oriented mills increasingly purchased domestically manufactured looms. By 1929 the Toyoda Loom Work's 14 best customers (those buying more than 1,000 Toyoda power looms) were integrated mills, 12 of which were Japanese and two of which were based in China. They purchased 24,781 non-automatic Toyoda power looms between 1923 and 1929, equivalent to 52 percent of their 1929 stock of looms.

Table 7: Classification of Power Looms used by the Members of the Enshu Export Cotton Textile Industry Trade (March, 1937)

Company/Inventor Model (Location)	Less Than 36"	More Than 39"	More Than 40"	More Than 50"	More Than 60"	More Than 70"	Total
Toyoda Model (Nagoya)	667	730	5,961	1,014	56	14	8,442
Enshu Model (Hamamatsu)	40	297	1,136	72	57	–	1,602
Suzuki Model (Hamamatsu)	202	188	522	952	290	55	2,209
Hirano Model (Nagoya)	1,160	547	746	566	102	17	3,138
Iida Model (Hamamatsu)	674	104	765	90	54	–	1,687
Suyama Model (Hamamatsu)	243	600	217	–	–	–	1,060
Nisshin Model (Hamamatsu)	364	368	330	4	16	–	1,082
Sakai Model (Hamamatsu)	48	670	224	8	–	–	950
Nogami Model (Nagoya)	256	220	248	12	–	–	736
Others	419	200	839	500	56	73	2,087
Total	4,073	3,924	10,988	3,218	631	159	22,993

The Toyoda Loom Works continued to confront significant competition from rival domestic power loom manufacturers in selling to the independent weavers, who were increasingly oriented to making broadcloth for domestic and (expanding) foreign sales. With the immediate market success of automatic looms in the integrated mill market by their founder Sakichi's new firm, the Toyoda Loom Works future sales would become increasingly dependent on capturing a larger share of the growing market for broad power looms in the specialized weaving production centers, the Sanchi. Table 7 shows the extent of competition among domestic loom producers in the

export-oriented Enshu district in 1937, with the largest single share (37 percent) being held by the Toyoda Loom Works in the growing broad loom segment [Izumi, 1980, p. 15].

The Toyoda Automatic Shuttle-Changing Loom: Corporate Industrial Research, Indigenous Development, Technology Transfer and International Competitiveness

Sustained Japanese research into automatic looms began in 1898 when a technologist from Osaka Spinning Company, Takeo Yamanobe, returned from America in 1898 with an automatic loom from the Draper Company. In 1900, the major spinning companies sent a group of technical specialists to the United States to study the automatic loom that had been invented by J.H. Northrop and commercially introduced by his employer, the Draper Company, in 1895. Inventing the Draper automatic loom involved numerous complementary inventions and a scale of industrial research that resulted in a rate of patenting at Draper surpassed only by the most inventive American companies at the turn of the century such as General Electric and Westinghouse. The two most fundamental inventions were the Draper automatic loom weft-replenishing mechanism and the warp-stop motion. The former pushed a yarn-filled bobbin into place within a shuttle and pushed out the empty bobbin when its supply of yarn was exhausted without stopping the operation of the loom. Because the bobbin was inserted without stopping or even slowing the operation of the shuttle and the loom, the Draper loom was called a *bobbin-changing* automatic loom. To enable the weaver to operate a larger number of looms now that the time-consuming task of changing the weft supply was mechanized, a key complementary invention was the warp-stop motion, invented to ease the weavers' "mental anxiety" from monitoring the action and preventing faulty cloth resulting from breakage in the warp yarn [Mass, 1989].

The Osaka Spinning Company, Calico Finishing and Weaving, and the Mie Spinning Company installed Draper looms in their mills as early as 1900. (Outside of the United States, the Draper Company inventions were more frequently known as Northrop looms, primarily because the Drapers participated in establishing the more export-oriented British Northrop Loom Company to market their inventions in Europe and elsewhere.) Japanese mills had experimented with both Draper (U.S.) and Northrop (British) automatic looms. Because they had difficulty maintaining the looms in operating condition, they usually used the looms as simple power looms after removing the automatic attachments [Hayashi, 1983, p. 12. These three companies failed in their early efforts to operate automatic looms, but they amalgamated over time to form one of the six major spinners, Toyo Spinning.

Sakichi's attempts to develop a loom that could automatically replace the weft when exhausted began in 1902 soon after these first automatic looms arrived in Japan. But Sakichi pursued the development of an automatic *shuttle-changing* loom rather than striving to imitate or further develop Northrop's

design. Interestingly, automatic shuttle-changing looms were developed and introduced in Britain, but they were even less commercially successful than the meager penetration of the loom market by the British Northrop Loom Company's bobbin changer. (Less than 5 percent of British looms were automatic on the eve of World War II.) [Mass and Lazonick, 1990].

In addition to the Draper and Northrop automatic looms, other foreign models of automatic looms imported into Japan included the Stafford, Henry Bayer, Ruchi, Hartmann, and Kip-Baker looms. Domestic rivals included the Ariuma, Sakamoto, Suzuki, Noue, Kimoto Steel, and Osaka Machinery automated looms. Contrasting the differences in technology strategies across all these countries and enterprises is beyond the scope of this paper. The principal concerns addressed here are related to the technology strategy at Toyoda.

In a 1929 article published in the Japanese trade journal, *The Textile Review*, Kiichiro Toyoda explained the history of research and development for an automatic shuttle-changing loom at Toyota Automatic Loom Works. The central determining factor around which other important considerations revolved was the significantly greater machine precision required to integrate the bobbin-changing mechanism with the rest of loom operations compared with the shuttle-changing mechanisms. Because the bobbin was inserted into the operating shuttle in the former case, whereas the much larger shuttle was replaced in the latter, the bobbin-changer required machine tolerances no greater than 1/16 inch compared to 1/8-inch tolerances for the shuttle-changer.

The implications of the differences in precision standards were dramatic in a number of areas: the extent of complementary invention required for integrated operation with the rest of the loom's component parts; the extent of machine vibration, increasing yarn breakage and machine wear; the costs of loom manufacturing; the extent of mechanical expertise required for both installation and machine maintenance as machine integrity degraded with use; and the extent of retraining required for weavers. For each of these issues, the differences favored the automatic shuttle-changer. Noting the differences in cotton and yarn quality in Japan compared to the United States, Kiichiro explained, "Because looms in Japan must be able to weave using this sort of yarn, this issue structured research on automatic machinery, especially in the design of the warp stop and let-off motions" [K. Toyoda, 1929, p. 20].

The main advantages of the bobbin changer were that: 1) less energy was required to change the much lighter bobbin than the heavier shuttle, a difference of slight economic consequence; and 2) the smaller bobbin could be stored in larger quantities in the bobbin-magazine compared with a smaller number of shuttles requiring more frequent refilling and more labor time in preparation before installing in the shuttle magazine.

A mill with a 1,000 normal power looms required more than 300 weavers out of a total mill work force of four to five hundred workers. A mill with 1,000 automatic shuttle-changing looms required only 30 weavers

(only 20 under the ideal conditions at the Toyoda pilot mill) and a total of only 50 mill workers. The additional savings on mill labor in a mill with 1,000 bobbin-changing looms was possibly as much as 12 workers. However, Toyoda developed a larger shuttle that could carry a larger bobbin, requiring less frequent refilling of the shuttle magazine. With the larger shuttles, the difference in the number of mill workers was reduced to seven fewer workers on bobbin-changers. In either case the labor savings were small relative to the other factors influencing relative costs, and the labor cost savings was of course of less consequence in lower-wage Japan than in the United States.

Even though the shuttle-changer required less redesign and material change on the rest of a non-automatic loom than would a bobbin changer, the required complementary invention and improvements in manufacturing were considerable. In their first efforts at the Kariya experimental plant, Kiichiro attached shuttle-changing mechanisms to two hundred normal looms produced at the Toyoda Loom Works. His summary of the experience was that, "It was a monumental failure...With hindsight, this project appears stupid, but at the time we were working hard to understand the calibration of automatic looms. As one might expect, the looms ran as if possessed by demons. They repeatedly broke down and refused to run smoothly" [K. Toyoda, 1929, p. 23].

Over the years, the efforts at redesigning weft exchange mechanisms provided an important stimulus to more extensive inventive activity. Sakichi's inventions were not a solo effort, but increasingly relied on an a group of contributors whom he and Kiichiro assembled. Although the company lists a total of 85 patents and 28 utility models registered for Sakichi Toyoda, the listing explained that, especially in Sakichi's later years, Kiichiro and two employees were also involved in inventive activities. Research by Ishii Tadashi of the Japanese Patent Office and Shoji Okumura, an independent historian of technology, has established that Sakichi's actual role was significantly less than he was credited with in the celebratory biography issued shortly after his death, which was edited by Kiichiro and Risaburo. This biography is the source drawn on, directly or indirectly, by all English-language accounts. The Patent Office lists 29 patents awarded to Sakichi, with many of the others actually obtained by Kiichiro [Okumura, 1985, p. 108-9; Ishii, 1979]. It is clear that Kiichiro was principally responsible for the company's inventions after 1921.

The increased tendency toward corporate as opposed to individual invention was a more general phenomenon, even in the area of weaving technology. Ishii has graphed the trends in loom-related patents for all of Japan from 1907 to 1921 for patents registered to individuals and patents registered to companies. Those graphs indicate that annual company patents varied between one to ten with no trend (but with an average estimated by the authors of around five), while individually held patents clearly trend down from the 60-70 per year range to between 20 and 30 per year by the end of the period. On the other hand, corporations held 65 percent of the 131 weft-

replacement motion patents taken out from 1926 to 1932 [Ishii, 1979, no. 4, p. 27; and no. 5., p. 17].

Despite these indications of significant corporate efforts at developing looms capable of automatic weft replacement, Toyoda Automatic Loom's sole significant surviving competitor during the prewar era was the automatic bobbin-changing loom supplied by the Enshu Loom Company. The development of the Enshu loom was primarily the result of President Sakamoto's effort. He was an exceptional inventor who did not develop an internal research staff and organization remotely close to the scale attained by the two Toyoda firms. However, Sakamoto had developed an enduring if periodic working alliance with Toyo Spinning, a cloth manufacturer with the longest sustained interest in developing the automatic bobbin-changing loom. Toyo Spinning also made an exceptional commitment of resources toward the loom's successful development.

Enshu Loom originated as a single-product, narrow loom manufacturer in 1920. Having worked as chief engineer at the Kimoto Ironworks, Sakamoto was asked to take charge of renewed experiments with Northrop automatic looms at Toyo Spinning in 1920 at the request of Toyo's manufacturing supervisor, Aizaburo Mano. Sakamoto was hired as an engineer at Enshu Loom in 1921. He spent five years and 20,000 yen developing an automatic bobbin-changing loom prototype, adapting the Draper design. During this time, Dr. Mano reattached the automatic mechanisms to the original imported automatic looms in 1923, and initiated a four-year intensive study (1925–1929) in two Toyo factories of ten or more types of automatic looms and attachments. The Enshu automatic loom received widespread public attention when 529 looms were installed at the Nakabayashi Integrated Cloth Company in October 1929 with "120 of the leading lights of the textile machinery industry in attendance" [Yanagihara, 1979, p. 41-42, 46; Suzuki, 1949 p. 192-96; Uno, p. 519-20].

In terms of market share and overall prewar competitive performance, sales of the Toyoda automatic loom increased from 44 in 1925 to a prewar peak of 12,104 by 1937, while Enshu Loom had first year sales in 1926 of 1,126 automatic looms and rose to a pre-war peak of 10,717 in 1935 [Taniguchi, 1985, pp. 63-64].

As was the case in the development of the Draper automatic loom, the increasing mechanical complexity of inventing commercially acceptable automated machinery required organizing industrial research on a significantly larger scale, a process reflected in the increasing number of technical high school graduates entering engineering positions in the textile machinery firms. In 1900 1.7 male graduates per year were so employed, whereas the rate of hire was at 3.4 per year by the 1930s. Over the entire period over a third of these hires went into the Toyoda Loom Works alone. For the period 1926-1931 the Toyoda Loom Works made 18 such hires, and the much smaller, but rapidly growing, Toyoda Automatic Loom Company hired 14 [Taniguchi, 1985, pp. 55-56]. As noted earlier, Toyoda's main automatic loom rival Enshu Loom

had key individual engineers and acquired technical knowledge by drawing from its alliances with leading manufacturers, but Enshu Loom had no comparable internal staff for industrial research. Furthermore, the organizational development of manufacturing and marketing at Toyoda Automatic Loom Works was essential not only to make and sell the new invention, but also as a source of experience essential to further refinement of the initial innovation.

A Merger Attempt and Failed Technology Transfer

Having provided the Japanese textile industry with textile machinery since its founding, Platt Bros. was very interested in the opening of the Karitani Factory and the operation of 520 Toyoda automated looms. Mitsui Bussan, Platt's representatives in Japan, provided a full report. Platt ordered 205 automated looms shipped to their plant in Bombay, India for close examination. On the basis of this experience, they decided to pursue the purchase of the Toyoda patent rights. The negotiation began in April 1929 and lasted for several months.

The results were better than Toyoda expected. Platt wanted to purchase the patent rights in various countries outside Japan on the basis of a royalty contract. Toyoda preferred a lump-sum payment. Platt wanted exclusive access to all loom markets west of Singapore, including India. Because of the extreme complexity of the negotiations, Platt Bros. invited Toyoda Kiichiro to Britain.

At the time, however, Kiichiro was in the United States, showing two looms to the dominant American loom producers, Draper and Crompton & Knowles. In response to the Platt negotiations, he hurried back to Japan and then set off immediately for Britain. Kiichiro met with his employee Chosaku Suzuki and Aoki of Mitsui Bussan. He closed the deal after two months on December 24, 1929. According to the terms of the contract, Platt Bros. gained the production and marketing rights for every market except those of Japan, China, and the United States for £100,000.

A key Toyoda engineer, Suzuki accompanied one automatic loom to Britain in January 1930 in order to assist Platt Bros. in starting up production. Suzuki spent one and a half years in Britain. After some seven months, Suzuki was able to undertake testing a prototype loom. His report was as follows:

> The so-called first step of prototyping two machines has been completed, and these machines are now in actual operation at the Preston factory. This is most heartening. Looking at the manufacturing from its initiation to the present, it is altogether like the Hioki Factory period of our own company's development. I mostly leave these difficulties to your imagination.
>
> Moreover, because of the increasing severity of the recession, and various manufacturing practices, we still can not produce looms of the same quality as the two sample looms sent from our company in Japan. The exhaustive and precise nature of loom manufacture surprises the foreigners at every turn. This pleases me that these

> Englishmen who refused to recognize the merit of automating [to produce the] automatic loom are beginning to perceive the necessity for them. In this way, we gradually work towards operation of the looms at 244 rpm [p. 142].

One response to the severe decline of the British cotton trade was the concentration of textile firms through an amalgamated organization, the Lancashire Cotton Corporation (LCC), created in January 1929. One of the tasks of this organization was the rationalization of machinery and equipment. In order to assist members in their choices of equipment, the Lancashire Cotton Corporation solicited from each automatic loom manufacturer forty machines to be tested between the end of 1931 and 1932. In order to enter this competition, Platt Bros. rushed the start-up of production in order to have forty machines on hand for the test. Suzuki was crucial to this process. At the end of March 1932, forty machines were shipped to the LCC. The results of this test demonstrated that the Northrop, Vickers-Stafford, Whittaker, and Platt-Toyoda looms were all competitive. Although there was greater breakage and waste on the Platt-Toyoda looms, significant improvement in these aspects occurred over the four-month test.

Qualified as these results might be for Platt-Toyoda, this was a notable achievement, given that some of the looms were run for the first time during the testing period and this was, in effect, the first order of the Toyoda loom design produced in Britain. In addition, the other three loom manufacturers and in particular the Lancashire looms included in the test were using fully trained workers, which was not the case for the Platt-Toyoda looms [Lancashire Cotton Corporation, 1931]. The fact that this level of testing – in terms of machines, duration, conditions, and independence from company access to experimentation for purposes of learning – could become a basis for assessing technological and business potential, is in stark contrast to the history of testing and experimentation at Toyoda enterprises described above.

In May 1931, with his mission coming to an end, Suzuki prepared to return to Japan. Based on his experiences in guiding the prototype development of the Platt-Toyoda automatic loom, he wrote up detailed instructions, which were submitted to Mitsui Bussan and then passed on to Platt Bros.

Soon after Suzuki returned to Japan, in November 1931, Platt Bros. contacted Toyoda Automatic Loom, claiming that because of the errors and deficiencies in the blueprints, explanations, and models submitted under article 7 of the contract, requiring that "precise information and detailed warnings be outlined," they would be unable to market the automated loom. Estimating a loss of £50,000, Platt Bros. demanded a reduction in the patent rights transfer fee. In December 1931, £61,500 was to have been paid. Platt Bros. proposed postponing this payment.

Toyoda quickly conducted a study evaluating the Platt Bros. claims. The results suggested the following:

> The errors in the blueprints are regrettable. However, for the most part they are trivial, being largely revisions made during prototyping. We do not believe that these errors support the extent of the damages. Our company provided Platt Bros. two sample looms, and in addition sent Suzuki to guide the prototyping. Had these opportunities been sufficiently used, these damages should have been avoided. Thus we cannot agree to a reduction in the patent transfer fee. However, because of the various serious problems afflicting Britain because of the Depression, we should do what we can to in some small way alleviate the Platt Brother's patent fee burden. Let us begin these discussions [pp. 146-7].

After extensive negotiations, the two companies reached a compromise. Platt had already paid Toyoda Automatic Loom Company £38,500. They negotiated a settlement substituting a single payment of £45,000 for fifteen payments scheduled over seven years, totaling £61,500 pounds. The renegotiated contract was signed by Platt Bros. in England in July and by Kiichiro in Japan in September 1934.

The production and marketing of the Toyoda-Platt automatic loom were never established on a sustainable basis. Only 200 looms were sold over the next two years of production. The reasons for the failure of the Platt-Toyoda loom are disputed by the two sides.

From the beginning of negotiations, Kiichiro considered it highly likely that Platt was pursuing a preemptive strategy of purchasing Toyoda's patent rights in order to forestall competition. As a defensive technology strategy, buying the Toyoda patent rights was at least partially successful. By means of this agreement, Platt Bros. delayed the competition and diffusion of Toyoda automatic looms into their markets in Asia, particularly their large Indian market, and into Europe as well. By 1936, the Toyoda company began negotiations through the Mitsui Bussan London office to allow it to sell its own automatic looms directly in what until then had been Platt's exclusive territory.

A new agreement was negotiated in 1937 whereby Toyoda would pay Platt 3 pounds, 10 shillings for every automatic loom sold in India; outside of India, but within the registered area for patent rights, the payment was 1 pound, 15 shillings; and elsewhere the payment was one pound. Toyoda was once again able to export its automatic loom directly to the whole world. Shortly thereafter the Japanese economy was militarized, and by the war's end automatic loom patents taken out in various foreign countries had expired.

For a time Platt Bros. aggressively continued to pursue formalizing its relationship with the Toyoda Automatic Loom Works through its Mitsui agents. Mitsui had been Platt Bros.' exclusive agent for both weaving and spinning machinery imported into Japan. At the same time, it represented both Toyodas (the Loom Works and the Automatic Loom Works) in domestic and foreign sales. Platt Bros., anticipating its impending competitive decline, was eager to explore the possibilities for further collaboration and possible merger with the Japanese companies. Mitsui and the older Toyoda Loom Works were

ambivalent about Platt's proposals, and the Toyoda Automatic Loom Works was clearly reticent from the start. The Toyoda Automatic Loom Works was the technology driver and the faster growing company, less interested in joining with companies that might slow it down.

The development, production, and sales of automatic looms spurred the development of spinning machinery at the Toyoda Automatic Loom Works. For the period 1927-1929, the Toyoda Automatic Loom sales of weaving machinery exceeded 7 million yen, whereas the value of spinning machinery sold was only 265,000 yen. During the next three Depression years, the value of weaving machinery sales was almost 4 million yen, and spinning machinery sales rose to 2.7 million yen. Beginning in 1933, spinning exceeded weaving machinery sales and continued to do so through 1938. During this period, annual spinning machinery sales averaged over 5 million yen, nearly 75 percent greater than the not quite 3 million yen average for annual weaving machinery sales [Toyoda, 1967]. Mitsui was confronting a problem increasingly common among trading companies involved both in importing and in representing domestic companies that had become increasingly successful in production oriented toward import substitution. By the early 1930s Mitsui suffered a stagnation and loss of the spinning frame import business similar to what it had earlier experienced with British imports into Japan. The problem was managing relations with the foreign client and deciding when and how the exclusive contract could be broken or amended. In this case Mitsui's exclusive trading for Platt Bros. was contractually limited to spinning equipment, but practically the limitations on representation were generally applied to all textile machinery. Mitsui brought both Toyodas to the table with Platt Bros., where Mitsui was looking to resolve its own internal conflicts [Taniguchi, 1992, p. 99].

Policy transitions were to be expected as circumstances changed. The contrast in methods of managing those transitions provides a window into the extent of changes in the relative competitive strengths of the firms, the perception of these changes, and their impact on business strategies. Thus, within Mitsui there were differing perspectives on the value of merging Platt Bros., a mature company, with the two rapidly emerging Toyoda firms. The manager of Mitsui's textile machinery department, Furuichi, openly stated that "...the two (Toyoda) firms have little or nothing to gain from Platt Bros. cooperation, that they have already copied all the best of Platt Bros. designs and can continue to do so, that Platt Bros. have nothing of real value to add to the proposed merger and that both firms would be better off without our participation" [Platt Bros. Archives DDPSL 1/106/37 March 30, 1931].

The senior Mitsui managers from Osaka and Tokyo, Seko and Nanjo, respectively, still saw value in Platt Bros.' participation, although the magnitude of that value was open to question. Toyoda Loom's president Kanematsu argued that Platt Bros. must purchase stock shares at face value. John Bissett, the Platt Bros. director responsible for technology, was in Japan at the time negotiating for Platt. Bissett maintained that "Platt's name, experience,

manufacturing knowledge, research, and contact with the textile trades in all the countries of the world had a definite value and would have to be paid for by some tangible share recognition of that value." In response, the Mitsui Bussan Tokyo senior manager reported to Bisset of Kanematsu's "certain" belief that his company could do anything Platt Bros. could do, and do it better and cheaper. With this in mind Kanematsu "would not seriously consider Platt's expected price for participation in the merger" [Platt Bros. Archives DDPSL 1/106/37 April 8, 1931].

Bissett was surprised to discover that one enduring result of Platt's licensing the Toyoda automatic loom patent was a diminution of his Japanese counterparts' respect for his company's capabilities. According to Bisset,

> Toyoda Automatic Loom is still willing to negotiate but the price is going up...(O)ur deal with Toyoda for the manufacturing rights of the automatic loom is acting as a handicap. First of all it has filled Automatic loom's mind with exaggerated ideas of the value of their loom. Next they are firmly convinced that as textile machinists they are now really superior to Platts and other English firms, which they say are without new ideas...Finally, they have not said, but have done everything to indicate without actually saying it, that they look down on us for having paid so much and having paid so little discussion, very poor business people! All this is no doubt part of the scheme of bargaining but it is disquieting to think there is just a little real substance in it. However, I'll treat it as bargaining [Platt Bros. Archives DDPSL 1/106/37 April 23, 1931].

Another factor reflecting and conditioning the relative change in competitiveness of the British and the Japanese firms was the continuing depression in sales of Platt machinery, whereas 1931 saw a recovery in sales for both Toyodas. In March 1931 Bissett reported that both companies were occasionally engaging in price wars. During the next month trade conditions had changed sufficiently so that by late April he wrote that, "...both firms have booked good orders. They...(will) be busy for the next eight or nine months...This has stiffened the attitude of both firms. They also know the prices which we have been quoting and how far below them they can sell" [Platt Bros. Archives DDPSL 1/106/37 April 23, 1931].

A third factor undermining the basis for corporate amalgamation was the large difference in the relative valuation of the two companies. Particularly vexing was the disparity in perceptions of the value of the fixed assets (land, buildings, factory, machinery, patterns, furniture, office equipment, and so forth) of the Toyoda Automatic Loom Works. Toyoda Loom Works put the value at 1.0 million yen, the Automatic Loom Works self-valuation was 1.67 million yen, and Bissett's valuation was a fraction over 1.2 million yen. Furthermore, the rough calculations advanced by Mitsui to explain the value basis of the two Toyodas drew on the companies' closely held financial records. Bissett was initially assured that these records were going to be made

available to him, but the "books" never materialized [Platt Bros. Archives DDPSL 1/106/37 May 16, 31, 1931; Taniguchi, 1992, pp. 114-15].

The large differences in valuation were an outcome of dramatically different conceptions of how to justify value determinations. In particular, the Toyoda Automatic Loom Works was notable for its low operating capital and low profitability resulting from its high development costs. There was no means to establish a common basis for defining the terms and levels of asset valuations. As a result there was a large spread in the participants' current capitalization of the various companies' expected future revenue streams. Mitsui managers attempted to serve as intermediaries in the negotiations, but the gap was too great. Disagreements and changing assessments among Mitsui managers diffused its support and ability to broker any short-term resolution. Meanwhile, as negotiations stretched on, the changing relative capabilities and performances of the machinery suppliers led the Mitsui senior managers most predisposed to value Platt's current strengths to back away from supporting any measures that might inhibit the development of the Japanese firms.

Mitsui Bussan, the initiator of the merger discussions, was at the start more concerned about damaging its relationship with Platt Bros., but the negotiations did accomplish their goal of "strengthening their ties to the two Toyodas in order to more fully participate in the development of the domestic textile machinery market" [Taniguchi, 1992, pp. 99, 120]. Mitsui's policy shifts and relative failure to guide the merger negotiations to completion are readily comprehensible within the context of developing Japanese self-sufficiency and export competitiveness in textile machinery production.

Thus, the negotiations broke down because the two Toyoda companies disagreed about their respective market valuations, and both refused to open their books for the other and to Platt. The older Toyoda company was secure with rising sales to specialized weavers, and the newer Toyoda company was beginning a high-wire act in pursuing the development of an automobile business. The Toyodas in effect withdrew from negotiations by late May 1931.

Finally, Platt Bros. strategic orientation cannot be adequately assessed without linking the overlapping patent and merger negotiations with the simultaneous formation by the leading British textile machinery firms of Textile Machinery Makers, Ltd. (TMM). The Platt Bros. Board of Directors approved their participation in the amalgamation on September 17, 1931. Platt wrote to Mitsui before the end of the month explaining that future merger proposals would have to be put before the TMM board. The letter to Kiichiro with complaints about the technology transfer process and the request for renegotiation of the patent license fee soon followed in November. In the midst of depressed trade, the efforts to rationalize domestic production and curtail price competition were accompanied by contraction in the resources devoted to research and development. Bissett, the director who not only was most active in assessing new technologies and the technological capabilities of the two Toyodas, but who also served as manager of the Experimental and Research Department, newly established in June 1928, retired from Platt Bros.

in November 1931 at exactly the same time that Platt's complaints forced renegotiation of the Toyoda licensing fees. Although Platt later renewed a proposal for merger in 1933, neither company responded [Platt Bros. Archives, DDPSL 1/91/5 September 17, 24, November 4, 1931; 1/91/31 June 13, 1928, November 4, 1931; Taniguchi, 1992, pp. 117].

Technology Transfer from Toyoda to Toyota

As noted earlier, before Kiichiro traveled to England in 1929 to conduct the patent negotiations with Platt Bros., he visited the leading loom manufacturers in the United States, Draper and Crompton & Knowles. The official and widely reported purpose of the trip to the U.S. was to attempt to sell automatic loom patent rights or at least to set a price basis for comparison and negotiation with Platt. The British-based head of the textile machinery division of Mitsui Bussan, Furuichi Tsutomu, tells a different story. Aware that about 70 percent of American looms were already automatic and that the remainder were weaving cloth more difficult to adapt to automatic looms, and believing that Toyoda's asking price at double the Platt licensing fee was highly unrealistic, Furuichi attempted to excuse himself from the negotiating effort. Kiichiro met with Furuichi privately and explained that "these proceedings are not in order to sell in the United States...I entreat you to come with us [so] I can act freely." Wherever Furuichi and Kiichiro traveled, Kiichiro was absorbed in the study of machine tools. Having already decided to attempt automobile manufacturing in Japan, Kiichiro was using the patent rights negotiations as a pretext for his research [Furuichi, 1959a, p. 22].

It is well known that, with Sakichi's blessing, the fees from Platt Bros. were to be devoted to developing automobile-related research and development. Kiichiro left the patent negotiations to Furuichi and other Mitsui representatives, and he spent his time studying machining and machine tools, visiting auto assembly plants and parts manufacturers in the United States and Britain. Returning from his tour in March 1930, Kiichiro organized a group of engineers and began research on gasoline engines within the Toyoda Automatic Loom Works.

Simultaneously with his direction of auto research and product development, Kiichiro set about developing the company's capabilities for precision machining and improved mass production methods, prerequisites for future automobile manufacturing. He introduced the first assembly line conveyer belt in Japan – for loom assembly within Toyoda Automatic Loom Works. He also imported high-quality German and American machine tools; he installed an electric furnace in the foundry to provide high-grade castings; and he introduced Japan's first molding machine. Kiichiro also hired a chemical analyst, and constructed the facilities for chrome plating in order to improve the precision and durability of the automatic loom's rotating parts. In effect, Kiichiro was upgrading the loom manufacturing capability as a test bed and training site for developing automobile manufacturing capabilities. How

effective and profitable these techniques were for loom manufacturing as well is a matter for future research. The Toyoda Automatic Loom Works, as shown in Table 8, had machine orders far exceeding its current production capacity. Instead of expanding to fill existing orders, Kiichiro was leading his company into a high-risk strategy to be in on the start of the Japanese automobile industry.

Table 8: Toyoda Automatic Loom Company, Orders and Deliveries, 1932-1937 (Semi-Annual Data)

	Looms			Spinning Frames		
Year	Orders	Deliveries	Unfilled Orders	Orders	Deliveries	Unfilled Orders
1932	5,024	1,719	5,242	386	195	581
1932	2,886	1,981	6,147	226	177	630
1933	1,043	1,937	5,253	285	213	702
1933	3,331	2,096	6,488	645	262	1,085
1934	6,862	3,112	10,238	1,486	369	2,202
1934	2,330	3,638	8,930	324	440	2,086
1935	1,349	2,947	7,332	53	662	1,371
1935	906	3,437	4,801	399	525	1,245
1936	6,195	3,737	7,259	145	702	688
1936	20,912	4,951	23,220	1,575	635	1,628
1937	9,268	6,459	26,029	594	504	1,718
1937	1,030	5,645	21,414	221	431	1,508

In September 1933 Kiichiro oversaw the completion of the Type A engine prototype. In December Kiichiro asked Risaburo to convene an emergency board of directors meeting, where the board approved the establishment of an Automobile Department retroactive to September 1, 1933. At an extraordinary meeting on January 29, 1934, Toyoda Automatic Loom Works stockholders voted to increase the company's capitalization to 3 million yen and to add automobile manufacture and steelmaking to the businesses listed in its articles of incorporation. In 1935 the Ministry of Commerce and Industry announced the plan that would become the Law Concerning the Manufacture of Motor Vehicles, enacted in May 1936. The plan made it clear that only a small number of domestic auto producers would be allowed to compete, each participant having to pass a capacity hurdle of 20,000 cars. The automobile department at the Toyoda Automatic Loom Works completed its first Model A1 passenger car prototype by May 1935, and in August, the company increased its capitalization to 6 million yen after the Cabinet decided to accept the outline of the vehicle manufacture bill.

The first use of the "Toyota" name appeared on the Model AA automobile developed in 1936. The Toyota Motor Co., Ltd. was established with a capital of 12 million yen in August 1937. Risaburo Toyoda was president and Kiichiro Toyoda was executive vice president. The organizational structure consisted of seven functional departments including administration,

sales, manufacturing, engineering, and technical. Kiichiro was the head of the research department, but he was also directly in control of the "total vehicle engineering administration," a department with responsibility to improve all processes and products in coordination with the other departments. Furthermore, the manufacturing and engineering departments were to work closely together in order to build low-price, high-quality vehicles; "the respective managers of each department were given simultaneous managerial control of the other department" [Toyota, 1988, p. 67]. The innovative strategy and structure of the Toyota Motor Corporation continued for a time to draw upon the capabilities developed through the organizational experience of industrial research, product development, and manufacturing at the Toyoda Automatic Loom Works in addition to the critical new resources Kiichiro and other Toyota managers integrated in order to "leap" into automobile production. Not only did the organizational capabilities of Toyoda Automatic Loom provide a resource platform upon which to attempt another "leap," both technological and organizational, but several product generations of success reinforced the vision of top managerial and technical leadership oriented to take on the challenges of integrating industrial research, product development, and manufacturing in a new industry.

References

Annual Report of the Commissioner of Patents, 1907-25, (Washington, DC).

Bi Gong, "Biography of Sakichi Toyoda" (in Chinese), *Huashang Shuehang Lianhehuai Banniankan* (Semi-annual Journal of The Chinese Cotton-Mill Owner's Association), 10, no. 2 (1947).

Cusumano, Michael, *The Japanese Automobile Industry*, (Cambridge, MA, 1985).

Farnie, D.A., "The Textile Machine-Making Industry and the World Market, 1870-1960," *Business History*, 32 (October 1990).

Furuichi, Tsutomo, "Onko Chisin" (Warm Remembrances), *Boshokku kai*, 50, no. 10, October, 1959a, 20-24.

_____, "Onko Chisin," (Warm Remembrances), *Boshokku kai*, 50, no. 11, October, 1959b, 42-50.

Hayashi, Takeshi, "The Automatic Loom and the Automobile," in *Entrepreneurship*, 5 (March 1983).

_____, "Historical Background of Technology Transfer, Transformation, and Development in Japan," The United Nations University, Japan, 1979.

Hunter, Janet, "British Training for Japanese Engineers – the Case of Kikuchi Kyozo," in H. Cortazzi and G. Daniels, eds., *Britain & Japan, 1859-1991* (London, 1991).

Index of Patents Issued from the United States Patent Office, 1926-1932, (Washington, DC).

Ishii, Tadashi, "Tokkyo kara mita sangyo gijutsu-shi – Toyoda Sakichi to shokki gijutsu no hatten" (The Development of Industrial Technology from the Viewpoint of Patent Rights – Toyoda Sakichi's Inventions of Textile Machinery), *Hatsumei* [Invention], 76, nos. 1-6 (1979).

Izumi Takeo, *Transformation and Development of Technology in the Japanese Cotton Industry*, The United Nations University, Japan, 1980.

Kobayashi, Kesaji, "Strategies for Developing New Technology: A Comparison between the Northrop and the Toyoda Automatic Looms," *Journal of Business Studies* (Ryukoku University) 35, (June 1995), 12-26.

Kuwahara, Tetsuya, "The Business Strategy of Japanese Cotton Spinners: Overseas Operations 1980-1931," Kyoto Sangyo University.

_____, "The Japanese cotton spinners' direct investments into China before the Second World War," in Teichova, Alice, M. Levy Leboyer, and H. Nussbaum, eds., *Historical Studies in International Corporate Business*, (Cambridge, 1989).

Lancashire Cotton Corporation, "Official Report Concerning a Test of Automatic Looms, Etc., Made in 1931," *The Journal of the Textile Institute*, 23, (March 1932), 25-42.

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

_____, "Indigenous Innovation and Industrialization: Foundations of Japanese Development and Advantage," Association of Japanese Business Studies, Best Papers Proceedings, Eighth Annual Meeting, 1995, 1-22.

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

_____, "The Decline of a Technological Leader: Capability Strategy, and Shuttleless Weaving, *Business & Economic History*, 19 (1991), 234-44.

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, Diffusion and Development: Fostering Private Capabilities and The Roots of the Japanese 'Economic Miracle,'" *Business & Economic History*, 22 (Fall 1993) 151-68.

Morris-Suzuki, Tessa, *The Technological Transformation of Japan: from the Seventeenth to the Twenty-first Century* (Cambridge, 1994).

Nakaoka Tetsuro, "The Role of Domestic Technical Innovation in Foreign Technology Transfer: The Case of Japanese Cotton Textile Industry," *Osaka City University Economic Review*, 18 (1982), 45-62.

_____, "The Learning Process and the Market: The Japanese Capital Goods Sector in the Early Twentieth Century," Suntory-Toyota International Centre for Economics and Related Disciplines, London School of Economics, Discussion Paper, No. JS/94/271, January 1994.

Okumura Shoji, *Shikurodo to Wata: Ito to Orimono no Gijutsushi* (The Silk Road and Cotton: A History of the Technologies of Yarn and Cloth) Tokyo, 1985.

Platt Bros. Archives, Lancashire Record Office, Preston, (PRO) England, DDPSL Collection.

Suzuki, Jun, "Chiho Kiki Kogyo to Gokansei – Meijiki no Rikishokki Seizogyo," ("The Regional Machinery Industry and Interchangeable Parts Manufacture: The Meiji Period's Power Loom Manufacturing Industry"), *Shakai Kagaku Kenkyu*, 46, (December, 1994).

Suzuki, Tokuzo, "Jidoshokki ni tsuite no Omoide," ("Memories of Automatic Looms"), *Seni Kiki Gakkaishi*, 2, no. 1 (1949) 188-196.

Taniguchi, Yutaka, "Senkanki niokeru Nihon-boshoku-Kikai Kogyo no Tenkai," ("The Development of Spinning and Weaving Machine Industry During Interwar Period in Japan"), *Sangyo-keizei Kenkyo*, Kurumo University, June 1985.

_____, "Sen Kyuhaku Sanju Zengo no Boshoku Kiki Kogyo ni okeru Nichiei Kankei no Ichidanmen-Puratto-Ryotoyoda no Gappei (Gapppen) Mondai wo Megutte" ("One Phase of Japanese-British Relations in Textile Machinery Industries circa 1930s: Focus on the Merger Problem Between Platt and Both Toyodas"), Ohishi Kaichiro, ed., *Ryotaisenkanki Nihon no Taigaikankei* (International Economic Relations during the Interwar Period), Nihon Keizai-hyoronsha, 1992, 89-129.

Toyoda Automatic Loom Works Company History Editorial Committee, 40-nenshi (The First 40 Years). Toyoda Automatic Loom Works, Ltd. (Toyoda Jido Shokki Shashi Henshu Iinkai, *Yonjunen-shi*, Toyota Jido Shokki Seisakusho (1967), p. 116; TI, p. 22.

Toyoda Risaburo, "Jidoshokki Sentaku no Hitsuyo Joken," ("Necessary Conditions for the Choice of Automatic Looms"), *Boshokku kai*, 18, (September 1929) 9-10.

Toyota Motor Corporation, *Toyota: A History of the First 50 Years* (1988).

Toyowa Kogyo Roquju Nenshi (Toyowa Industries 60 Year History), Keno Yoshida, Hiro Hayashi, and Shunichi Mikono, eds., (Keizai Zasshi Diamond Co., 1967).

Uno, Yonyoshi, "Nakabayashi Menpu Gomon Kojo ni okeru Sakamotoshiki Jidoshokki no Jisseki" ("Actual results of the Sakamoto Authomatic Loom at the Nakabayashi Cloth's Gomon Factory"), *Boskokeku kai*, 20, no. 6, June 1929.

Yamazaki, Hiroaki, "Ryotaisenkanki ni okeru Enshu Men orimonogyo no Kozo to Undo" (Structure and movement of the cotton weaving industry in Enshu district in the interwar period), *Keiei Shirin*, 6, nos. 1-2 (1969).

Yanagihara, Toru, "Development of Cotton Textile Industry and Textile Machinery Industry in Prewar Japan," photocopy, January 8, 1979.

Yonekawa, Shin'ichi, "University Graduates in Japanese Enterprises before the Second World War," *Business History*, 26 (July 1984).