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International Patent Control and Transfer of Knowledge: The United States and Japan before World War II

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My aims in this essay are to clarify the role and effect of the international patent control carried out by the General Electric Company in the interwar period on knowledge transfer between the United States and Japan, and to examine the effects of this process on Japan's innovative behavior. In previous studies on GE's international patent control, I showed that in order to transfer technological knowledge safely, GE made its Japanese affiliated companies set up a patent department and transferred functional capabilities of patent control to them. After the organization of an international patent control system, GE transferred a good deal of technological knowledge continuously and utilized it in Japan until the outbreak of the Pacific War. In the interwar era, GE obtained about 12,000 patents that were applied for and registered in the United States. In Japan, GE applied for and registered about 3,000 patents in the name of affiliated companies. Therefore, GE transferred about one-fourth of its U.S. patented inventions to Japan, and made patent portfolios in both countries. In this essay, I will compare GE's U.S. and Japanese patent portfolios and analyze how they were linked.

My aims in this essay are to clarify the role and effect of the international patent control carried out by General Electric Company (GE) in the interwar period on knowledge transfer between the United States and Japan, and to examine the effects of this process on Japan's innovative behavior. In previous studies on GE's international patent control, I showed that, in order to transfer its technological knowledge safely, GE

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required its Japanese affiliated companies to set up a patent department and transferred functional capabilities of patent control to them.[1] After the international patent control system was organized, GE transferred a great deal of technological knowledge continuously and utilized it in Japan until the outbreak of the Pacific War. Nevertheless, GE also received some knowledge from Japanese engineers under the same system. In this essay, I will compare GE's US and Japanese patent portfolios and analyze how they were linked. The linkage will be measured by the number of patents and by the technological classifications of inventors. I will analyze the linkages and try to answer some questions: What kind of technological knowledge has been transferred over the Pacific Ocean, and to what degree? What kind of knowledge transfer has an effect on the long-term innovative behavior of Japanese companies, and to what extent?

I focus on GE and its Japanese counterparts, Tokyo Electric Company and Shibaura Engineering Works, Ltd., two companies that were merged in 1939 to become Tokyo Shibaura Electric Company, now Toshiba, to explain the knowledge transfer between the two countries. Mira Wilkins mentions that GE did business by transferring technological knowledge or patents to affiliated electrical companies, and exploited its knowledge through such companies in specific territories.[2] Leonard S. Reich and George Wise clarified the origin and organization of GE's research and development activities in detail.[3] Reich also described GE's technology transfer from the point of view of lamp technology and international lamp cartels.[4] On the other hand, from Japan's side, Hoshimi Uchida and Shin Hasegawa showed that technology was introduced in the electrical equipment, electric lamp, and vacuum tube fields via contractual relationships between GE and Japanese companies.[5] Although these

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[1] Shigehiro Nishimura, "General Electric's International Patent Management before World War II: The 'Proxy Application' Contract and the Organizational Capability of Tokyo Electric," *Japanese Research in Business History* 21 (2004): 101-25; Shigehiro Nishimura, "Diffusion of Intellectual Property (IP) Management after World War II: Role of the Japan Patent Association," *Kansai University Review of Business and Commerce* 12 (March 2010): 19-39.

[2] Mira Wilkins, *The Emergence of Multinational Enterprise: American Business Abroad from the Colonial Era to 1914* (Cambridge, Mass., 1970); Mira Wilkins, *The Maturing of Multinational Enterprise* (Cambridge, Mass., 1974).

[3] Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (New York, 1985); George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (New York, 1985).

[4] Leonard S Reich, "General Electric and the World Cartelization of Electric Lamps," in *International Cartels in Business History*, ed. Akira Kudo and Terushi Hara (Tokyo, 1992).

[5] Hoshimi Uchida, "Western Big Business and Adoption of New Technology in Japan: The Electrical Equipment and Chemical Industries 1890-1920," in *Development and Diffusion of Technology: Electrical and Chemical Industries*, ed. Akio Okocho and Hoshimi Uchida (Tokyo, 1980), 145-72; Shin Hasegawa, "Competition and Cooperation in the Japanese Electrical Machinery Industry," in *International Cartels in Business History*, ed. Kudo and Hara, 165-86; Shin

previous studies focused on GE's foreign business in Japan through technology transfer, they did not indicate the scale of GE's patents in the United States and Japan, and the amount of knowledge transfer that took place between the two countries. In this essay, I would like to supplement some details by presenting patent data.

In addition to clarifying the number of patents transferred between the two countries, I present a mechanism that facilitates knowledge transfer. One mechanism was the patent control or patent management contract concluded between GE and its Japanese affiliated companies. It is possible that international patent control contracts had a significant long-term influence on Japanese national innovation systems through corporate patent management. Although international patent control and contracts seem to have passed almost unnoticed in the literature, John Cantwell and Tetsuo Tomita have drawn attention to their existence. Cantwell, in a survey of the *Official Gazette* of the United States Patent and Trademark Office, pointed out that the inventors named in the patents acquired by GE in the United States were from a large number of countries outside the United States. He argued for international R&D activities by multinational enterprises in the 1930s.[6] Tomita's research involved a study of the Japanese situation through a similar survey of Japan Patent Office materials.[7] He discovered that there were a large number of patents among those acquired by Japanese electrical enterprises whose inventors were non-Japanese. He pointed out that this phenomenon shows that patent rights were transferred among cartel companies, and proved that technological transfers were carried out via these cartels. Unfortunately, neither Cantwell nor Tomita tells us why, or for what purpose, patent rights were transferred or the effects that such transfers had on the management of the companies involved.

This essay will proceed in the following sequence. The next section will shed light on the number of patents GE applied for in the United States and their classification. Next, GE patenting in Japan will be discussed, and the linkages between the U.S. and Japanese patent portfolios will be examined. Then, the impact of knowledge transfer on the innovative capabilities of Japanese companies will be considered.

Hasegawa, "International Cartel and the Japanese Electrical Machinery Industry until Second World War: A Case Study of the Vacuum Tube Manufacturers," *Aoyama Business Review* 20 (March 1995): 29-45.

[6] John Cantwell, "The Globalization of Technology: What Remains of the Product Cycle Model?" *Cambridge Journal of Economics* 19 (1995): 155-74; John Cantwell and Pilar Barrera, "The Localisation of Corporate Technological Trajectories in the Interwar Cartels: Cooperative Learning versus an Exchange of Knowledge," *Economics of Innovation and New Technology* 6 (1998): 257-290.

[7] Japan Patent Office, *Kogyo Shoyuken Seido Hyakunen Shi* [One Hundred Years of the Industrial Property Rights System] vol. 1 (Tokyo, 1984), 662-68; Tetsuo Tomita, *Shijo Kyoso Kara Mita Chiteki Shoyuken* [Intellectual Property Rights Seen from the Perspective of Market Competition] (Tokyo, 1993), 101-10.

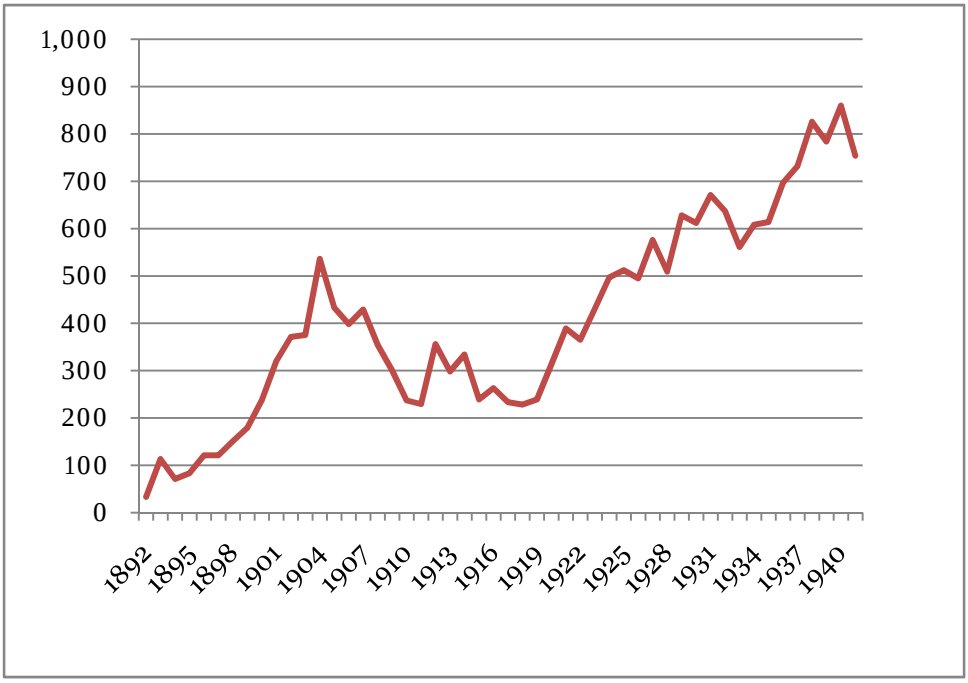
GE Patenting in the United States

Patents filed, 1892-1941

GE has historically held a large number of patents issued in the United States. To estimate the number of patents held by GE, this study considered patents issued from January 1, 1892, to December 31, 1945, whose rights were held by GE at the time of issue. The number of such patents is 21,387. Among them, the patents for which applications were filed from January 1, 1892, to December 31, 1941, are abstracted as a sample of this study. The number of such patents is 20,353. Thus, although this number is based on applications resulting from inventions, it does not represent all of the applications. This could be because some applications were approved by examiners and registered as patents, and others were rejected and were not counted as applications. We will consider the number 20,353 as representing the effective applications on which patents were eventually issued.

The annual trend of GE's patent applications is shown in Figure. 1. The figure shows that the first stride of patent applications occurred in the early 1900s. The first peak, at 536 patents, was seen in 1904. While patent

Figure 1
GE Patents Filed, 1892-1941



Note: U.S. patents issued and assigned to the General Electric Company from 1892 to 1945; sorted by application date. N=20,353.

applications decreased to around 270 per year during the 1910s, their number increased again after World War I, from around 400 to 600 per year. The second stride appeared in the interwar period, from 1922 to the early 1930s. Having slightly fallen in the first half of the 1930s, applications again increased after the second half of the 1930s, from around 600 to 800 per year. The number of patent applications reflects a spirit of invention or research and development (R&D) activities to some extent.[8] This spirit was first activated after 1900 when GE Research Laboratory, the first industrial laboratory, was founded, and again in the interwar period. For the purpose of research, it would be appropriate to divide the period into two terms: before and through World War I, 1892-1921, and the interwar period, 1922-1941.

Subsequently, we examine what kind of patents GE had filed by patent classification. Table 1 shows the top thirty patent classes filed from 1892 to 1921, sorted by the current U.S. Classification (USC). The most dominant class was USC 318, "Electricity: motive power system": 659 applications, or 8.25 percent of the total of 7,984. The second largest was USC 310, "Electric generator and motor structure": 541, or 6.78 percent; the third was USC 415, "Rotary kinetic fluid motors or pumps": 350, or 4.38 percent. Patent applications classified as motors, generators, and electrical apparatus accounted for relatively higher proportions in the table. It is notable that about 72 percent of patent applications were concentrated in the top thirty classes.

In the same manner, Table 2 shows the top thirty classes of GE's patents filed between 1922 and 1941. The highest position was held by USC 361, "Electricity: electrical system and devices": 744 applications, or 6.02 percent of the total of 12,369. The second largest was USC 313, "Electric lamp and discharge devices": 742, or 6.00 percent; the third was USC 318: 656, or 5.30 percent. About 65 percent of patent applications were concentrated in the top thirty classes.

A comparison between the pre-1921 and the interwar periods reveals some points. First, the distribution of patent classes in the interwar period was spread more widely than in the pre-1921 period. The concentration ratios of the top thirty classes dropped from about 72 to about 65 percent. Second, the ratio of USC 313, "Electric lamp and discharge devices," rose during the interwar period. When USC 315, "Electric lamp and discharge devices: system," was added to a similar class, USC 313, the ratio of the combined classification rose to 10.33 percent (1,277 applications) of all patent applications in this period. This trend was affected by industrialization and diffusion of radio equipment and wireless telecommunications in and after the 1920s. In contrast, some classes showed a decline in their relative proportions. For example, USC 310, "Electric generator and motor structure," declined from 541 applications or 6.78 percent to 343 applications or 2.77 percent, and USC 318 decreased from 659 applications or 8.25 percent to 656 applications or 5.30 percent, although these classes still occupied relatively higher ranks.

[8] Another element that has an influence on the number of applications is the patenting policy.

Table 1
Classification of GE's U.S. Patents, 1892-1921

USC	Title	1892-1921	%
318	Electricity: motive power systems	659	8.25
310	Electrical generator or motor structure	541	6.78
415	Rotary kinetic fluid motors or pumps	350	4.38
324	Electricity: measuring and testing	339	4.25
361	Electricity: electrical systems and devices	336	4.21
200	Electricity: circuit makers and breakers	271	3.39
313	Electric lamp and discharge devices	238	2.98
307	Electrical transmission or interconnection systems	228	2.86
335	Electricity: magnetically operated switches, magnets, and electromagnets	210	2.63
191	Electricity: transmission to vehicles	194	2.43
336	Inductor devices	193	2.42
219	Electric heating	159	1.99
362	Illumination	151	1.89
315	Electric lamp and discharge devices: systems	140	1.75
314	Electric lamp and discharge devices: consumable electrodes	131	1.64
363	Electric power conversion systems	129	1.62
123	Internal-combustion engines	124	1.55
338	Electrical resistors	120	1.50
174	Electricity: conductors and insulators	116	1.45
417	Pumps	112	1.40
322	Electricity: single generator systems	109	1.37
439	Electrical connectors	108	1.35
60	Power plants	104	1.30
73	Measuring and testing	104	1.30
337	Electricity: electrothermally or thermally actuated switches	102	1.28
74	Machine element or mechanism	101	1.27
416	Fluid reaction surfaces (i.e., impellers)	99	1.24
246	Railway switches and signals	90	1.13
388	Electricity: motor control systems	88	1.10
323	Electricity: power supply or regulation systems	84	1.05
	The others	2,254	28.23
	Total	7,984	

Note: Top thirty U.S. classes, U.S. patents applied for from 1892 to 1921, of the patents issued and assigned to General Electric Company from 1892 to 1945.

Table 2
Classification of GE's U.S. Patents, 1922-1941

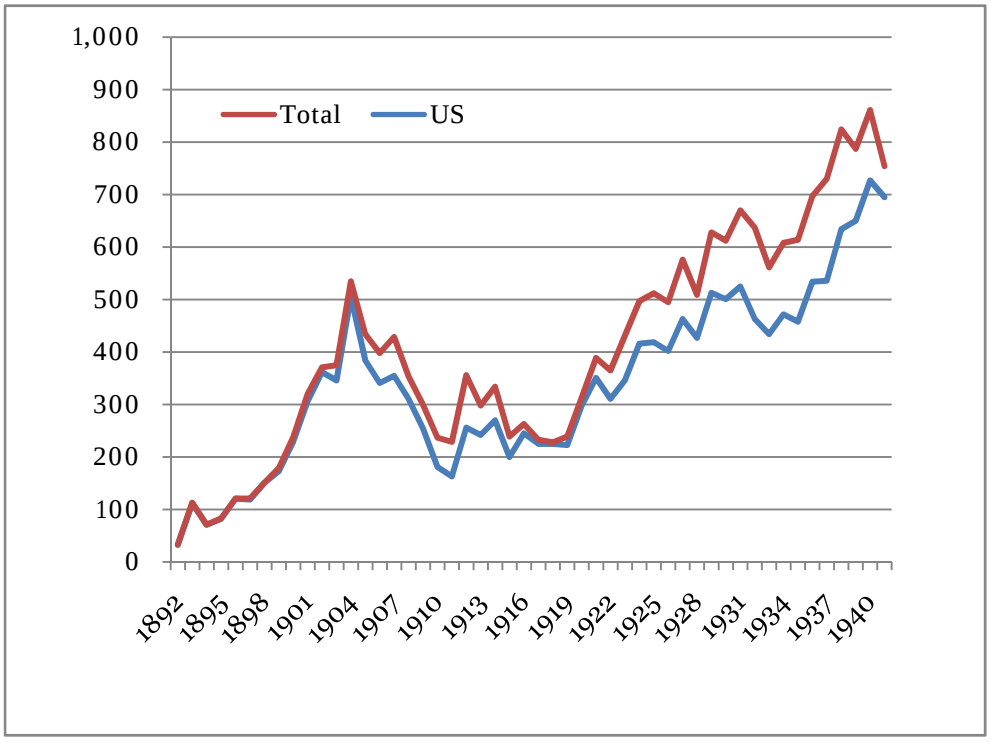
USC	Title	1922-1941	%
361	Electricity: electrical systems and devices	744	6.02
313	Electric lamp and discharge devices	742	6.00
318	Electricity: motive power systems	656	5.30
315	Electric lamp and discharge devices: systems	535	4.33
200	Electricity: circuit makers and breakers	398	3.22
307	Electrical transmission or interconnection systems	378	3.06
363	Electric power conversion systems	376	3.04
310	Electrical generator or motor structure	343	2.77
324	Electricity: measuring and testing	333	2.69
219	Electric heating	278	2.25
174	Electricity: conductors and insulators	275	2.22
218	High-voltage switches with arc preventing or extinguishing devices	272	2.20
337	Electricity: electrothermally or thermally actuated switches	258	2.09
335	Electricity: magnetically operated switches, magnets, and electromagnets	243	1.96
323	Electricity: power supply or regulation systems	210	1.70
336	Inductor devices	206	1.67
415	Rotary kinetic fluid motors or pumps	196	1.58
62	Refrigeration	193	1.56
439	Electrical connectors	180	1.46
362	Illumination	156	1.26
322	Electricity: single generator systems	155	1.25
340	Communications: electrical	138	1.12
428	Stock material or miscellaneous articles	126	1.02
73	Measuring and testing	111	0.90
60	Power plants	109	0.88
455	Telecommunications	106	0.86
74	Machine element or mechanism	103	0.83
148	Metal treatment	101	0.82
65	Glass manufacturing	97	0.78
330	Amplifiers	90	0.73
	The others	4,261	34.45
	Total	12,369	

Note: Top thirty U.S. classes, U.S. patents applied for from 1922 to 1941, of the patents issued and assigned to General Electric Company from 1892 to 1945.

Place of inventions

One of the characteristics of GE's patents was that the inventors were not resident in the United States alone but scattered all over the world.[9] Figure 2 shows line graphs, one line indicating GE's patent applications as a whole and another, patent applications based on inventions by U.S. residents.[10] The gap between the two lines indicates the patents based on inventions by foreign (non-U.S.) inventors. The volume of such patents increased, and this trend was maintained to some degree during the interwar period.

Figure 2
Addresses of Inventors



Note: Based on U.S. patents issued from 1892 to 1945, sorted by application date. N=20,353. Divided by first inventor's address.

Table 3 lists the countries of the inventors of GE's patents, and the numbers and ratios. It is notable that this table is based on a total of 22,644 inventors and 20,353 patent applications. All the inventors during the thirty years from 1892 to 1921 comprise about 89 percent U.S. residents and about 11 percent foreigners. Thus, GE had imported foreign

[9] Cantwell, "The Globalization of Technology," 155-74.

[10] When a patent has multiple inventors, the place of residence of the patent is judged by the first inventor's address.

technology and knowledge up to about 10 percent of its total technological knowledge. The largest portion of imported technology was from Germany, at 564 patents, or 6.65 percent, followed by the United Kingdom, with 231 patents, or 2.72 percent. The ratio of U.S. inventors declined to about 77 percent during the interwar period, while the portion of imported knowledge on a patent basis climbed to about 23 percent. The largest portion was imported from Germany (1,924 patents or 13.58 percent of total inventors); the second was from the United Kingdom: 639 patents or 4.51 percent. GE imported foreign technology or foreign-created knowledge not only from European countries but from Japan as well; the country contributed 131 inventors to GE's patents, or 0.58 percent of all inventors, in the interwar period.

Table 3
List of Inventors' Addresses

	1892-1921		1922-1941		Total	
	N	%	N	%	N	%
United States	7,547	89.02	10,948	77.28	18,495	81.68
Germany	564	6.65	1,924	13.58	2,488	10.99
United Kingdom	231	2.72	639	4.51	870	3.84
The Netherlands	4	0.05	324	2.29	328	1.45
France	68	0.80	102	0.72	170	0.75
Japan	5	0.06	126	0.89	131	0.58
Austria-Hungary	25	0.29	30	0.21	55	0.24
Canada	7	0.08	47	0.33	54	0.24
Switzerland	16	0.19	14	0.10	30	0.13
Sweden	5	0.06	1	0.01	6	0.03
Italy	2	0.02	3	0.02	5	0.02
Russia	1	0.01	2	0.01	3	0.01
Brazil	1	0.01	2	0.01	3	0.01
Norway	1	0.01	1	0.01	2	0.01
Columbia	1	0.01			1	0.00
Serbia			1	0.01	1	0.00
China			1	0.01	1	0.00
South Africa			1	0.01	1	0.00

Note: Based on patents applied for from 1892 to 1941, issued from 1892 to 1945. Inventors' addresses are based on 22,644 inventors included in 20,353 patents.

This mode of patent dealing gave GE exclusive rights in the United States to utilize the inventions of foreigners, or the rights to apply for U.S. patents based on such inventions. There were two cases: one was when GE bought the rights of the inventions of foreigners via individual contracts on a case-by-case basis. The other concerned the international patent control contracts that GE had long previously concluded with major foreign

electrical companies long ago—British Thomson-Houston (BTH) in 1897, Compagnie Française de l'Exploitation des Procedes Thomson-Houston (CFTH) in 1892, and Allegemeine Elekricitäts-Gesellschaft (AEG) in 1903.[11]

In the BTH case, the patent agreements provided as follows. First, it was agreed that GE was obliged to "assign all patents and patent rights for the United Kingdom and the British possessions in Europe; also patents of its controlled companies; also new patents, the British Company to pay expense of taking out new patents." Subsequently, the agreement noted that GE "will require all engineers in employ to assign all patents and will communicate such inventions to British Company." Finally, GE would "offer British Company any inventions or patents purchased." In return, BTH had to fulfill some obligations based on other clauses. BTH would "assign all patents and patent rights in so far as they relate to the United States and the Dominion of Canada; also patents of its controlled companies; also new patents, the General Electric Company to purchase." Furthermore, BTH had to "require all engineers in employ to assign all patents and will communicate such inventions to the General Electric Company." Finally, in addition to the obligations to GE, BTH would "offer General Company any inventions or patents purchased."[12] GE concluded similar contracts with other electrical companies, including its Japanese affiliated companies.

GE Patenting in Japan

GE business in Japan

Before analyzing GE's patenting in Japan, or the knowledge transfer between the United States and Japan, we need to examine how GE conducted foreign business in Japan and how knowledge transferred to Japan has been exploited. GE had not set up wholly owned subsidiaries in Japan, but made substantial minor investments in affiliated companies, and provided such companies with technology, patents, and know-how.[13] GE tied in with Tokyo Electric Company in the electric lamp, radio tube, and other light electrical appliance fields, and with Shibaura Engineering Works in the electrical equipment and apparatus sectors.

Tokyo Electric Company was founded in 1890 as Hakunetsu-sha, Ltd., by Ichisuke Fujioka and Shoichi Miura. At that time, all incandescent lamps installed for lighting purposes were made in foreign countries and imported; there was no facility to manufacture lamps in Japan. Fujioka entered into the lamp business aiming to manufacture incandescent lamps

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[11] Shigehiro Nishimura, "Foreign Business and Patent Management before WWI: A Case Study of the General Electric Company," *Kansai University Review of Business and Commerce* 11 (March 2009): 77-97.

[12] General Electric Company, "Report upon Foreign Business," Exhibit A, Section 1-b (22 Nov. 1918), 28, in Owen D. Young Papers, box 59, folder 202A, St. Lawrence University, Canton, N.Y.

[13] Wilkins, *The Emergence of Multinational Enterprise*; Wilkins, *The Maturing of Multinational Enterprise*.

domestically.[14] The goal of Tokyo Electric in its early days was above all to produce Japanese-made lamps that could compete with imported foreign-made lamps. Fujioka and Yoshio Shinjo, an engineer who joined the company in 1899, experimented with and improved the manufacturing technique. However, considering that the company's products had to compete with foreign-made lamps in the same market, Tokyo Electric's level of technology was certainly low. In order to close the technology gap with foreign companies rapidly and to realize domestic production, Tokyo Electric concluded a contract with GE that covered capital participation as well as patent and technical tie-ins in 1905 and began introducing foreign technology.[15] GE acquired a 51 percent share in Tokyo Electric, which effectively became a subsidiary.[16] Tokyo Electric was awarded an exclusive license for GE's patents in Japan and related technological knowledge. On the basis of this agreement, GE supplied Tokyo Electric with machinery and equipment to manufacture incandescent lamps, and dispatched W. T. McChesney, an engineer, to install the machinery, oversee operations, and impart lamp-manufacturing know-how.[17] Tokyo Electric's personnel were also permitted to visit GE's factories and receive technical training there.[18] Soon, through the use of lamp-manufacturing machinery and equipment as well as knowledge transfer via personnel, the lamp production processes that previously had been carried out primarily by hand became mechanized and dramatically improved, and Tokyo Electric's lamps became highly competitive. The adoption of foreign technology led Tokyo Electric to a dominant position in the Japanese market.

Shibaura Engineering Works was founded in 1875 by Hisashige Tanaka as the Tanaka Manufacturing Works. It was soon placed under the control of Mitsui, and its name was changed to Shibaura Engineering Works.[19] The company was not commercially successful for some time. Then, Keijiro Kishi, a manager in charge of electrical engineering since August 1900, took over the leadership of the company and improved its performance; it was no longer under the control of Mitsui and became a corporation in its own right.[20] With Kishi as the core member, several development activities were undertaken, and the company's technological level was by no means lower than that of its competitors. However, Jugoro Otaguro, an executive managing director, was not satisfied with the

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[14] Shotaro Yasui, ed., *Tokyo Denki Kabushiki Gaisha goju nen shi* [A Fifty-year History of Tokyo Electric Company, Ltd.] (Tokyo, 1940), 6.

[15] Yasui, *Tokyo Denki Kabushiki Gaisha goju nen shi*, 97-100.

[16] If stocks held by individuals are taken into account, the share of GE was over 70%.

[17] Uchida, "Western Big Business and Adoption of New Technology in Japan," 155-57.

[18] Yasui, *Tokyo Denki Kabushiki Gaisha goju nen shi*, 113-14.

[19] Yasuichi Kimura, ed., *Shibaura Seisakusho 65 nen shi* [A Sixty-five-year History of Shibaura Engineering Works, Ltd.] (Tokyo, 1940), 11-23.

[20] Kimura, *Shibaura Seisakusho 65 nen shi*, 37-44.

progress. Looking at the rapid technological progress in electrical engineering in Europe and North America, Otaguro concluded:

> The manufacturing technology of machines has progressed very rapidly in Japan since engineers have been sent to foreign countries and have become very talented experts. However, there is still no comparison between Japan and the West. Japanese industrial technology should be on a worldwide research footing. . . . in brief, we ought to conduct research by mixing our ideas with theirs.[21]

Shibaura then concluded a contract covering capital participation and technology sharing with GE in November 1909, mediated by Takashi Masuda of Mitsui & Company. GE invested money in Shibaura, purchasing about 30 percent of its shares. The main provisions of the contract provided for the following: the granting of patent licenses to Shibaura; the transfer of research and technological information to Shibaura; the training of Shibaura's employees in GE's factories and the dispatch of GE's professionals; offering blueprints of factory designs and the supervision of factory construction; and guidance for corporate managers.[22] These provisions were an attempt to realize Otaguro's concept of "conducting research by mixing our ideas with theirs." Here, the technological interaction by which Shibaura made use of GE's technology and thereby enhanced its own development to higher technological levels was institutionalized by this contract.

In October 1939, two affiliate companies with ties to GE merged to become Tokyo Shibaura Electric Company, now Toshiba. The contracts between GE and the affiliated companies were unified and acceeded to by Toshiba. GE had 30.29 percent of capital stock in Toshiba through the International General Electric Company (IGEC), GE's wholly owned subsidiary, at the point of the amalgamation.

Quantitative linkage between the United States and Japan

GE's patent control method in Japan during the interwar period was different from the method before World War I in an important way. Before 1919, GE had filed patent applications with the Japan Patent Office and controlled them directly.[23] However, after 1919, GE patents were applied for, registered, and controlled by Tokyo Electric, Shibaura Works, and Toshiba. That is, GE's patents were registered in the names of the Japanese companies as rightful patent holders. GE exploited their patentable knowledge through the business management of its affiliated companies indirectly.

GE's international patent control system was based on contracts with the affiliated companies. In June 1919, IGEC negotiated a contract renewal with Tokyo Electric and Shibaura Engineering Works, concluding new

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[21] Ibid., 53.

[22] Uchida, "Western Big Business and Adoption of New Technology in Japan," 154.

[23] Nishimura, "General Electric's International Patent Management before World War II," 104-15.

agreements.[24] In the agreement between IGEC and the Japanese companies, some clauses were markedly different from the earlier agreement in regard to patents, for now they included the international patent control contract for GE patents.[25] This contract transferred to the Japanese companies the right to apply in Japan for patented technology owned by GE in their own names; the Japanese companies could apply for and acquire a patent with themselves as the rightful claimants within Japan. In accordance with this contract, Tokyo Electric and Shibaura Engineering Works applied for, registered, and subsequently controlled GE patents in their own names. The method that IGEC contracts provided was almost the same as the scheme of knowledge transfer between GE and BTH, and GE and AEG. It could be considered that GE extended its international patent control system outside the leading industrial countries, to second-major industrial countries such as Japan. This is one of the substantial features of GE's international business strategies developed during the interwar years.

Certain principles were laid down with regard to this proxy application. First, the patents Tokyo Electric and Shibaura could apply for were, as the words of the contract indicate, patents regarding technical areas under which each company was granted exclusive licenses. Second, with respect to any patent for which a proxy application was made, GE would transfer to each company the right to apply for the patent at a price of one dollar per application. Third, each company would translate into Japanese any patent specification document sent from the United States and would submit it to the Japan Patent Office along with the attached deed of assignment. Last, as also stated in the contract provisions, the Japanese companies would bear all expenses connected with patent management, such as the application fee, annual fees, and the like.

Provided that Tokyo Electric and Shibaura Engineering Works had enough capability to apply for, maintain, and control them, GE allowed those companies to manage its Japanese patents as proxies. GE had in fact to bolster their organizational capabilities to operate international patent management via the proxy application contract. Therefore, in the early 1920s, GE required Tokyo Electric and Shibaura Works to organize well-furnished patent departments. Tokyo Electric and Shibaura hired patent experts from the Japan Patent Office to head their patent departments in 1921. By having adequate facilities to deal with patents, GE could build up a global scheme for knowledge transfer. In fact, GE could transfer large amounts of knowledge under this system.

Figure 3 shows a comparison between the trends of the U.S. patents and Japanese patents, based on application date. As mentioned above, GE's patents had been registered in the names of GE, IGEC, Tokyo Electric, Shibaura Engineering Works, and Toshiba. The zigzag line showing Japan's patent applications represents the patents applied for in the names of GE, IGEC, and the three Japanese affiliate companies, except

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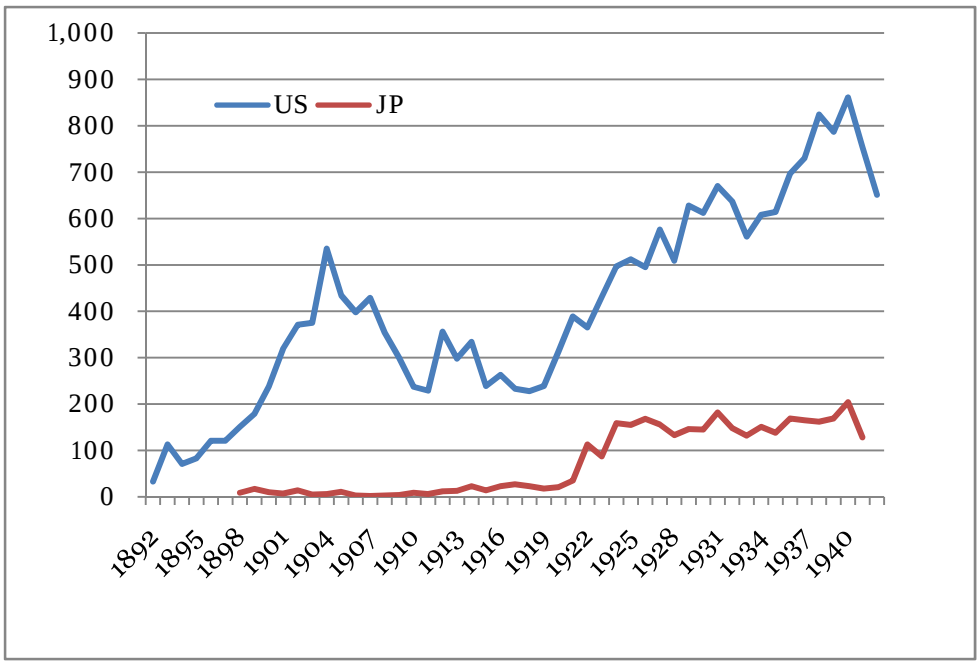
[24] GE, "Report of Foreign Business."

[25] About the contracts, see Nishimura, "General Electric's International Patent Management before World War II," 116-20.

those whose inventors were Japanese; that is, the figure shows the patents of affiliated companies whose inventors were foreigners.

Figure 3
GE Patenting in the United States and Japan



Note: The number of U.S. patents are those issued from 1892 to 1945 and sorted by application date. Japanese patents included GE patents issued in the name of affiliated companies, issued from 1898 to 1945, sorted by application date.

From this figure, it can be seen that the number of GE's Japanese patent applications before 1921 was much lower than thereafter. After 1922, GE's patent applications increased to about 150 per year, and that level was maintained, with nearly one-fourth of the patent applications filed in the United States. Under the patent control contracts, about 25 percent of patentable knowledge of GE had been transferred to Japan, and patents were filed continually.

Qualitative linkage by classification

Which fields of technology had been transferred to Japan? This question requires some attention. First, which patentable technology option should apply to the patents held by the affiliated companies? Under the contracts, a huge volume of patent specifications was regularly sent from GE to each company. This does not mean that the Japanese companies went ahead and submitted all the patent specifications that arrived. They had the right to choose which patents sent from GE to apply for, and it was also up to them to choose whether or not to continue paying the annual fee required for retaining a patent right. The decisions on which patents arriving from

GE to apply for, and whether or not to continue paying the annual fee (that is, whether or not to retain the patent right), were made by the patent section within each company. Only those patents deemed necessary for business purposes were applied for and registered in Japan. This type of contract was adopted as a means to maintain and exploit GE's foreign patents in each country effectively. Second, the patentable claims that affiliated companies chose not to file were returned to IGEC; IGEC had the option to file the claim itself.

Now let us analyze the classes of GE's Japanese patents. Table 4 shows the distribution of patent classifications. The sample comprises 3,010 patents filed from January 1, 1922, to December 31, 1941, and registered thereafter, and it includes patents of foreign inventors. Among the 3,010 patents, 2,903, or 96.4 percent, were inventions by U.S. residents; the other portion consisted of inventions by Germans, Dutch, British, and others. The patents whose inventors were European residents could have been filed under the same contracts with European companies affiliated with GE, but the practical treatment of such European-based patents is not clear so far.

The table classifies 3,010 patents by the Japan Patent Classification (JPC) of 1921, which consists of 207 classes. Although the JPC had no relationship with the USC, and the two distributions of U.S. and Japanese patents cannot be compared directly, we can grasp the trend or outline of knowledge transfer. The highest patent class was JPC 199, "High-frequency telecommunication," with 340 patents, or 11.30 percent. As described above, GE's U.S. patents were mostly in the field of radio tubes. As the U.S. classification combined this field with "lamp and discharge devices," when the JPC 199 patents were added to JPC 200, "Electric lamp," the proportion of "lamp and discharge devices" in the Japanese portfolio rose to about 21 percent. This ratio is higher than the corresponding ratio in the United States; GE's patents related to electric lamps and radio tubes were more intensively filed in Japan than in the United States. Therefore, it is notable that the knowledge transfer in those fields was comparatively high, or that Japanese companies "pulled" more information from their parent company during the interwar period. On the other hand, it is confirmed that knowledge in the electrical apparatus and equipment field was continually being transferred from the United States to Japan.

Transfer of Knowledge and Local Invention

Transfer to invention: Tokyo Electric's case

In this section, we consider the long-term effects of technology transfer under the international patent control contracts on the Japanese innovation system. First, we examine the case of Tokyo Electric.

Tokyo Electric was engaged in inventive activity from the beginning. We find the company's patent situation at its founding by Hakunetsu-sha

Table 4
Classification of GE's Japanese Patents: 1922-1941

JPC	Title	1922-1941	%
199	High-frequency telecommunication	340	11.30
193	Electrical control and regulation	296	9.83
200	Electric lamp	289	9.60
192	Electric power transmission and distribution	276	9.17
194	Electric switch	258	8.57
191	Electric transformer	242	8.04
190	Generator and motor	113	3.75
195	Electrical and magnetic measuring instrument	113	3.75
201	Electric heating: except electric furnace	84	2.79
105	Ceramic making machine	82	2.72
182	Plastics	75	2.49
197	Telegraph and telephone: the wire system	73	2.43
196	Electrical and magnetic measuring	61	2.03
206	Electrical treatment	60	1.99
198	Electric signal and electric indication	58	1.93
154	Metalwork	56	1.86
207	Electric: a miscellany	54	1.79
188	Electric insulation	42	1.40
156	Glass and enamel	37	1.23
19	Heat insulation, cool insulation, and refrigeration	28	0.93
27	Power transmission device	27	0.90
187	Electrical conduction	25	0.83
6	Steam turbine	23	0.76
1	Measuring instrument	23	0.76
106	Metalworking machine	21	0.70
144	Inorganic compound	17	0.56
4	Sound recording and sound regenerating	16	0.53
3	Optical instrument	14	0.47
14	Steam generator	11	0.37
20	Pump	11	0.37
145	Organic compound	11	0.37
	The others	174	5.78
	Total	3,010	

Note: Top 30 Japanese classes, based on the GE patents issued in the name of affiliated companies, applied for from 1922 to 1941, and issued from 1898 to 1945.

in 1904.[26] Two patents were registered by the individuals concerned, although there was no patent filed in the name of the company. One of the patents, No. 2366, "Incandescent Lamp," was filed in 1894, of which the holder was Fujioka. This patent covered the "Fujioka-type Lamp," which was put on the market. This device was a lighting apparatus that had a changeover switch to candlepower in the socket rather than a reinvention of the lamp itself. Another patent, No. 6381, "Warning Device for Electric Leakage," was filed in 1902, and this was jointly held by Fujioka and Shinjo. These patents indicate that even prior to the contract with GE, Tokyo Electric personnel were engaged in technological development activities. Following the 1905 contract, Tokyo Electric promoted R&D of lamps and lamp manufacturing methods concurrently with the adoption of foreign technology. In 1912, Tokyo Electric formed a laboratory within the company, which enhanced its organizational capability in terms of development. As a result, from 1906 to 1918, the number of patents filed and registered by Tokyo Electric increased to sixteen.[27]

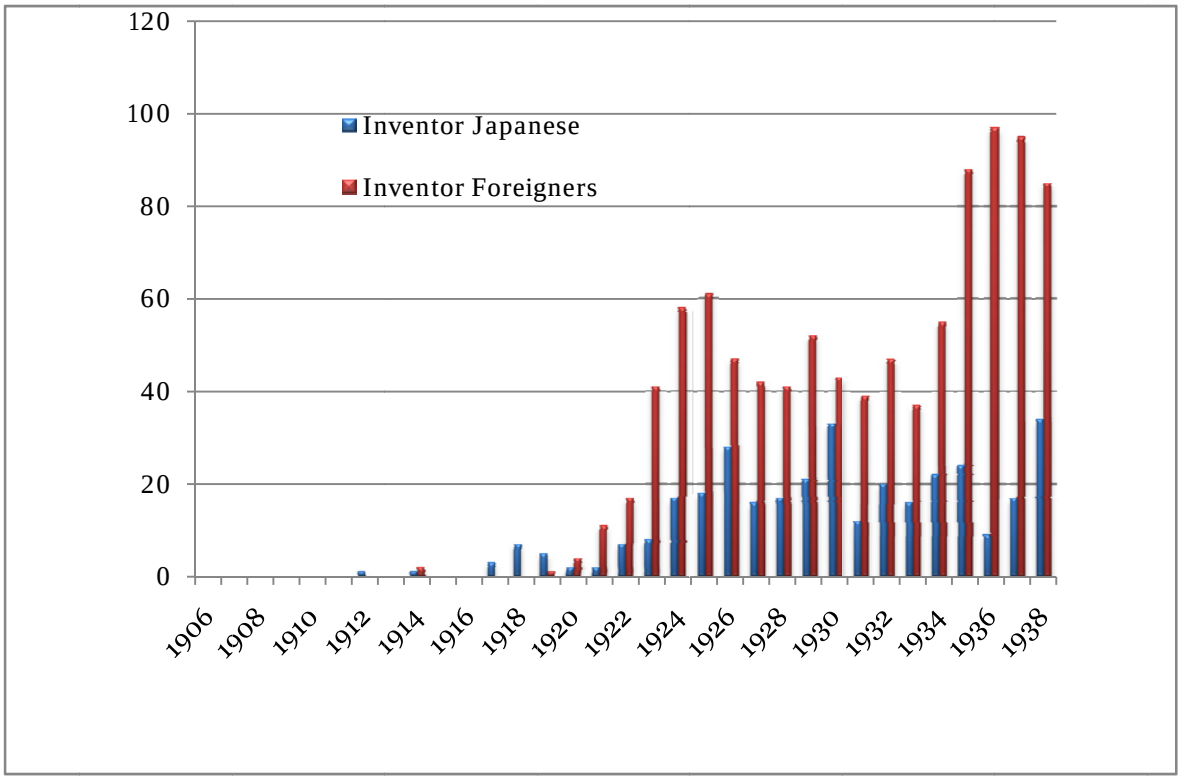
After the international patent control contract of 1919, especially after 1922, one year after Tokyo Electric reinforced its patent department, the inventive activity of Tokyo Electric had grown further. Figure 4 shows the trends within Tokyo Electric's patents, divided into those invented by foreigners, which were applied for as a proxy to GE, and those invented by the Japanese. The number of patents for inventions by foreigners, which means knowledge inflow into Japan, soared from the mid-1920s, and the number of applications increased to between forty and sixty per year between the latter part of the 1920s and the mid-1930s. The inflow indicated by these patents again soared from the mid-1930s to a high of ninety-six applications in 1936. On the other hand, the number of patents for inventions by the Japanese, which means the results of the R&D activities of Tokyo Electric, increased from five in 1919 to twenty-eight in 1928. Although that number fluctuated, an average of twenty patents per year was filed from that time onward. We can see that the inflow of technology and Japanese R&D were activated simultaneously during the interwar period.

Figure 5 shows the linkage between inflow of technology and Tokyo Electric's inventions based on patent classification. This figure shows 207 classifications of the JPC on the horizontal axis, and the percentage of each class in the patents of Japanese and foreign inventors. Again, the patents whose inventors are foreigners indicate knowledge inflow, and patents whose inventors are Japanese indicate invention within Tokyo Electric. This figure shows that the field in which knowledge inflow was active was also active in developing and inventing. For example, JPC 105, "Ceramic making machine," JPC 199, and JPC 200 indicate this trend. On the other hand, in JPC 154 "Metalwork" and JPC 156 "Glass and enamel," inventive activities were comparatively higher than inflow of technology. This could

[26] The number of applications indicates patents that were registered. There is no material available that indicates the entirety of applications.

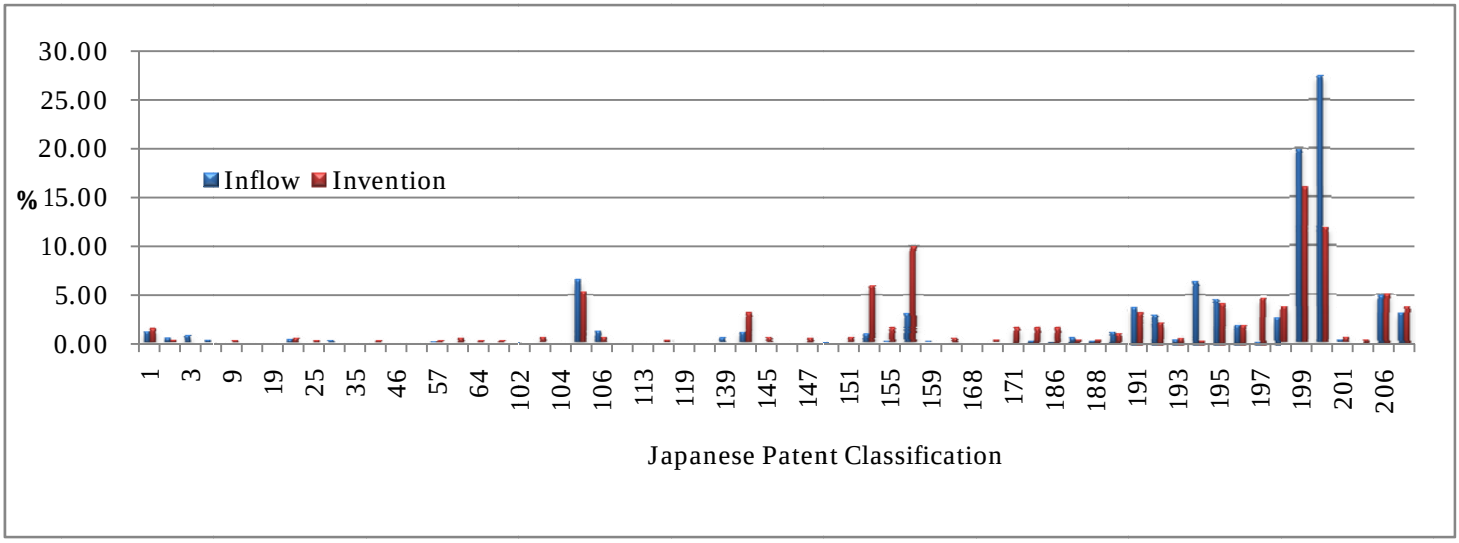
[27] This includes fourteen patents invented internally and two patents bought from outside.

Figure 4
Tokyo Electric's Patents



Note: The patents were issued from 1898 to 1945 in the name of Tokyo Electric and Tokyo Shibaura, which were applied for by Toshiba's "Mazda" Division, and sorted by application date from 1906 to 1938; divided by first inventor's address.

Figure 5
Technology Inflow and Invention: Tokyo Electric



be because Tokyo Electric devoted comparatively more energy to the development of electrical materials.

Transfer to invention: Shibaura Engineering Works case

The engineers at Shibaura had been engaged in the development of technology prior to the contract. Seventeen patents originated by Shibaura were registered before 1911. Among them, nine were invented by Keijiro Kishi. One of his patents, No. 5087, "Magnetic Paddy Iron Core for Dynamos and Motors," filed in 1901, was of such a high level that the invention was patented not only in Japan but also in the United States, Germany, France, and Great Britain, and it was awarded a Gold Medal when it was displayed in the St. Louis exhibition of 1905.[28]

On the other hand, filing procedures were also undertaken individually by inventors, and patents were registered in the inventor's own name during that period. Inventions created at the Shibaura works belonged to the individual inventors, and were not administered by the works.[29] When Shibaura entered into a contract with GE in 1912, it appointed a person to be in charge of patent affairs exclusively. The establishment of the patent section was driven by Kishi as a management activity. The purpose of its creation was to encourage inventions by institutionalizing "a system, for example, by which the company awards prize money to persons who invent excellent devices in the Works."[30]

The number of patent applications filed by Shibaura between 1912 and 1920 increased to 114. First, an increase in applications was brought about by the expansion of technological development stimulated by the inflow of knowledge from GE. Shibaura acquired many blueprints and a great deal of technological information by dispatching its engineers to GE's plants and laboratories.[31] Those visiting the United States took the initiative in development and patenting after their return home. On the other hand, there were several patents generated in the process of adapting foreign technologies to the humidity of the Japanese climate. It is said that most proposals managed by the patent section were from the design department and manufacturing sites rather than from the laboratory. Most inventions at that time were produced by developing apparatuses based on blueprints and other information supplied by GE.

Figure 6 shows the progress of Shibaura's adoption of foreign technology and R&D activities. It is obvious that the number of patents invented by foreigners, which indicates the adoption of technology, soared from 1922 onward. From around a hundred per year between 1922 and the mid-1930s, it peaked at 140 in 1931. On the other hand, while the number of patents invented by the Japanese was approximately fifteen per year

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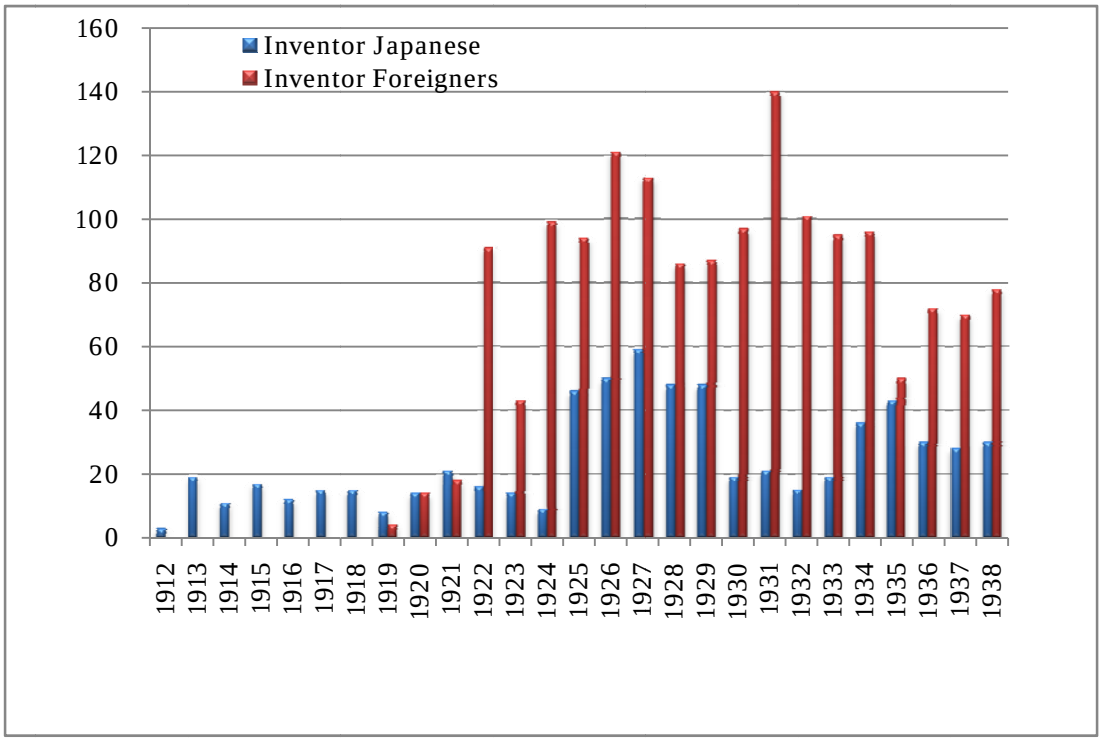
[28] Takekichi Otake, ed., *Kogakuhakushi Kishi Keijiro den* [The Life of Keijiro Kishi, Doctor of Engineering] (Tokyo, 1931), 28-30.

[29] Kimura, *Shibaura Seisakusho 65 nen shi*, 182.

[30] Otake, *Kogakuhakushi Kishi Keijiro den*, 31.

[31] Uchida, "Western Big Business and Adoption of New Technology in Japan," 157-58.

Figure 6
Shibaura's Patents

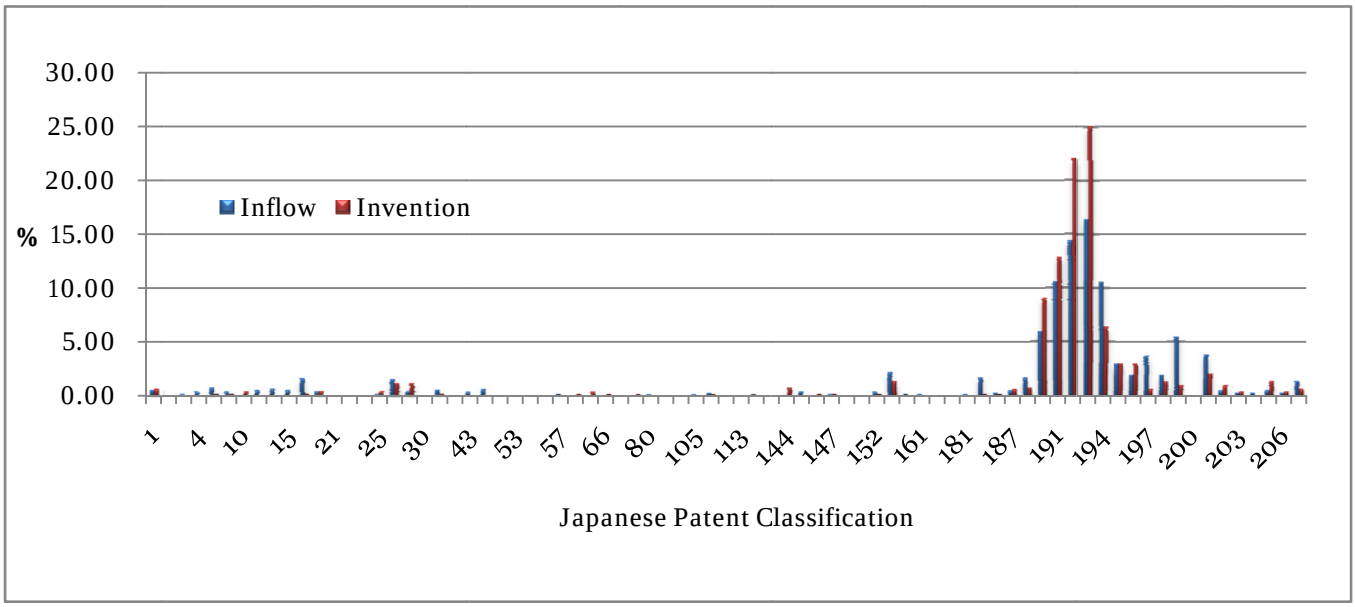


Note: The patents were issued from 1898 to 1945 in the name of Shibaura Engineering Works and Tokyo Shibaura, which applied by Toshiba's Shibaura Division; and sorted by application date from 1912 to 1938. Divided by first inventor's address.

until 1924, this increased to a high of fifty-nine in 1927. The figure shows that until 1929 the number of patents for inventions by Japanese engineers increased in line with those invented by foreigners. In other words, there was a certain linkage between the adoption of foreign knowledge via proxy application and the R&D activities of Shibaura Engineering Works.

Figure 7 shows the linkage of inflow of technology and invention for Shibaura Engineering Works in the same manner as shown in Figure 5. As in the case of Tokyo Electric, it is notable that the field in which knowledge inflow was active was also active in development and invention. This is seen in such classes as JPC 190 "Generator and motor," JPC 191 "Electric transformer," JPC 192 "Electric power transmission and distribution," JPC 193 "Electric control and regulation," and JPC 194 "Electric switch." This could be because the inflow of knowledge fostered invention in Japanese firms, or because of some kind of technological or knowledge interaction.

Figure 7
Technology Inflow and Invention: Shibaura



Conclusion

This essay raises a few questions: What kind of technological knowledge has been transferred over the Pacific Ocean, and to what degree? What kind of knowledge transfer has an effect on the long-term innovative behavior of Japanese companies, and to what extent?

In the interwar era, GE obtained about 12,000 patents that were applied for and registered in the United States. In Japan, GE applied for and registered about 3,000 patents in the name of affiliated companies. Therefore, GE transferred about one-fourth of its U.S.-patented inventions to Japan, and the company constructed patent portfolios in both countries.

Knowledge flow during the interwar period was made possible by a scheme in which GE contracted with its affiliated companies—namely, Tokyo Electric, Shibaura Engineering Works, and Toshiba in Japan—to control foreign patents in each territory for each other. Global networks of such a scheme fostered and secured international knowledge transfer, and this is seen in the case of Japan as well. Tokyo Electric and Shibaura received large amounts of technological knowledge covered by patents; further, knowledge transferred to Japan stimulated inventive activities in Japanese companies along with organizational capabilities for patent control. The result of technology interaction with affiliated companies appeared in the growth of patent applications. Accumulated R&D capabilities in Japanese companies served as one of the foundations of revival and high-rate economic growth after World War II.

During the interwar period, under the international patent control scheme, GE received the benefit of knowledge flow to Japan. GE applied for patents invented by Japanese engineers, which were limited to those applied for during the period 1922 to 1941, and numbered ninety-seven. Among those patents, twelve were classified under USC 313 “Electric lamp and discharge device.” This class included a famous invention, an inside-frosted bulb, which was invented by Kitsuzo Fuwa. At almost the same time, Marvin Pipkin introduced the same invention in the United States. Besides this class, seven patents each were classified under USC 361 “Electricity: electrical systems and devices” and USC 501 “Compositions: ceramic.” The number of patents classified under USC 501 is comparatively very low; however, this class contains inventions by U.S. engineers. Therefore, GE's patents were complemented by knowledge created by Japanese affiliated companies in some fields.

One can also point out the simultaneity of inventions in different countries. During the interwar period, GE and its Japanese affiliated companies put their development resources into similar fields. Electric lamps and discharge devices and radio vacuum tubes were “hot” fields, as were electrical equipment and apparatus meant for more voltage. While some fields found favor with single companies, in other fields the companies devoted their energies to the same specific technology at the same time. This phenomenon was probably caused and mutually affected by international knowledge transfer instituted by patent control contracts.