The Watchmaking Enterprises and the Growth of a Special-purpose Machine Tool Industry in Japan (1890-1960)*

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Abstract

This paper focuses on the production of machine tools by the Japanese watchmaking companies, particularly within the group Hattori & Co (current Seiko Group), between the 1890s and the 1960s. The workshop set up by this company to provide machines for its own needs led to the creation of an autonomous company at the beginning of the 1960s, Seiko Seiki Ltd, a competitive firm producing machines for customers out of the group. This spin-off process is the result of the development of organizational capabilities since the interwar period, which process is examined in this contribution.

Since the first attempts to manufacture watches in Japan, the use of precise machine-tools appeared to be a key issue to be able to produce watches accurate enough to compete with foreign watches. Hattori Kintaro, who opened a manufacturing plant at Tokyo in 1892, did acquire Swiss, German and American machine tools as early as the middle of the 1890s and went on until the Second World War. Besides, he opened a workshop within his factory in which foreign machine were copied. He engaged some University graduate engineers after World War I to supervise this production. The in-house manufacturing of machine tools grew steadily after World War II, in the context of the organization of the mass production of watches by University graduated engineers, numerously engaged by Hattori & Co in the 1950s. Machine-tools were a key element of this new system of production. Some Swiss automatic lathes were chosen and copied within the company, with the collaboration of the machine maker Tsugami and the professor Aoki Tamotsu from the University of Tokyo. The know-how obtained in this process made it possible for Hattori & Co to raise its range of products and to become a competitive machine tools maker, through its firm Seiko Seiki (1964).

Classification codes: L 64, N 65, N 85, O 32

Keywords: Machine tool, Watchmaking, Hattori & Co, Technology transfer

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Introduction

Today, Japan is the world's leading machine tool producer, with around 30% of the world market. It has been in the lead since 1982, whereas it was only the fourth largest producer, behind the United States, Germany and the USSR, in 1975.[1] Two factors are traditionally put forward to explain this dominant position, which Japan acquired in the course of the 1980s.[2] First of all, it was due to a technological revolution, with the advent of numerical controls (NC) and the development of machining centres. Although Japan was late in acquiring this new technology which appeared in the United States in the early 1950s, it was quick to take it on board and use it to ensure its growth worldwide. The proportion of NC-equipped Japanese machine tools rose from 7.8% in 1970 to 49.8% in 1980 and 75.7% in 1990.[3] Second, it was a consequence of a domestic industry that flourished after the Second World War. Demand from domestic industry (automobiles, shipbuilding, electronics, machines, etc.) underpinned the growth of the machine tool industry in Japan. Even though it only became the No. 1 manufacturer worldwide at the beginning of the 1980s, Japan did not completely gear this industry to exports, as it did for the majority of its other industrial sectors. The share of exported machine tools rose from 7.7% in 1970 to 39.5% in 1980 but subsequently averaged 37.2% in the 1980s.[4]

Yet the success of the Japanese machine tool industry worldwide was also due to the great diversity of firms that helped found it. There were not only a handful of large firms producing highly standardized machines, especially for the machine and automobile industry. After 1945, newcomers also began to arrive, in particular textile and mechanical engineering firms that diversified into the machine tool sector (Moriseiki, Toshiba, Toyoda, Tsudakoma, etc.).[5] These were generally former users of machine tools, whose repair and maintenance workshops had reached a sufficiently high technological level to enable them to start producing their own machine tools in the interwar period, then selling them. This is what happened in particular in the watchmaking industry, the subject matter of this paper.

1. The Japanese machine tool industry: a general overview

The machine tool industry underwent a classic process of technology transfer in Japanese economic history, characterized by the appearance of an import substitute industry.[6] However, this sector has a special feature: machine tools were one of the main instruments designed to facilitate the development of the Japanese machine industries, such as arms, shipbuilding, railways and electrical engineering.

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[1] Sangyo Gakkai (1995), *Sengo nihon sangyo shi*, Tokyo: Toyo keizai shinposha, p. 403.

[2] Sangyo Gakkai (1995), op. cit., pp. 382-412 and Fujita Yasumasa (2008), *Kosakukikaisangyo to kigyo keiei – naze nihon no mashiningusenta ha tsuyoi no ka*, Kyoto: Koyoshobo.

[3] Sangyo Gakkai (1995), op. cit., p. 401.

[4] Sangyo Gakkai (1995), op. cit., p. 401.

[5] *Nihon kaishashi soran*, Tokyo: Toyo keizai shinposha, vol. 1 (1995).

[6] Sawai M. (2006), "L'industrie japonaise des machines-outils et les Etats-Unis pendant les périodes de l'avant-guerre et de la guerre", *Histoire, Economie et Société*, vol. 2, pp. 227-243, Sawai M. (2000), "Meiji koki no kosakukikai kogyo", *Osaka Economic Papers*, vol. 50/1, pp. 1-30 and Nagao K. (2004), *Nihon kosaku kikai shiron*, Tokyo : Nikkan kogyo.

The need for precise machine tools largely explains the specificity of this sector, where imported and domestic products coexisted, whereas the latter tended to replace the former in the other sectors of the economy.[7] From a relatively early stage, there were two types of machines: imported, higher-quality machines that were more expensive and were meant for the army and major companies, and lower-quality, cheaper machines produced domestically that were purchased by the many small companies that appeared in the 1890s. Four phases of development can be seen between 1860 and 1960.

The first one was that of Japan's initial contact with machine tools (1860–1914). This era was characterized by imports of machines, mainly from the United Kingdom, Germany and the United States.[8] They were initially purchased to equip the arsenals of the army and the navy.[9] Civilian customers mainly came under the heading of heavy industry (shipbuilding, railways, machines). Domestic production slowly got under way in the 1880s. The country's first lathe was reportedly built in 1885 by the founder of Ikegai Iron Works to meet his own needs.[10] Here as well, demand from the military sector fuelled growth. Mindful of the need to promote a domestic machine tool industry, the army was instrumental in facilitating technology transfer to private companies after the war with Russia, for example by forwarding blueprints of machines and sending its own engineers.[11] Yet despite the sharp increase in domestic production, the industry continued to rely heavily on imports.

Technology transfer really came in a second phase, lasting from 1914 to 1930. The main technique used was that of reverse engineering. This period was a transitional phase marked by a balance between imports and production, which revealed a bipolarization of demand between purchasers of expensive, high-performance imported machines (army, heavy industry) and those who preferred cheaper, lower-quality domestic goods (small firms). The first machines were exported, but primarily concerned trade towards zones under Japanese influence and were probably meant for Japanese companies. At this stage, the industry was not yet able to compete on the world market.

The third phase was a period of strong growth in the sector due to the wartime manufacturing boom and was characterized by predominantly domestic production (1930-1945). Initially, imports, primarily from the United States and Germany[12], also grew, peaking at 24,800 tons in 1939. Subsequently, however, the Japanese government introduced import controls (1936) while the United States banned machine tool exports to Japan (1940), leading to a sharp drop in imports. At the same time, domestic production mushroomed, rising from 14,000 tons in 1935 to 100,800 tons in 1938 and a peak of 140,753 tons in 1943. As a result of this expansion, the number of companies increased from 397 in 1932 and 1978 in 1938, with a clear majority of small firms.[13] This led directly to intervention by the State, which sought to plan this expansion by adopting a law on the machine tool industry (1938).

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[7] Minami R. e.a. (1995), *Acquiring, Adapting and Developing Technologies: Lessons From the Japanese Experience*, Macmillan, and Kyokawa Y. (1995), *Nihon no keizai hatten to gijutsu fukyu*, Tokyo: Toyo keizai shinposha.

[8] Sawai M. (2006), "L'industrie japonaise…", op. cit., p. 228.

[9] Yamazaki H. (2004), *Nihon keieishi no kiso chishiki*, Tokyo: Yuhikaku, p. 54.

[10] Nakaoka T., Suzuki J. and Miyachi M. (2001), *Sangyo gijutsushi*, Tokyo: Yamakawa, p. 171.

[11] Nihon sangyo gijutsushi gakkai (2007), *Nihon sangyo gijutsushi jiten*, Tokyo: Shibunkaku, p. 71.

[12] Sawai M. (2006), "L'industrie japonaise…", op. cit., p. 228.

[13] Friedman D. (1988), *The Misunderstood Miracle. Industrial Development and Political Change in Japan*, New York: Cornell University Press, p. 43.

The objectives of that law was to support the growth of the production, as well as the increase of the technological level of domestic firms, through the adoption of fiscal and financial measures favoring the companies of more than 200 machines,[14] in order to develop the equipment of firms in arms production and aeronautics.[15] This policy encouraged the concentration in the machine tools industry and led zaibatsu to invest and diversify into this sector.[16] Exports continued to grow but remained limited to the empire.

Finally, the fourth phase is that of reconstruction (1945–1960). Machine tools played a key part in Japanese industrial policy, for they were expected to bring about the rebirth of an export-oriented domestic industry. Once again, domestic machines coexisted with foreign machines. After the US authorities lifted their export ban, imports rose from 81 tons in 1950 to 14,611 tons in 1960. In parallel, the State backed the rebirth of a domestic industry geared to civilian production, for example by deciding to grant subsidies for prototype design (1953).[17] Initially boosted by the Korean War, domestic production took off, rising from 2,948 tons in 1950 to 6,591 tons in 1955 and 59,616 tons in 1960. Yet despite this strong growth, the Japanese machine tool industry was still in its infancy and was only a very small player on the world market (see table 1). Its share of world production was a mere 5.2%, and above all it had a trade deficit in this sector. It still lagged far behind the two machine tool giants, the United States and Germany. However, the growth of Japanese machine tool production in the 1950s allowed newcomers, including watchmaking firms, to enter the market.

Table 1: World machine tool production and use, in millions of dollars and as a %, 1960[18]

	USA	Western Europe	Japan	Communist countries	Other	Total
Production	786	1242	164	938	14	3144
as a %	25.0	39.4	5.2	29.8	0.4	100
Use	629	1093	214	938	270	3144
as a %	20.0	34.7	6.8	29.8	8.6	100

2. Machine tool use and production in the Japanese watchmaking industry

The precision of machine tools, primarily automatic lathes, became a crucial issue as soon as the first attempts at large-scale manufacturing of watches in Japan were made. In order to compete with imported watches, watches manufactured in Japan had to be sufficiently accurate and therefore produced using imported machines. Accordingly, Osaka Watch Manufacturing Co. and Japan Pocket

[14] Tsushosangyosho (1976), *Shoko seisakushi*, Tokyo: Tsushusangyo kenkyusha, vol. 18, pp. 450-469.
[15] Sawai M. (2005), "Taiheiyo sensoki no kosakukikai kogyo", in *Senjiki nihon no kigyo keiei*, Tokyo: Bushindo, pp. 41-108.
[16] Keieishi gakkai (1996), *Nihon kaishashi kenkyu soran*, Tokyo: Bushindo, pp. 244-245.
[17] Nihon sangyo gijutsushi gakkai (2007), op. cit., p. 71.
[18] Jones D. (1984), "Machine Tools: Technical Change and a Japanese Challenge", in Shepherd G., *Europe's Industries*, Ithaca and London: Cornell University Press, p. 195.

Watch Manufacturing Co., two firms that started making watches in the early 1890s, both relied on foreign machine tools, American for the former and Swiss for the latter.[19] This was also the case with the leading Japanese watchmaking firm, Hattori & Co Ltd. (Seiko), whose origins dated back to the late 1870s.[20]

2.1 Hattori & Co's acquisition of machine tools before the Second World War

The founder of Hattori & Co, Hattori Kintaro, managed a watch repair workshop in Tokyo (1877) then a sales outlet (1881). During the 1880s, he established himself as one of the leading watch importers. Subsequently, as a result of the boom in the Japanese watchmaking market, he started manufacturing clocks (1892) then pocket watches (1895) in his factory Seikosha. He succeeded brilliantly, particularly as far as watchmaking was concerned, a sector in which Hattori had no competitors until Citizen Watch Co was founded in 1930. Even though Hattori & Co benefited from a protectionist customs policy, with customs duties on nickel and silver watches rising for example from 5% of the value before 1899 to 50% from 1906 onwards,[21] the company owed its success to the adoption of an industrialized production mode, which was organized in a two-phases process.

Table2: Japanese and Hattori & Co watch manufacturing, as the number of watches, in ten-yearly annual averages, 1905–1945[22]

	1905–1915	1916–1925	1926–1935	1936–1945
Watches	695,444	966,400	1,831,058	1,519,242
Hattori & Co watches	324,330	551,909	845,647	396,611
Hattori & Co as a %	46.6	57.1	46.2	26.1
Watches	62,220	212,572	588,581	1,124,299
Hattori & Co watches	60,256	168,935	313,220	839,260
Hattori & Co as a %	96.8	79.5	53.2	74.6

Firstly, there was a phase of setting up the production of watches. It took place from 1892 to World War I and was characterized by a strong dependence on imported machines and some attempts to copy them. Imports consisted of specialized machines, primarily automatic lathes for manufacturing specific watchmaking components, such as plates, blanks, gears and balance wheels, as well as pinion cutters.[23] They were not directly available, either on the Japanese market or through the major trading

[19] Uchida H. (1986), *Osaka Watch Incorporated, 1889-1902*, Tokyo: Hattori Seiko Co and Hirano M. (1957), *Meiji zenki Tokyo tokei sangyo no rodoshatachi*, Tokyo: s.n., pp. 144-146. However, owing to financial reasons, these two companies stopped making watches, in 1905 and 1901, respectively.

[20] Hirano M. (1968), *Seikoshi hanashi*, Tokyo: Seiko and Seiko Co (1996), *Seiko tokei no sengoshi*, Tokyo : Seiko Co.

[21] Okurasho (1960), *Nihon kanzei – zeikanshiryoka*, Tokyo: Okurasho zeikanbu, vol. 2.

[22] Seiko Institute of Horology, Tokyo. No figures are available for before 1905.

[23] For the machines in use in American watchmaking factories in the late nineteenth century, see Marsh E.A. (1896), *The Evolution of Automatic Machinery as Applied to the Manufacture of Watches at Waltham, Mass., by the American Waltham Watch Company*, Chicago: Geo. K. Hazlitt & Co.

houses. Destined for a specific clientele, they were manufactured abroad by specialized firms or directly by watchmaking enterprises and were therefore hard to procure. This was the main reason why Hattori went on two business trips to the United States and Europe. The first took place in 1899, and led him to tour the large US watchmaking plants (Waltham Watch Co and Elgin Watch Co), who refused to sell him machines.[24] However, he could order some from the company Brown & Sharpe, which sold to Hattori in 1902 an automatic screw machine and a universal grinding machine.[25] He then travelled to Germany, where he bought his first foreign machines.[26] His second trip came in 1906. As he had become one of the largest importers of American watches to Japan in the meanwhile, he received a warm welcome at Waltham Watch Co, which agreed to sell him machines.[27] Finally, Hattori also picked up foreign watchmaking machines in Japan: when Japan Pocket Watch Manufacturing Co went bankrupt, he bought up the firm's Swiss machine tools in 1901.[28]

The other way to acquire machine tools was to manufacture them in a plant. The technical staff of the company was then limited and consisted mainly in mechanists whose training was essentially practical. Here, mention should be made of the key role played by Yoshikawa Tsuruhiko, a former employee of a Japanese watch dealer who set up in business in 1886 as an independent mechanic in the Tokyo area.[29] Yoshikawa, who was hired by Hattori in 1892 as a technical director for the Seikosha plant, supervised the production of the machines needed to manufacture clocks, and then watches. His first machine was a pinion cutter, which he built in 1909 on the basis of a manufacturers' catalogue as well as his direct observation during Hattori's second trip to the United States, in which he took part.[30] Until his retirement in 1932, he headed an internal machine workshop in Seikosha which developed a number of specialized machines, in particular screw-making machines, turning machines and various lathes.[31] The models copied were Swiss and American, and the production technique used was that of reverse engineering. This workshop also served as a training centre for technicians in charge of watch manufacturing at Seikosha. Hattori tried as well to employ graduates from the technical colleges, as it happened at that time in big industrial companies, but was unsuccessful until 1914. The first engineer hired trained in such a school was Masaki Shigeki, engaged in 1900 after the end of his studies in mechanics at the Tokyo Higher Technical School (current Tokyo Institute of Technology). However, he already left Seikosha in 1905 for the Ministry of telecommunications.[32] No other graduates from technical colleges were engaged until 1914. The production of machines within the company was until then carried out by Yoshikawa and mechanists trained under his direction. Nevertheless, this technical staff lacked theoretical knowledge to supervise and support the adoption of the mass production system.

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[24] Wakayama S. (2002), *Tokeio: Seiko okoku wo waraita otoko*, Tokyo: Seiko Institute of Horology, p. 172.
[25] Kindly communicated by Ross Thomson, University of Vermont, USA.
[26] Wakayama S. (2002), op. cit., p. 176.
[27] Wakayama S. (2002), op. cit., p. 208.
[28] Hirano M. (1957), *Meiji zenki…*, op. cit., pp. 145-146.
[29] Hirano M. (1973), *Yoshikawa Tsuruhiko*,Tokyo : Seiko Co.
[30] Wakayama S. (2002), op. cit., p. 213.
[31] Hirano M. (1973), *Yoshikawa …*, op. cit., p. 48.
[32] Uchida H. (1985), *Tokei kogyo no hatten*, Tokyo: The Seiko Institute of Horology, p. 377.

In a second phase, which began during World War I and may be related to the production of weapons, Hattori did hire engineers who graduated from colleges and universities. The first one is Takeuchi Ryuzo, trained at the Tokyo Higher Technical School. He was engaged in 1914 in order to oversee the electrification of factories and the reorganization which followed.[33] However, the engineer who played the most important role is Kawada Genzo, son-in-law of Hattori Kintaro and responsible for the production of machines from 1917 to 1946.[34] Graduated from the Department of machines of the Faculty of engineering of the University of Tokyo in 1915, he was then hired by the Kawasaki Shipbuilding Co before joining Seikosha in 1917 to manage the section of machines and the production of military equipment.[35] He became member of the board of directors of Hattori & Co (1917) and of the factory of watches, Daini Seiksoha Co when it was founded (1937), two positions he occupied until 1946.[36] The production of watches on a large scale was organized at Hattori under his direction. The number of technicians and engineers (*gijutsuin*), whose training background is unknown, increased from 21 persons in 1929 to 36 in 1935 and 43 in 1940.[37]

At the end of the war, the Seikosha plant did hold 4'367 machines.[38] Yet in-house production did not suffice to meet overall needs. Hattori kept on importing products, especially from Swiss companies, in particular Henri Hauser SA, which supplied Omega, as well as automatic lathes manufacturers such as Bechler, Pétermann and Tornos. Between 1900 and 1920, these firms brought out new and extremely precise models called "Swiss lathes", whose main feature was that they brought the part to be machined to a fixture and not the opposite, as was the case with the other manufacturers. These new models quickly proved to be a real hit with watchmaking manufacturers.[39] In the 1930s, the factories of the Hattori group were equipped with these new Swiss machines tools.[40]

Hattori's main rival, Citizen Watch Co, founded in 1930, adopted a similar policy of acquiring watchmaking machine tools, also based on Swiss imports (Dixi, Mikron, Lambert, Pétermann)[41] and on the manufacturing of machines in the company's workshops. Here as well, the models were Swiss: the first automatic lathe that Citizen produced in 1937 was a copy of a Bechler lathe.[42] Nevertheless, Citizen adopted an original strategy by spinning the machines workshop off into a legally independent subcontracting firm, Nitto Precision (1938). Subsequently, however, the latter firm was merged back into Citizen in 1940, as part of the shift to a wartime production mode.[43]

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[33] Uchida H. (2000), *Evolution of Seiko, 1892-1923*, Tokyo: The Seiko Institute of Horology, p. 91.
[34] The University of Tokyo, Library of the Graduate School of Economics, report of Hattori & Co, April 1936.
[35] Uchida H. (1985), *Tokei…*, op. cit., pp. 401 and 413.
[36] Hirano M. (1968), *Seikosha…*, op. cit., p. 82.
[37] Hirano M. (1968), *Seikosha…*, op. cit., annexe pp. 22-23. Unknown before 1929.
[38] National Diet Library, Tokyo, GHQ SCAP, CPC12099-12101, Kure Naval Arsenal (Stored in Hattori Seikosha), Code Number 39-158(e), 23 January 1948.
[39] Cortat A., « Tornos », in *Dictionnaire historique de la Suisse*, www.dhs.ch and Marti L. (1999), « Nicolas Junker, Fabrique de machines, Moutier (1883-1905) ou les difficultés d'une entreprise innovante à la fin du XIXe siècle », in Tissot L., « Entreprises et réseaux. Les acteurs de l'industrialisation dans l'Arc jurassien », *Actes de la Société jurassienne d'Emulation*, pp. 298-305
[40] *Hiaringu*, Tokyo : Seiko Institute of Horology, vol. 4, p. 12 and *Hiaringu*, op. cit., vol. 10, p. 2.
[41] Interview with Motomochi Kuniyuki, a former Citizen engineer, Tokyo, 26 April 2007.
[42] Haruta H. (2006), *Tokeiya ga sodateta sekai no besutosera mashin. Citizen Cincom monogatari*, Tokyo: Nikkan, p. 20.
[43] Citizen Co (2002), *Shashi*, Tokyo: Citizen Co, vol. 1, p. 41.

2.2 Changes in the Swiss machine tools export policy (1934-1965)

The 1930s were a pivotal decade for the watchmaking industry. On the one hand, the nature of the product changed radically, with a shift from pocket watches to multifunctional wristwatches (calendar, chronograph, automatic mechanism, etc.). In addition, new materials began to be used widely (alloys for balance wheels, artificial stones to replace rubies).[44] This created a need for new types of machine tools that were increasingly precise and suited to the assembly of increasingly complex mechanisms. What is more, the main watchmaking nations (Germany, the United States and Japan) redirected their own watchmaking industries to arms manufacturing. As a result, R&D in the machine tool field moved away from watchmaking as such. Thanks to this combination of factors, Switzerland had a virtual monopoly over the production of new machine tools for the watchmaking industry in the 1930s. In order to defend their dominant position, Swiss watchmakers set up a cartel in the interwar period, recognized and supported by the State from 1934 onwards, which strictly controlled exports of machine tools that were "specifically for the watchmaking industry".[45]

In 1934, the Swiss watchmaking industry drew up a list of machines which were first subject to heavy export duties, then to the granting of official export licences from 1939 onwards.[46] After the war, the Swiss authorities set up a special body to monitor the purchase or sale of such machines. Machor SA, whose shareholders came from the watchmaking industry, the machine industry and the workers' trade union FOMH, was established for this purpose in 1946.[47] It leased watchmaking machine tools, but only to countries that had signed a watchmaking agreement with Switzerland. However, as the Japanese watch market was not liberalized until 1961, imports of watches to Japan were subject to a very strict quota system.[48] In view of these conditions, Machor refused to deliver the machines ordered by Hattori & Co and Citizen in the early 1950s, even though all were aware of the ineffectiveness of such a policy, which encouraged Japanese manufacturers to copy Swiss machines. The watchmaking manufacturers, who controlled Machor, knew that their restrictive policy was ineffective but maintained it until 1965 as leverage to force open the Japanese watchmaking market. The director of Ebel, Charles Blum, cogently summed up the position of the Swiss watchmakers in 1959: "The said restrictions could however be maintained, in any event as a negotiating tool".[49] Meanwhile, the Japanese proceeded to copy these machines.

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[44] Information kindly provided by Jean-Michel Piguet, assistant curator at the International Watchmaking Museum of La Chaux-de-Fonds.

[45] Donzé P.-Y. (forthcoming), « Un cartel contre les transferts de technologie : l'horlogerie suisse (1900-1970) », in Cortat A., *Entreprises et cartels en Suisse. Etude de cas*, Neuchâtel : Alphil.

[46] Koller C. (2003), *« De la lime à la machine ». L'industrialisation et l'Etat au pays de l'horlogerie. Contribution à l'histoire économique et sociale d'une région* suisse, Courrendlin : CSE, p. 468.

[47] *Feuille fédérale*, 1950, p. 71.

[48] Nihon tokei yunyukai (1985), *Yunyu tokei no ayumi: nihon tokei yunyu kyokai 30 nenshi*, Tokyo : Nihon Tokei Yunyūkyōkai.

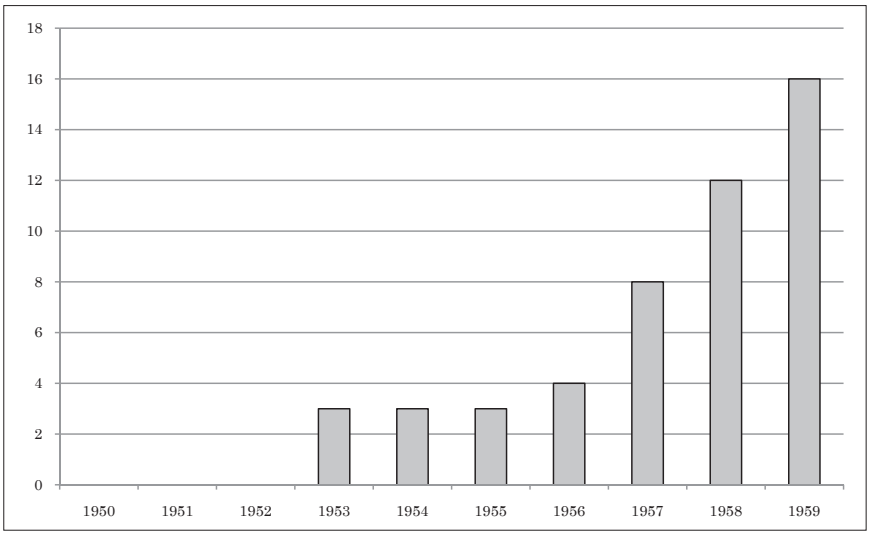
[49] Archives of the Republic of Canton of the Jura, Porrentruy (Switzerland), Fonds Péquignot, 122, minutes of the « Statut horloger » working group, 14 August 1959.

2.3 Hattori & Co's acquisition of Swiss machine tools after 1945

After the war, new machine tools were needed to rebuild the Japanese watchmaking industry. The State, and in particular the Ministry of International Trade and Industry (MITI), opted for a deliberate policy of equipment modernization based on an ambitious plan to double wristwatch production capacity by pooling facilities at Hattori, Citizen and Orient. It earmarked around 250 million yen over a one-year period (1952), broken down as follows: building extensions – 25 million; new machine tools – 155 million, including 60 million for machines imported from the US and Switzerland; and materials imports – 60 million. The funds were borrowed from the Development Bank of Japan, an institute founded in 1951 to help rebuild the country.[50]

The production of machine tools within the watchmaking companies after 1945 must be viewed in the context of the implementation of the mass production system, similar to that observed in aeronautics and machine tools sectors before and during World War II.[51] Numerously engaged at Hattori & Co at the beginning of the 1950's, the university graduated production engineers reorganized the production system, a process in which the massive use of precise machine tools played a key role. During the 1950's, a total of 49 engineers who graduated from universities was hired by Hattori & Co for its watchmaking plants (cf. figure 1).

Figure 1: University graduated engineers hired by Hattori & Co, 1950-1959[52]



These engineers were trained in the major faculties of engineering of Japan, mainly at the Department of precision machines of the University of Tokyo (former Department for Arm Production, 10 engineers) and the Faculty of engineering of the University of Yamanashi (6 engineers). They

[50] *Nihon keizai shimbun*, 6.12.1951.

[51] Maeda H. (2001), *Senjiki kokuki kogyo to seisan gijutsu keisei – Mitsubishi kokuki enjin to Fukuo Junji*, Tokyo : Tokyo University Press and Yamashita M. (2002), *Kosakukikai kogyo no genba shi, 1889-1945 – shokuninwaza ni idonda gijutsushatachi*, Tokyo: Waseda University Press.

[52] Seiko Institute of Horology, enjinia no torokubo, 1950-1959.

did set up a new system of production based on the perfect interchangeability of parts, thanks to the adoption of new tools such as blueprints with tolerance standards, gauges, quality control, thousandth of millimeters as basic unit (rather than hundredth of millimeters), etc. In this context, the use of high-quality machine tools turned out necessary because they allowed the realization of this new system of production. Yet import of foreign machines and technology transfer was hampered by opposition in Swiss watchmaking circles to machine exports to Japan. Unlike other sectors of industry, there were no technical assistance contracts or joint ventures in the field of machine tools for watchmaking before the early 1960s.[53] Technology transfer took a more traditional form, that of copying. It was facilitated by research conducted in several bodies, particularly at the Faculty of engineering of the University of Tokyo and at the Machine Laboratory (*Kikai shikenjo*) of the Ministry of Commerce and Industry (MITI since 1949).

At first, the watchmaking firms benefited from the research activities carried out at the Faculty of engineering of the University of Tokyo in the interwar period, under the auspices of the Department for Arms Production (*Zohei gakka*).[54] This body, which was founded in 1887 to train engineers for the army and navy arsenals, started doing research in 1920 on mass production of munitions that was also made available to civilian industry. The main professor active in this field was Aoki Tamotsu (1882-1964),[55] trained under the direction of Okochi Masatoshi, professor at the Department (1911), director of the Rikagaku Research Center (1921) and influent industrialist heading the Riken Konzern (1927).[56] A graduate of the Engineering Faculty of the University of Tokyo in 1920, Aoki was appointed professor at the Department. After studying mine and torpedo manufacturing, he shifted the focus of his research to systems for mass production of weapons in use in Germany and encouraged the use of machine tools that were accurate to thousandths of millimetres – not hundredths – as well as complete interchangeability of parts. He also worked from 1928 onwards for civilian industry (cameras, watches, measuring instruments), where he adopted a similar policy of reliance on machine tools. In all, he published and translated from German some forty works on the use of machine tools in industry. After 1945, he moved to the watchmaking industry, becoming president of the Horological Institute of Japan (*Nihon tokei gakkai*) when it was restructured in 1948.[57] In addition, he worked as a consultant for watchmakers, including Hattori.[58]

The second centre which supported Hattori & Co in its policy to produce machine tools is the Machine Laboratory, established by the Ministry of Commerce and Industry in 1937, particularly with the aim to support the national production of machine tools and the rise of the technological level of the machine manufacturers. Indeed, until the end of the war, this laboratory did evaluate the quality

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[53] Nihon Kosaku kikai kogyokai (1982), *Haha naru kikai 30 nen no ayumi*, Tokyo: Nihon Kosakukikai Kogyoukai, p. 88.
[54] Tokyo University (1987), *Tokyo daigaku hyakunenshi bukyokushi*, Tokyo: Tokyo University, vol. 3, pp. 235-252. This is one of the ten departments of the Faculty of engineering. The others are aeronautics, applied chemistry, architecture, civil engineering, electricity, machines, metallurgy, mines and shipbuilding.
[55] *20 seki nihonjin na jiten*, Tokyo: Nishigai, vol. 1 (2004), p. 12
[56] Udagawa M. (2002), *Nihon no kigyokashi*, Tokyo : Bunshindo, pp. 205-216.
[57] *Kokusai tokei tsushin* (1979), pp. 44-45.
[58] *Kokusai tokei tsushin* (1979), p. 47.

of machines the authorities asked private companies to copy (*sodoin shiken kenkyu*).[59] After the war, the Machine Laboratory did continue its task to break down foreign machines it imported. They were analyzed during some workshops in which took part engineers from private firms, contributing then to diffuse techniques and knowledge to them. The Machine Laboratory diversified as well into several civil sectors, of which the watchmaking industry.[60] Hattori & Co and Citizen took actively part to the R&D led by this laboratory, through the Association of the Japanese Clock-/Watch-making Industry (*Nihon tokei kogyokai*).[61] Founded in 1946, this association gathered academics, among whom professors and researchers of the former Department for Arms Production of the University of Tokyo, representatives of private firms, as well as the employees of the Machine Laboratory, where R&D took place. It mainly focused on the production of particular parts for watches (gearing, spring, etc.), but developed also some machines specifically designed for watchmaking.

The experiences acquired through common R&D allowed then Hattori & Co to envisage the internal production of machine tools needed for the setting up of the system of mass production. At first, starting in the early 1950s, Hattori tried to order machines from its former Swiss business partners but was turned down by Machor and some machine manufacturers, a development which paradoxically accelerated the process of technology transfer. In 1952, two employees from the Seiko group, Hattori Reijiro, the grandson of the founder of the company and director of Seikosha (the clock factory) and Fuse Yoshinao, a member of the board of directors of Daini Seikosha (the wristwatch factory) went on a tour of the West, to visit various watch and machine manufacturing plants and observe the production modes in use. In the United States, they visited the Elgin and Waltham factories as well as the machine tool manufacturer Brown & Sharpe.[62] In Switzerland, they primarily toured Longines, where they had access to the manufacturing rooms, as well as numerous machine manufacturers (see table 3). In 1953, Hattori Shoji, the president of the group, and Sato Saburo, technical director at Seikosha, went on a three-month tour of Switzerland, Germany and France. They mainly visited German watchmakers as well as various firms in Switzerland.

Table3: Swiss firms visited by Hattori Reijiro and Fuse Yoshinao, 1952[63]

Watchmakers	Parts manufacturers	Machine manufacturers
Lanco, Longines, Movado, Vulcain, Zodiac	Incabloc	Bechler, Hauser, Kummer, Mikron, Oerlikon, Safag, Société genevoise, Studer, Tripet

Upon his return, Hattori Shoji arranged to acquire these technologies, with a view to not only importing Swiss automatic lathes but also manufacturing them in his own plants. For this purpose, in the first half of the 1950s he sent several of his engineers on study tours of Switzerland as an

[59] Sawai M. (1990), "Kosaku kikai", in Sinichi Y., *Sengo nihon keieishi*, Tokyo: Toyokeizai, vol. 2, p. 147 and *Kikai jikkenjo nijungo nen shi*, Tokyo: Kogyogijutsuin kikaijikkenj (1963), pp. 56-57.
[60] *Kikai jikkenjo* ... (1963), op. cit., pp. 65-68.
[61] *Nihon tokei kyokai 30 nen shi*, Tokyo : Nihon tokei kyokai (1980), pp. 16-18.
[62] Seiko Co (1996), op. cit., pp. 39-40.
[63] Seiko Co (1996), op. cit., p. 39.

essential part of engineer training at his firm. During their stay, they wrote reports on the machines observed and their possible use. These documents were then discussed by the technical directors of Daini Seikosha, who picked what they felt was the best automatic lathe and decided to produce it in Japan.[64] This was the M7 lathe by Tornos, which was very popular immediately after the war and was considered one of the most accurate automatic lathes.

Tomine Ritsu, the engineer supervising this technology transfer, was representative of the new generation of university engineers recruited by Hattori & Co from the late 1930s onwards who helped introduce a mass production system in watchmaking. These engineers, who were trained at engineering faculties, especially the Department for Arms Production of the University of Tokyo, brought with them new theoretical skills as well as the experience acquired during wartime production, which were harnessed by Hattori & Co's technological development unit. Tomine, who was born in 1917, earned his engineering degree at the University of Tokyo in 1941. That same year, as an engineering officer with the navy, he joined Mitsui Seiki, a mechanical engineering firm that began manufacturing machine tools during the war. He joined Daini Seikosha in 1955 and stayed there for the rest of his career, becoming director of Seiko Seiki in 1964 then director of Daini Seikosha in 1968.[65]

Initially, Hattori & Co attempted to order M7 automatic lathes. An order for 200 lathes was placed with Tornos in 1955 but the latter refused to honour it, citing the firm's reduced production capacity. Hattori & Co then offered to sign a technical agreement for licensed manufacturing of lathes in Japan but the Swiss firm rejected the offer. At the end of the day, Hattori & Co decided to handle the technology transfer itself in cooperation with Tsugami Machine Manufacturing. To copy the M7 lathe, which Hattori & Co had picked up at a trade fair in Osaka, the company sent a model to Tsugami along with an order for 1,000 units (1956).[66] Tsugami was a precision instrument firm founded in 1923 in which Hattori had invested in 1928 before it was bought up by the Mitsui zaibatsu in 1934, giving birth to Mitsui Seiki. However, the founder of Tsugami left the company to set up his own machine tool firm under the name of Tsugami Machine Manufacturing. After 1945, it produced specialized automatic lathes to turn out manufacturing parts for the photographic and radio industry.[67]

Copies of the M7 lathe were made via reverse engineering, a slow process which posed several technical problems, especially when it came to producing the central cam and its ball bearings[68] – where the very high quality of the Swiss model allowed an extremely high rotation speed and thus high-quality work – as well as with parts assembly. At this point Tsugami turned to Professeur Aoki,

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[64] *Hiaringu*, op. cit., vol. 18, p. 4.
[65] *Hiaringu*, op. cit., vol. 18.
[66] *Hiaringu*, op. cit., vol. 18, pp. 6-7.
[67] *Tsugami*, Tokyo: Daimond, 1971, p. 89.
[68] As the quality of Japanese ball bearings was not yet sufficiently high in the mid-1950s, they had to be imported to a large extent. The development of a domestic ball-bearing industry was a MITI priority immediately after the war, as this technology was key to the growth of other industrial sectors. In particular, the machine tool industry became one of the main customers of Japanese ball-bearing manufacturers, absorbing 2.0% of domestic production in 1948 and 11.7% in 1954. Ueda H. (2002), "Sengo fukkoki no bearingu sangyo", in Hara A., *Fukkōki no nihon keizai*, Tokyo : Tokyo University Press, p. 237.

who was responsible for finishing the job. The first copies of the Swiss lathe were produced in 1957 and bore the name of T7. The Hattori & Co employees used the term "Japanese Tornos" (*wasei torunosu*) to describe these machines.[69] Tsugami went on to develop various versions of his T7 automatic lathe, which was produced by the hundreds to equip the Japanese watchmaking industry and which was successfully exported, including to the Swiss market.[70]

2.4 The birth of new machine tool companies

The experience gained in copying the Tornos automatic lathe led Hattori & Co to keep on copying machines, but in its own plants. Accordingly, it set up a machine tool manufacturing unit in the 1950s, making it possible to limit its dependence on Swiss machines.[71] At the beginning of the 1960s, Daini Seikosha boasted several foreign machine tools (Cazeneuve, Dixi, Schäublin, Reischauer, Jung, Studer, etc.). They were covered in detail in the company newspaper and served as a model for products manufactured in-house.[72] However, not everything was copied, as Japanese firms kept buying machines from Swiss manufacturers in the 1960s and 1970s. For example, in the early 1980s, all of the automatic lathes at the Ono factory (Daini Seikosha) came from Tornos.[73] Yet when trade in watchmaking machines was liberalized in Switzerland (1965), the Japanese watchmaking industry no longer needed its Swiss connection and did not order large quantities of machines.

Daini Seikosha's division for the production of machine tools gave rise to a spin-off in 1964, Seiko Seiki Ltd. That same year, the latter attended a machine tool fair in Japan, where it introduced itself as a manufacturer of foreign machine tools.[74] It worked on developing machine tools for watchmaking then switched in the 1970s to machines for clients outside the group. This desire to sell outside the group, in particular to the photographic industry, was behind the decision to set up an independent firm. From 1976 onwards, non-watchmaking customers outside the watchmaking sector have accounted for more than half of turnover.[75] Even today, Seiko Seiki is still an independent firm linked to the group Seiko Instruments Inc. (SII, ex-Daini Seikosha).

Seiko's main rival, Citizen Watch Co, developed along similar lines. During the 1950s, many Swiss or American machines were copied (automatic lathes, millers, pinion cutters, etc.) in the factory's workshops, under the guidance of a new generation of engineers who had graduated from the best engineering faculties in the country.[76] The search for markets outside the company began at a very early stage. In 1955, Citizen started delivering automatic lathes to the precision apparatus industry.[77] The company began exporting, first to China (1958) then to India (1960),[78] a trend which led to

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[69] *Hiaringu*, op. cit., vol. 30, p. 54.
[70] *Tsugami*, op. cit., p. 116.
[71] *Hiaringu*, op. cit., vol. 24, p. 25.
[72] *Daini Seikosha*, vol. 74 (1962), pp. 18-21.
[73] *Hiaringu*, op. cit., vol. 30, p. 53.
[74] *Daini Seikosha*, vol. 108 (1964), pp. 56-57.
[75] *Daini Seikosha*, vol. 272 (1976), p. 28.
[76] Haruta H. (2006), op. cit., p. 23.
[77] Haruta H. (2006), op. cit., p. 27.
[78] Citizen Co (2002), op. cit., vol. 2.

the establishment of two machine tool firms within the group in 1960. The first, Citizen Precision Co, manufactured both parts for watchmaking and specialized machine tools for the production of such parts. In 1963 it became a joint venture when the Swiss manufacturer of watchmaking stones, Lucien Méroz, took a stake.[79] Even today, it is majority owned by the Citizen group. It has developed its production for the automobile industry and has primarily expanded in Germany and the United States.[80] The second, Tokai Precision Co, was set up in 1960 by Citizen Watch Co and one of its subcontractors, Star Precision Co.[81] Under the name of Star Micronics, it went on to become a major machine tool producer during the 1970s, and the Citizen group still has a large stake in the firm.

Conclusion

The concept of dual structure (*niju kozo*) is a decisive notion in the history of Japan's industrialization.[82] With this system, large, dynamic, competitive and innovative companies coexist with small firms based on cheap labour, which operate as subcontractors for the large firms and absorb cyclical shocks. In the specific case of machine tools, the fragmented structure of the industry was not however due to the survival of small, relatively static firms that depended on the large companies. Rather, their existence met a specific market need. They offered flexible production of specific machine tools, produced in small quantities, a tendency that became more widespread with the advent of NC.[83] The machine tool firms founded in the early 1960s inside the Hattori & Co and Citizen watchmaking groups fitted right into this context. These small firms were not relics of the past but rather flexible, dynamic firms that adapted rapidly to changing market needs.

The Japanese watchmaking industry thus developed in a specific fashion, diversifying into machine tool manufacturing in the 1950s and 1960s. Its two main rivals on the world market followed different development paths. In Switzerland, with very few exceptions, the production of machines began outside the watchmaking firms themselves but long remained dependent on these same firms. Most of the companies concerned were subcontractors who primarily worked for the watchmaking companies, the most well known being Tornos, Pétermann and Bechler. In the United States, the first machines custom built for watchmaking were purchased from tool makers such as Brown & Sharpe,[84] as well as produced in watch factories, particularly at Waltham Watch Co, but led to only a few spin-offs, the main one being the Waltham Watch Tool Co.[85] What made the Japanese case special was the difficulty in obtaining foreign machine tools after 1945 and hence the need to produce them domestically, a process which led to the acquisition of new skills which were then put to commercial use. Technology transfer entered a critical phase in the 1930s and 1940s, with the help of the institutions which the

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[79] Tsusansho (1968), *Gaishikei kigyo*, Tokyo : Tsusansho.
[80] Haruta H. (2006), op. cit., p. 146.
[81] Ishikawa H. (1971), *Citizen no seimitsu keiei*, Tokyo: Gakushu kenkyu.
[82] Nakamura T., Odaka, K. and Umemura M. (1989), *Nihon keizaishi VI: Niju kozo*, Tokyo; Iwanami shoten.
[83] Friedmann D. (1988), op. cit.
[84] Hounshell D. A. (1984), *From the American System to Mass Production, 1800-1932*, Baltimore/London: The Johns Hopkins University Press, p. 75.
[85] Harrold M. C., *American Watchmaking. A Technical History of the American Watch Industry, 1850–1930*, Columbia: NAWCC, 1984, p. 25.

State had established to monitor wartime production. The Department for Arms Production of the University of Tokyo played a decisive role for the watchmaking industry, not only because it worked on the production and dissemination of high-precision machine tools in the Japanese watchmaking sector but also because it provided a venue for training a new generation of engineers, who in 1945 took over the production of machine tools in Japanese watchmaking factories, for example Tomine Ritsu at Hattori & Co.

By taking advantage of the opportunities available to them, first on an expanding domestic market then on the world market, these machine tool factories went on to become independent, competitive firms. More specifically, this trend should be seen as part of the overall diversification strategy of Japanese industry during the high-growth years (1955–1975).[86] Watchmaking was no exception, and the new skills acquired with the introduction of system for mass production of watches were used in other industries, such as machine tools and precision instruments. As a result, Citizen Watch's watchmaking-related turnover fell from 96.3% in 1951 to 80.0% in 1970.[87] By spinning off new skills and diversifying markets, companies like Hattori & Co and Citizen helped Japan become the world's leading machine tool manufacturer.

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[86] Hakoda S. (1988), *Takakuka senryaku to sangyo soshiki*, Tokyo: Shinzansha.

[87] *Kaisha yoran*, Tokyo: Diamondo, 1950-1970. Owing to the special structure of the Seiko group, which consists of three sub-groups of independent firms, it is not possible to determine watchmaking's share of total turnover.