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TECHNOLOGY, MANAGEMENT AND MARKET FACTORS IN THE DEVELOPMENT OF THE JAPANESE MACHINE INDUSTRY: A STUDY OF THE INTERWAR DECADES*

KONOSUKE ODAKA

Abstract

Empirical records in the inter-war period indicate that subcontracting in Japanese machine production began to spread only after the mid 1930s. The reasons for the timing may be ascribed to the gradual overcoming during the period of deficiencies in technological and/or managerial capabilities of the manufacturers of machine parts and components, as well as to the increasing size of the market for the final products. The formation of the inter-firm linkages was a prerequisite for the development of the machine-building industry, on which the post-war economic growth was to be securely founded.

I. *Introduction*

Japan's machine industry attained a considerable degree of development after World War I. This paper examines its development in the two decades (1920–39) of the inter-war period.

The production of machinery consists of processes for producing parts and components using relatively labor-intensive technology and requiring high labor skills. Because of these technological factors, parts and components can be supplied and special services rendered by "ancillary" (subcontracting) firms.[1] The development of a subcontracting system thus becomes a prerequisite for the growth of the machine industry. Most, though not all, Japanese subcontractors are medium- and small-scale firms.

It is not coincidental that the problem of small subcontracting firms was discussed intensively in the late inter-war period in Japan, with particular reference to the machine industry. The debate centered on the weak business performance and pre-modern management practices in these ancillary firms. It was then argued that large industrial firms (assemblers) sheltered themselves from business fluctuations by "exploiting" ancillary firms which relied on cheap and abundant labor to survive. Characterized by low wages, poor working conditions, and frequent business failures, ancillary firms were regarded as the symbol of capitalist evils.

* This article constitutes a revised version of a paper originally read at the Molokai workshop held in 1979. The conceptual framework draws heavily on Ishikawa and Odaka (1979). Editorial assistance by Dr. Charles Weathers is gratefully acknowledged.

[1] An ancillary firm is either an independent or a subcontracting manufacturer of original components and /or replacement parts which are supplied to a primary firm, or the producer of finished products, commonly called an assembler.

Granting that there were such undesirable aspects to the development of the industry, it must be emphasized that this common wisdom does not tell the whole story. By adopting relatively labor-intensive methods of production, small firms contributed greatly to expanding employment opportunities, linking the indigenous to the modern segments of industry, and disseminating technological information throughout the economy (as they did again after World War II). However, when the factories were arranged in the order of their sizes (in terms of the number of their employees, for instance), their productivity and the values of their wages displayed a clear declining trend. This implies that industrial dualism consisted not simply of two pillars, big and small factories, but also of a continuous spectrum of medium-sized workshops of varying sizes. It is quite possible that in the inter-war period small- and medium-scale firms contributed not only to capital formation but also to the reduction of income inequality by increasing the number of employment opportunities.

In the late 1970s there was a surge of interest in the choice of "appropriate" technology that would satisfy two conflicting economic objectives, namely rapid industrialization and the creation of employment opportunities [see, e.g., Ishikawa (1979)]. The borrowing of advanced, capital-intensive foreign technology, usually limited to a few large-scale corporations and seldom diffused to small firms, gives rise to excess demand for skilled manpower while failing to reduce high unemployment among the unskilled. Consequently, industrialization has often resulted both in insufficient employment opportunities for the urban poor and the emergence of a dual structure in which modernization has coexisted with, but had little interaction with, the traditional modes of production.

Might it not be better to adopt more labor-intensive technology that is appropriate for small-scale enterprises? A case in point is the machine and metal-fabricating industries in Southeast Asia. The interwar experiences of Japan's machine industry may shed light on this contemporary issue: under what economic and organizational conditions, and through what processes, would a prospective medium- or small-scale machinery manufacturer acquire the technological and managerial capabilities to become a self-sustaining and competitive ancillary firm? In this essay I will review some historical data while considering the following questions: (1) how can a firm improve its technological or managerial capabilities?; (2) how can each step of this progress be brought about?; (3) what are the "appropriate" choices of products, equipment and techniques that the firm is obliged to make in the progress of growth?; and (4) what, if any, public assistance should be extended to the ancillary firms?

Brief commentaries on each of these factors are combined below with the examination of some Japanese experiences, followed by some short concluding remarks.

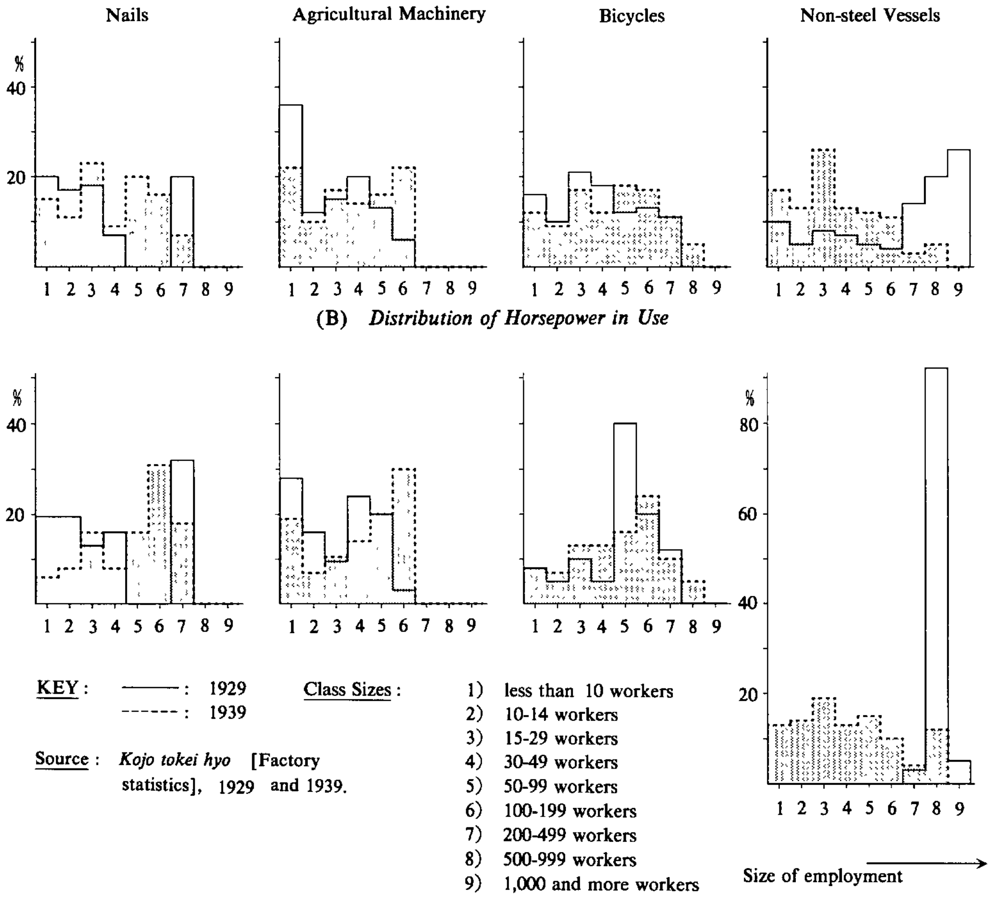
II. *The General State of the Industry*

First, in order to provide some perspective on the state of the Japanese machine industry during the inter-war period, I have prepared a set of diagrams (Figures 1–3) depicting the distribution of machine-producing enterprises by scale of employment and horsepower in use for 1929 and 1939. These years may not be a particularly ideal choice but the use of other years does not significantly change the overall tendency, which is of primary concern here.

The firms shown in Figure 1 are characterized by the small scale of their operations, while the firms depicted in Figure 3 are primarily giant firms, notably manufacturers of steel vessels.

FIGURE 1. SIZE DISTRIBUTION OF MACHINE-BUILDING ESTABLISHMNTS (I)

(A) *Distribution of Production Workers Employed*



By contrast, Figure 2 indicates a distribution pattern that is relatively uniform among varying scales.

Many branches of manufacturing industry recorded significant changes in the distribution of enterprises between 1929 and 1939. The relatively smaller enterprises dominated in 1929, whereas the tendency was somewhat reversed ten years later. The only clear exception to this trend was enterprises producing non-steel vessels, but this is obviously because this particular sector was a declining industry.

The machine industry made strong efforts during the inter-war years to achieve an international standard of product quality and made considerable progress in this regard. The bulk of the most modern, sophisticated machinery produced in Japan was manufactured by select giant factories under the close influence of the government, which provided various protective measures in the form of import restrictions and production subsidies. One cannot ignore here the important role played by Army and Navy Arsenals in upgrading the

FIGURE 2. SIZE DISTRIBUTION OF MACHINE-BUILDING ESTBLISHMENTS (II)

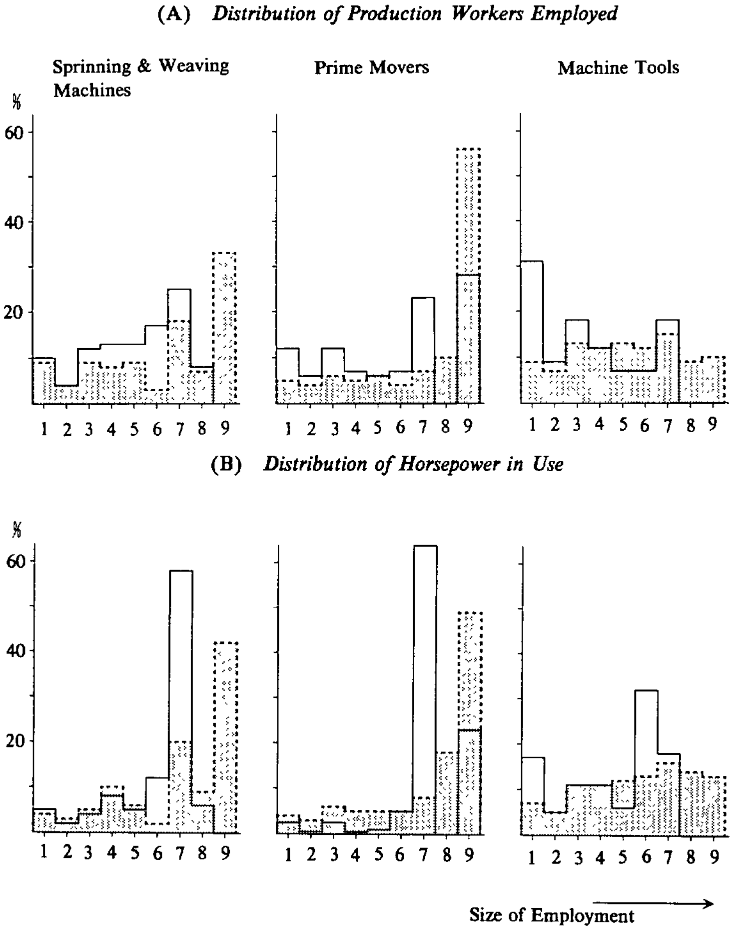


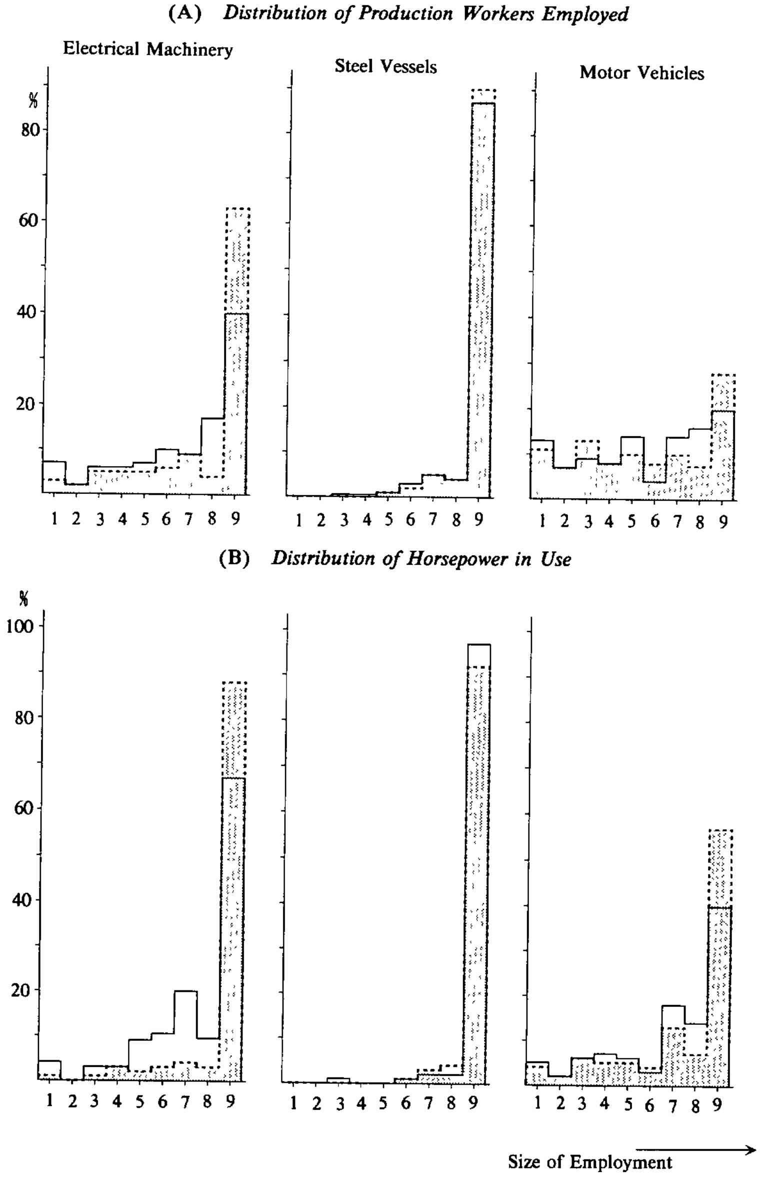
TABLE 1. THE PROPORTION OF PERSONS WORKING IN FACTORIES WITH FOUR EMPLOYEES OR LESS, 1930

(in per cent)

Industrial Categories	Proportion
Foods and Beverages	96.1
Miscellaneous	92.2
Ceramics	73.1
Metal Products	73.1
Machinery	46.0
Textile	30.5
Others	50.3

Source: Yamanaka (1941), No. 249, p. 109.

FIGURE 3. SIZE DISTRIBUTION OF MACHINE-BUILDING ESTABLISHMENTS (III)



technological capabilities of the industry. Motor vehicle production was not an exception here, although it was still an infant industry in 1939. Some medium-sized firms also accumulated enough strength to achieve international competitiveness toward the end of the period, as evidenced by the case of Toyoda Automatic Loom Works.

It should be noted that the above figures exclude enterprises with four workers or less; such enterprises offered relatively abundant employment opportunities in those days, as shown in the factory statistics (see Table 1). The majority of these enterprises were engaged either in the production of simple machine components and spare parts, or in repair work. On the basis of detailed comparisons of the Census of Population (*Kokusei chōsa*) and the Factory Statistics (*Kojo tōkei hyō*) for 1930, Yamanaka (1949) observed that the small sector consisted of two kinds of enterprises: those catering to the repair and installation demands of relatively large, modern factories, and the independent owner-operated factories that were involved in relatively indigenous operations such as smelting and wire manufacturing. He also noted the bimodal size distributions of enterprises in terms of employment in the manufacturing of watches, electrical machines and tools, and agricultural machinery.[2]

The Japanese machine industry in the inter-war era consisted of two independent sectors: (i) the modern "capitalistic" sector, in which relatively advanced technology and capital-intensive, specialized machinery were widely utilized, and (ii) the traditional, "backward" sector which relied more on labor-intensive, small-scale operations using relatively inexpensive, general-purpose machinery, and which was engaged in the manufacture of simple devices and/or the repair of products originally imported or produced by the modern sector.

Finally, Table 2 reports the competitive position that was achieved by the machine industry in the early 1950s. While the Japanese economy struggled to recover from war damage, it suffered from the Dodge deflation in the late 1940s. It was only after the mid-1950s that an abundance of foreign technology began to flow in, helping to transform the nation's industrial structure. Thus, the information in this table may be utilized to measure the technological level attained at the end of the inter-war decades. On the premise that this procedure is permissible, one notes that only a handful of machine products had caught up with the engineering standards of the more advanced industrialized countries by the mid-1950s. This was ascribed to the small size of the fimrs, relatively backward technology, and low capital intensity. One may infer that Japanese machine production in the inter-war decades was still in its adolescent stage of development.

III. *Technological Conditions*

It is often said that the technological gap becomes more difficult to overcome the longer a country waits before commencing industrialization. This statement, however, is not necessarily correct, since a follower country may skip intervening steps; new avenues of technology may be explored and new commodities developed in order to meet the requirements of its particular environment, socio-economic system, and other conditions.[3]

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[2] The author was told at Nagasaki Dockyard of Mitsubishi Heavy Industries, Ltd., that the relatively enterprising skilled ex-employees in these days in advanced, large-scale factories would open small workshops of their own after they quit their companies.

[3] For instance, with the introduction of small-scale, high-speed computers, an entirely new, special method for manufacturing dies was contemplated. The idea was to form a die by combining specially designed metal wires. Such a die, after being used, could be easily dismantled to form an entirely new die for use in other products. It would contribute not only to scaling down the optimum size of production but also to make obsolete the die-making skills that have hitherto been considered indispensable. By the same token, the wide application of computerized machine tools may eventually make it feasible to manufacture a large number of models in small quantities. Follower countries may be in a much better position to assimilate such new developments. See, for instance, Miwa (1978, pp. 197–202).

TABLES 2. INTERNATIONAL COMPETITIVE POWER OF THE JAPANESE MACHINE INDUSTRY (1950–54)

Industry	Country of comparison	Relative price (domestic/foreiqn)
1. *Highly Competitive*		
Bicycle parts	U.K.	0.78
Binoculars	U.S.A.	0.28–0.46
Bus chassis (diesel-operated)	U.S.A.	0.75–0.85
Cotton spinning machines	U.S.A.	0.55–0.67
Diesel engines	Int'l mkt price	0.86
Sewing machines	U.S.A.	0.45–0.53
2. *Moderately Competitive*		
Bearings	Sweden	0.91–1.21
Bicycles	U.K.	0.97
Cameras	U.S.A.	0.69–0.96
Cargo vessels	Int'l mkt price	1.23
Hand-operated desk calculators	Sweden	0.91–0.94
Motor cycles	Italy	1.12
Steam locomotives	Int'l mkt price	1.11
Wrist watches	Switzerland	0.90–1.11
3. *Not Competitive*		
Automatic lathes	U.S.A.	0.78*
Dry-cell batteries	U.S.A.	1.35
Electricity generators (steam-operated)	Int'l mkt price	1.33
Electric motors	U.K.	1.08–2.08
Passenger motor vehicles	U.S.A.	1.84**
Radios	U.S.A.	1.53–2.07
Telephones	U.K., West Germany and Switzerland	1.20–1.83
Telephone switchboards (automatic)	West Germany	1.79
Truck chassis	U.S.A.	1.37
Wireless transmitters	U.S.A.	1.46

Source: Adapted from Hayashi (1961, pp. 117–35).
Notes: * Substantially inferior in quality.
** A comparison of domestic prices in the respective countries.

The initial conditions of modern economic growth vary from one country to another. For instance, the experience of a country with a comparative advantage in mining is undoubtedly different from that of another whose strength lies in agriculture. Any society, however, develops indigenous technologies that are essential for day-to-day activities, even though this technology may be used in a primitive cottage industry or a family enterprise. In fact, it would be advisable to encourage the use and refinement of traditional industries to provide a necessary link between imported and indigenous technologies, to create as many employment opportunities as possible, and to conserve foreign exchange. Of course such choices are more limited in certain industries than others; in Japan, a hybrid of Western and traditional technologies was easier to establish in textile manufacturing but was almost impossible to institute in the iron and steel industry [see Ranis and Saxonhouse (1985) and Ono (1985)].

Contrary to common belief, metal-working and machine industries offer a comparatively wide range of choices. First, machine production is relatively labor intensive compared with other manufacturing operations, notably continuous process industries [Ozaki (1976, p. 98)]. According to one survey report, during the interwar years an additional unit of equipment investment produced the greatest employment growth in the machinery industry: the ratio of additional employment to a unit of investment was 1.7, 2.1, and 3.2 times larger in machine building than that in the textile, metal-producing, and chemical manufacturing sectors, respectively (average figures for years 1922-36) [see Arisawa (1959, pp. 12-15)].

Second, machine elements have much in common irrespective of their functions. By the same token, the production of any machinery may be broken down into several common operations, i.e., casting, heat treatment, forging, welding, machine fabricating (turning, shaping, planning, and milling), stamping, painting, plating, assembly and testing [Odaka (1983)]. It is precisely for these reasons that machine production technology lends itself to wide application and to cross-fertilization of new ideas. Consequently, its use is likely to have a multiplier-cum-accelerator effect in fostering the growth of the technological potential of the economy, thus preparing the way for the next stage of industrial expansion [cf. Rosenberg (1963)]. One could, therefore, make a case for protecting such domestic potentials, provided that the choice is feasible and prospects for the industries' growth reasonably good.

The most important technological factors acting against the successful growth of indigenous firms are the indivisibility of production processes, the existence of scale economies, and the high degree of engineering sophistication. First, if the production process requires an uninterrupted flow of goods and materials, the entire production system has to be considered as an integrated unit of production. Oil refineries are a good example of this. As pointed out in the previous paragraph, however, this does not apply to the discrete process industry, which includes both metalworking and machine industries.

Second, the existence of large economies of scale prohibits the entry of small-scale firms which cannot compete with the more favorable cost conditions of larger corporations. Consider, for example, the operations of assembling, machine fabricating, forging, casting, and stamping. In motor-vehicle production, stamping is typical of operations exhibiting large economies of scale. In contrast, processes such as machine fabricating do not require long production runs and are suited to small-scale firms; this is partly because such firms often produce small lots of made-to-order goods, whose production requires relatively high skill levels. It is no accident that assembly operations, which are also relatively labor intensive, are often established at a relatively early stage of industrialization. For instance, realizing the growth potential of the Japanese market, Ford and General Motors established assembly plants after the 1923 Kanto Earthquake, Ford in Yokohama in 1925 and General Motors in Osaka in 1927.[4] One could probably make a similar observation concerning the electric appliance industry.

Third, the degree of engineering difficulty depends on the nature of the technology, i.e., the mode of production (such as whether or not the process is capital intensive), product

[4] At the same time, those companies may have been pursuing managerial expansion on a worldwide scale. Both Ford and G.M. established their assembly plants in other parts of Asia as well: Ford opened its C.K.D. (completely knocked down) factory in Singapore in 1926 and General Motors one in Jakarta in 1928.

quality, and the type of raw materials. Even considering the above factors, however, some processes are inherently more difficult than others. In general, machines are relatively easy to manufacture if their mechanical structure is the key feature (e.g., spinning and sewing machines), but difficult to manufacture if they use massive power, even though their mechanism is simplicity itself (e.g., propellers and dies) [Tomizuka (1972, p. 12)].

The Japanese had accumulated considerable experience in machining operations by the beginning of the Taisho era, and they also had a long history of meeting the continuing (and probably increasing) demand for metal products such as swords and agricultural tools. Modern casting operations, however, were something new. When the Toyota Motor Company was formally established in 1937, the company had great difficulty in casting engine blocks despite its experience in manufacturing automatic looms. Die making was equally, if not more, difficult, and Toyota had to seek outside expertise [Odaka, Ono and Adachi (1988, ch. 4)]. Nissan Motor Company, on the other hand, had fewer problems because it took over a manufacturing line previously run by the Graham-Paige Motor Company, which had once been an automobile producer in the United States (*ibid.*). For this reason we may safely speculate that Toyota more closely represented the engineering standard of the day.

It is not easy to measure the technological standard of the Japanese machine industry in the interwar period in terms of either engineering capabilities or human skills. There are, however, a few indications that it was making steady progress.

Japan was ready by the end of the nineteenth century to develop her own machine industry. In 1899, upon return from a study trip abroad, Taisuke Shioda, one-time director of Mitsubishi's Kobe Shipyard, was very optimistic about the future of the Japanese shipbuilding industry and the engineering capacities of the nation.[5] The only misgiving he had, he said, was that Japanese production workers lacked formal education [Shukuri (1932, p. 524); see also Shioda (1938)].

As early as in 1889, Shotaro Ikegai completed two units of the first general-purpose lathe ever produced in the country, although the significance of machine tools was not to be fully recognized until the Russo-Japanese War. In the early part of the twentieth century, the Ikegai Company worked to improve the precision standard of their products with the help of an American engineer, W.C.A. Francis, who was employed by Ikegai between 1906 and 1907 before joining the faculty of Tokyo Technical High School (now Tokyo Institute of Technology). Even in the extremely busy years during World War I, the company continued studying imported American lathes intensively, and finally completed its own standard Model G in 1921. Machine tools were extremely sensitive to the ups and downs of business cycles, however, and Ikegai's growth was checked by the arrival of the post-World War I recession. It was only after the Manchurian Incident of 1931 that the company finally recovered from the long period of economic stagnation. In 1935, the company produced an improved lathe and two types of milling machines, adopting and developing further the basic ideas of German and American models [Ikegai (1941, pp. 1–100)].

These developments are reflected in the industry's statistics, which recorded a rapid

[5] However, this did not mean that Japanese shipbuilding was competitive in the world market. For instance, in the years shortly before World War I (1912–13), only the cost of shell production was comparable with that in England, as this was the most labor-intensive operation. By contrast, the manufacturing of machinery, internal combustion engines, and internal furnishing was at least 50 percent more expensive in Japan than in England (Tasugi 1941/1987, p. 165).

increase in the overall domestic production of machine tools from a meager level of less than 10,000 tons before 1934 (and no more than 5,000 tons in 1930) to about 100,000 tons in 1938. This growth reached a peak in 1943 and the level was reached again after the mid-1960's [Kikai Shinko Kyokai (1968, p. 56)].

Kishiro Ikegai, the company's chief engineer, believed that Japanese machine tools in the early part of the twentieth century were not necessarily inferior to those of Western countries. When he visited the United States in 1919 to observe the country's machine tool production, he envied the overwhelming presence in the country of machine power, which was used extensively for work that would be done manually in Japan by skilled craftsmen. Nonetheless, he was unimpressed with the U.S. engineering standards because he saw little difference between the two countries in terms of basic intellectual and designing capabilities. As a matter of fact, he said he seldom copied foreign-made machinery in developing his own models [Hayasaka (1943, pp. 12–18, 35–39 and 134)].[6]

Another illustrative example comes form the autobiography of Masayoshi Yasui (1979), the founder of Brother Sewing Machine Company.

Yasui's father ran a repair shop for industrial sewing machines, mostly German-made, which were designed for the production of straw hats. Because his father was physically fragile, the younger Yasui was obliged to learn the trade while he was still very young. He had mastered it by the time he was sixteen years of age.

In 1921, at the age of seventeen, Yasui spent two months in the city of Osaka where he learned the nature and the growth potential of the sewing machine business. Upon returning to his native city of Nagoya, he enrolled himself for two years at a night school in an occupational training center run by the city. While still at the school he heard of case hardening, which he judged to be of great importance for the production of sewing machines. Having determined to master the method, he built a small furnace by himself and conducted a series of experiments for two to three months until he finally gained complete command of it. This experience proved to be of high value later on when he and his brother manufactured and marketed their own products.

Subsequently, Yasui wanted to design and produce a sewing machine which could compete with America's Singer. As a first step to achieve this end, he designed an improved model of a sewing machine for straw hats. This was necessary because the old model needed constant repair and left him no time to devote himself to the new project. Within a year, around 1926/27, he successfully completed a new model which was far superior to the imported one.

About this time a younger brother of Yasui went into the production of shuttle hooks, a sewing machine component. Naturally Yasui helped him build up the factory by manufacturing most of the machine tools needed: a lathe, a milling machine, and various tools and jigs. In order to manufacture a compressor, for instance, they made use of a second-hand Ford engine with six cylinders, which was welded to a steel tank. Ugly in appearance, it nevertheless served their purpose perfectly. Within three months (in the summer of 1932) their factory started turning out its products, which, according to Yasui, were in no way inferior to German

[6] Note, however, that the Ikegai Company was always very eager to learn from foreign models (Ikegai 1941, p. 69). What Ikegai meant to say here is that he had always manufactured machines of his own design, never merely imitating foreign products.

models. Subsequently, mass production began in October of the same year, with the product selling for 70 sen, or 15 sen cheaper than imported brands. Fortunately, the re-embargo of gold exports in 1931 and an upward revision of import tariffs (June 1932) worked favorably for the Yasuis. After 1932, Yasui's product sold for about ¥1.20 whereas the imported models sold for about ¥1.70.

By the winter of 1932 Yasui developed a sewing machine of his own design. With the financial help of a few interested persons, he managed to establish his own factory in October 1933, hiring about 50 workers and producing 60 sewing machines per month. In January 1934, the factory was duly incorporated and named Nippon Mishin Seizo Kabushiki Kaisha (Japan Sewing Machine Manufacturing Company).

Many years later Yasui made his first visit to Singer in the United States (November 1950). While he was completely taken by surprise by the physical scale of the factory, he found little to learn in terms of production technologies. True, Singer was superior in many aspects of its production techniques, especially plating and hardening. Nonetheless, he felt that Singer's standard of excellence was within reach and that his company could easily catch up with it within a few years. Yasui began exporting his model to the United States in 1952.

The above illustrations suggest that the economy was endowed with engineer-cum-entrepreneurs who were ready to promote the growth of indigenous machine production. The industry abounded with many such examples.

However, fate was against the development of such technological capabilities. Hoshino found that American technology surpassed that of the Japanese after 1920; this was mainly due to deficiencies in the Japanese industrial structure, in particular the lack of a well-developed subcontracting network [Hoshino (1966, Part I, ch. 2)].

An ad hoc measure of technical standards can be made by observing the proportion of general-purpose lathes among machine tools of all kinds installed in a machine shop. It is not

TABLE 3. THE PROPORTION OF GENERAL-PURPOSE LATHES TO THE TOTAL NUMBER OF MACHINE TOOLS IN OPERATION

(per cent)

Year	Subject Surveyed	Proportion
Mid-1930's	Ehime Tekko Kumiai [Industrial Association of Machine Shops in Ehime Prefecture]	54.0
	Kochi Tekko Kumiai [Industrial Association of Machine Shops in Kochi Prefecture]	50.0
	Kure Navy Arsenal	42.9
	Toyo Kogyo Company, Ltd.	33.9
1952	All of Japan	40.6
	All of U.S.A.	22.5

Sources: Waraya (1938, pp. 57 and 117), and Hayashi (1961, p.412).

surprising that lathes comprised approximately 50 percent of the machine tools owned by small factories in provincial regions such as Kochi and Ehime Prefectures. However, the situation was not much better in the most advanced companies, such as Toyo Kogyo and Kure Navy Arsenal, although the latter's machinery must have been far superior in quality (see Table 3).[7]

Toyosaki reports the results of a series of tests conducted in 1937 on the physical accuracy of horizontal milling machines. In terms of the size of measurement errors, he discovered that the domestic-made models were, on the average, inferior to the international standard by approximately 20 to 25 per cent (Table 4). The same author also reports that, of the machine

TABLE 4. A COMPARISON OF AVERAGE MEASUREMENT ERRORS: DOMESTIC AND FOREIGN HORIZONTAL MILLING MACHINES*

(1937)

Tests		Domestic/Foreign	Tests		Domestic/Foreign
1		1.11	6		1.39
2	front/rear	1.54	7		2.10
	left/right	0.95	8		0.86
3	vertical	0.83	9	vertical	1.73
	horizontal	1.06		horizontal	1.31
4	front/rear	1.07	10	table	1.17
	left/right	1.55		knee	1.05
5		0.93			
				Average	1.24

Notes: * The domestic models were exact copies of the foreign model imported in 1927. The tests were conducted in 1937 when the machines had been in use for seven years or longer.

Source: Derived from Toyosaki (1949, p. 164).

TABLE 5. THE PROPORTION OF DOMESTICALLY MANUFACTURED MACHINE TOOLS IN USE AT MAJOR MACHINE-BUILDING FACTORIES, 1924

(per cent)

Machine Tools	Proportion
Lathes	51.0
Drilling machines	42.8
Planers	42.1
Grinding machines*	31.7
Milling machines	23.6
Total	40.9

Note: * Inclusive of all other machine tools not listed herein.

Sources: Toyosaki (1949, p. 76).

[7] The sizes of these factories in terms of the number of employees were as follows: Ehime 10 (1936), Kochi 13 (1936), the Toyo Kogyo 800 (1937), and Kure Navy Arsenal 20,325 (1936, regular workers only) (Waraya 1938, pp. 117 and 135, and *Toyo Keizai kabushiki kaisha nenkan* [Oriental Economist's Company Almanac], vol. 15 (1937), p.486 and *Kaigunsho nempo* [Statistical Yearbook of the Navy], 1937). Toyo Kogyo in this table is the

tools in use at major representative factories in 1924, an average of 41 per cent were supplied domestically (Table 5). Such being the case, it is not surprising that the Procurement List (*Kobai meibo*) of the Japanese Navy consisted almost entirely of "giant" firms, reflecting in part the manner in which the government supported the activities of the industry.[8]

It was estimated that in 1940 the engineering standard of Japanese machine tools was approximately twenty years behind that of the United States [Kikai Shinko Kyokai (1968, p. 57)]. Interestingly enough, this estimate coincides with the figure suggested by the staff engineers who were involved in automobile production at Toyota: they reported that the motor vehicle industry was approximately twenty years behind the Western countries when its domestic content program began in 1935–36.[9] The technological gap was not narrowed until much later when post-World War II growth was well under way. According to a study report of imported machine tools that were granted duty-free privileges,[10] the single Japanese product on a par with the international standard in 1955 was drilling machines, to which milling and boring machines were added in [*ibid.*, pp. 86–111].

IV. *Demand Conditions*

Both technological and market factors dictate the structure and performance of the machine-building industry. A spectrum of technological choices is possible, with a vertically integrated operation at one extreme and a completely disaggregated structure at the other. In fact, however, the industry consists in general of two types of economic organizations, assemblers and ancillary firms. The latter, in turn, are classified into (i) manufacturers of complete parts and components (such as carburetors and turbines), and (ii) firms which offer well-defined industrial services (such as plating and painting).[11] The degree of integration varies from one country to another and also from one period to another.

The other important factor determining industrial structure is the size of markets inclusive of domestic and foreign. The following four factors are pertinent:

1) the degree of market fragmentation, caused, for example, by excessive product specification;
2) the size of the replacement market, which is determined in part by the durability of the product;
3) the opportunity for ancillary firms to serve more than one industrial group; and
4) the possibility for developing a new type of product which is not only cheap and attractive to the domestic market, but is also shielded from international competition

same company as the producer of Mazda vehicles in the post-World War II decades.

[8] *The 1942 Procurement List (Showa 17-nen rinji kaigun kobai meibo)* contains only a few companies, which may be considered "medium-sized." Of the total of 113 companies listed therein, seven (or only 6.2 per cent) were non-stock corporations. The situation was much the same in the case of the 1935 edition of the *List*.

[9] Based on the author's interview survey.

[10] The underlying policy was that the privilege would be granted by the government's administrative order, when a particular machine tool was absolutely necessary for the Japanese industry and yet could not be produced domestically for technological reasons.

[11] A complete part (or component) is defined to be a product that serves one or more well-defined purpose(s) but does not by itself constitute a self-contained mechanical system.

by its indigenous characteristics.

Factors 1 and 2 work negatively, while 3 and 4 work positively in the development of ancillary firms.

The early experience of automobile manufacturing testifies to the importance of market factors. When the United States began the commercial production of industrial machinery and of consumer durables, it could rely on domestic industries for basic materials and necessary parts and components, and the maintenance of machine tools could be contracted out if necessary [Rosenberg (1963)]. This arrangement was extremely beneficial for the young automobile industry, not only because the latter could exploit the expertise that had been accumulated in the economy over the years, but also because it meant significant capital savings. The demand for auto parts and components was nominal, since the market for motor cars was still at an infant stage; the average cost of production would have been much higher if the industry had chosen to supply most of the required intermediate inputs, as was the case in Great Britain.[12]

Similarly, the Ford Motor Company achieved significant cost reductions by concentrating on the production of a selected model, the Model T. This decision led to the company's early success.

Things are drastically different for a follower country in which the metal-fabricating and machine industries are underdeveloped. When primary firms begin operating in such an environment, they naturally have to import most of the required parts and components, not to mention basic raw materials. It is vital for a country to nurture its industrial foundation by strengthening the potential of the related industries.

These observations point to the importance of developing a bread-and-butter model at a reasonable price with a design and specifications that match environmental conditions and are suitable to use in the country. Thus the marketing of commercial vehicles (buses and trucks) should perhaps precede full-fledged production of passenger cars. This choice is advantageous because, first, the manufacturing of passenger vehicles requires a higher standard of engineering sophistication and, second, the parts and components of commercial vehicles are more interchangeable among different models.

Considering this, some parts of machine-producing operations can be either "made" (supplied internally) or "bought" (subcontracted). To develop a subcontracting network, however, there are certain prerequisites: parts and components, although manufactured separately and independently, must be sufficiently homogeneous in quality and well-balanced in engineering precision, and reliable delivery must be guaranteed so that the necessary quantity can be supplied at any time on request. Given these conditions, subcontracting increases the economic efficiency of the system by

a) making it possible to take advantage of the segmented labor market by employing cheap labor, thus avoiding an increase in the capital coefficient;
b) making fuller use of small-scale financial intermediaries with limited capacity for credit resources;

[12] Maxcy and Silberston (1959, ch. 1) suggest that this in fact was the reason why Great Britain was soon surpassed in automobile production by the U.S., despite the fact that the former was the first country to produce automobiles commercially. However, the American automobile production was characterized in the 1930's by a weakening of the subcontracting arrangements.

c) achieving a higher rate of utilization of the given capacity by serving multiple commodity markets;
d) taking advantage of economies of scale, which are realized only by ancillary firms serving many customers [Stigler (1951)];
e) promoting competition among ancillary firms; and
f) reducing inventory costs of subcontracting firms.

In addition to these factors, the choice of make or buy is influenced by industrial secrets, specialized technology not obtainable elsewhere, etc. But most of these factors ultimately involve cost considerations of one type or another [Culliton (1942)].[13]

Because the machine industry can operate in a totally disaggregated fashion, each commodity can be produced through the cooperation of a multitude of medium- and small-scale firms, whose activities are highly competitive and linked (or coordinated) by an assembler that not only puts out the final product but also acts as an information clearinghouse [Imai (1976, ch. 10)]. The division of work through subcontracting not only results in lower production costs, but may also initiate new activities and industrial diversification [Jacobs (1969, ch. 2)]. This is primarily because an ambitious subcontractor will not be content with being subordinate to assemblers and others, but will utilize its facilities and expand them to serve a variety of other customers. By contrast, if the main lines of production involve only the assembly of parts and components that are imported or of low domestic content, the prospects for such technological cross-fertilization are dim.

V. *Institutional Conditions*

According to the standard argument, the poverty and income inequality that have prevailed among workers in medium- and small-scale firms in Japan since the inter-war years originated in the economic exploitation of modern "monopolistic" capitalism. Furthermore, smaller enterprises were characteristically dominated by unpaid family workers whose willingness to work long hours for low wages sustained the system. It was only after 1960 or so that medium-sized businesses challenged this common notion with their high growth potential and their strong inclination toward managerial rationalization [Nakamura (1976)].

In order to see the extent of vertical disaggregation among firms, we can look at the quantities of purchased intermediate products (parts and components) and subcontracted services that are contained in the final output. Because such data are hard to collect, however, I have included the proportion of the costs of raw materials and intermediate goods in the total manufacturing cost of a commodity, assuming that (i) the materials/output ratio remained more or less constant over time, and (ii) the relative prices of raw materials, produced parts and components and output did not change systematically over time. Such information, though fragmentary, is presented in Tables 6, 7 and 8.

These data are consistent with the findings from field surveys that subcontracting was widely practiced in the interwar period, especially from around 1932 to 1934 [see Tasugi

[13] While Culliton's monograph (1942) is an excellent contribution, it is devoted almost exclusively to static considerations. The issue of make-or-buy should be posed in the context of dynamic growth.

TABLE 6. THE PROPORTION OF MATERIALS PROCUREMENT IN THE TOTAL MANUFACTURING COST*

(per cent)

(A) Selected Industrial Groups
(B)

Industrial Groups	Proportion	
	1935	1950
Production of cotton spinning and weaving machine	35.5	53.0
Shipbuilding	33.5	57.2
Production of Automobiles	39.5	68.1

Sources: The 1935 figures are based on a survey by Mitsubishi Keizai Kenkyujo (Mitsubishi Economic Research Institute), as quoted by Hayashi (1961), p. 157; the 1950 figures are derived from Tsusho Sangyo Sho (The Ministry of International Trade and Industry), *Kogyo tokei hyo* [Census of Manufactures], 1950.

(B) Niigata Tekkojo (Niigata Engineering Company)

Year	Proportion
1915	40.4
1920	38.2
1925	27.6
1930	32.0
1935	40.4
1938	36.8
1965	49.8

Sources: The interwar data are based on *Toyo Keizai kabushiki kaisha nenkan* [Oriental Economist's Company Almanac], various issues; the 1965 data are taken from Okura Sho Shoken Kyoku (Securities Bureau, Ministry of Finance), *Yuka shoken hokokusho soran* [Collected Biannual Corporate Reports], 1966. The figures are on a fiscal year basis.

Note: * Materials costs here are inclusive of raw materials cost and the costs of procured parts and of subcontracted works.

TABLE 7. THE PROPORTION OF SUBCONTRACTED WORK IN MANUFACTURING COST: THE CASE OF COTTON SPINNING/WEAVING MACHINE PRODUCTION

(per cent)

Category	1934	1950
Cost of Procured Parts	7.8	13.9
Cost of Subcontracting	22.1	55.9
Total	29.9	69.8

Source: Hayashi (1961, pp. 255-56).

TABLE 8. MATERIALS AND INTERMEDIATE INPUTS PER UNIT OF OUTPUT AT MITSUBISHI HEAVY INDUSTRIES, LTD.

Year	Input/Output Ratio*
1919	0.11
1920	0.17
1921	0.16
1922	0.18
1923	0.09
1924	0.13
1925	0.19
1926	0.15
1927	0.21
1928	0.24
1929	0.17
1930	0.16
1931	0.24
1932	0.14
1933	0.22
1934	0.47
1935	0.32
1936	0.35
1937	0.41
1938	0.83
1939	0.83
1940	0.92

Note: * The ratio was estimated as follows: (total materials and intermediate costs/total revenue) ÷ (price index of machinery/price index of iron and steel). The price indices have been taken from Miyohei Shinohara, *Mining and Manufacturing*, Long-term Economic Statistics of Japan, vol.10 (Tokyo: Toyo Keizai Shimpo Sha, 1972), p. 149. The Mitsubishi data have been compiled by the author from the company record.

(1941, pp. 183–194)]. This was due in particular to the abandonment of the gold standard (December 1931) and the subsequent massive devaluation of the yen, which resulted in a significant reduction in imports and a contrasting increase in exports. In addition, the long-awaited upturn of business conditions raised the rate of capacity utilization beginning in 1932 or 1933 [see Odaka (1975, p. 518)], which caused existing factory owners to look for partners who would be willing to subcontract portions of their jobs.

According to surveys done independently by Fujita (1965) and the cities of Osaka and Yokohama in the mid-1930's, the subcontractors were mostly medium- or small-scale enterprises employing 200 or fewer workers and located mainly in the large metropolitan districts such as Tokyo, Osaka, and Nagoya. A survey of subcontracting practices conducted by the Ministry of Commerce and published in 1936 revealed that the most common subcontracting operation in the year 1934 was machine fabricating (30 per cent), followed by casting (27.3 per cent), fabrication of thin sheet metal (5.2 per cent) and forging (4.9 percent) [Tasugi (1941/1987, p. 221)]. The capital equipment owned by these smaller factories was not particularly impressive; the factories were seldom equipped with machinery for specific purposes, such as milling machines. To compensate for this, workers displayed surprisingly high manual dexterity, using nothing but general-purpose lathes, most of which were poorly conditioned, to manufacture various machine parts.[14] It is interesting to note that research on this period has confirmed expectation that machining operations were dominated by relatively small-scale firms (*ibid*., p. 201).[15]

It seems pertinent to cite the example of Kure Navy Arsenal, which began to encourage the development of ancillary firms in about 1935 and achieved unexpected success. The effort was initiated in 1934 by an official of the prefectural government of Kochi, which wished to encourage the growth of local manufacturing activities. As of 1933, the prefecture remained grossly underdeveloped, with manufacturing production being limited to the repair of parts and components for cement, paper, and silk-reeling industries and the repair services of buses and fishing boats. With a few exceptions, factories were quite small in size, with an average of ten workers or less.

At the beginning, the Arsenal anticipated at least three difficulties: insufficient technological capability, irregular delivery, and expensive production costs. To the surprise of the Arsenal officials, however, experimentation eliminated all three problems. The attempt was so encouraging that the Arsenal later expanded the ancillary network to other prefectures.

The main problem was organizational, rather than technological, upgrading. The Arsenal's policy was (1) never to renovate original production facilities, with the only exception being that the manufacturers be required to adopt the limit-gauge system,[16] (2) to encourage the specialization of production processes and of products in order not only to reduce unit costs but also to improve product quality, and (3) to eliminate the exploitation of intermediary merchants by making full use of the network of manufacturers' associations (*kogyo kumiai*, instituted by the Act of Manufacturers' Association of 1931), which offered both a financial resource and a marketing channel.

In addition, the prefectural government helped private manufacturers by letting them use public facilities for raw materials testing, casting, exterior finishing, and water pressure experiments. The government also located trading firms for the purchase of raw materials in bulk and for promoting new sales [Waraya (1938, pp. 1–73)].

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[14] For one thing, traditional craftsmanship still lingered among the medium- and small-scale firms, and apprenticeship training was still practiced in many such *machi koba*, or small, family-operated factories. When the establishment of the Toyota Motor Company was announced publicly, quite a few such old-fashioned, ambitious craftsmen swarmed at the company gate seeking employment. However, such an incident never repeated itself (based on the author's interview survey).

[15] The distribution of firms engaged in machining and finishing operations suggested the existence of two optimum sizes of factories. It is of some relevance to make a brief remark on such a finding. There seems to be at least a critical point in the growth of a firm when it ceases to be a small workshop run by an owner-operator. The size may be too small in an engineering sense but too big to be managed in an informal, familial style with all the administrative tasks handled by a master craftsman. Consequently, there comes a time when the optimum size in the engineering sense does not agree with that in the organizational sense; this is a critical point for growth. In the inter-war years, it was estimated that such a point was reached when a weaving factory owned from 30 to 50 sets of weaving machines; the point was reached sooner in the case of a machine shop (15 to 20 machine tools). According to Tasugi, there is truth in the old Japanese saying that "boils and weavers collapse when they get bigger." [Tasugi (1941/1987, p. 76)].

[16] In 1919, Takuo Godo, a high-ranking Navy officer, introduced the limit-gauge system to Kure Navy Arsenal. As a result, production costs were reduced by 30 per cent and man-hours by 48 per cent. Delivery time was also considerably shortened.

TABLE 9. NUMBER OF FIRMS IN THE AUTOMOBILE INDUSTRY

Year	Importation and Assembly of Automobiles	Manufacturing of Automobile Parts and Components
1929	12	132
1930	8	143
1931	10	170
1932	10	237
1933	7	335
1934	4	402
1935	4	351

Source: Jidosha Mondai Kenkyujo (1940, p. 31).

This case is significant for two reasons. First, it suggests that institutional and managerial factors may weigh more heavily than technological factors. Second, it demonstrates the great benefit of research institutes, experimental stations, and trade associations, through which technological information may be transmitted, new appropriate technologies devised and tested, and quality control techniques assimilated.

However, things did not always develop smoothly. Take, for instance, the Japanese motor vehicle industry, which was still at the infant stage of development in the 1930's. While the manufacturing of automobile parts and components began with the importation of motor vehicles, in the earlier days they were almost entirely cheap, imitation parts of poor quality. The number of parts' manufacturers increased rapidly after around 1930, as shown in Table 9, but about 80 per cent of them were small factories employing 30 or fewer workers. Neither their technological nor managerial capacities qualified them to serve as independent ancillary firms.

We might insert here an experience of the Toyota Motor Company. The company had little expertise in 1937, when it was formally established, other than in machining and forging. Precisely for this reason, it took much trouble to identify manufacturers of automobile parts and components. To begin with, no die makers existed during the inter-war period. When Kojima Press established its corporate tie with Toyota in 1937, for instance, it recruited a die-making craftsman from outside the firm and purchased secondhand machines from the Army Arsenal.

Even after Toyota identified prospective ancillary firms, however, the latter did not necessarily satisfy the Toyota engineers; there were leaks in radiators procured from one ancillary firm, and the margin of error in the quality of procured carburetors was too wide. Similar problems occurred in other parts such as distributors, spark plugs, fuel pumps, oil heaters, and so on.[17]

Raw materials proved to be another bottleneck. The domestically manufactured steel plates were too hard because their carbon content was too high. Consequently, pressed products had many defects, and for a while more than two-thirds of them did not pass the final testing procedure. It is estimated that the quality of Toyota's pressed products reached a

[17] Based on the author's interview survey.

permissible standard as late as in 1954–55, and the satisfactory level only after 1965 [Odaka, Ono and Adachi (1988, pp. 129–30)].

All in all, the records of the inter-war period give one the impression that the network of ancillary firms was relatively underdeveloped at the time. At least in terms of intertemporal comparison, subcontracting was less frequent in the inter-war years than in the post-World War II decades. In general, the big companies, which made up much of the relatively advanced sector of the economy, preferred to produce machine parts and components themselves. At this particular point in history, the Japanese development pattern was perhaps closer to nineteenth century Europe than to the United States.

VI. *Concluding Remarks*

Ancillary development in the Japanese machinery industry took a course quite distinct from that of the United States. First, the Japanese machine industry was uneven in terms of technological standards. Although there were some distinguished engineers and production designers, the overall capabilities of the industry were relatively limited. Second, the Japanese market was not large enough for scale economies to be easily realized. In the United States, the machine tool industry was strong enough prior to the appearance of large-scale assembly operations for the manufacturing of industrial, transport, and consumers' durable machinery. In Japan, by contrast, the growth of the latter preceded (or paralleled) that of the former. Whereas American primary firms could "buy" most of the necessary parts and components, Japanese machine producers had to resort to "making" them. It was only toward the second half of the 1930's that subcontracting gradually became common among manufacturing industries. In certain branches of the machinery industry such as motor vehicle manufacturing, however, substantial development of ancillary firms had to wait until the post-World War II decades.

This explains why Japanese primary firms have had relatively strong coordinating power over their ancillary firms. A good example is the post-World War II automotive industry, in which the majority of ancillary firms have strong, preferential ties with a single primary firm. There have been certain exceptions. Ancillary firms in the production of textile machine and sewing machines, for instance, were better developed even in the interwar decades and had therefore relatively more independent, equal relationships with their assemblers, but this was by no means a prevalent pattern.

In sum, the evidence suggests that the subcontracting practices in the machine industry were still in their formative stage during the inter-war decades and that fuller development had to wait until after the beginning of World War II.

HITOTSUBASHI UNIVERSITY

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