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THE SIGNIFICANCE OF STANDARDIZATION IN THE DEVELOPMENT OF THE MACHINE-TOOL INDUSTRY: THE CASES OF JAPAN AND CHINA (PART II)

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IV. *The Chinese Machine-Tool Industry and the Progress of China's National Standards Promotion Policy*

1. *Our Viewpoint Concerning Comparison*

In the previous sections of our paper we have confirmed the indispensable role of standardization in accomplishing the quality improvement of Japanese machine tools. The experience in prewar Japan has very instructive implications when we examine the technological development of the Chinese machine-tool industry. For the recent progress of Chinese machine-tool technology shows some basic similarities to that of Japanese machine-tool technology during the period 1940–1960 in the sense that the Chinese machine-tool industry now faces the transitional phase marking the gradual surperseding of imitative technology to attain competitive power with foreign machines. In the case of the Japanese machine-tool industry, however, the development in the later period cannot be understood without recognizing the significance of the establishment of a technological basis, which itself was particularly due to the evolution of industrial standards during the war.

This is the main reason we try to analyze the technological level of the Chinese machine-tool industry from the viewpoint of industrial standards. The Japanese experience in the development of industrial standards during the war period can be considered to provide an appropriate measure for comparison, since the machine tool industry had to adopt the *de facto* compulsory national and military standards in the wartime planned economy. More fundamentally, as was mentioned in Section I-1 of Part I, the Chinese and Japanese machine-tool industries share similar patterns of historical development and have both been involved in the catching-up process as late-comers under the *standardization from above* policy.

It is true that our analytical viewpoint for the comparison may appear to be too specific or narrow for grasping the technological level of the Chinese machine-tool industry, but today even in China both standardization and quality control are considered as the most important key factors for realizing rapid industrialization. That is, the real development of a manufacturing (particularly machine-tool) industry with greater competitive power and improved quality is inseparable from standardization and quality control. In this sense

our analysis focuses on an aspect of a very central issue in contemporary China. But it is again to be noted that, although both standardization and quality control are keys to the success of rapid industrialization, each of them is not a sufficient but a necessary condition for it.[44] For standardization is indispensable for actualizing the potential quality when it is not realized, since the standardization level must meet a kind of pseudo-equilibrium with the technological level.

In China, and from 1978 especially, standardization has been recognized and shouldered as one of the most significant means to facilitate rapid industrialization and has been promoted in a policy known as the "3-hua (3化)" campaign.[45] In 1978 the State Bureau of Standardization was expanded to reorganize and strengthen the central and local networks for standardization at various institutional levels. Research institutes for standardization, standards information centers and product inspection stations began to be established all over the country. In the same year China became a member of the International Organization for Standardization. That is to say, from 1978 standardization policy in China moved into a new era of successive full-scale promotion measures, which have contributed to improvement of the quality of machinery.

2. *Development of the Chinese Machine-tool Industry and Standardization*

It is no overstatement to say that there existed no machine-tool industry at all in prewar or pre-liberation China. On the other hand, the textile machinery and ship-building industries were of a non-negligible size in the machinery industry of those days. Consequently, some primitive machine tools (hand-powered lathes, belt-driven engine lathes, shapers and hacksawing machines) and spare parts for them were produced imitatively in small numbers mainly for repair and maintenance purposes. Apart from these few exceptions, virtually all machine tools were imported from various countries, including Great Britain, the United States, Germany and Japan.

Thus different foreign standards prevailed throughout China. British and American standards were very popular in Central and Southern China, for instance, whereas Japanese ones dominated in the Northeast (the Manchuria region) and Northern China, and German standards dominated in the machine tools supplied to the Chinese military. In some cases, various countries' standards simultaneously applied to different parts of the same machine, such machines commonly being called "all-nation brand" machines.[46] Although the Chinese

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[44] Standardization and quality control, in our view, do not share equal significance. Rather, the former is a prerequisite for the latter.

[45] After two decades neglect, the State Council re-emphasized the necessity of promoting (1) *biaozhun-hua* (标准化; standardization); (2) *xilie-hua* (系列化; simplification or integration); and (3) *tongyong-hua* (通用化; deepening of interchangeability) in the very important resolution for industrial modernization "Zhonggong zhongyang guanyu jiakuai gongye fazhan ruogan wenti de jueding (caoan)" [The Party Central Committee's decision on some problems for accelerating industrial development (Draft)] (issued in July 1978; see Section 10, and also Section 19 for quality improvements). For the recent official definitions of *xilie-hua* and *tongyong-hua*, see GB 3935.1-83, "Fundamental terms of standardization, part 1." For some conventional definitions, see also Zhao Dong-wan, "Dangqian jixie gongye fazhan zhong de jige wenti" [Some problems in the recent development of the machinery industry], *Jingji guanli*, Nos. 5 and 6, 1980.

[46] A more striking case can be found in the double standards in Shanghai prior to the Liberation, when residents of the city had to bear the inconveniences originating from the use of both 220 and 110 voltages for electric supply and appliances.

Standards Association (CSA) was established in 1934 and started to set up provisional national standards, such standards, needless to say, had little meaning in this situation. This notwithstanding, to understand the subsequent development, two facts must be pointed out as regards industrialization in prewar China, namely, (1) a technical committee for fixing industrial standards was, after all, organized as early as in the 1930's; and (2) the Chinese machinery industry had already accumulated a certain potential for imitating foreign technology.[47]

After Liberation, a genuine machine-tool industry at long last came into existence and immediately began full-scale development with the aid of the Soviet Union, since the machine-tool industry was considered a key industry for building a general machinery industry to serve as the core for rapid industrialization under socialist economic planning. The production capacity of the machine-tool industry increased enormously during the period of the first (1953–57) and second (1958–62) Five Year Plans. In 1952, 13.7 thousand machine tools were produced, more than twice the prewar maximum (5.4 thousand in 1941), and this figure was again doubled in the subsequent decade.[48]

Still, as a matter of course, the industry's growth was attended with various difficulties, the most serious being the quality problem. Although almost all machine tools produced were patterned after Soviet models during the first FYP period, the types or classes were exclusively limited to low-quality universal-type machine tools. Furthermore, there was a very high proportion of defective products, mainly due to the shortage of skilled labor.[49] In those days almost no quality standards were applied and no scientific product inspection was yet implemented. If they had already been institutionalized, the rate of waste articles must have been much higher than the observed. In other words, the capacity to imitate standard Soviet machine tools was not yet sufficiently fostered in China.

During the second FYP period, and especially during the years of the Great Leap Forward (1958–60), machine-tool production underwent an extraordinary expansion. This, however, did not mean real development of the industry. Many of the machine tools produced in this period could be considered as typical examples of inappropriate "appropriate technology." Production by indigenous methods, known in Chinese as *tu-fa* (土法), was strongly recommended in the course of the moral mass-movement. Consequently, a great number of simplified machine tools as intermediate technology were produced by various unique devices even in small towns and rural villages. Although such machines were without exception cheap and labor-intensive, their quality was out of the question. Apart from such extreme examples as concrete-made lathes, wooden bearings, bamboo-made belts, etc., many of the junior-type machine tools produced usually in non-state-owned machine shops were also said to be unable to meet minimum quality requirements.

On the other hand, China had already built (or rebuilt) about twenty modern machine-tool factories by the end of the second FYP. Not a few of them were constructed with the

[47] The potential must be considered to have been greatly oppressed by the Japanese economic invasion in the 1930's. For detail, see Kiyokawa, "Chūgoku sen'i kikai kōgyō."

[48] For precise figures, see State Statistical Bureau, PRC (ed.), *Statistical Yearbook of China, 1981*, (foreign Chinese edition, Hong Kong: Jingji-daobao-she, 1982), p. 227.

[49] The utilization rate of machine tools was also very low, chiefly because of the poor planning for specialization and coordination. See Guojia-tongji-ju (ed.) *Woguo gangtie, dianli, meitan, jixie, fangzhi, zaozhi gongye de jinxi* [Recent development of the iron & steel, electric power, coal, machinery, textile and paper industries in China] (Beijing: Tongji-chuban-she, 1958), pp. 132–38.

aid of the Soviet Union, Czechoslovakia, East Germany and Hungary. Those modern factories even gradually began to trial-produce some high-performance, large-sized and high-precision machines such as automatic lathes, vertical lathes, jig boring machines and hobbing machines. A few research institutes for machine tools were also established, and designing capacity gradually expanded. But full-scale production of high-grade machine tools was almost impossible, since industrial standards were practically nil. That is, they were hardly implemented, although standards had already been set up on paper in considerable numbers.

In 1957, the State Bureau of Standardization was at long last established and standardization cautiously commenced. But it should be noted that, prior to 1957, not a few "ministry standards" had already been fixed under the auspices of each ministry.[50] For instance, the Ministry of Foreign Trade had to set up inspection standards for exportable goods at an earlier stage in order to promote exports. Similarly, the Ministries of Metallurgical Industry and Light Industry had fixed a number of basic standards. In the case of the First Ministry of Machine Building (FMMB; now the Ministry of Machine Building Industry) which was established in 1952, most fundamental standards for such things as, say, tolerances and fits, threads and shaft couplings were set up from 1955 by the Standardization Department in the Ministry. After the establishment of the State Bureau of Standardization, standards for machine elements, automobile parts and so forth increased more steadily. In the case of the machine-tool industry, a number of standards for machine tools proper were fixed in a lump in 1960.

In 1962, the Chinese standardization policy entered a new phase with the enactment of the Administrative Regulations for Technical Standards of Industrial and Agricultural Products and Engineering Constructions. The standardization prior to the year may be characterized as the stage of provisional standardization, for almost all standards up until that time were said to be precise copies of Soviet standards (GOST). This was reasonable in a sense, since most of China's basic modern technology had been imported from the Soviet Union in the 1950's. Yet it must also have been one of the reasons that industrial standards were hardly implemented in China's manufacturing industry in those days,[51] because technological level of the Chinese industry could not fulfill exactly the quasi-Russian standards which embodied the much higher technological level than Chinese one.

After 1962, the Bureau initiated fresh efforts to set up appropriate and feasible standards and, as is shown in Fig. 9,[52] the accumulated number of standards increased steadily after 1963. Nevertheless, the great influence of Soviet standards is said to have prevailed at least up to the end of the 1960's. Soon after getting on the right track, however, the standardization work unfortunately almost came to a stop during the years 1968–72, in the midst of the so-called Cultural Revolution (1966–76). Although it recovered gradually from 1973,

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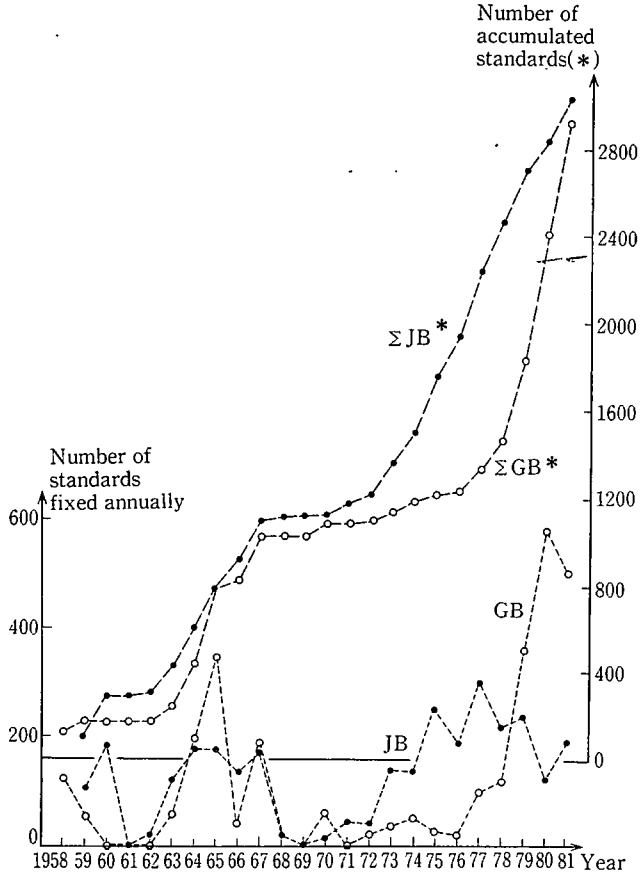
[50] For more details on the historical development, see *Zhongguo biaozhun-hua 30 nian* [30 years of standardization in China], ed. by special committee, Beijing: Jishu-biaozhun-chuban-she, 1979.

[51] It must also have been an indirect cause of the fact that "arbitrary standards" (*tu-biaozhun*; indigenous standards) prevailed with the combined machines of indigenous and imported technologies during the Great Leap Forward period.

[52] In the case of Chinese standards, ministry standards should be regarded as a part of national standards. JB and GB denote, respectively, FMMB standards and national standards. The latter includes standards for items other than machinery, including a small number of standards for agricultural products (1–2%). As our figures are gross estimates from the catalogue of all national and ministry standards, both new and revised standards are included.

FIG. 9. DEVELOPMENT OF CHINESE STANDARDS



Source: Guojia-biaozhun-ju, *Zhonghua renmingongheguo gong nong ye chanpin gongcheng jianshe guojia biaozhun he bu biaozhun mulu 1982*, Beijing, 1982

it is quite doubtful whether the new standards were faithfully implemented, since the social attitude of despising standards had become deeply diffused within the economy during the Cultural Revolution.

It may, however, safely be claimed that modern state-run factories steadily accumulated production experience and gradually extended the range of trial production of quality machine tools in the 1950's and 1960's, as well as in the 1970's. Table 7 clearly shows the gradual upgrading of machine types for trial production.[53] Typical universal-type machine tools were trial-produced in the 1950's, whereas in the 1960's slightly higher grade machine

[53] Factories in Table 7 are limited to those which provide information on installed equipment. Although the information on mother machines in those plants was very scarce, more precise data are in general available for the machine tools produced. See, for example, Xinhua-chuban-she (ed.) *Zhongguo gongshang qiye minglu* [Directory of industrial and commercial enterprises in China], Shanghai: Xinhua-chuban-she, 1981.

TABLE 7. DEVELOPMENT OF MAJOR CHINESE MACHINE-TOOL FACTORIES IN THE 1950'S AND 1960'S (Main Products and Equipment)

Main Products	Installed Equipment
1. Harbin Measuring and Cutting Tool Works (哈尔浜量具刃具厂)	
Various precision measuring instruments and tools (most of them the first of their kind in China). Optical instruments.	Established in 1955, with the aid of Soviet Union. More than 150 machines (lathes, shapers, thread cutting lathes, milling maching, drilling machines, planers) made in U.S.S.R., Czechoslovakia and Hungary. Most of automatic and semi-automatic machines Soviet-made. 10% skilled workers.
2. Dalian Machine Works (大連机床厂)	
Engine lathes (C620-3, 1958) Hydraulic profiling lathes (1961). Unit-type drilling machines (UT013)	Self-designed automatic special-purpose machines (1956).
3. Shenyang No. 1 Machine Tool Works (沈阳第一机床厂)	
"Dongfanghong" precision lead-screw lathes (SM 8620; Soviet standards). Semi-automatic multispindle lathes (1965). Engine lathes (C630; C640; Soviet designs). Camshaft special purpose lathes (1963). Precision thread cutting lathes (C868A, 1963)	Established in 1955 with the aid of U.S.S.R. Self-contained factory. Previously a repair workshop of Mitsubishi, Japan (1935). Large-sized lathes (MC3; Soviet-made). Surface grinders (Soviet-made). Large-sized drilling machines (Czechoslovakian made). Planers (East Germany-made). Multi-spindle drilling machines (Soviet-made). Gear shavers. Gear cutters.
4. Shenyang No. 2 Machine Tool Works (沈阳第二机床厂)	
Radial drilling machines (Z35; ZB53; Z310) Vertical drilling machines (ZA135; Z525; "Yuejin"). "Dongfanghong" horizontal boring machines. Jig boring machines.	Remodeled in 1955 with 157 imported machines from U.S.S.R. and Czechoslovakia. Specialized as boring-machine factory (1960's). Previously a repair workshop of Sumitomo, Japan.
5. Shenyang Heavy Machine Tool Works (沈阳重型机床厂)	
14-ft double housing planers (1950). 5-ton hammers (1952). Rolling mills (1958).	Established with Soviet technological assistance. Previously a machine shop of Sumitomo Metal, Japan. About 400 machine tools including large-sized lathes and planers. Gear milling machines. Hydraulic presses.
6. China-Czechoslovakia Friendship Machine Tool Works (中捷人民友谊厂)	
Radial drilling machines. Semi-automatic horizontal boring machines (T611D, 1961). Jig boring machines.	Established with the aid of Czechoslovakia. Previously a workshop of Mitsubishi, Japan.
7. Tianjin City United Machine Tool Works (天津市連合机器厂)	
Engine lathes (copies of Japanese models, 1951)	60 Soviet lathes installed around 1951.

8. Beijing No. 1 Machine Tool Works (北京第一机床厂)

Involute gear cutters (Y228, 1959). Planer-type milling machines (1964). 2400 milling machines per year. Various types of lathes.

A factory consolidating previous arms-repairshops. Soviet assistance in 1958. 85% of the 700 machine tools domestically made.

9. Beijing No. 2 Machine Tool Works (北京第二机床厂)

First grinder in 1953. Horizontal boring machines (1964). Universal grinders (1967).

Previously a water-wheel manufacturing factory. From the mid-1960's specialized in precision grinders. Party automated.

10. Beijing No. 3 Machine Tool Works (北京第三机床厂)

Vertical drilling machines (Z525B). Milling machines. Grinders.

Most of installed equipments domestically made (partly flow-production). A consolidated factory of about 100 tiny shops.

11. Jinan No. 1 Machine Tool Works (济南第一床厂)

Lathes (C616; C616A; C864T). Face Lathes (C6020, 1959). "Dongfong" high-speed lathes. Precision lathes (1967). Precision tap lathes (1963).

Mechanization rate, 77% (around 1960). Many Soviet-made machines. Specialized in lathe production. Poor casting and forging shops.

12. Jinan No. 2 Machine Tool Works (济南第二机床厂)

Planers (copies of Japanese and Soviet models; 1958). Shapers (B616, 1962). Unit-combined machine tools (planer-shaper-milling machines; B212)

320 machine tools. Previously a Japanese arsenal. Planers made in U.S.S.R. and East Germany. Vertical lathes. Specialized in planer production.

13. Shanghai Machine Tool Works (上海机床厂)

The first production of grinders in 1950. 150 various grinders per month. Surface grinders (1955). Ball-bearing automatic grinders (1956). Gear grinderss (1963). Precision grinders (1964). Semi-automatic precision cylindrical grinders (1966)

Previously a branch of China Agriculture Machine Co. (1946). 30% skilled workers. Expanded in 1955 by installing Soviet, Czech and East German machines. Japanese lathes and an American turret lathe also installed. Specialized in grinder production.

14. Shanghai No. 2 Machine Tool Works (上海第二机床厂)

Junior machine tools. Grinders (CK371).

Established in 1958 with the aid of U.S.S.R.

15. Shanghai No. 3 Machine Tool Works (上海第三机床厂)

Grinders (1961; 1962). Jig boring machines (1965; 1966). Optical tool grinders (M9017, 1968).

Established in 1958 through consolidation of 5 machine shops.

16. Shanghai Tool Works (上海工具厂)

Small cutting tools. Precision machines (1964). Micro-drills (1964).

Involute-gear testers (East German made; domestic). Zeiss optimeters (East German made; domestic). Partly flow production (1959).

17. Nanjing No. 1 Machine Tool Works (南京第一机床厂)

Automatic lathes (C107A, 1958; C104A, 1959). Gear cutters (Y12Z). Buffing machines.

Previously a branch of China Agriculture Machine Co. 400 precision lathes (1962).

18. Nanjing No. 2 Machine Tool Works (南京第二机床厂)

Hobbing machines (Y320K, 1959). Gearhoning machines (Y4632). Gearshavers (Y4232C).	About 200 machine tools. Specialized in gear cutters in the 1960's.

19. Wuxi Machine Tool Works (无锡机床厂)

Lathes (after 1952). Centerless grinders (M1025, 1958; M1040). Automatic ball-bearing grinders (M8820). Internal grinders (M221; MZ208).	Previously Kaiyuan Iroworks. About 600 machine tools. Specialized as grinder factory after 1958.

20. Hangzhou General Machine Works (杭州通用机械厂)

Centerless grinders.	Installed imported machines from U.S.S.R. and Czechoslovakia in 1955-56.

21. Wuhan Heavy Machine Tool Works (武汉重型机床厂)

Vertical lathes (C534J, 1960; C5102-1A, 1963). Planers (B7242A; B7288; B7289). Milling machines (X206J; X210). In 1958, produced 215 machine tools. Various large-sized machine tools.	Established in 1958 with the aid of U.S.S.R. About 5000 machine tools including precision machines made in U S.S.R., Czechoslovakia and East Germany. Also Soviet-made planers, vertical lathes and helical tooth cutters.

22. Wuhan Machine Tool Works (武汉机床厂)

Grinders (M612; M6420F, 1959; M6615; M6620). Tool grinders (1964; 1969)	Established around 1956 by consolidating 50 tiny shops. More than 200 automatic machine tools (1964). Specialized in grinder production.

23. Chongqing Machine Tool Works (重庆机床厂)

Gear hobbing machines (Y32, 1958; Y30-1, Y35-1, 1960; Y381; Y3150A; Y3150H). Bevel gear cutters (Y25A). Worm wheel hobbers (YG3780).	Constructed by Soviet's design.

24. Changsha Machine Tool Works (长沙机床厂)

Various types of lathes. Broaching machines (1959). Slotters (B540). Hydraulic shapers.	Constructed by Soviet's design. Specialized in lathe and slotter production.

25. Kunming Machine Tool Works (昆明机床厂)

Horizontal boring machines (1958; T4132; T3614, 1964; T716). Milling machines (X432B; Y460). First semi-automatic profile milling machines in China (1965).	Established in 1939 with the aid of U.S.A. Germany-made shapers and milling machines. 28 high-quality mother machines. Constant temparature room.

Notes: 1) Figures in parentheses indicate the year of first trial production.
2) The machine-tool model notation indicates the basic parameters of machine tools. For instance, C6140: C—lathes; 61—the ordinary type; 40—the maximum cutting diameter in terms of millimeters, etc.

Sources: 1) Ajia-kenkyūjo (ed.), *Chūgoku kōgyō kōjō sōran* [Directory of manufacturers in China], mimeograph, 1965 and 1970.
2) Japan External Trade Organization (ed.), *Chūgoku no kikai kōjō* [Machinery workshops in China], Tokyo: JETRO, 1968 and 1975.

tools (e.g. jig boring machines, semi-automatic multi-spindle lathes, semi-automatic profile milling machines and semi-automatic cylindrical grinders) were developed in various state-owned factories. By assembling the fragmentary information, we may draw some conjectures regarding the trial productions in that period: (1) the quality of the newly produced machine tools was not fully satisfactory; (2) those factories had often to face difficulties in mass-production; and (3) the quality of mother machines even in such state-owned factories was not infrequently wanting because of the inability to replace older models.

In the 1970's, prototype production was further extended to include some new models of precision, heavy-duty and high performance machine tools. A typical example was the simple NC lathes whose production started from the mid-1970's, even though the quality is said to still give some problems even today. From about the same period, the import of high quality machine tools has rapidly increased, and the number of licence agreements with foreign machine-tool makers has steadily expanded. These recent developments may be interpreted as symptoms of an extrication from the stage of imitation of Soviet universal machine tools. But we consider that a necessary condition, the development of standardization, had to be satisfied to realize the extrication.

3. *A New Stage of Standardization*

At the beginning of the 1970's, Chinese machine-tool production showed a great leap to about 160 thousand machines annually from an average 55 thousand in the 1960's. This scale of production is not greatly different from that of the Japanese machine-tool industry. The total number of installed machine tools in China (2.7 million units in 1978) is well comparable to that of advanced countries. This rapid increase can be considered to have been mainly due to drastic expansion of production in various factories other than those of the so-called specialized key enterprises, since the latter accounting for only a small proportion of all factories was fully controlled under the national planning.

So far, precise time-series figures have not been publicized, but it is known that 189 specialized machine-tool plants were already in existence in 1966, and that the number gradually increased to 372 in 1972 and to 625 in 1980.[54] In the course of this development, (1) machine tool types steadily extended from 550 in 1965 to 839 and 997 in 1974 and 1979 respectively; and (2) the geographical overconcentration of machine-tool plants in the coastal regions was also gradually rectified, as is shown by Fig. 10, although the traditional major cities, such as Shanghai, Shenyang, Beijing and Tianjin, still accounted for very high proportions. In any case, the development of the Chinese machine-tool industry in the 1970's can be regarded as a remarkable one insofar as the quantitative aspect is concerned.

This did not mean at all, of course, that the Chinese machine-tool industry had no problems. In fact the quality of Chinese machine tools continued to pose serious difficulties despite—or because of—the high domestic-supply ratio (about 80%). Among the contribut-

[54] A recent directory, which appears to cover most machine-tool plants, provides more detailed information on the machine-tool industry. The industry has 513 plants and workshops with 568 thousand workers, composed of such sub-sectors as 171 machine-tool factories in the narrow sense (280,901 workers), 89 tool factories (92,005), 54 standardized part and machine-element factories (55,828), 39 press factories (33,145), 56 part and accessory factories (29,211) and so forth. The figures for workers include workers in attached facilities (e.g. nursery schools, clinics, etc.). See Xinhua-chuban-she (ed.) *Zhongguo gongshang qiye minglu.*

FIG. 10. GEOGRAPHICAL DISTRIBUTION OF MACHINE-TOOL FACTORIES IN CHINA (1981)

Note: Figures in parentheses stand for the aggregate number of workers. ■ denotes 10,000 workers and above, ⊙ and ● denote 5,000 and above, and 1,000 and above, respectively.

Source: Compiled from Xinhua-chuban-she (ed.) *Zhongguo gongshang qiye minglu*, Shanghai, 1981.

ing causes, the first that must be singled out is the fact that many of the mother machines in machine-tool plants are already obsolescent because of almost negligible replacement investments. More than half of the installed machine tools in the industry are said to have been employed for more than fifteen years. The situation is, if anything, worse for major factories, since most of them were constructed in the 1950's. That is to say, obsolete machines with more than twenty years of operation in those factories account for at least a third of their equipment.[55]

Secondly, the more recently produced machine tools are of inferior quality, despite the fact that the major part of production was made up of the simplest universal machine tools, namely lathes, planers and slotters. This can be attributed to (1) the poor quality of the mother machines; (2) the prevalence of "indigenous standards" (*tu-biaozhun*; 土标准) from the Cultural Revolution period; and (3) the poor capacity for designing. Thirdly, as was revealed by some surveys conducted in 1978, the rejected-article ratio in the industry is extraordinarily high, probably because standards are often disregarded. It was not rare, apparently, for 20–30 percent of finished goods to be rejected at the final inspection.[56] Even the products of major factories were not necessarily exceptions,—the milling machine made by the Beijing No. 1 Machine Tool Works,[57] the C618K-2 lathe by the Shenyang No. 3 Machine Tool Works and the bearings made by the Luoyang Bearing Works coming to mind as examples.

All of these difficulties suggest that development of the Chinese machine-tool industry so far has essentially been quantitative expansion without much qualitative amelioration. The second and third difficulties, in particular, can be considered to originate from the insufficient implementation or complete disregard of standards, and imperfections (e.g. obsolescence, insufficiency, inappropriateness, defects) in the standards themselves. As of 1978 the Chinese machine-tool industry was governed by 569 national (GB) and 2372 ministry (JB) standards for machinery and machine tools proper. This accumulated number of fixed standards is never small as compared with the experience of the Japanese machine-tool industry, although the number of standards is not necessarily a measure of the substantial effects of standardization.

Table 8 shows us the dates when representative standards for important machine-tool parts, materials, related machine elements and accuracy inspections were first fixed as national or ministry standards. It can be seen that in China most of fundamental standards for machine tools were established by the mid-1960's. Those standards, however, appear to have embodied some serious problems. First, as was already pointed out, Chinese standards were exact translations from Soviet standards, GOST's. Therefore, they were not necessarily appropriate for Chinese machine tools, but rather could be regarded as a kind of symbolic

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[55] *Almanac of China's Economy* (since 1981) contains precious information on the recent situation. We use the Chinese edition, *Zhongguo jingji nianjian* (Beijing: Jingji-guanli-zazhishe), since the English edition is partly abridged.

[56] See, for example, *Biaozhun-hua 30 nian*, p. 22.

[57] The Beijing No. 1 Machine Tool Works now produces milling machines under a licence agreement with the Hitachi Seiki Co. (Japan). They are struggling to bring the new machines up to Hitachi Seiki's accuracy standards, but a great deal of time is required in realizing it. The inspection tools are imported ones and/or are provided by Hitachi Seiki. Beijing No. 1 Machine Tool is still a self-contained plant and produces almost all parts, including milling cutters and even electric motors. Thus the products are very costly and inefficiently labor-intensive in comparison with the production in Japan.

TABLE 8. DATES FOR THE ESTABLISHMENT OF MACHINE-TOOL-RELATED STANDARDS: JAPAN AND CHINA

[ ] Japanese standards,
〈 〉 Chinese standards;
The years indicated are the earlist dates at which typical related standards were set up.

- A Fundamental System of Machine-tool Standards
  - Structure
    - Structured Element
      - Fit
        - Hole-Shaft — [JES 1926: Morse taper shanks-sockets] [JES 1937: T slot]; 〈GB 1973: Morse taper〉 〈GB 1959. T slot〉
        - Screws — [JES 1924]; 〈GB 1956〉
      - Surface Finish, Roundness — [JES(T) 1944]; 〈JB 1960〉
      - Power Transmission — [JES 1937: Motion direction]; 〈None〉
    - Body
      - Arms, Columns, Headstocks [None→JIS]; 〈JB 1975〉
      - Beds, Tables [None→JIS]; 〈JB 1978〉
      - Tool Slide, Carriages [None→JIS], 〈JB 1973〉
    - Transmitting System
      - Mechanical
        - Shafts — [None→JIS]; 〈JB 1960. Spline shafts〉
        - Bearings — [JES 1937-39] [JES(T) 1944-45: Precision type]; 〈J 1958〉 〈GB 1964〉
        - Gears — [JES 1936: Involute gear]; 〈JB 1960〉
        - Belt Pulleys — [JES 1927]; 〈GB 1972· Leather belts〉
      - Electric — [None→JIS]; 〈JB 1980〉
      - Hydraulic — [None→JIS], 〈JB 1976〉
    - Oil-circulating System — [JES 1927 Oil windows]; 〈JB 1959〉
    - Accessories
      - Jigs, Fixtures — [JES(T) 1945], 〈JB 1980〉
      - Centers — [JES 1937]; 〈JB 1975〉
      - Chucks — [JES(T) 1944]; 〈GC 1960〉
  - Function & Accuracy
    - Static Accuracy
      - Accuracy Inspection
        - Engine Lathes — [JET(T) 1940], 〈GC 1960〉
        - Drilling Machines — [JES(T) 1942], 〈GC 1960〉
        - Milling Machines — [JES(T) 1940], 〈GC 1960〉
        - Planing Machines — [JES(T) 1941], 〈GC 1960〉
        - Shaping Machines — [JES(T) 1941], 〈GC 1960〉
        - Grinding Machines — [JES(T) 1944], 〈GC 1960〉
        - Gear Cutting Machines — [None→JIS]; 〈GC 1963〉
      - Apparatus for Static Inspection — [JES(T) 1944], 〈GL 1962〉
    - Dynamic Function
      - Dynamic Test for the Above Machines — [None→JIS], 〈JB, gradually from 1977〉
      - Apparatus for Dynamic Testing — [None→JIS], 〈JB, gradually from 1977〉
  - Tools
    - Tools
      - Drills, Reamers — [JES 1926 Drills] [JES 1939: Reamers]; 〈GR 1960〉
      - Gear-cutters — [JES(T) 1945 Straight bevel gears, Pinion cutters]; 〈GR 1960〉
      - Grinding Wheels — [JES(T) 1942], 〈JB 1971〉
      - Cutting Tools — [JES(T) 1943: Milling cutters]; 〈GR 1960〉
    - Tools for Testing and Inspection
      - Limit Gauges — [JES 1930]; 〈GL 1962〉
      - Dial Gauges — [JES(T) 1945]; 〈GL 1962〉
      - Block Gauges — [JES(T) 1944]; 〈GL 1962〉
  - Raw Materials
    - Machine Oil
      - Cutting Oil — [JES(T) 1945]; 〈SYB 1959〉
      - Lubricating Oil — [JES 1932]; 〈SYB 1962〉
    - Steel Materials
      - for Tools [JES 1938: Carbon steel] [JES(T) 1939: High-speed steel]; 〈YB 1959: Carbon & High-speed steel〉
      - for Machine Elements [JES(T) 1939. Carbon steel] [JES(T) 1941· Ball bearing steel]; 〈YB 1965〉
    - Castings — [JES 1924], 〈JB 1972〉
    - Cemented Carbide — [JES(T) 1944]; 〈JB 1974〉
  - General — Classification, Technical Terms, Designing Standards [None→JIS]; 〈GB 1959〉

goals, since the technological level of Soviet machine tools was far advanced. The imported standards thus exerted an undesirable influence on Chinese engineers in the sense that such overly sophisticated standards produced a tendency of getting engineers not to regard the standard as "must" criteria.

Secondly, the revision interval for Chinese standards was too long. For instance, while most accuracy inspection standards were set up as early as 1960 (see Table 8), they were revised for the first time only in 1978. In China there existed a great many standards which went neglected without any checking or revising for more than ten years, whereas industrial standards are normally revised within five years in industrialized countries. A summary report of the State Bureau of Standardization confirms that most prevailing standards are still essentially copies from Soviet standards of the 1950's and 1960's, and that 70–80 percent of the Chinese standards fall behind those of industrialized countries in respect of the technological levels required in the standards.[58]

While the above two difficulties are problems of the standards and the standardization system themselves,[59] the question of whether fixed standards were sufficiently implemented or not is a more serious and substantial problem for judging the effectiveness of standardization in China. The State Bureau of Standardization has itself pointed out the serious situation of imperfectly implemented standards in the 1970's. That is to say, three typical undesirable cases: (1) production after no standards; (2) the degradation of standards; and (3) the disregard of standards, were not uncommon in the production of manufacturing goods in China. Conservatively speaking, more than 20 percent of national and ministry standards were said to fail to be implemented.[60] This can be regarded as one of the main direct reasons for mass production of low quality machine tools in the 1970's.

Other surveys on the implementation of standards, conducted in 1978, also confirm the similar facts. One survey suggests, furthermore, that fully one third of the cases involving failure to implement standards was due to insufficient recognition of the great significance of standards.[61] This is a matter of grave importance, since national and ministry standards a compulsory standards in China; and the great advantages of standardization had been fully proven for various cases by the mid-1970's. Thus the government has had to take decisive steps to promote real standardization and its full-scale implementation since 1978.

In 1978, based on the Central Committee's Decision for Accelerating Industrial Development, the State Council drastically reorganized the State Bureau of Standardization and its subordinate institutions, further unifying the central and local networks for standardization. With the enactment of the Regulations for the Administration of Standardization of the People's Republic of China the next year, a new age of standardization may be said to have dawned. A great many standards have been set up every year since 1979, and the

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[58] See the Report of the State Standards Administration on Strengthening Standardization Work (Dec. 1982), which is reproduced in *Almanac of China's Economy, 1983*, pp. VIII: 129–31 (Chinese edition). See also *Biaozhun-hua 30 nian*, pp. 16–22.

[59] One may point out, as a third difficulty, the very small proportion of basic standards among national stanards (7.6% as of 1978). Since the basic standard is the basis for the further development of property standards and method standards, this weakness may exert a certain unfavorable influence on the future development of standardization.

[60] See *Almanac of China's Economy, 1981*, p. IV: 177 (Chinese edition), and *Almanac of China's Economy, 1983*, p. VIII: 130 (Chinese edition).

[61] See *Biaozhun-hua 30 nian*, pp. 180–85 and pp. 116–17.

accumulated numbers not only of national and ministry standards but also of regional (provincial and city) and enterprise standards are increasing rapidly. Consequently, the average age of standards has become considerably lower (less than five years), while the technological levels of Chinese standards are, it is said, gradually catching up with those of the 1970's of industrialized countries.

On the other hand, the Bureau began to extensively promote the quality control movement, since standardization and quality control support inseparably each other. A "quality month" campaign, a national high-quality medals system (a variant of the certification marking system) and an all-round quality control movement were initiated in 1978, 1979 and 1980, respectively. These radical reforms, including a partial switching to ISO from 1982, appear to us too precipitate and drastic, but there can be no doubt that a new stage of standardization has commenced.[62] If prevailing standads can be adequately implemented, the upgrading of low-quality machine tools in China may be realized in the near future.

4. *Summary Evaluation from Our Comparison*

We have now sketched the development of the Chinese machine-tool industry from the viewpoint of the deepening of standardization. It has only been several years—from around 1978 at the earliest—that distinct signs of a new development of both the machine-tool industry and standardization emerged under the promotion of the "Four Modernizations" policies. The great significance of quality and performance of machine tools is gradually being grasped among engineers. Technology transfers and imports of quality machine tools are steadily expanding. The production of precision, high-performance and NC machine tools on a fair scale has been underway for several years. These recent developments in the machine-tool industry can be considered as symptoms of the transition from the stage of imitative technology.

In other words, the Chinese machine-tool industry of the period prior to 1978 held some similarities to Japan's machine-tool industry of the wartime, particularly with respect to technological level and the degree of standardization. Table 8 suggests the scale of the technological gap between the Chinese and Japanese machine-tool industries from the standpoint of the disparity in the dates of the establishment of machine-tool-related standards. That is, comparison of the dates at which corresponding Chinese and Japanese standards were fixed discloses a technological gap of at least two decades between the two industries. Taking into consideration the relative degrees of implementation of standards, the gap must be interpreted as being from two to three decades.

The accumulated number of Chinese standards (as of the 1960's, say) was never small in comparison with the experience of Japan, viz. JES and JES(T). Hence, it is to be understood that the real difficulties consisted in the implementation or technological management of standards, not in the system for setting up standards itself. In fact national and ministry standards have not even today been fully implemented in China. This is a serious and deep-rooted problem, particularly in a planned economy, since the standards have been clearly

[62] The new stage is, we believe, characterized as the third phase of standardization. Our demarcation for China's standardization is: First stage [–1961]: borrowed standards; Second stage [1962–1977]: the transition to domestic standards, including the vacuum of 1968–72; Third stage [1978–]: real progress in standardization.

meant to be compulsory. In any event, China's standardization prior to 1978 can be considered not to have achieved such great effects in improving the product quality of machine tools as was the case in the Japanese machine-tool industry of the wartime.

Two reasons may be adduced for the insufficient implementation or slow diffusion of the compulsory standards in China. First, the so-called *quanneng* (全能; all-round or self-contained) factory system has been institutionally encouraged in the past, and indeed still prevails. Insofar as the self-contained factory system is not radically reconsidered, therefore, standardization cannot effectively promote the deepening of interchangeability and specialization. Secondly, the quality improvement effect of standardization through the strengthening of competition has been rather small in China, since the price system has been extremely insensitive to differences of quality under the Chinese economic system. That is, the incentives for implementing standards or improving quality appear to be weaker as compared with the planned economy of wartime Japan.

Thus, some incentive or competition system to enhance quality improvement has, we believe, to be introduced into the Chinese economy in order to speed up reduction of the technological gap with industrialized countries. Otherwise it will take a considerably long time for the machine-tool industry to upgrade the general quality of its products. Such a policy might, for instance, take the form of a quality-adjusted price system. And the quality competition that this would provoke might in its turn spur active R & D activities to improve quality. But it should be reiterated that standardization would then still be indispensable for rapidly diffusing the effects throughout the industry as a whole.

V. *Concluding Remarks*

In the foregoing discussion we have clarified the indispensable role of standardization in upgrading the quality of machine tools. It should be emphasized enough that improvement of machine quality and the production of high-quality machines is the most significant problem in the process of technological development of the machine-tool industry in late-industrializing countries. For the machine-tool industry in such countries has, without exception, to start with the production of low-quality machine tools or the imitative production of foreign machines. Furthermore, the prices of such machine tools are normally very expen-, sive for their quality. Whether or not the quality can be improved (or the price reduced as in the Japanese experience) thus holds the key to guaranteeing the competitive power necessary to facilitate rapid development under the open-economy system.

In the case of machine tools imitative production, which inevitably give rise to machines of much lower quality than the originals on which they are modeled, appears to be almost the only reasonable type of technological adaptation—i.e. it is a suitable form of appropriate technology. Although we may find not a few examples of so-called "appropriate technology" (viz. conventional types combining indigenous with modern technology) in the Chinese machine-tool industry of the Great Leap Forward and Cultural Revolution periods, their accuracy and performance were simply not adequate. That is, "conventional appropriate technology" in machine-tool production exerts an unfavorable influence on the machinery industry as a whole, since the machine tool is the mother machine for building other machines. This is perhaps a unique feature of the machine-tool industy alone.

In some rural industries, such as sugar manufacturing, paper-making, weaving and tea processing, we may find typical "conventional appropriate technologies" which do possess adequate competitive power against modern methods of production. In such cases, and such cases alone, is it worthwhile to discuss whether the short-run employment effect of appropriate technologies should be given first priority or not. But the competitive power of "conventional appropriate technology" is nonexistent in the case of the machine-tool industry, where low-quality machine tools produced by imitative technology of foreign machines can be regarded as the only feasible form of appropriate technology in the broader sense.

In late-industrializing countries, the imitative production of foreign machines is, we consider, an effective and unavoidable step in overcoming technological underdevelopment particularly in the case of the machine-tool industry. Thus, the upgrading of machine quality and the superseding of imitative technology are mutually-related crucial issues to be solved for the sustained development of late-comers' machine-tool technology. As has been confirmed, standardization can greatly contribute to a solution of the two problems, although standardization is not a sufficient, but only a necessary condition.

Standardization may, in general, facilitate the promotion of quality improvement and market expansion through the intensified competition resulting from the deepening of interchangeability and specialization. Furthermore, it may provide the opportunities for standard-designing and readjustment of various machine types incorporating different foreign technologies, particularly in the case of late-industrializing countries. At first, *standardization from above* is to be encouraged in those countries, since it holds the promise of more powerful and immediate effects. Later, R & D activities and quality controls by the enterprises themselves may be better strengthened gradually through *standardization from below*. At any rate, standardization is undoubtedly the most effective means to upgrade appropriate technology in the broader sense, i.e. the imitative production of low-quality machines.

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