How the Yankees Lost Their Know-how

For a century after the American Civil War, the machine tool industry of the United States was the star performer, worldwide, in the design and production of high-capacity, high-productivity machine tools.

This was no cultural or technological accident, for the drills, lathes, milling machines and other pieces of equipment that are the master tools of every metalworking economy were designed and produced in the United States to meet the requirements of users who, from the start, had to pay wages higher than those prevailing in the industries of Western and Eastern Europe.

In its own shops, the U.S. machine tool industry practiced cost-minimizing, the managers and engineers acting to offset increases in their own costs by improving their own productivity. As a result, the prices of their products, the basic machines for all U.S. industry, rose more slowly than the wages of labor. From 1939 to 1947, average hourly earnings of industrial workers in the United States grew 95 percent, while the prices of machine tools increased only 39 percent.[1] Therefore, all users of machine tools saw the new, higher-performance machinery as an increasingly attractive alternative to the employment of manual workers in industry. As U.S. industry was well served with effective equipment, offered at an attractive price, productivity was improved throughout the entire industrial system. That is how one industry employing 85,000 people had a decisive impact on the competence of the whole U.S. industrial system.*

Rising productivity, then, was a derived effect of the effort by industrial managements, both the producers and the users of machine tools, to retard the growth of their own costs of production. That pattern of general practices was the central mechanism within American industry that yielded the United

*In 1978, U.S. industries used 3,365,700 machine tools. National Machine Tool Builders Association, *Economic Handbook of the Machine Tool Industry, 1980/81* (Washington, D.C., 1980).

States the highest rate of output per person in the world, and an average increase in productivity of about 2.5 to 3 percent a year. American economists and historians recognized that growth rate as an integral factor in American prosperity.

Furthermore, the U.S. industrial tradition has included an understanding that it is entirely possible to combine top wages with low costs for quality products. What it takes is systematic attention to product design and all-around plant efficiency, so that increased productivity of labor and capital can offset rising wages. That is how the U.S. auto industry, after World War II, paid the world's highest wages per hour while producing cars in the Ford, Chevrolet and Plymouth lines that were the world's least expensive in terms of price per pound of vehicle.[2]

That is what "Yankee know-how" meant, and the machinery-producing companies were crucial to it. It was their ability to hold down costs that made their products attractive, and yielded the ripple effect of high productivity through the rest of the system. The U.S. machine tool industry also enjoyed a worldwide reputation for the outstanding productivity of its capital, and for machine reliability under taxing conditions.

There is nothing in this record to explain the deterioration in the performance of the U.S. machine tool industry, which began in the 1960s and by 1978 had progressed so far that, for the first time, the United States imported more machine tools than it sold abroad.[3] During 1980, U.S.-based machine tool factories supplied less than three out of four machine tools purchased by American industry. Year by year, in increasing numbers, the factories of Western Europe and Japan have been offering and selling quality equipment at attractive prices in the United States.

What had happened? Beginning in the late 1950s and culminating in the mid-1960s, a new set of rules was installed at the decision-making level of many industrial firms. Government contracts for the military and space agencies were assigned to companies on a cost-plus basis. This gave the contracting firms a strong incentive to run up costs, and the cost overruns were actually encouraged by the Pentagon's managers and the federal government's economists, on the grounds of "bolstering the economy" and "getting America moving again."[4] For the firms involved, high bids and subsequent overruns became normal operating procedure. These rules—exactly contrary to the traditional cost-minimizing—set a pattern of cost-maximizing within limits of available federal subsidy. Cost-maximizing became the dominant theme among the 37,000 industrial firms, or parts of firms, organized by the Department of Defense to meet its requirements. By 1980, prices of the military-serving goods produced by this network of firms were rising 20 percent annually.[5]

The Pentagon had also become a major client-manager of the machine tool firms, and cost-maximizing became the pattern in important parts of that industry, with effects that were far-reaching. In 1981 the Department of Defense owned 103,000 machines in use by major and subcontracting firms. Their value exceeded $1.7 billion. Also, the Pentagon has maintained "two industrial reserves of machine tools," the "General Reserve" and "Plant Equipment Packages" that range from a few machines to complete production lines held as reserve industrial capacity.[6]

In the 1950s, the Air Force became a principal sponsor of technological development in the machine tool field. The Air Force decided to push for computer-controlled machine tools (numerical control)* capable of shaping intricate parts of large size to accurate dimensions, the better to assure a high strength-to-weight ratio for large structural components of major aircraft.

With this new technology, parts of the operation previously assigned to skilled machinists—reading the blueprint, translating that information into movements of the machine tools—was now supplanted by prerecorded control information for the machine, in much the way that the holes in the paper roll control the player piano. This made possible an accuracy in repeatability of operations, especially for intricate metalworking, that was previously unattainable.

Even while the development of ingenious new mechanisms proceeded, the firms engaged in this effort found themselves catering to a state management for whom capability and performance were the dominant requirements, while cost was a matter of less significance. The Pentagon, when assigning "weights" to the criteria used for selecting industrial contractors, gives cost a value of 15 percent.[7] These criteria dominated the selection process among alternative design options in the development of numerical control technology.

So for leading firms of the machine tool industry, those best able to do research and new product development, the relationship with the Department of Defense became an invitation to discard the old tradition of cost-minimizing. It was an invitation to avoid all the hard work—the difficulties of changing internal production methods, modifying design of product, etc.—that is needed to offset cost increases. For now it was possible to cater to a new client, for whom cost and price increase was acceptable—even desirable.[8]

Accordingly, a new management style was encouraged within the machine tool industry of the United States, so that from 1971 to 1978 prices of machine tools rose, on the average, 85 percent, while the average hourly earnings of U.S. industrial workers increased 72 percent.[9] That inversion of

*The desired movements of workpieces and cutting tools, corresponding to blueprint specifications, are recorded as numerical information on punched cards, tapes, or in magnetic signal form. Hence the name given to this technology: numerical control.

the classic cost-minimizing pattern now meant that users of machine tools who still sought to hold down their costs had no incentive to purchase the new machines.

This pattern in the United States, from 1971 to 1978, was in dramatic contrast to the relationship between labor costs and machine tool prices in Japan. There, during the same years, machine tool prices rose 51 percent, while average hourly earnings of workers grew 177 percent.[10] Whereupon Japanese industry adopted the strategy of cost-minimizing that had long been recognized as the hallmark of U.S. industrial performance.

The consequences have been far-reaching for U.S. productivity and industrial competence. By 1978 in the United States, where there was a cost deterrent to the purchase of new metalworking machinery, only 31 percent of U.S. machine tools in use were less than ten years old. In West Germany the figure was 37 percent, but in Japan it was 61 percent.[11]

When the prices of American-built machine tools became unattractive to American users, there was no automatic shift to foreign sources at possibly more favorable prices: Machinery buyers are necessarily cautious about changing their suppliers. Managers are leery of buying industrial equipment from unfamiliar sources whose quality and reliability are not well known to them. Machinery buyers value a vendor who is near enough to service the equipment and can supply spare parts speedily. Machine downtime can be very costly. All these are biases in favor of known and accessible machinery suppliers. Therefore a move to purchase new machinery abroad requires more than a major price advantage.

As the age of the U.S. machine tool stock increased, industry began to lose the buoyancy of productivity that had long been the effect derived from the installation of new production equipment. For the important decade 1965–1975 this showed up in the differential productivity growth rates of U.S., West German and Japanese manufacturing. The average annual rates of improvement were 10 percent in Japan, 5 percent in West Germany, 2 percent in the United States. In 1980 U.S. productivity was *minus* 0.5 percent,[12] a stagnation unprecedented in American experience and the lowest rate of productivity growth of any industrialized country in the world.

The editors of *American Machinist,*[13] reflecting on the 1978 age of the U.S. machine tool stock, noted that it was virtually identical with the situation in 1940—at the end of ten years of the Great Depression, a long period of depressed investment in new production equipment. The failure some forty years later to replace old equipment in the United States was the direct consequence, not of depression, but of the collapse of cost-minimizing in the machine tool industry. And the falling rate of U.S. manufacturing productivity growth after 1965 was, in turn, strongly affected by the aging stock of production equipment.

By 1980 U.S. machine tool firms, employing 85,000 people, could no longer supply more than 24.6 percent of the machine tools purchased by American firms. Indeed, by mid-1981 Japan was providing 40 percent of the very important new class of computer-controlled vertical "machining centers" purchased by U.S. firms.[14] A machining center is an exceedingly versatile piece of major equipment, capable of applying many types of tools to the workpiece. Japanese models of this advanced machine tool, of quality comparable to the U.S. product, are offered at about 40 percent below U.S. prices. In 1979 the machine tool industry of Japan produced 14,317 of the new class of machines compared with 7,174 built in the United States.[15]

Again, there is no evidence to suggest that this set of effects was planned or intended by the managers of the U.S. machine tool industry or federal officials in the military, space, and nuclear agencies, who have become increasingly influential as state managers in a widening sector of U.S. industry. The managers of the machine tool firms simply acted to maximize their profits by applying a series of well-accepted methods. These included investment abroad; diversification of U.S. investments into other than machine tool firms; managerial decision-making with an eye to short-term results; a collateral emphasis on money-making by means remote from production—as from investments in the money markets; intensified managerial control in an attempt to make money and extend decision power; alliance with federal government managers in the effort to secure assured sales to federally subsidized, military-serving firms.

Foreign investment, along with licensing and other arrangements by U.S. machine tool firms, supported expansion of machine tool production, especially in Western Europe, to serve growing world markets. The editors of *American Machinist* have compiled reports (unpublished) on "foreign arrangements" by U.S. firms.* The earliest of these listings, in 1966, filled ten typescript pages. By 1974 the tabulation had expanded to thirty pages, and the 1981 roster (incomplete at this writing) will exceed forty pages. By 1972, overseas production facilities accounted for sales of $450 million in Western Europe alone.[16] As the financial fortunes of the U.S. machine tool industry became less tied to the competence of its domestic production, the firms were under less pressure to try for higher productivity in their U.S. plants; instead, they were offering equipment from their foreign production sources at prices

*American machine tool managers have emphasized licensing agreements with foreign firms, more so than the German industry, which has been an important foreign investor. See Alice Amsden, *Internationalization of the Machine Tool Industry,* United Nations, Centre on Transnational Corporations, 1982. Licensing the use of available designs and technique is an important form of capital export which is not counted in the statistics of "direct foreign investment." Blueprints, details of materials specifications, and production technique all have real value as "capital" but do not have the money form which is the conventional unit of measure of capital import (or export).

attractive to buyers outside the United States. The hard work and innovation needed to enhance efficiency at home could be avoided by managers who were making money from the new foreign production facilities.

Especially during the 1960s, the argument was heard that selling from a U.S. production base was necessarily difficult because of high U.S. wages. At one time machine tool firms, and companies in many other U.S. industries, had applied managerial and engineering competence to offset the U.S. wages. But this demanding managerial enterprise could be avoided once the explicit goal became making money, not making machines. The money-making could be accomplished while the foreign managers, engineers and workers did more of the planning and producing. The top managers and stockholders of U.S. machine tool firms have increasingly preferred that sort of development, even while opportunities for productive livelihood in the United States have deteriorated. By 1980, the almost 25 percent of U.S. machine tool purchases that were imported meant that at least 25,000 jobs in this single, crucial industry were exported. And the sales in Western Europe alone from the foreign-based production of U.S. firms account for at least another 15,000 jobs. These two forms of job loss for Americans add up to almost half the total 1977 employment in the U.S. machine tool industry.

Much like other U.S. industries, the machine tool firms have swung toward short-term profitability. The consequences for the character of their own investments and productivity are far-reaching. The very industry that developed the new computer-controlled (numerical control) machine tool technology has installed few of these machines in its own production system. By 1978 the metalworking equipment used by the machine tool industry itself included only 3.7 percent of numerically controlled machine tools.[17] The managers evidently feared the high fixed costs of the advanced equipment. When operated at a small percent of their capacity, the result is high cost per unit of work done. The larger machines in particular weigh heavily on overhead when sales are depressed.

Therefore the machine tool industry managers designed a production system that would be highly responsive to short-term market fluctuations. This included producing in small lot sizes; massive reluctance to standardize components and develop modular patterns for machine tool design; emphasis on product variety within single factories and firms. As one might expect, this management style boasted of providing "custom-built" machine tools to suit "unique" customer requirements. But the system that served this objective also operated at a relatively low level of productivity and at high cost. And it limited research and development to a few of the industry's larger firms.

By 1980 it had become clear that substantial efforts to design and apply mass production methods to the manufacture of these new instruments of

mass production were being conducted primarily outside the United States. In December 1979 and February 1980 I observed the construction of the first computer-controlled production systems in machine tool factories in Budapest, Hungary, and Nagoya, Japan. As I surveyed U.S. and foreign exhibits of numerically controlled machining centers at the International Machine Tool Show (Chicago) in September 1980, I asked a principal U.S. maker, "What is the lot size in which these machines are produced?" The sales manager answered: "Well, you don't produce a $350,000 machine for inventory. When you order one, we make it for you." By contrast, the Japanese firms, both large and small, are manufacturing numerically controlled machining centers on regular monthly schedules. They count on attractive price and high quality to sell their product to a worldwide market. One of the smaller Japanese firms (100 employees) participating in the show announced that its production rate was at a steady thirty units a month. That way, the representative explained, it is possible to schedule delivery of components from various suppliers with long lead times, and also to benefit from good prices under conditions of assured purchase. That is the kind of production system that delivers machining centers at prices averaging 40 percent below comparable U.S.-produced equipment.

At this writing, it is clear that the Japanese strategy succeeds and that the one-at-a-time, even ten-at-a-time, output of the principal U.S. machine tool firms assures them technological backwardness and a loss of market position within the United States and around the world.

To protect themselves against the hazards of an uncertain domestic market for machine tools, U.S. manufacturers sought out various kinds of product diversification in this country and looked for promising investments abroad. At the same time they learned to combine production of machine tool components abroad with assembly and sale in the United States. Several of the important U.S. firms at the 1980 International Machine Tool Show had made advantageous arrangements with companies in Western Europe and Japan to produce for them. The machines would carry the nameplates of the U.S. firms, which would do the merchandising in the United States. A large exhibit displayed by a principal American machine tool firm indicated that half the machines offered were built abroad to the firm's specifications. That company is well on the way to terminating its role as a producer and limiting itself to money-making by means of market management.

This major shift of emphasis makes for a fine showing on the profit and loss statement, but carries as a liability less design, less production, and therefore less opportunity for productive livelihoods in the U.S. factories of the machine tool industry. The new strategy of the industry's managers has also been developed at high administrative cost. In 1977, for every 100 produc-

tion workers in U.S. manufacturing industry as a whole, there were on average 43 administrative, technical and clerical employees. In the machine tool industry the ratio was 56 per hundred, 30 percent higher than the general average.[18] That lavish employment of administrative controls adds heavily to production expense, and puts U.S. machine tool firms at a still more severe cost-price disadvantage, even in the U.S. market.

The machine tool industry has long been a key factor in war production, its equipment being vital to the great factories that produced the tanks, artillery and endless tons of munitions for the armed forces of the United States in their various wars. But it was the Air Force in the late 1950s that combined efforts with the machine tool industry and a team of technologists at MIT to produce the new numerical-control (NC) machine tool technology. The service's requirements governed the choice of designs, and these led to the production of a line of machine tools so expensive as to be out of reach of most metalworking firms in the United States. Thus, the principal firms of the U.S. machine tool industry that collaborated with the Air Force in the development of the new technology effectively restricted themselves to the aerospace industry and similar markets.

By 1979, after this technology had been available for more than twenty years and had been endlessly promoted in the trade press, only 2 percent of all the machine tools in use in the United States were of the numerically controlled class. High prices and technical complexity put the American-produced NC machines out of reach for the majority of metalworking firms. It was left to the machine tool industries of Western Europe, and also notably of Japan, to set up high-capacity production systems for the mass production of quality numerical-controlled machine tools of the sizes and classes that are of interest to medium- and small-sized firms.

The Pentagon's central administrative office, which controls the operations of 37,000 industrial prime contractors, is probably the largest single direct owner of machine tools in the United States. This state management has not only sponsored crucial research and development within the machine tool industry, but also has generated the large purchase of machine tools for aerospace, ordnance and related industries. And it has been active in defining problems for research and development. A two-and-a-half-year study, sponsored by the Air Force's Wright Field research establishment and the Lawrence Livermore National Laboratory, and completed in 1980, marshalled the technical brains of American, European, and Japanese universities and technical institutes to define the new problems and goals to be confronted in the design and employment of machine tools. Five volumes of technical papers were published.[19] But entirely missing from this vast study was any reference to productivity, to production organization, to the design of production operations in the industry. It was apparently assumed that the organization and conduct of production were in such good order as to require no discussion. For the needs of the Air Force, they probably are.

From the standpoint of the national economy's stake in improved productivity, the enterprise was obviously flawed. And it also contributed to an already strong alliance between major machine tool firms and the state managers. When the U.S. Army convened a mobilization exercise conference in 1980, the chief executive officers of two of the major U.S. machine tool companies were among the handful of top industrial managers invited to attend.

Historically, the productivity of labor has been addressed by managers as a principal way to take maximum advantage of resources in production. Following the teachings of Frederick Winslow Taylor, managers have sought to subdivide and simplify production tasks, removing discretion in the conduct of work from the individual performer. So, reliance on the simplification of work and the transfer of discretion to engineers and technicians has been characteristic of the managerial tradition in U.S. industrial life. Skill on the plant floor has meant mainly manual-manipulative dexterity. The country's machine tool firms seem to have been unaware of or unconcerned by a major transformation in the conditions of industrial work brought about in part by their own industry, notably by the development of numerically controlled machine tools.

With numerically controlled machine tools, manual dexterity is the bare beginning of the skills required of the operator. If there is to be a stable and high utilization of equipment, the operator must understand how the machine performs, must be prepared to intervene when there is malfunction, must anticipate such malfunction, and adjust programs that, being man-made, can include error.

With the new technologies, productivity of capital becomes more important in terms of cost than productivity of labor. Optimum results are obtained, not by maximizing manual dexterity or physical exertion, but rather through sustained optimum use of the capital equipment. But managements have yet to recognize this change and to make the appropriate alteration in wage, employee training and similar policies.

For the most economic operation under these conditions, machinists and allied workers, to the limit of each person's ability, must be upgraded into computer technology, and responsibility and discretion must be delegated to the machine operator. But that view of the matter is hardly discussed in American industry. However, in 1979 I found that at a major

Japanese machine tool firm the importance of capital productivity was fully understood and that management had been able to achieve rates of equipment utilization, reductions of downtime and the like, reductions of working capital requirements, to a degree probably unprecedented in the machine tool industry.

By treating numerical-control technology as another device for deskilling workers, lowering job ratings (and job pay rates), U.S. managers have discovered a new device for their contest with workers. At the same time, they have introduced a grave contradiction. For whenever the organization of work contradicts the requirements of technology, a sure result is an economically flawed use of the latter. In the present case the harmonious mode of work organization must include systematic cooperation (rather than "every man for himself"), elaboration of worker skills rather than simplification, and motivation for stable, reliable work as a built-in style of producing.

The managers of the U.S. machine tool industry have held to their methods of operation with great tenacity. These are the ways and the skills they grew up with and have always known, the ones that for a long time were good enough to build a worldwide reputation for U.S. machine tools, and even now can sustain a profit position for their enterprises. However, these methods have meant less employment for all the relevant occupations, as factories outside the United States have displaced at least one out of four U.S. technicians, engineers and blue-collar workers.

The range of consequences for the machine tool managers' financially successful style of operation can be confidently forecast, for the basic pattern has already been seen. The example is the machine tool industry of Great Britain, whose managers, operating in the cradle of the industrial revolution, had created a long, enterprising, and financially successful tradition. However, after World War II major forces in the industry gave priority to new strategies for making money rather than to innovations for making machines. By 1980 more than 65 percent of England's new machine tools were imported. The managers of the industry aimed at near-term profits and ignored requirements for production competence. Alfred Herbert Ltd., the flagship firm of British industry, sustained by government subsidies for about a decade, had 7,000 employees as recently as 1979; only 350 remained in 1981. That startling decline contributed to the loss of production competence in the rest of British metalworking.

In 1959,[20] I reported on the low productivity style of operation in the machine tool industry of Great Britain and other Western European countries. The report said two things: first, that the industry that produced the implements of mass production was not using that mode of organization in its own operations; second, that in order to recognize the feasibility of doing

so, the industry needed to gain certain new knowledge. Accordingly, I designed a set of about fifteen inquiries that could be carried out in a short time.*

The British industry's management, seconded by a formal government report,[21] was notably vigorous in rejecting all the principal recommendations of that study with respect to improving productivity of operations in their industry. The "old boy" network of senior managers succeeded in fending off that momentary disturbance to their well-established managerial status quo. By the mid-1970s, however, major firms of the British machine tool industry had reached a terminal condition of business deterioration. The pattern of production deficiency coupled with short-term money-making had finally run its course.

The managements of the U.S. machine tool industry have followed a parallel path. When *The New York Times* reported on my 1959 report, the National Machine Tool Builders Association were asked their opinion. A spokesman reserved comment until the findings could be studied and discussed; that study and discussion are apparently still going on.[22]

In papers to the American Society of Mechanical Engineers, I attempted to press these points, recommending that as a public service ASME should sponsor an inquiry into ways of raising the productivity of the U.S. industry and urging "that stable production systems must be introduced into machine tool and allied industries in order to make possible the production of quality products at low prices . . . to encourage modernization of U.S. manufacturing equipment and a firm position in the international market."[23] Establishment consensus has continued in a pattern exactly opposed to the recommendations first made in 1959.[24]

One of the interesting features of these patterns of managerial decline is the unwavering allegiance of the principal managements in the industry to an ideology that justifies their ways of operating and thus the relevance of their own job skills. They argue that as long as their market is as unstable as it has been for decades, then the technologies of mass production are fundamentally inappropriate to their industry. However, they have also declined to investigate possible strategies for effectively stabilizing market demand. And yet they could ponder the example of the Japanese and Western European ma-

* These inquiries were designed to answer a series of rather straightforward questions. For example: What proportion of machine tool components could be composed of standardized sets of gears, shafts, slides, hand wheels, bearings, etc.? To what degree is it feasible to compose diverse machine tools from sets of modules, so that modules could be produced in quantity but used in diverse arrangements to construct the desired stock of machine tools? What cost reductions and productivity gains would be obtained by such methods?

chine tool firms, which have learned to operate in diverse markets so as to stabilize their net market situation, while offering quality equipment at prices attractive enough to generate markets.

By 1981 the managers of the U.S. machine tool industry were clearly locked into a pattern that combined money-making and low productivity with investment abroad and short-term financial strategies. They also modified important parts of the older tradition of cost-minimizing in their own operations to take advantage of cost pass-along, even cost-maximizing, in the service of the federal government's state managers.

As an inevitable result of these changes in mode of operation, prices of U.S. machine tools have become progressively less attractive as tradeoffs for industrial labor. Accordingly, the U.S. machine tool industry has been diminished as a production entity, being progressively less able to supply even the domestic market in the face of competition from abroad.

At the same time the state managers of the United States can regard themselves as well served by the same U.S. machine tool industry. The firms that design and construct equipment for them within a cost-maximizing framework are well suited to the state management's needs. Thus, the normal functioning of the state managers contributes to the deteriorating competence of the U.S. machine tool industry with respect to its wider civilian market.

The private and state managers within and around the U.S. machine tool industry have pursued their normal objectives of profit-making and power expansion with acceptable success. But the production consequences of these strategies have included backwardness in the design of products and in the production operations of the industry, finally resulting in a growing inability to supply their vital products to the rest of U.S. industry.

What has been described here as a pattern of the U.S. machine tool industry is important not only in its own right but as a model that has been repeated many times over in other basic industries of the United States. The almost 25 percent dependence on imports for machine tools in U.S. industry is slated to rise to 30 percent and more. As this process continues, the discussion of a point of no return will cease to be an academic exercise.

MANAGING FOR PROFITS/POWER

Managerialism, the main method of decision-making in industry, has a number of sustaining features: the work of decision-making tends to be separated from producing; the decision occupations are organized in hierarchies; the command for every manager is to strive to become a more important manager; finally, income is directly related to position in the hierarchy. But these characteristics of managerialism can operate in various organizational frameworks: as managers are oriented primarily to profit or primarily to production, to short- or long-term profits, together with profit-making (as in a business firm) or with direct power accumulation (as in government).

What has been happening to managing for profit and managing for power in the United States?