Pragmatism won't reverse drop in U.S. machine tools

Adapting our machine-tool industry to "market demands" rather than adopting Hamiltonian economic policies is madness. Anthony K. Wikrent reports on a RAND study.

The Decline of the U.S. Machine-Tool Industry and Prospects for Its Sustainable Recovery
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U.S. machine-tool makers booked new orders of $513.8 million this past September, the highest monthly level ever. It is the first "boom" the industry has enjoyed since the late 1970s, when it was written off as a "sunset" industry by the free marketeers and post-industrial ideologues alike. Within a few years, during the early 1980s, about half the U.S. capacity for making machine tools had been eliminated, compelling even the "free market" Reagan administration to initiate government measures to protect an industry deemed vital to national defense preparedness. Now, at the same time the U.S. industry is watching orders flood in, German and Japanese machine-tool makers face deep recessions in their home markets. But a recently completed study by the RAND Critical Technologies Institute (CTI) warns that U.S. tool makers must move quickly and decisively to "turn U.S. research leadership in the latest technologies into a market success that lasts beyond the present recovery." Otherwise, the study warns, the U.S. industry may relive the disaster of the late 1970s to early 1980s: "a recession followed by a rapid surge in demand that U.S. machine-tool builders do not have the capacity to meet, thereby allowing imports to win a larger share of the U.S. market."

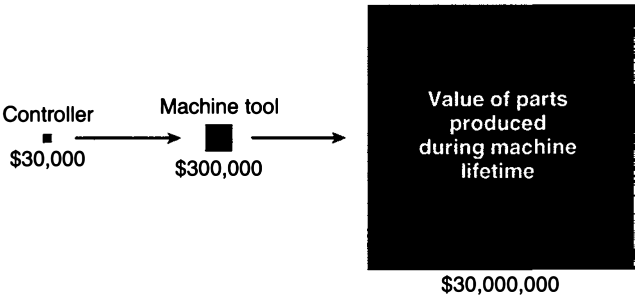
CTI was established under the Defense Authorization Act of 1991, to provide analytical support on technology issues to the President and other policymakers, and to improve understanding of how efforts to promote technological development help achieve national policy objectives. In the Defense Appropriations Act of 1992, Congress explicitly mandated a study of the U.S. machine-tool industry. It is the first study completed by CTI.

The machine tool industry has been one of the most extensively studied industries in the world, though it is actually quite minuscule compared to other industries. The entire U.S. industry, if taken together, would not even make the list of the 100 largest U.S. companies.

The importance of the machine tool industry lies in the fact that it builds the machines that produce other machines. Every facet of our everyday lives originates in some way with the machine-tool industry. The cup from which you drank coffee this morning was made in a mold that, in turn, was made by a machine tool. The engine block in your car was machined in a machine tool; the body panels were stamped in dies that were produced on machine tools.

In his 1947 memoirs, Fred H. Colvin, who spent 60 years at the cutting edge of machine tool technology, and served for many years as editor of *American Machinist,* wrote: "Textile machinery, automobiles, locomotives, printing presses, electric generators, airplanes, diesel engines, jet-propelled craft, motion picture cameras, linotype machines—all of them wonderfully interesting and useful machines in themselves, and all playing a significant part in the daily affairs of this exciting planet—exist only by virtue of the lathe, the planer, the slotter, the boring machine, and the other members of the great machine tool family. But more than this,

FIGURE 1
Importance of technology in machine tools



Source: RAND/Critical Technologies Institute.

machine tools are distinguished by a remarkable feature that places them almost in the category of living things and permits one to speak literally and not figuratively of their organic evolution. For machine tools are *the only class of machines that can reproduce themselves.*

"The parts of a lathe are made on a preexisting lathe, and the lathe thus made is used to turn out parts for a third-generation lathe, and the third-generation lathe begets the fourth, and so on through succeeding generations *ad infinitum.* One can almost think of these machines as propagating their species in accordance with the Biblical injunction given to old Adam and his children" (emphasis in original).

The impact that machine tools have on industrial productivity is thus enormous. For example, adding a $30,000 computer controller to a machine tool may increase its productivity by 10%. That might translate into $3 million more in parts produced on that machine tool. The CTI study explains at the beginning, "there is a risk that, without healthy domestic machine-tool makers, U.S. manufacturers will not have access to the latest technology" (see **Figure 1**).

CTI also noted that, because the U.S. machine-tool industry is comprised mostly of small firms with 50 or fewer employees, studying the industry provides useful insights into the problems of small and medium-sized establishments (SMEs), such as their access to financial capital and the fact that they are often burdened with a poorly educated workforce.

Historical development

The most crucial importance of machine tools is that since they are the machines that make all other machines, the first step in diffusing new scientific breakthroughs throughout the economy, is to apply them to machine tools.

A look at the history of machine tools shows this—which is a glaring omission in the CTI report. The modern machine-tool industry originated in the United States in the early 1800s, and American machine-tool makers dominated the world up until the disastrous 1970s and 1980s. As usual, the British have attempted to claim that the development of modern machine tools took place in England; and, as usual, their claim is one part truth and nine parts falsehood. Long before the American republic was founded, Leonardo da Vinci made numerous drawings of many types of machine tools, working out principles of focusing circular action on a workpiece that are still applicable today. By the early 1700s, much of his knowledge had become concentrated in France. A French scientific encyclopedia of 1717, for example, portrays a slide rest used for positioning a workpiece.

Concerning the British claim, Joseph Wickham Roe, in his 1916 *English and American Tool Builders,* includes the following, revealing paragraph: "Sir Samuel Bentham, who was a inspector general of the British Navy, began the design for a set of machines for manufacturing pulley blocks at the Portsmouth navy yard. He soon met Marc Isambard Brunel, a brilliant young Royalist officer, who had been driven out of France during the Revolution, and had started work on block machinery through a conversation held at Alexander Hamilton's dinner table while in America a few years before. Bentham saw the superiority of Brunel's plans, substituted them for his own, and commissioned him to go ahead." The Brunel machines were built by Henry Maudsly, whom the perfidious British hold up as the father of machine tools.

The reference to Hamilton is key: Any reader of U.S. Secretary of the Treasury Hamilton's 1791 *Report to Congress On the Subject of Manufactures* would know that Hamilton strongly believed in government support and direction of industrial development.

The strongest surge of development of modern machine tools, and the industrial concept of "tolerances," began when the U.S. War Department laid down a requirement for standardized firearms with interchangeable parts with which to equip the American military in the early 1800s. The key to satisfying this quest was the development of "machine" tools that could repeatedly perform the same task of drilling or grinding or filing with great precision. (This capability to perform the same function over and over again while maintaining the same accuracy is known as repeatability.) The first recorded U.S. War Department contract specifying firearms with interchangeable parts was given to Simeon North in 1813—during the Second War for Independence—for 20,000 pistols. Manufacturing that many pistols with interchangeable parts was simply impossible using hand tools, the standard means of fabricating firearms up to that time. By 1818, North had developed and installed the first milling machine in his plant in Middletown, Connecticut.

Under the guidance of John H. Hall, a woodworker from Portland, Maine who invented a rifle that loaded at the breech rather than the muzzle, the U.S. government's Harper's Ferry Arsenal in Virginia from 1819 to 1840 became a manufacturing development laboratory, with as much money and effort devoted to the design and fabrication of new machine tools, as to the production of Hall's breech loading rifles.

Among the many machines Hall designed and fabricated, were three types of what became known as milling machines: plain milling, rise-and-fall milling, and hand milling machines. The head of the Ordnance Department during this time was Col. Decius Wadsworth, whose motto was, "Uniformity, Simplicity, and Solidarity." In June 1815, Wadsworth, with the help of his long-time friend Eli Whitney, set new standards for the manufacture of military firearms.

The first commercial applications of these new military technologies were focused on the development of standardized textile machines for the mills in the river towns of New England.

By the 1850s, the United States had created a machine-tool industry that would lead the world for the next 120 years. In 1854, an alarmed British Parliament dispatched engineer Joseph Whitworth to report on the developments in America. Whitworth wrote that "The laboring classes [of America] are comparatively few in number, but this is counter-balanced by, and indeed may be regarded as one of the chief causes of, the eagerness with which they call in the aid of machinery in almost every department of industry. Wherever it can be introduced as a substitute for manual labor, it is universally and willingly resorted to. . . . It is this condition of the labor market, and this eager resort to machinery wherever it is applied, to which, under the guidance of superior education and intelligence, the remarkable prosperity of the United States is mainly due."

The next great impetus for the development of machine tools came in the 1890s, with the mass production of bicycles. This was followed in just a few years by the mass production of automobiles. By the 1920s, the modern machine tool was well established. Only incremental refinements would be made over the next decades.

Then, in the 1950s, the U.S. Air Force initiated the development of numerically controlled (NC) machine tools; that is, machine tools that could be guided in repetitive jobs by coded tapes or punch cards, rather than a human operator. This soon led to the development of computer numerically controlled (CNC) machine tools in the 1960s and 1970s.

The fateful post-industrial shift

During the massive merger and acquisition "boom" of the 1960s, many U.S. machine-tool companies were bought by conglomerates. Machine-tool companies at the time were enjoying record profits, as U.S. automakers retooled to produce the more streamlined cars of the late 1960s, and U.S. aerospace firms raced to keep NASA flying to the Moon, and the Air Force and Navy flying in Vietnam. But rather than reinvesting a greater percentage of these record profits into the development of CNC machine tools, these companies were forced to hand the money over to their owners, the conglomerates. When the "post-industrial" policy led into the recession, then stagflation, of the late 1960s and early 1970s, the conglomerates dumped their holdings, which left a number of machine-tool companies nominally independent, but financially crippled. The CTI study notes that "the financial managers of these diversified corporations [conglomerates] were unfamiliar with the particular requirements and highly cyclical nature of the machine-tool industry. When profits plummeted, the conglomerates sold off their machine-tool acquisitions rather than put in the investments required to develop a new CNC product line and upgrade production equipment. This stands in stark contrast to Japan, where the dominant machine-tool makers have grown through internal expansion rather than acquisitions."

Thus, CNC technology was created in the United States, but commercial success was won by Japan.

The first really large leveraged buyout in the United States was of Houdaille Industries, a conglomerate which had absorbed a number of machine-tool companies, including Burgmaster Corp. in 1965. Burgmaster had become the largest U.S. machine-tool maker west of the Mississippi, after developing a turret drill press in the late 1940s. The Houdaille LBO was performed by Kohlberg Kravis Roberts, for $355 million in 1978-79, and it was ten times the size of any of the handful of LBOs that had been heretofore undertaken.

"Wall Street recognized immediately that the rules were no longer the same. . . . There were virtually no limits on how large a buyout could be," Max Holland wrote in his 1989 book, *When the Machine Stopped*. The financiers made a killing, but Houdaille was devastated. Recounting an interview with Allan Folger, then president of Burgmaster, Holland wrote, " 'After the buyout, Houdaille per se changed,' Folger later recalled. 'It seemed to lose its equilibrium.' Financial expertise became the single most valued resource, and understandably so. 'Accounting hires grew faster than manufacturing hires' because managing for cash flow 'to service the debt became the whole end,' said Folger. Corporate headquarters now demanded so many extensive financial reports that even Folger, with his capacity for numbers, came to believe that it interfered with attempts to improve Burgmaster's product and defend its market."

The "free market" ideology that allowed this type of situation, also prevented any implementation of a national policy on machine tools, thereby hindering standardization of CNCs, and preventing the healthy growth of the market needed to sell them. The lack of national standards, the CTI study explains, "slowed the diffusion of NC throughout U.S. industry by increasing the risk of obsolescence for early adopters, and increasing the complexity and cost of the controller units, as no one U.S. manufacturer attained sufficient economies of scale."

By contrast, in Japan, the government laid out a common standard; tax credits were given for the purchase of new machine-tool technologies; and grants were given to small Japanese firms to help them buy new CNC machines. Moreover, the Japanese government passed a law requiring half of all machine tools produced by 1977 to be CNC. Though this ratio was not achieved, the result of these various government interventions was that one Japanese firm, FANUC—which had developed the first numerical controllers that were both reliable and cheap—emerged as the undisputed world leader in CNC tools, commanding an estimated 70% of the market today.

Patrick McGibbon, of the Association for Manufacturing Technology (formerly the National Machine-Tool Builders Association), argues that controllers for machine tools were not standardized in Japan, either. Other companies, such as Mitsubishi or Hitachi, had much better controllers than FANUC, but they were also more expensive. McGibbon explains that U.S. machine-tool makers in the late 1970s had created a crisis for themselves by accumulating a three- to four-year backlog of orders. Consequently, U.S. makers had to begin turning back customers. Naturally, U.S. makers chose to sacrifice the small job shops that bought mostly standardized machine tools on which there were low profit margins, and concentrated instead on building for large manufacturing companies, such as the automakers, or Caterpillar or Deere, which required specialized machine tools. These were "high-end" machine tools that required a lot of engineering work, and which therefore had much more "value added," i.e., more money for the machine-tool builder.

But, the small job shops also needed to equip themselves with new CNC machine tools if they were to remain competitive, as we discuss more below. FANUC chose to target these small job shops, and developed less expensive controllers that these customers could afford. Still, according to McGibbon, FANUC had to sell a huge amount of its controllers in order to break even.

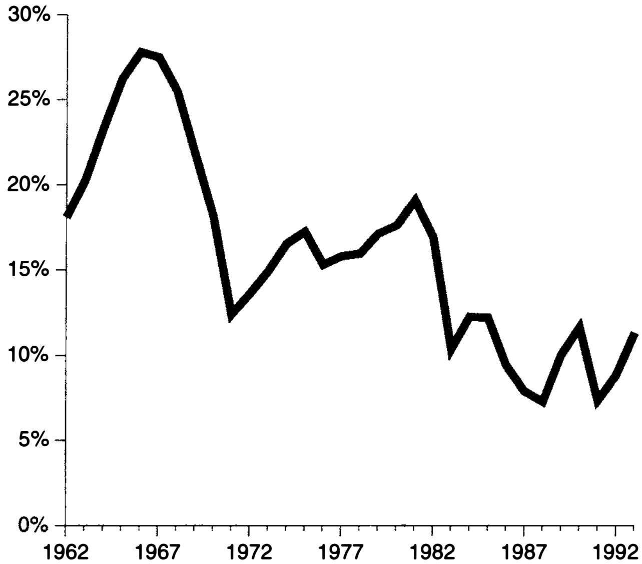
Once a shop had bought a FANUC controller, it was very difficult to switch to a different supplier because of the lack of standardization in controllers—both Japanese and American. McGibbon notes that FANUC is now in trouble, because it attempted to lock in its customers by refusing to make FANUC controllers compatible with machine-tool components of other manufacturers, creating a great deal of resentment, and wholesale defections of its customers to other suppliers. It appears to be an error of corporate strategy similar to Wang Corp.'s refusal to make its equipment and software compatible with IBM's in the early 1980s.

Still, the Japanese lead in CNC machine tools is clear. In 1991, the percentage of U.S. production of machine tools that were CNC (as measured by value of tools sold) was 7%. Japan had reached 9% as early as 1979, and by 1991, Japan's percentage of CNC tools was 30%.

The CTI study thus identifies two reasons for the decline of the U.S. machine tool industry: the collapse of the U.S. domestic market for machine tools, and the emergence of strong competing industries overseas, especially in Germany and Japan. Unfortunately, CTI looks at the symptoms without identifying the causes: the initiation of the Council on

FIGURE 2

U.S. share of world machine tool production



Source: Association for Manufacturing Technnology (formerly National Machine Tool Builders Association).

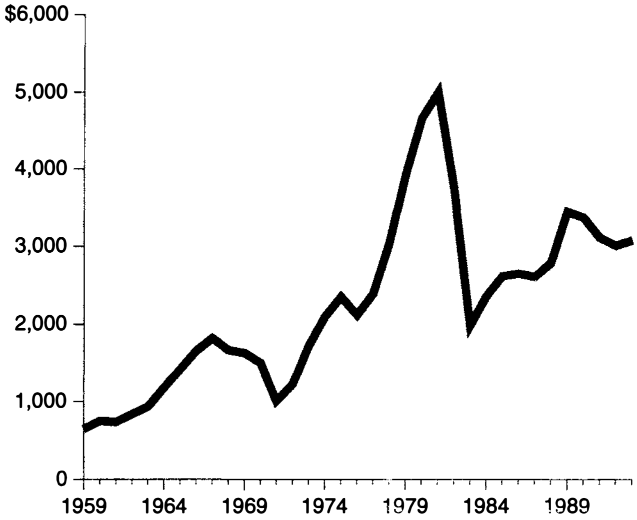
Foreign Relations' policy of "controlled disintegration" of the world economy, spearheaded by the 1973 and 1979 oil crises, and the imposition of double digit interest rates by Federal Reserve Chairman Paul Volcker in 1979. This deliberate shift to a post-industrial policy brought the U.S. machine-tool industry to its knees. In 1980, the U.S. industry accounted for one-fifth of the world's total production of machine tools (see **Figure 2**). But, in just one year, 1982 to 1983, U.S. production of metal-cutting machines fell 53%, while that of metal-forming machines fell 37%. U.S. consumption has collapsed by around one-third since the late 1970s. At the same time, real consumption of machine tools leaped 104% in the Pacific Rim countries, and jumped 55% in western Europe. Today, the United States accounts for less than half the world's production of machine tools.

Chronicle of the collapse

U.S. machine-tool production collapsed accordingly: In 1991, U.S. production was 42% of the level it was in 1980 (**Figure 3**). Total employment in the U.S. industry peaked in 1967 at 116,400 employees, and has fallen from 108,000 in 1980, to 51,900 in 1993. (These figures are only for machine-tool makers; they do not include production of machine-tool accessories.) Employment as of August 1994 was up slightly to 53,700 (see **Figure 4**).

The 1967 Census of Manufactures counted 1,253 firms in the industry. The 1992 census found only 977 firms (including makers of machine-tool accessories, as well as firms

FIGURE 3
U.S. shipments of industrial machine tools
(millions $)



Source: Association for Manufacturing Technology (formerly National Machine Tool Builders Association).

FIGURE 4
U.S. machine tool manufacturing employment
(thousands of people)

Sources: Bureau of Labor Statistics, *Employment, Hours Earnings, 1909-1990,* and September 1994 monthly edition.

producing machine tools). In an April 1994 report, the U.S. International Trade Commission noted that the number of firms had remained relatively constant from 1987 to 1992 only because "foreign producers have increased capital investments in U.S. firms, or have established new production facilities in the United States." This was largely in response to the threat of more protectionist measures than the Voluntary Restraint Agreements (VRAs) which the Reagan administration had negotiated with Japan and Taiwan.

The collapse of U.S. production is apparent in statistics for both units and dollar volume. Advances in technology, however, particularly in the past five years, may render year to year comparisons meaningless. Patrick McGibbon notes that productivity on one machine tool, as measured by the amount of time required to cut a standardized part, has improved by a factor of ten *twice* in the past 13 years—fairly typical for the industry.

In an attempt to gauge the true extent of the collapse of the U.S. market for machine tools, CTI took statistics for metal use by industry sector in 1977, and scaled them up to a projected 1987 level, adjusted for inflation, then compared the resulting numbers to actual 1987 metal use. The resulting figures show the dramatic drop in metal use by U.S. industry (see **Table 1**). Total 1977 metal use was $173.871 billion, and the scaled up figure for 1987 was $223.619 billion. Actual 1987 metal use was $132.918 billion—40.56% less than the projected, scaled up use.

The collapse in metal use is even more pronounced among the industry sectors that are the largest users of machine tools. The automobile industry, which accounts for 30-40% of machine-tool consumption each year, registered a collapse in metal use of 47.96%. The aerospace industry is traditionally the second largest consumer of machine tools, accounting for 10-20%. The CTI study did not break out the aerospace industry, but metal use by "other transportation equipment," collapsed 68.56%. The third largest machine-tool consuming sector, manufacturing of household appliances, which usually accounts for around 10% of U.S. machine-tool consumption, showed one of the smallest collapses, 39.78%. Two other large machine-tool-using industries, farm and garden equipment, and construction equipment, which each account for slightly less tool consumption than home appliance manufacturing, showed declines of 69.65% and 69.19%, respectively.

Unfortunately, the U.S. Census of Manufacturing uses dollar value, not actual weights of metal used, as the metric for their census which is conducted every five years. However, note that the CTI figures for "metalworking machinery and equipment" registered a collapse in metal use of 40.34%, very close to the 42% collapse in the dollar value of machine-tool production from 1980 to 1991, reported above.

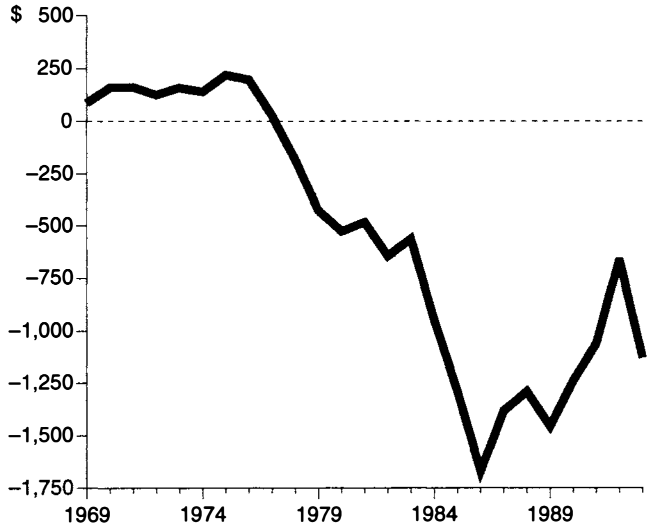
To further check the validity of CTI's analysis of metal use by industry sector, *EIR* calculated the decline in overall use of iron and steel, as measured in net tons by the American Iron and Steel Institute (AISI). Note that the CTI figures are for all metals used, not just iron and steel. However, the

TABLE 1
Reduction in use of metal by U.S. industry
(millions $)

Industry	Actual 1977	Scaled up 1977	Actual 1987
Motor vehicles and equipment	18,186	23,389	12,171
Screw machine products and stampings	9,656	12,418	8,154
Construction and mining machinery	4,714	6,063	1,865
Other transportation equipment	3,882	4,993	1,570
Farm and garden machinery	2,414	3,104	942
Chemicals and selected products	2,121	2,728	624
Electrical industrial equipment and apparatus	3,704	4,764	2,836
General industrial machinery and equipment	4,041	5,197	3,372
Engines and turbines	2,853	3,670	2,209
Metalworking machinery and equipment	2,334	3,002	1,791
Household appliances	2,156	2,773	1,670
Materials handling machinery and equipment	1,145	1,472	576

Source: RAND/Critical Technologies Institute.

FIGURE 5
U.S. machine tool trade balance
(millions $ for new complete tools)



Source: Association for Manufacturing Technology (formerly National Machine Tool Builders Association).

collapse in iron and steel use validates the finding of the CTI. The auto industry used 21.490 million tons of iron and steel in 1977, but only 11.343 million tons in 1987. That's a collapse of 47.22%, very close to the 47.96% collapse found in the CTI study. Use of steel in agricultural machinery collapsed from 1.017 million tons, to just 394,000 tons, or 61.26%; again, close to the 69.65% collapse in the CTI figures. Finally, the only other comparable industry breakout in the AISI statistics was for "appliances, utensils, and cutlery," which fell 23.30% from 2.129 million tons to 1.633 million tons. That is not nearly as bad as the 39.78% collapse in the CTI figures, but still, it indicates how terribly U.S. industrial demand for machine tools shrank during the 1980s.

At the same time as the U.S. market collapsed, imports racked up huge gains in market share (see **Figure 5** and **Table 2**), for two reasons: First, U.S. machine-tool makers had traditionally buffered themselves from swings in the economic cycle by building up large back orders during boom times, which were worked off during bust times. The CTI report points out that this strategy "was sustainable so long as two conditions held: 1) Few alternative sources of supply were available; and 2) the technology was relatively stable. These conditions ceased to apply in the early 1980s." McGibbon's discussion of why FANUC came to dominate CNC machine tools, above, is illustrative.

Second, while the U.S. market was collapsing, the German and Japanese markets continued to expand. Japanese

TABLE 2
U.S. industry share of domestic machine-tool markets, 1982-91
(percent)

	1982	1985	1988	1991
All machine tools	73.6	58.6	52.6	54.9
Metal-cutting machine tools	72.6	56.7	48.5	53.8
Metal-forming machine tools	77.5	64.2	61.4	57.0
All numerically controlled	64.6	45.5	48.0	46.6
Boring & drilling machines	73.1	55.5	55.4	49.8
Gear-cutting machines	71.9	60.5	25.6	51.1
Grinding machines	77.4	70.2	52.9	60.6
Horizontal NC lathes*	51.8	42.9	34.9	39.8
Vertical NC lathes*	72.3	48.0	59.5	66.0
Non-NC lathes*	48.9	39.2	13.6	42.4
Milling machines*	73.4	54.6	60.1	71.6
Machining centers*	63.1	37.0	48.2	50.6
Station type	98.9	95.1	75.8	64.8
Other metal-cutting machines	65.0	45.1	36.1	25.7
Punching & shearing machines	65.4	60.0	68.0	69.2
Bending & framing machines	79.3	64.8	54.3	58.1
Presses	87.6	71.5	58.8	59.6
Forging machines	74.8	66.9	51.2	24.3
Other metal-forming machines	64.6	57.7	68.3	53.4

* Categories covered by Voluntary Restraint Trading Agreements (VRAs).
Source: RAND/Critical Technologies Institute.

consumption of machine tools grew from less than $2 billion in 1975, to $8.3 billion in 1991, while German consumption grew from $792 million in 1975, to $6 billion in 1991. By 1990, both the German and Japanese markets for machine tools were twice the size of the shrunken, weakened U.S. market: U.S. consumption had not even doubled, moving from $2.2 billion to $4.2 billion in the same years.

Their growth meant that the German and Japanese machine-tool makers could continue research and development programs rather than scaling back production, while U.S. machine-tool makers, haunted by the financial legacies of the 1960s, had already slowed technological innovation. Thus, reports CTI, "When demand for machine tools began to pick up, spurred by the defense buildup and the retooling of U.S. automakers, the Japanese were able to make dramatic gains in market share by delivering new, reliable CNC tools within weeks. To make matters worse, they could sell these tools at a price U.S. machine-tool makers could not match, thanks to large cost advantages, and generous export finance."

One of the key developments behind the Japanese price advantage, according to the CTI, was their shift to modular assembly of machine tools. In the United States, most machine tools built were specifically designed and built for an individual customer—the high value-added machine tools that McGibbon says U.S. makers chose as their focus in the late 1970s. In effect, U.S. machine-tool makers were specialists in their respective small niches of the market. "By designing their tools for ease of production and commonality of parts across machines," the CTI study notes, "Japanese machine-tool makers were able to achieve greater economies of scale, while still producing an array of tools that covered most of the specialized functions which customers desired. In the leading Japanese firms, modularization cut the number of separate parts and tools by up to 90%. This, in turn, made CNC tools affordable to even the smallest job shop, creating a new market." This was particularly devastating for U.S. makers, where, unlike the rest of the world, price has been the most important factor for purchases of machine tools.

But at the same time that they were able to undercut prices of U.S. makers, the Japanese were also able to greatly increase the reliability of their machine tools. The standardization of the machine tools and their components made it easier to improve reliability. With reliability and technological sophistication being the most important considerations, in most other major machine-tool markets, the United States lost world market share, as well as domestic market share (see **Table 3**).

The shape of the world industry changed dramatically. In 1980, the ten largest machine-tool makers were U.S. firms, accounting for over 15% of world output. By 1990, however, only one U.S. firm could be counted among the world's top ten. In 1991, according to *American Machinist,* 29 of the world's 60 largest machine-tool firms were Japanese, and 20 were German. Only 5 U.S. firms could be counted among the 60 largest firms in the world. **Table 4** shows that even the largest U.S. machine-tool makers are now much smaller than their German and Japanese counterparts. The largest Swiss machine-tool company, George Fischer, had sales of $333 million in 1992; the largest Italian company, Comau SpA, had sales of $280 million.

TABLE 3

Japanese firms are the dominant CNC machine-tool suppliers

	Percentage of world production	
	1975	1990
United States	17	7
Germany	18	19
Japan	8	24

Source: RAND/Critical Technologies Institute.

Financial bias against manufacturing

The U.S. machine-tool industry is comprised mostly of very small firms that are private companies, which are not publicly traded on stock exchanges. In 1992, there were only 12 U.S. machine-tool companies that were publicly held, a number which includes firms that are part of larger, publicly traded parent companies. Only nine firms had sales of over $100 million a year. The small size of the industry and its component firms makes for a disturbing dilemma: While the production of machine tools is a very capital-intensive undertaking, many banks and financial firms simply refuse to take the time to learn about the industry, or to deal with small firms. One banker told CTI that it could cost as much as $20,000 to process an industrial loan for $80,000—approximately the cost of a new, mid-line machine tool. Consequently, most U.S. machine tool firms are compelled to rely on retained earnings or family savings (if family-owned) in order to fund expansion or capital expenditures. McGibbon states flatly that "small companies are being murdered" by the financial and banking systems.

The situation is made even worse by U.S. customers, which traditionally proffer payment only after their order has been installed and tested in their facility. By contrast, in other countries, the customers help finance the development and construction of new machine tools by means of progress payments. In Japan, this is facilitated by the *keiretsu,* the families of companies that maintain long-term alliances with one another. Interlocking directorships and extensive cross-ownership of stock cement these alliances. The banks in a particular *keiretsu,* therefore, are very familiar with the operations and financing requirements of the industrial firms to which they are allied.

Similarly in Germany, most banks maintain ownership

TABLE 4

Eleven largest machine-tool makers in Japan, Germany, and the U.S.

(millions $ in 1992 sales)

Country	Sales	Country	Sales	Country	Sales
Japan		**Germany**		**United States**	
Amada Co. Ltd	$1,090.1	Thyssen Maschinenbau GmbH	$600.0	Giddings & Lewis Inc.	$571.7
Yamazaki Mazak Corp.	734.5	Schuler Group	529.6	Ingersoll Milling Machine Co.	410.0
Okuma Machinery Works	603.0	Trumpf Group	410.4	Cincinnati Milacron Inc.	380.0
Komatsu Ltd.	513.3	Mueller-Wiengarten AG	324.1	Litton Industries Inc.[3]	306.0
Toyoda Machine Works	473.1	Gildemiester Group[1]	304.8	Gleason Works	147.3
Mori Seiki Co. Ltd.	458.7	Grob-Werke GmbH & Co. KG	268.9	Hurco Companies, Inc.	87.8
Toshiba Machine Co. Ltd.	435.2	MAHO Group[2]	267.9	Fadal Engineering Co. Inc.	87.3
Fuji Machine Manufacturing Co. Ltd.	432.7	Pittler Consolidated Group	262.5	Hardinge Brothers Inc.	84.8
Nippei Toyama Corp.	378.3	Boehringer	245.9	Monarch Machine Tool Co.	77.9
Sodick Co. Ltd.	311.7	Alfinger Kessler Sondermaschinen	243.3	Allied Products Corp.	73.0
Hitachi Seiki Co. Ltd.	281.7	Traub Group[1]	214.5	Newcor Inc.	62.6

Source:U.S. International Trade Commssion, *Metalworking Machine Tools and Accessories,* April 1994.
[1] Gildemiester Group and Traub merged in 1993.
[2] MAHA and Deckel AG (1992 sales were $197 million) merged in 1993.
[3] Litton Industries is the parent company of Lamb Technicon and other machine tool companies; the sales figure is for the machine tool companies only.

stakes in the companies they lend to. The CTI study also notes that "much of the financing for the machine-tool firms in Germany comes from a system of local cooperative banks with specialized knowledge about the region's industries." It should be clear that if the United States wishes to nurture small industrial firms, it is moving in the wrong direction by permitting the large money-center banks to extend their activities across the country. Machine-tool makers and distributors which participated in the CTI study complained that bankers retain a strong bias against manufacturing, especially if it is cyclical, as the machine-tool industry is.

Present U.S. tax laws are not helpful, for either machine-tool makers, or their customers. Historically, an investment tax credit has been a very strong stimulus to sales of machine tools. When such credits are repealed, the tax benefits of purchasing a new piece of equipment are not realized until long after the equipment has been purchased. Sales of machine tools in the United States have always fallen steeply after an investment tax credit has been repealed (see **Figure 6**). All types of organizations that participated in the CTI study—machine-tool makers, distributors, users, and government—ranked an investment tax credit as one of the most beneficial policies that could be enacted on the federal level to assist the industry.

One very troubling result of the capital starvation of the U.S. machine-tool industry is that its own machine tools are very old. CTI recounted that its investigators, when visiting a machine-tool production facility, would frequently be shown tools that were decades old. In one instance, the maker proudly pointed out that he was using a machine tool that was nearly 100 years old! (See **Table 5.**)

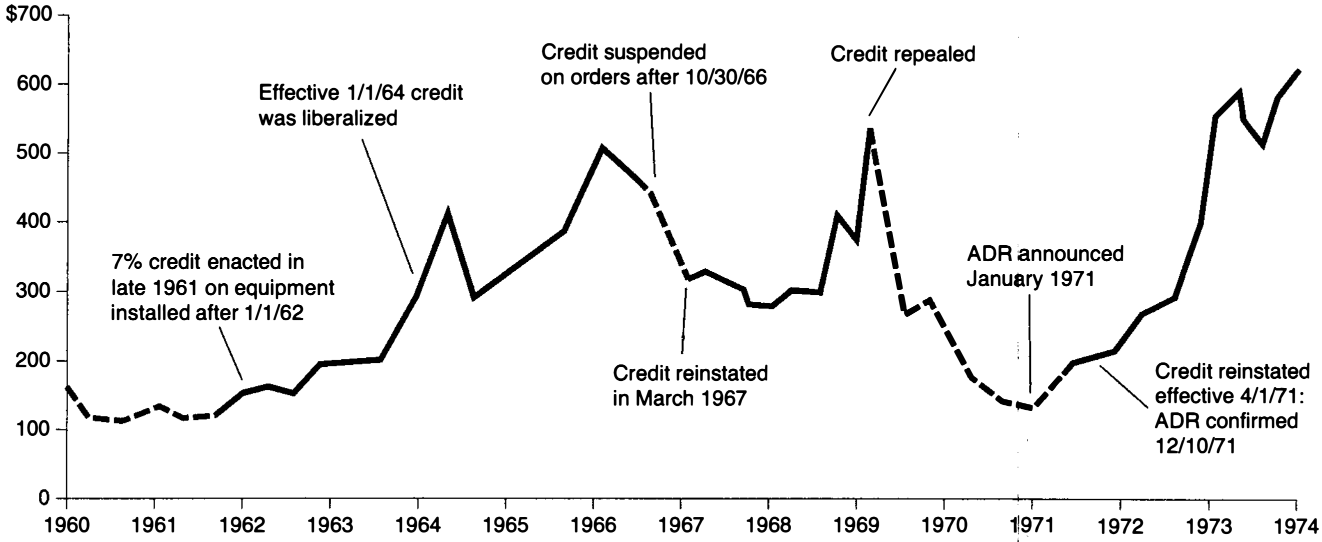
A dumbed-down workforce

Another major concern for the U.S. machine tool industry is the extremely low level of skills inculcated into the emerging labor pool by the U.S. education system. Many firms reported that they cannot afford to train workers in advanced technology, because they have to concentrate on providing remedial education in basic reading, writing, and arithmetic. The CTI appendices state: "Concerns over general education focused on three points: the lack of new employees' basic skills; the changing skill requirements for machine tool producers; and the negative perception of manufacturing in the education system of the United States. Participants felt that many workers in the industry operate at only 5th- or 6th-grade level, with little or no English ability. This lack of basic skill is becoming an increasing problem as computer numerical control technology shifts skill requirements away from machining to general problem-solving and communications skills."

"This contrasts with Japan and Germany," the study states, "where manufacturing continues to be held in high prestige, and where machine-tool makers and users can recruit from a pool of young people who have, in many cases, mastered two languages and advanced math and science."

The difference in educational levels of the machine-tool workforces of the three nations is especially striking. About 4.5% of the workforce of the U.S. machine-tool industry are engineers. Somewhat over half of these are college-trained. In all U.S. manufacturing industries, 5.75% of the workforce

FIGURE 6
Effect of the Investment Tax Credit on the U.S. machine-tool industry
(millions $ of orders)



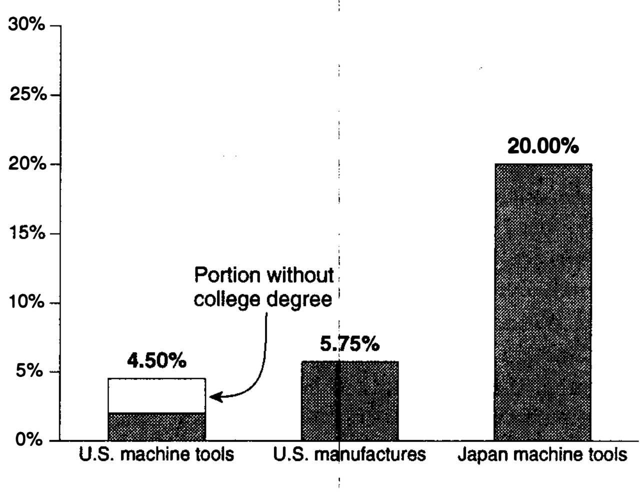
Source: RAND/Critical Technologies Institute.

TABLE 5
Japanese firms employ more advanced manufacturing technology
(Japan/U.S. ratio)

New manfacturing technique	Small and medium-size establish-ments (SMEs)	Large establish-ments
NC/CNC machine tools	1.4	1.1
Flexible manufacturing cells	4.3	1.9
CAD	1.1	0.9
Automatic inspection	2.9	1.5
Handling robots	4.1	1.4
Automatic warehouse equipment	5.8	1.8
Assembly robots	2.1	1.2

Source: RAND/Critical Technologies Institute.

FIGURE 7
Percentage of U.S. workforce employed as engineers



Source: RAND/Critical Technologies Institute.

are engineers. In Japan, the CTI estimated that 20% of the machine tool workforce are engineers (see **Figure 7**).

Comparing these figures to Germany is difficult, because the Germans break down their workforce into specific categories. But, according to the figures kept by the German machine-tool producers association, at least 7.0% of the German machine-tool workforce are engineers. Assuming that one-quarter of administrators are engineers, the figure may be as high as 9.1%.

In addition, the German machine-tool industry benefits greatly from an excellent national system of apprenticeships, which trained 9.8% of the workers in that country's machine-tool industry.

The combined effect of using older machine tools and a less skilled workforce is likely to devastate the U.S. industry in the future. The CTI report notes that "chief U.S. rivals use their own factories as test beds for the latest tools, relying on workers to come up with new incremental improvements in products or the process of making them. This includes not only engineers, but production workers as well. . . . Without a broadly skilled workforce to replace the old generation of machinists, it will be difficult to generate the continuous product and process innovations that are critical to success in machine tools."

As one major distributor of both U.S. and Japanese machine tools told the CTI investigators, "The Japanese will purchase the latest million-dollar flexible manufacturing cell and put an engineer on it for the first few weeks to ensure that it is operating properly and to search for any ways of improving its performance. A typical U.S. firm will stick an operator on it whose only skill is knowing the difference between the red and green buttons [to turn the machine on and off]. Then they wonder why they don't get the expected return on their capital investment."

Rapidly changing technology

Machine-tool technology remained relatively unchanged from the late 1800s until the 1960s, when CNC machines began to dramatically reduce the time required to set up and perform machining operations. The major consideration in buying new production equipment is increased productivity. For machine tools, this means reduced cycle time—the amount of time required to load the tools and workpiece into a machine, set up or program its operations, perform the operations, and unload the finished workpiece to make room for the next workpiece. A new machine tool should be able to cut the amount of time to perform all these functions, while also performing its operations with greater accuracy and better repeatability.

McGibbon said the rule in the industry is to "keep the spindle turning" (referring to the rotating shaft to which is attached the cutting tool that is applied to the workpiece. On some machine tools, such as lathes, the workpiece is attached to the spindle, and the cutting tool is brought into contact with the workpiece as the spindle and attached workpiece rotate).

James J. Bushong, vice president of Hitachi Seiki U.S.A. Inc., wrote in the June 1994 issue of *Production:* "At least one industry source estimates as little as 11% of the available production time is used for cutting metal. As a turning machine producer over many years, our experience indicates approximately 25% of available production time is used for cutting. About 60% is used for setup, and the remaining 15% is taken up in non-cutting operations such as machine loading and extraneous slide motions."

Numerical control reduced typical setup times from days to hours. Computer numerical control (CNC) did not reduce initial setup times by much, but follow-on setups were reduced to mere minutes—provided that much of the setup work previously done by human machinists, such as bolting a workpiece in place, could be performed by machines. Thus,

TABLE 6

Trends in machine-tool components and systems

Component/system	1988	1993/94	Near future
Speed			
Spindle rpms	6,000	8,000	30,000-40,000
Number of spindles on machining center or lathe	1	1-2	2 or more
Cutting tools	Titanium nitrade coatings	Cubic boron nitrade (CBN) diamond coatings	Perishable tooling
Automatic tool change time	45 sec.	15 sec.	10-12 sec.
Quality			
Precision and repeatability:			
General machining	0.005 in.	0.0005 in.	0.0001 in.
Grinding	0.005 in.	0.0001 inc.	0.00002 in.
Flexibility			
Metal-forming die change times	4 hours	5-15 minutes	

Source: U.S. International Trade Commssion, *Metalworking Machine Tools and Accessories*, April 1994.

robotics came to be very important in machine-tool design. The CTI study notes: "The Japanese have coined a new word that roughly translates to 'mechatronics,' which sums up the major change that has taken place in machine-tool technology; new innovations in machine tools now combine the mechanics of cutting and forming metal with the software and hardware (electronics, sensors) that control this process."

For metal-cutting machine tools, spindle speed is one of the major measures of performance. The faster the spindle speed, as measured by revolutions per minute (rpm), the greater the energy-flux density of the machine tool, since more work is being performed on the workpiece per quantum of time. Since the application of electric motors to machine tools early in this century, spindle speeds were 1,000 to 1,600 rpm. In the late 1980s, the machine-tool industry was set on its ear by spindle speeds of 6,000 rpm. In the past few years, machine tools with spindle speeds of 8,000 to 15,000 rpm have been introduced. At the 16th Japan International Machine Tool Trade Fair in late 1991, Niigata Engineering displayed a milling machine with a main spindle top speed of 100,000 rpm. Within the next few years, it is expected that top spindle speeds of 30,000 to 40,000 rpm will be routine (see **Table 6**). Some very specialized machines with spindle speeds of 200,000 rpm have been reported in the past few months.

The benefits of high-speed machining include reduced heat effects, which are responsible for up to 60% of machining inaccuracy. Heat distorts both the workpiece, and the machine tool itself. In tests of high-speed machining of cast iron in 1992, LeBlond Makino Machine Tool Co. found that most of the heat generated by the cutting process is concentrated in the tiny zone immediately ahead of the cutting tool. High-speed machining allowed the cutting and removal of the heated cast iron before the higher temperature could be dissipated into the rest of the workpiece, eliminating a major source of distortion.

Another benefit of high-speed machining is higher quality finishes. This means that fewer machining operations need to be performed on a workpiece. The finish of a workpiece coming off a high-speed milling machine can be so fine, that the workpiece need not be sent on to a grinding machine, as has been the norm for the past century. As an indication of what this means for productivity, *Production* magazine reported in January 1993 that a joint study by Cummins Engine Co., and LeBlond Makino showed that two machine tools equipped with high-speed spindles had the same output as a transfer line (a specialized production line equipped with custom-built machine tools) equipped with 26 machine tools operating at slower spindle speeds.

Many new problems are presenting themselves to machine-tool makers, as materials such as titanium, magnesium, or aluminum replace steel in many applications that need to be machined. In an automotive door panel, for example, the safety engineers may want one end to crumple in a collision, while the center of the door panel remains rigid. To achieve this, two different pieces of steel with different characteristics and thicknesses would have to be bolted or welded together. But in making aluminum, you can change the characteristics of the same piece of metal by varying certain aspects of the production process, such as drawing the aluminum out from the casting rollers faster. Thus, the same sheet of aluminum can have different characteristics in different places—unlike steel, in which the characteristics remain uniform throughout the entire sheet. By replacing the steel door panel with aluminum, engineers eliminate a step in the production process (bolting or welding the two pieces of steel together), reducing costs and improving reliability. But it is now more difficult to machine that door panel, because, for example, if the aluminum is being cut, the tool or the cutting speed may have to be changed to deal with the different characteristics now found in the same sheet of metal.

High-speed machining is only one of 23 new technologies that CTI identified as being most important to the future development of material-shaping processes. Other new technologies that are rapidly changing the use and shaping of metal include processes that form desired shapes by depositing metal or metal-composite powders layer upon layer. The end product is so close to the final shape required, that the need for much machining is eliminated (see **Table 7**).

CTI's survey of these areas revealed a disturbing trend: The United States is a world leader in the research and development of almost all these technologies, but is a market leader in only about half. The older the technology was, the more likely it was that the United States had ceded R&D leadership as well as market leadership. There are 15 technologies that are at most 10 years old, for example; the United States is the R&D leader in 13 of them, and the market leader in 8. But in the eight technologies that were 15-30 years old, the U.S. leads R&D in only three areas, and is a market leader in just one area.

TABLE 7

Summary of technology areas relevant to the machine-tool industry

(U.S., Japan, Germany)

Key technology area	Critical?	Age (years)	Research leaders	Market leaders
Electro-discharge machining	Y	20	U.S.,J	J
High-speed machining	Y	15	U.S.,J	U.S.,J
New machine configurations	N	10	U.S.	U.S.,J
Precision machining	N	10	U.S.,J	U.S.,J
Waterjet machining	N	10	U.S.	U.S.
Improved formability	N	10	U.S.	U.S.
Layered manufacturing	Y	5	U.S.	U.S.
Net shape manufacturing	N	5	U.S.	U.S.
Flexible machining systems	Y	10	U.S.,J	J
Flexible transfer lines	Y	10	G,J	G,J
Laser welding	N	20	G,J,U.S.	G,J
Laser cutting	N	20	G,J,U.S.	G,J
Automated transfer	N	20	G,J	G,J
Cutting fluids	N	10	J	J
Flexible fixturing	N	5	U.S.,G,J	G,J,U.S.
Coordinate measuring machines	Y	15	G,U.S.	G,U.S.
Cutting tools	N	10	U.S.,J	J
Artificial intelligence	Y	10	U.S.,J	J
Computer integrated manufacturing	Y	15	G,U.S.	G
Computer numerical control	Y	30	U.S.,J	J
Electronic data interchange	N	10	U.S.,J,G	U.S.,J,G
Micromachines	N	5	U.S.,J	U.S.,J
Display technology	N	10	U.S.,J	J

Source: RAND/Critical Technologies Institute.

Failure to question policy axiomatics

The CTI study concludes by reviewing the four policy options available to government:

• maintain the policies of 1987 to 1993, in which the government focused on supporting basic research, and negotiated Voluntary Restraint Agreements to limit imports of certain machine tools from Japan and Taiwan;

• adopt a total free-market approach and leave the industry alone;

• protect and improve the industry, which would involve extending the VRAs with Japan and Taiwan and making greater efforts to ensure commercialization of R&D breakthroughs.

• make the United States a global player by attempting to aid U.S. machine-tool makers not only in the domestic market, but also in foreign markets, such as by devising new means of financing exports.

None of these options will work.

The CTI study is fatally flawed by its failure to address the underlying cause of the many problems it identifies. The decline of the U.S. machine-tool industry is not a process that can be isolated from the rest of the U.S. or world economy, which have, in fact, declined as quickly and as deeply as the U.S. machine tool industry has. Those who assert or believe that there was an economic "boom" during the Reagan-Bush years are looking not at the real, physical economy, but at the monetary aggregates that have grown cancerously by depriving the physical economy, such as the machine-tool industry, of the human and financial resources it needs to survive. CTI's discussion of the financial problems of the U.S. machine-tool industry leads in the right direction, but the authors are apparently fearful of following through to the proper conclusions.

In order to truly understand the causes of the decline of the U.S. machine-tool industry, the fundamental axioms of U.S. policies must be examined. Let us take some of the problems indicated by the CTI study, and examine their root causes.

As intimated before, the collapse of domestic demand for machine tools was the result of the shift to a policy of post-industrialism in the 1960s and 1970s. This shift was pushed forward under a number of disguises: free markets, deregulation, environmentalist regulation. It allowed a sustained assault on, and complete dismantling of, the policies and institutions of national banking that had been established by the first U.S. secretary of the treasury, Alexander Hamilton—at whose dinner table was launched one of the major impetuses for the development of our modern machine-tool industry.

The end of national banking meant that the federal government relinquished its constitutional mandate to "coin money and regulate the value thereof." The principal means of regulating the value of money is to ensure that credit is channeled only into those productive areas that will create new economic strength—roads and canals, or new machine tools, for example. Instead, the general welfare clause of the Constitution's Preamble has been ignored, and "money" has been allowed to seek the highest return. You may develop a revolutionary new machine tool, but if you can't promise investors a 15%, 20% or more return on their money, you're not going to get financing. So today we have speculation, financial derivatives, and legalized gambling—and a machine-tool industry half the size it was 15 years ago, which has lost the technological leadership it held for nearly two centuries.

The CTI report's discussion of the financial difficulties of the machine-tool industry is a case study of what happens when central banking and speculation have triumphed over national banking and wealth creation. "Is private credit the friend and patron of industry?" Hamilton asked in the 15th *Federalist Paper*. Reading the CTI paper, the clear answer is: "No."

In discussing the problem of a poorly skilled and schooled workforce, the plain fact must be faced that there has been a deliberate—and largely successful—attempt to transform the U.S. education system into a tool for the social engineering of a "New Age" of irrationalism and mysticism. This policy must be reversed.

The CTI study also discusses the collapse of U.S. machine-tool makers' export markets. Besides the problem of a post-industrial shift, there is also the problem of outrightly racist "depopulation" policies, as expressed by such documents as National Security Study Memorandum 200 written and promulgated by British agent Henry Kissinger when he was U.S. secretary of state and national security adviser in 1974. Kissinger's and London's policy *is to kill off the populations of the developing countries*. This policy was reaffirmed in 1979 under the Carter administration Secretary of State Cyrus Vance's *Global 2000 Report*, which calls for reducing the world's population to 2 billion. The International Monetary Fund "conditionalities" imposed on developing countries, which have devastated export markets for all types of capital equipment, can only be understood in terms of these policies of depopulation.

Until these population reduction policies are repudiated, anyone talking about improving U.S. export markets, or expanding world trade through GATT, is simply not dealing with reality.

The real problem is thus pragmatism. Rather than seeking to eliminate the source of these problems by attacking the faulty, *genocidal* axioms underlying U.S. policy, CTI ends up merely providing a list of the symptoms that are killing the patient. You want an economic boom? You want to expand global trade and create new markets for U.S. machine tools? Build high-speed rail lines along the old Silk Road from Europe to China, across Africa, and across South America. Build 500 nuclear power plants along the coasts of Africa and the Middle East to provide electricity and desalinated water. Get on with the task of putting a man, then colonies of men, on Mars. Then you'll see a true shortage of skilled labor!