The Technological Revitalization of a Mature US Industry: The Case of Machine Tools

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ABSTRACT

The US machine tool industry enjoyed a period of global dominance between the early 1900s and the late 1970s. In the final quarter of the last century, however, almost every major US producer lost domestic market share as a result of import competition. By the early 1990s, several segments of the US machine tool industry appeared poised on the edge of market exit. This paper argues that US producers have achieved a rebound in recent years. This rebound has been driven by a variety of innovation-related efforts, including improved machine design, increased R&D, a renewed emphasis upon export markets, and greater customization. Evidence comes from a national survey of 104 machine tool producers. A major finding is that recent employment growth has been concentrated among younger firms, especially those that have made strategic commitments to increased R&D spending, faster cycle times, and improved customer support. In contrast, the incidence of zero or negative employment growth is more pronounced among older firms, many of whom primarily serve local customers. The paper concludes with a brief discussion of possible futures for the US machine tool sector.

Keywords: US machine tool industry; competitive problems; techno-market recovery; import competition; export development.

INTRODUCTION

Mature industrial sectors that are exposed to severe import competition rarely exhibit positive employment growth, export expansion, or fast rates of new product development (Malecki, 1991). Many of these sectors are positioned toward the tail end of the product-life-cycle (PLC), where cost reduction tends to dominate strategic thinking at the corporate level (Vernon 1979). Conventional wisdom holds that advanced industrial economies no longer enjoy a comparative advantage in basic sectors such as steel, textiles, or apparel, if only because international competition at the mature end of the

PLC is overwhelmingly cost-based. In the United States, however, specialized production within many of the so-called twilight industries has resulted in positive employment growth in recent years (Florida 1996). Notable examples include apparel (e.g. New York City's garment district), steel (e.g. the minimill phenomenon), and machine tools (e.g. computer numerically controlled [CNC] machining centers). The machine tool (MT) industry is a particularly interesting example, in that this sector was poised on the threshold of extinction only a decade ago (Graham 1993). Beginning in the mid-1990s, however, the MT industry started to rebound in a number of unexpected ways. Since 1994, employment levels have stabilized, exports have expanded, and overall output has recovered dramatically (Aronson 1996; Robinson 1996).

Although the MT sector is not the only mature US industry to have experienced a commercial turnaround in recent years, we argue that this particular case is instructive in at least two ways. First, the United States lost its technological and market leadership in this industry more than 20 years ago (coincident with the rise of Japan and Germany as dominant international suppliers). Second, the industry remains geographically concentrated in the traditional manufacturing belt that fringes the Great Lakes. Thus, we are talking about an import-competing sector that remains rooted in the nation's oldest industrial region. On the face of it, these two factors alone suggest that the MT sector's recent revival has been noteworthy. After all, external competition comes mainly from the world's premier suppliers in terms of product quality (Germany and Japan). Further, over 60% of US employment in the MT sector is concentrated in core manufacturing-belt states such as Ohio, Michigan, and New York (most of which have been growing slower than the national average for many years).

The purpose of this paper is to examine the main organizational and technological factors that have contributed to the recent revival of the MT industry. Our evidence comes from a sample of 104 companies that participated in a national survey in the summer of 2000. Additional evidence comes from a series of follow-up inquiries, including 52 telephone interviews and 14 site visits. Before presenting our results, however, a brief research context is in order. Why is the machine tool industry worth looking at? Why did the industry start to decline in the first place? And, how did the industry manage to position itself on a recovery path?

RESEARCH CONTEXT

A machine tool is essentially a piece of equipment found on a factory floor that manipulates metal, often forming it into new machines or machine parts. Such tools come in a variety of sizes and types, ranging from relatively small CNC lathes to the enormous industrial presses that are used by automotive stamping plants. Placing a date on the emergence of the MT sector is still a matter of debate (see Nivin, 2000), though most scholars agree that the industry originally evolved as a spin-off from the armories in the second

half of the nineteenth century. The US government's demand for interchangeable parts in weapons in the early 1800s is widely credited as the first stimulus behind the industry's birth (Rosenberg, 1963). Also playing important roles on the demand side were the sewing machine, textile, bicycle, and automotive industries. According to Ashburn (1988), the sewing machine industry was the first to build on the manufacturing system developed by the arms makers. Specifically, machine tools were deployed to create standardized and interchangeable parts on a mass-production basis.

Despite the importance of the MT sector to firms in the various metalworking industries (notably automotive and aerospace companies), the strategic significance of this sector can ultimately be traced to its origins. Bluntly speaking, MT products are critical to weapons production. The first known example of this took place in 1813, when Simeon North was awarded a US government contract to produce interchangeable parts for guns (Nivin, 2000). Today, the MT sector remains pivotal to the interests of the US defense establishment (sophisticated weapons cannot be produced without the help of high-end machine tools). In this regard, the process of new product development within the MT industry typically entails the creation of faster and/or more flexible machines. While the fundamental principles that govern machine design have not changed very much over the last 100 years, the speed, accuracy, and versatility of such machines continues to improve. From the outset, then, it should be emphasized that 'innovation' within the MT sector usually entails a mix of software development (e.g. better control systems) and hardware enhancement (e.g. high-speed linear motors). The goal is to achieve faster machining speeds, along with improved accuracy and increased flexibility. Faster machining speeds flow from the use of more efficient electric motors; greater accuracy comes from improved fixtures and better software; while increased flexibility comes from the development of multi-axis machines.

From the outset, however, it should be stressed that machine tools are not generally in household use. Aside from the fact that industrial MT products are typically too large to fit into the average home, such products are also very expensive. To give a sense of price scale, a low-end tool such as a simple CNC lathe might cost anywhere between $5,000 to $50,000, whereas a high-end milling machine could cost as much as $8 million. Regardless of price, a notable characteristic of most MT products is that they last a long time (20 years or more). For example, most of the automated fastening machines that are currently used to rivet the wings for Boeing 747 aircraft were delivered to Boeing in the 1970s (Pritchard 2002). Machine longevity is both a drawback and an asset for the MT industry. On the negative side, the durability of well-engineered machines means that it might take an established customer many years to place a new order. On the positive side, machines with extended lifespans are coveted by clients. For MT suppliers, however, a critical problem is that demand

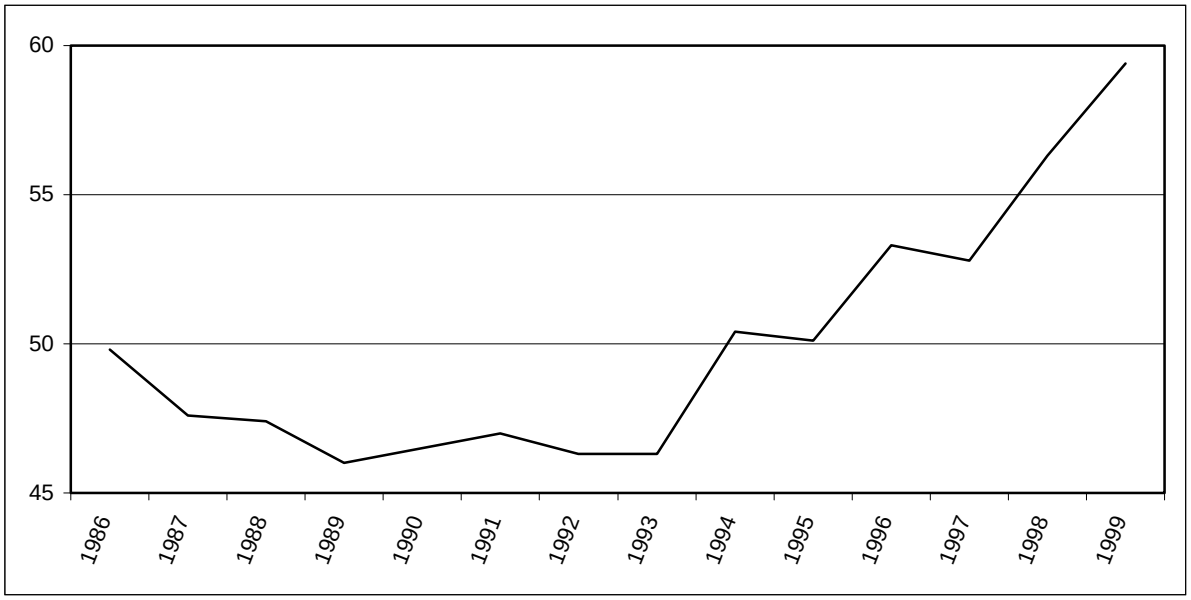
is structured by the unpredictable re-tooling requirements of customers that themselves face cyclical markets (e.g. firms in the automotive and aerospace sectors).

To counter this problem, US producers have long backlogged their orders to insulate themselves against cyclical downswings in demand (Finegold *et al.* 1994). We contend that this practice, though initially quite successful, laid part of the foundations for the industry's post-1975 slide toward diminished competitiveness. When Germany and Japan entered the global MT market on a large scale in the late 1970s, US consumers of MT products quickly realized that foreign equipment could be purchased with minimal delivery delays (and at lower prices).

From a strategic perspective, there is a general consensus in the literature that US producers relied for too long upon obsolete modes of business organization (e.g. backlogging, minimal customization, and poor after-sales service). The critical error was that the possibility of serious foreign competition was not factored into the business strategy equation (Dertouzos *et al.* 1989). Beginning in 1978 (which was the last time the US enjoyed a trade surplus in MT products), imports started to enter the US market on a significant scale. Today, imports account for over 60% of total domestic consumption, compared to only 20% in 1970 (US Department of Commerce 2000). The ability of foreign producers to dominate the US market so quickly exposed a number of underlying structural problems that persist within the US MT sector today (albeit in weaker forms). Specifically, the industry: (1) relied for too long upon US military procurement contracts; (2) produced over-engineered equipment for government clients (products that remain hard to sell to commercial manufacturers); (3) resisted or ignored the global trend toward closer supplier/client interaction; (4) failed to establish inter-firm partnerships for product development and/or marketing purposes; and (5) allowed itself to become integrated with multinational conglomerates that had no long-term interest in MT production (Finegold *et al.* 1994; Nivin 2000). In short, the industry had positioned itself (with government help) to perform as a second rate competitor by the time that global MT marketing took off in the late 1970s (Graham 1993).

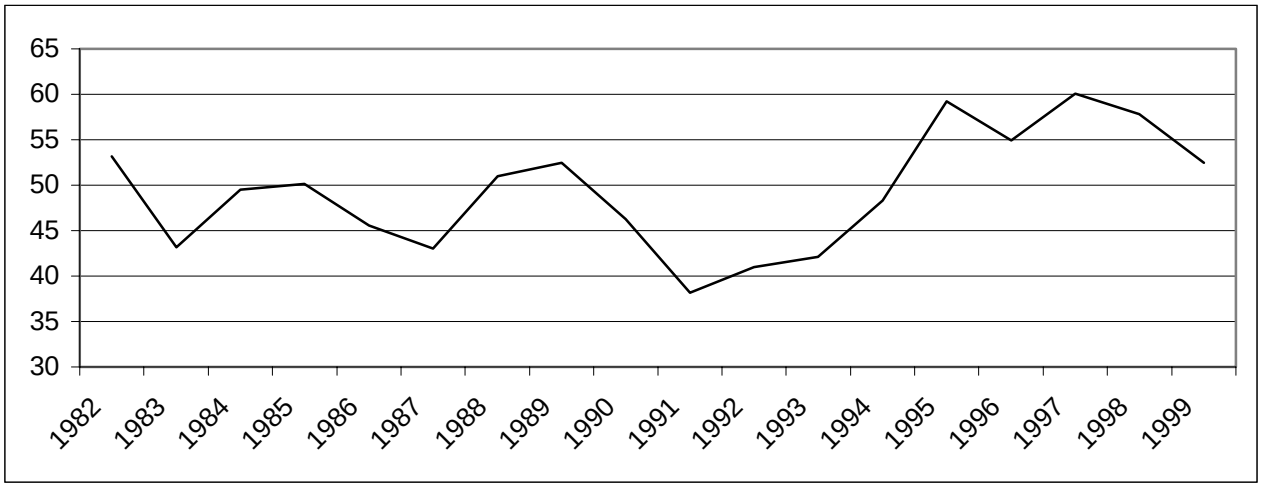
But none of this is fresh news. By now, in fact, there is little debate regarding the causes of the industry's decline. For example, few scholars would deny that the US government inadvertently played a key role by locking many producers into a technologically advanced but commercially doubtful trajectory of machine development (DiFilippo 1986). When the import gates opened in the 1980s, not even voluntary export restraint agreements could dissuade US buyers from purchasing foreign machines. Not surprisingly, then, several scholars writing in the early 1990s expressed concern that a US MT industry might not exist in the 2000s (e.g. Graham, 1993, Finegold *et al.*, 1994).

Figure 1. *Imports as a Percentage of US Machine Tool Consumption*



Sources: Association for Manufacturing Technology, US Department of Commerce

Figure 2. *US Machine Tool Shipments (in thousands of units)*

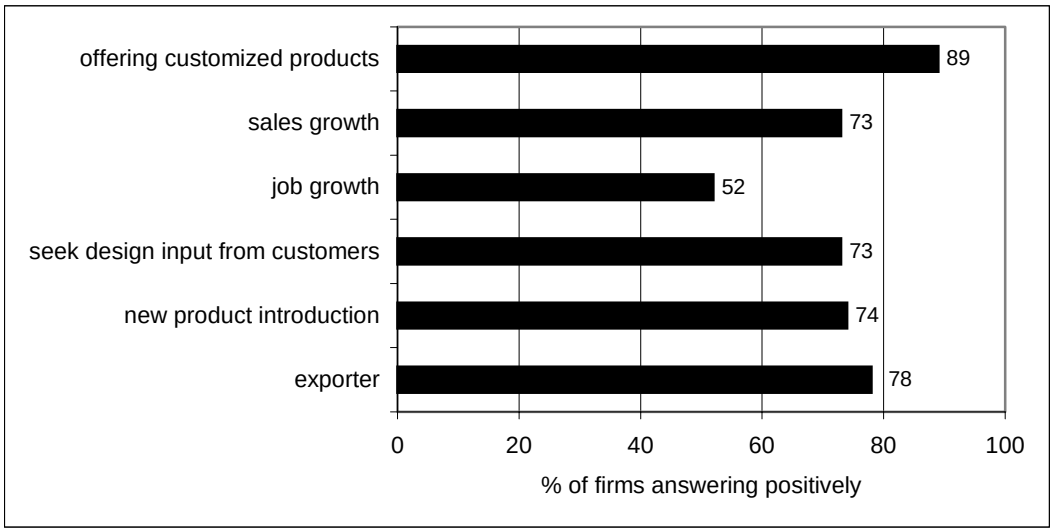


Sources: Association for Manufacturing Technology, US Department of Commerce

Figure 3. *Distribution of US Machine Tool Employment*

Sources: Association for Manufacturing Technology, US Bureau of the Census (2000)

Figure 4. *Firm Distribution for Key Variables*



To an extent, of course, many of these earlier projections have turned out to be true (Prestowitz 1988), especially with regard to import penetration and shipment levels (see Figures 1 and 2). This said, close to 10,000 new jobs were added to the US MT sector between 1993 and 1999, and exports as a percentage of total sales increased from around 15% in the mid-1980s to 30% in 2001 (AMT 2000). Although the industry is still dominated by small-and-medium-sized enterprises (SMEs) that employ fewer than 50 workers, average employment levels have recently been growing as a result of mergers and acquisitions (US Department of Commerce 2000). Still, the industry remains spatially concentrated in the nation's traditional manufacturing belt (Figure 3). Close to 65% of total MT employment is located within a seven state region that fringes the Great Lakes (Wisconsin, Michigan, Illinois, Indiana, Pennsylvania, Ohio, and New York). Although a gradual decentralization of MT employment has taken place since 1970 (see Kalafsky and MacPherson, 2002), the traditional manufacturing belt still contains a dominant share of national MT activity.

Set against this context, the remainder of this paper offers a firm-level perspective on the MT sector's recent commercial rebound. Despite counterproductive or nonexistent policy initiatives at the federal and state levels (discussed later), many US producers have become increasingly export active, while others have solidified their hold over key domestic customers. The question thus arises: how was this achieved?

SURVEY METHOD

In a first attempt to answer this question, self-administered surveys were mailed to a sample of 284 MT manufacturers in the summer of 2000. A four-page questionnaire was distributed to obtain firm-level information on R&D activity, employment levels, exports, competitive problems, recent growth performance, product policy (innovation and design issues), and technical aspects of production (e.g. cycle times, unit cost trends, average batch sizes). The sampling frame was drawn from the AMT's 1999 membership directory, which accounts for close to 90% of total US employment in the MT sector. Of the 480 firms listed in this directory, 196 were rejected from the final sampling frame (193 were found to be suppliers of accessories rather than machine tools, 1 was found to be a multi-product firm with only a minor MT focus, while 2 had ceased production since the 1999 directory was published). Given that our inquiry was designed to focus on MT producers only, the 'population' dropped from 480 to 284. After three rounds of contact (i.e. the initial mailing of the questionnaire, a postcard reminder 30 days later, and follow-up telephone calls thereafter), 104 valid returns were received (giving a final response rate of 36.6%).

Several approaches were employed in an effort to estimate nonresponse bias. First, t-tests and/or chi-square tests were applied to early and late respondents across several variables, including employment size, plant status (single versus multiplant), ownership (foreign versus domestic), export-intensity (proportion of sales from export mar-

kets), and firm age (number of years in the MT business). According to Babbie (1990), late respondents are thought to have more in common with nonrespondents than early respondents. Although the logic surrounding this approach is questionable, the fact that no significant contrasts emerged should be noted (early respondents were defined as within 30 days). A second test involved a comparison of the known characteristics of respondents and nonrespondents. Here, three attributes were tested (employment, plant status, and product focus), reflecting data availability. Again, no significant contrasts emerged. Last, we compared the geographic distribution of the sampling frame with the pattern of sample responses across several levels of regional aggregation. Chi-square tests did not point to significant differences between the sample distribution and the target population. In short, we believe that we have a sample that is spatially and structurally representative of the industry. [1]

EMPIRICAL RESULTS

As a starting point in the analysis, Table 1 provides a descriptive snapshot of the main characteristics of the sample. While some of these characteristics are suggestive of a mature industry, others are not. For instance, most of the survey firms have been in business for at least 50 years. There are few young companies in the sample, suggesting a low rate of new firm entry across the industry as a whole. Nevertheless, a majority of the survey firms introduced at least one new product over the study period (1995-1999). On average, newly developed products accounted for over 30% of the sample's recent outputs. This is a high proportion by almost any yardstick, especially for a mature sector (Malecki, 1991). In addition, the data indicate that most firms offer customized products, which was almost unheard of 20 years ago except among jobshops.

Further descriptive material is shown in Figure 4, which gives frequency distributions for a number of key variables. Of the 104 establishments in the sample, fully 82 (78%) serve foreign export markets; 77 (74%) introduced at least one new product between 1995 and 1999; 73 (70%) design their machines in close association with customers; while 52 (50%) created new jobs over the study period. All told, these characteristics are not suggestive of a mature industry.

This said, the recent revival of the industry can be traced to the efforts of certain types of firms rather than to the efforts of the population as a whole. To illustrate this point, Table 2 crosstabulates three categories of employment change (negative, zero, and positive) alongside the incidence of new product development (products introduced within the past five years) and export

Table 1. *General Characteristics of the Sample*

Characteristics	Mean	Median	High	Low
Employment	128.4	60	1200	4
R&D spending	5.8	5	25	0
Age	53	45	154	2
Innovation count	3.3	2	20	0
Innovation share	35.9	30	100	0
Customization	36.3	20	100	0
Export-intensity	14.9	10	70	0

1. Total employment in 1999
2. R&D spending as a proportion of sales
3. Number of years in the machine tool business
4. Number of new products introduced between 1995 and 1999
5. New products (1995-1999) as a proportion of 1999 sales
6. Percentage of 1999 output from customized products
7. Export sales as a percentage of total sales

Table 2. *Employment Change (1995-1999) by Innovation and Exports*

Employment change		*negative*	*zero*	*positive*	*total*
innovation	yes	18	15	44	77
	no	13	4	10	27
exports	yes	20	16	46	82
	no	11	3	8	22

Chi-square for growth by:	innovation	5.90	(p= 0.052)
	exports	5.44	(p= 0.065)

Table 3. *Employment change by commercial problems (ANOVA)*

Problem	negative	zero	positive	p-value
labor availability	3.85	3.65	3.21	0.536
cyclicality of demand	3.51	3.15	3.03	0.121
import competition	3.90	3.21	2.83	0.004
product liability laws	3.38	2.78	2.71	0.162
declining local markets	3.33	2.47	2.32	0.003
federal taxes	2.77	2.57	2.38	0.350
local/state taxes	2.64	2.47	2.35	0.535
worker compensation	2.56	2.42	2.30	0.592
domestic competition	2.51	2.47	2.79	0.397
government regulations	2.63	2.38	2.26	0.365
customer relocation	2.54	1.89	1.86	0.044
electricity prices	2.25	1.94	1.88	0.316
ISO certification	2.03	1.68	1.86	0.456
US export restrictions	1.87	2.10	2.01	0.725
access to export finance	1.71	2.21	2.05	0.211

mean score along a five-point scale, ranging from 1 (not a problem) to 5 (critical problem).

involvement. Although the chi-square tests fail to meet the usual 95% confidence level, they come remarkably close in both cases (p = 0.065). Of the 77 innovators in the sample, for instance, 57% (n = 44) created new jobs over the study period, compared to only 37% (n = 10) among non-innovators. More interesting, perhaps, is the fact that 48% of the non-innovators lost jobs over the study period, compared to 23% among innovators (p = 0.052). Similar distributions are evident with regard to export activity, in that firms that serve foreign markets are more likely to belong to the job-growth category than firms that serve home markets only (p = 0.065). At first blush, then, it would appear that the revival of the MT sector has been powered mainly by innovative firms that market their wares to foreign clients.

Keeping this point in mind, Table 3 collates our three categories of employment change alongside 15 competitive irritants that have been identified in the academic and trade literature as significant obstacles to growth among MT companies (Dertouzos *et al.* 1989; Finegold *et al.* 1994; Suzik 1999). Respondents were asked to rate the importance of each factor along a 5-point scale, ranging from 1 (not a problem in our competitiveness) to 5 (a critical problem). One-way analysis of variance (ANOVA) was employed to probe for differences among the three categories of employment change. While few of the contrasts are statistically significant, some of the results warrant brief mention. For a start, problems associated with finding and/or retaining skilled workers emerged as the top-ranked problem across all three categories of employment change (mean score = 3.57). As shall be shown later, this is a

rather complex problem that portends a deceleration of the sector's rebound over the long run. A second point is that the top-5 rankings are broadly similar across all three employment categories, with considerable mixing beyond that. In short, the chief problems facing the sector as a whole apply to shrinking, stable, and growing firms. Aside from labor availability, these problems most notably include cyclical demand, import competition, product liability claims, and declining local markets. A third point is that significant contrasts are evident for three potentially interconnected variables, including import competition, the relocation of longstanding customers, and declining local markets.

With regard to imports, firms that lost jobs over the study period cited foreign competition as the single most pressing issue (mean score = 3.90). While static and growing firms also rated import competition as being a serious problem (with respective mean scores of 3.21 and 2.83), the ANOVA results suggest that declining firms have been hit harder ($p = 0.004$). Declining firms have also been hit harder by customer relocations ($p = 0.044$) and local market shrinkage ($p = 0.003$). One possible interpretation of these findings is that imports have induced local market shrinkage (an external competition effect), while the relocation of longstanding customers has presumably added to the problem of operating on a local basis. Further, most of the firms that lost jobs over the study period were significantly older than the sample average, significantly smaller, and less likely to introduce new products than their counterparts in the other two groups.

As a further step in the analysis, respondents were asked to indicate whether or not they believed that the MT industry had experienced a technomarket rebound since the mid-1990s. Seventy-eight respondents (76%) answered 'yes'. Those answering 'yes' were then asked to rate the importance of various firm-level factors to the rebound process (those answering 'no' were evenly distributed across the three categories of employment change). A 5-point scale was again employed, ranging from 1 (not an important factor in our recent performance) to 5 (a critically important factor). As with Table 3, our 15 factors (Table 4) were identified on the basis of recent contributions to the academic and trade literature (e.g. Aronson 1996; Robinson 1996). The one-way ANOVA results are remarkable in several respects. First, the mean score gradient runs from low to high across the groups for 13 of the 15 factors listed. Second, significant group differences ($p = < 0.05$) emerged for 11 of the 15 factors. Third, the top-ranked factors represent producer-level responses to some of the key explanations for the MT sector's post-1980 decline. Specifically, firms in the positive growth category identified reduced cycle times, better customer support, improved machine design, and the use of fewer parts as major factors in their competitive rebound. While firms from the other two categories also ranked these factors as being important, the relative degree of emphasis is striking. For example, firms in the negative growth category rated 'cycle times' with

a mean score of 2.16, compared to a mean score of 3.52 among firms in the positive growth class (p = 0.007). As a further example, firms in the positive growth class rated the importance of increased R&D with a mean score of 3.19, compared to only 1.83 among firms that lost jobs over the study period.

Table4. *Employment Change by Rebound Factors (ANOVA)*

Factor	negative	zero	positive	p-value
shorter cycle times	2.16	2.89	3.52	0.007
fewer machine parts	1.86	3.16	3.05	0.005
improved machines	2.13	3.21	3.62	0.003
better customer support	2.20	3.05	3.65	0.004
greater customization	1.93	2.89	3.94	0.280
supplier improvements	2.03	3.00	3.36	0.003
strategic alliances	1.80	2.89	3.19	0.003
better technical data	2.13	3.21	3.44	0.007
use of the internet	2.26	3.05	3.23	0.068
better export access	1.73	2.61	2.88	0.011
government assistance	1.46	2.11	2.09	0.135
ISO compliance	1.83	2.68	2.80	0.054
increased R&D	1.83	2.68	3.19	0.002
better production methods	2.03	2.94	3.53	0.001
unit cost reduction	2.16	2.84	3.34	0.016

mean score along a five-point scale, ranging from 1 (not a factor) to 5 (critical factor).

It would, of course, be tedious to wade through all of the contrasts that are shown in Table 4. After all, the general picture is fairly clear. Specifically, firms in the positive growth category have placed stronger emphasis upon factors that pertain to delivery speeds, customer support, R&D, communications (e.g. use of the internet), machine design, the establishment of technical and/or marketing partnerships with complementary firms, and the use of new production methods (in this case, the use of flexible CNC workstations that are themselves used to produce similar types of machines). In essence, then, successful MT firms have been responding to many of the popular prescriptions listed in the recent management literature on industrial competitiveness (for a comprehensive overview, see Daniels and Radebaugh 1998).

An additional point worth noting is that firms that lost jobs over the study period turned out to be more locally oriented than their counterparts that retained or expanded employment. On average, firms that lost jobs obtained over 24% of their sales from customers located within the same metropolitan area, compared to an average of only 9% among firms in the other two groups (ANOVA; p = 0.019). In short, the incidence of job-loss is concentrated among old SMEs that rely heavily upon

geographically localized markets. An implication is that local orientation detracts from growth potential, and confirms previous findings that firms that rely on longtime local customers run the risk of no longer innovating for larger markets (Grabher 1993). Significantly, a substantial majority (85%) of the firms that belong to this particular category are located in the traditional manufacturing belt shown in Figure 3. In short, employment losses have been heaviest among firms located in the nation's oldest industrial regions. [2]

A final point concerns the extent to which US firms in the MT industry have forged supply contracts with foreign-owned durable goods producers that operate branch facilities inside the US. Recent evidence suggests that foreign manufacturing plants in the various metalworking sectors have tended to pull their longstanding (foreign) suppliers toward the US as part of a supply-chain maintenance strategy (i.e. retain key suppliers on a geographically proximate basis) (Banerji and Sambharya 1996; Shaver 2000). While there is good evidence that this practice is common, it should be noted that most of the survey firms that generated new jobs over the study period earned at least 10% of their 1999 revenues from sales to foreign subsidiaries inside the US (mean = 21%), compared to 6% among firms that lost jobs (3-group ANOVA $p = 0.008$). In short, MT firms in the positive growth category have managed to capture markets within the foreign-owned segment of the US manufacturing base. This can be regarded as a major achievement from a technological and marketing perspective, if only because foreign-owned manufacturing plants in the US typically operate with state-of-the-art facilities (Nivin 2000). In other words, the ability to serve a foreign-owned client located inside the US represents a vote of confidence in the US machine tool sector.

DISCUSSION

Despite the optimistic picture painted above, it should be remembered that import penetration now stands at approximately 60%, and there are few signs that US-based establishments will ever regain domestic market share unless foreign direct investment (FDI) in MT production increases dramatically. Further, the recent slowdown of the US economy portends a new phase of consolidation, rationalization, and/or downscaling across the MT sector as a whole. At present, the MT sector is now dominated by such large industrial groups as Yamazaki-Mazak, ThyssenKrupp, and UNOVA (parent of Cincinnati Machine, the largest US producer). Moreover, many MT companies are confronted with labor shortages (i.e. a general lack of skilled mechanical engineers and machine operators), and many have been forced toward highly specialized production in areas where future growth potential is uncertain (e.g. waterjet cutting, laser welding). On this note, we would characterize the US machinery sector as a trichotomy that includes: (1) a small number (n = 10) of large-scale producers that can offer a full range of flexible workstations (these are the high-end producers in terms of unit selling prices); (2) a secondary core of roughly 50 firms that

specialize in niche-markets (e.g. dry cutting, aircraft fuselage riveting); and (3) a larger mass of job-shops that specializes in tailor-made products (over 300 firms). Though it is widely recognized in the trade literature that job-shops are a major part of the MT industry in terms of growth potential (Oakey and O'Farrell 1992), we would argue that this is the sub-sector most at risk in terms of both domestic and foreign competition.

Lest we be misunderstood, it should be emphasized that job-shops are unlikely to disappear any time soon. Instead, the intent is to suggest that the days of the small machine shop are limited in light of increasing standardization. We expect to see a substantial rationalization of the industry at the SME scale within the next few years. On the other hand, some job-shops are likely to survive for a long time, if only because large producers are unlikely to manufacture specialized 'bits and pieces' on a tailor-ordered basis if they can help it.

With regard to first-division companies (i.e. major producers that offer diverse product lines), 6 of the 10 largest players in our sample are foreign-owned. Of the latter, 5 established branch facilities in the US during or immediately after the last export restraint agreement which was implemented in 1986.[3] Given that recent employment growth has been concentrated among larger firms, it is safe to suggest that many of the new MT jobs that were created over the mid-to-late 1990s were the result of capacity expansions among foreign subsidiaries. Although we do not have hard numbers to bolster this claim, we suspect that part of the MT sector's turnaround must reflect an FDI effect.

In this regard, follow-up interviews with some 66 companies (14 site visits and 52 telephone inquiries) yielded qualitative impressions that merit brief mention. Though we are not concentrating upon the details of these follow-ups in this paper, several findings ought to be flagged. First, high-end production is often concentrated within the foreign-owned segment of the industry. Although several US-owned firms successfully manufacture at the top end of the market (e.g. Cincinnati Machine, Haas), these producers are facing increased competition from firms that are either branch plants or were purchased by major transnational corporations headquartered in nations such as Japan, Germany, the UK, or Switzerland. Our interviews revealed that many of these high-end plants (and purchases) were established primarily to avoid potential access restrictions such as voluntary export restraint agreements. To an extent, then, US trade policy during the 1980s encouraged inflows of FDI within the MT sector. Further, these policy initiatives created a geography of inbound investment that closely matched the existing distribution of other metalworking plants (key MT customers) inside the US (for details, see Kalafsky 2002).

A further impression that was gleaned from our interviews concerns second-division firms, almost all of which are wholly US-owned. These firms produce mid-level products in terms of selling prices (typically less than $1 million per unit), and have experienced modest

employment growth as a result of specialization, customization, and niche-dominance. Interviewees in this group almost invariably indicated that they do not compete with first-division companies, and that constant innovation (e.g. the anticipation of customer needs) lies at the heart of their competitive strategy. Another common thread is that these firms are expected to 'turnkey' their products to meet the needs of potential and current customers. With only a handful of exceptions, customization is becoming a common customer demand throughout the industry, along with increased expectations of training and extensive after-installation support. The turnkey trend is important to note, as it causes additional burdens for already-challenged MT producers in that it has often led to increased retooling and customer support costs. Basically, many established manufacturers were forced to change design and production processes in order to survive.

With regard to third-division firms, however, our interview results revealed a more mixed picture. At the top-end within this group, several specialty producers have cornered the global market for machines that few first or second division firms would ever consider producing. While we are unable to offer specific examples without compromising the nondisclosure rules that guided our survey, we can state that most of these firms compete on the basis of unique products that are manufactured in small batches for global rather than national or regional markets. This particular subgroup within the third-division consists of approximately 40 firms (13% of the group total). Elsewhere within the third-division, however, the long-run outlook is not so good. Here, our evidence points to a number of strategies and practices that seem out of place in the 21st century, including order backlogging, the use of outmoded software control systems, reliance upon local customers (minimal interest or little capability in export development), and weak or zero investment in worker training. In many ways, these are the same competitive problems that caused the loss of market share to international producers in the early days of the domestic industry's decline. Old, family-owned, locally focused, and heavily oriented toward job-shop activity, these are the types of firms that typically populate the negative growth class shown in Table 2. To make matters worse, firms within this particular group have found that clients increasingly want flexible machines rather than dedicated equipment. While the need for customization is unlikely to disappear over the foreseeable future, it would seem that the market wants customized machines that are flexible rather than MT products that can only be deployed on a limited basis. Put another way, customers that formerly demanded job-specific machines now want multi-task products. A final issue is that these producers often compete on a price basis with low-cost rivals. This is a critical problem, as our initial research shows a growing group of customers (often subcontractors) taking a short-term approach to MT purchases, looking only at the life of their contract (and price) rather than choosing a machine with longevity. If this conjecture is correct across the demand side as a whole,

then the days of the typical job-shop are surely numbered.

CONCLUSION

The US machine tool industry has been described as a sunset sector by many scholars. While there is a good deal of truth to this perspective, notably with regard to import penetration, a residual core of technological competence remains inside the US. Firms belonging to the 'core' have recently created new jobs, expanded their export share, found new markets within the US itself, and initiated commercial partnerships with complementary firms (both foreign and domestic). Such firms have also emphasized a variety of useful initiatives to support future growth, including increased spending on applied R&D, sustained efforts to reduce cycle times, and improved customer support (i.e. better after-sales service). Despite frequent claims to the contrary, our evidence suggests that several key segments of the MT industry will remain intact for some time. The likely survivors with future growth potential include the small number of large producers that manufacture flexible workstations, several medium-sized producers that offer customized products, and a variety of job-shop producers that offer unique outputs (often aimed at specific industries). On the negative side, import competition (as well as domestic competition) threatens to eliminate many of the nation's older SMEs, many of whom are market-tied to local buyers that are either 'on the way out' or 'moving forward'. The strategic challenge for many of these producers is to keep pace with clients that want flexible equipment rather than dedicated machines. A further challenge is to cultivate distant markets as a counterbalance to weak or declining industrial demand at the local scale.

Looking to the future, it would seem that specialization and customization offer the best prospects for competitive survival at the firm level. Rather few US companies can manufacture CNC workstations for mass markets. Fewer still can export CNC products that can be installed, calibrated, and integrated with pre-existing systems *without* extensive technical support. There is little doubt that German, Japanese, and European producers have cornered the global market for high quality machines that can be purchased off-the-shelf. At the bottom end of the market, moreover, there is widespread agreement that low-end machines can be produced at highly competitive prices by manufacturers in nations such as Taiwan and South Korea. So, where does this leave the US MT sector? According to industry analysts (e.g. Haas, 2000), the answer lies in niche-based product innovation, custom work, and systems integration. Under systems integration, machines are designed by US firms – but critical items of hardware and software are sourced externally (i.e. imported). Here, the opinions of industry experts mesh closely with the findings from our follow-up interviews. An important implication is that domestic suppliers of accessories and parts will be increasingly threatened, as will a major US supplier of software controllers. A further implication is that US intra-industry trade in the machine tool sector will continue to ex-

pand. This suggests, among other things, that the foreign content of US MT exports will increase substantially over the 2000s.

Finally, it should be emphasized that our survey was conducted fully one year prior to the global economic slowdown that started in early 2001. Ongoing tracking studies by the authors suggest that recent job losses and plant closures have been overwhelmingly concentrated among third-division producers. As mentioned earlier, these producers are typically very small, very old, family-owned, locally-oriented, and apt to produce tailor-made equipment of a dedicated nature. Further, such producers are disproportionately represented in older industrial cities such as Buffalo, Cleveland, Cincinnati, and Detroit. While some of these cities have created new specializations in other sectors, the fact remains that virtually all of the major industrial centers that fringe the Great Lakes retain an above average proportion of total employment in basic metalworking activities (e.g. steel, auto parts, construction equipment). These cities also contain the bulk of the nation's 'high-risk' SMEs in terms of our survival prognoses.

ENDNOTES

1. The AMT membership directory does not capture the entire population of machine tool companies. This is because many of the nation's smallest MT firms are not AMT members. One possible reason for this is that AMT member services may not be terribly relevant to small firms that operate on a job-shop basis.

2. By itself, the incidence of negative employment growth does not necessarily imply poor business performance. After all, companies can often expand their sales while simultaneously cutting jobs via process automation. For this particular sample, however, the incidence of negative employment growth goes hand in hand with reduced output and/or a loss of market share. In short, firms that lost jobs over the study period also experienced declining sales.

3. A systematic assessment of the differences between foreign versus domestic MT establishments is planned for a separate paper. For now, however, it should be noted that foreign subsidiaries differ significantly from their US counterparts in terms of several variables, including: (1) market range (foreign establishments serve wider domestic markets than US companies); (2) import sourcing (foreign subsidiaries import a higher percentage of their inputs than US companies), and (3) establishment age (foreign subsidiaries are significantly younger than their US counterparts). No statistically significant differences were detected for performance-related variables such as employment growth, sales growth, or product innovation.

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