The Competitive Characteristics of U.S. Manufacturers in the Machine Tool Industry

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ABSTRACT. This paper examines the competitive characteristics of U.S. manufacturers in the machine tool (MT) industry. After several decades of decline, this industry has recently shown signs of a modest but sustained recovery. Empirical evidence from a national survey of 104 MT producers suggests that the revival of this sector has been driven by a combination of factors, including renewed export involvement, improved customer support, and better product design. Although most MT companies are small-to-medium-sized enterprises (SMEs), the survey data show that very small SMEs are poorly represented in the recovery thrust of the industry as a whole. Our principal conclusion is that the MT industry has been following an export-led path toward stabilization, but that certain types of small producers are unlikely to thrive for very long. The most serious problems facing small producers include shrinking local markets, import competition, shortages of skilled labor, and cyclical demand.

I. Introduction

After more than three decades of serious decline, evidence is mounting that the U.S. machine tool (MT) industry is in better shape today than at any point over the last 20 years (MacPherson, 2000; Nivin, 2000; Papke, 1996; Robinson, 1996; Stonecipher, 1997). Manufacturers in this industry produce capital goods that are critical to the production efforts of other firms, especially those that operate in the automotive, aerospace, and metalworking sectors. Although import penetration continues to grow faster than domestic production, U.S. exports of MT products expanded briskly over the 1990s. Throughout the mid to late-1990s, moreover, MT employment increased on an annual basis, portending a deceleration of the post-1980 wave of plant closures, downscaling initiatives, and bankruptcies. From a U.S. perspective, Stonecipher (1997) describes the recent recovery of the MT industry as a "back from the ashes" rebound that seldom occurs within any mature sector these days.

We argue in this paper that import competition has played a key role in shaping the recent export thrust of U.S. companies in this sector. While major foreign producers such as Japan and Germany operate with economies of scale, competitive prices, and high-quality products, smaller and less globally-oriented U.S. producers have recently responded by opting for specialized niche-markets. Further, we argue that the recent stabilization of the U.S. industry can be traced to a sector-wide reduction of the basic problems that initially prompted U.S. customers to opt for foreign rather than domestic machines. The switch toward imports occurred in the late 1970s at a time when most U.S. firms had little interest in export markets. Today, the story is different. Specifically, specialized U.S. producers increasingly emphasize export markets rather than domestic buyers. A major reason for this, as we show later, is that foreign producers have established an almost irreversible grip over the U.S. market, leaving domestic MT producers with only three possible choices: (1) recapture domestic clients; (2) find new customers abroad; or (3) try to do both of these things. On balance, our evidence suggests that option (2) has been the most successful strategy.

It is well established that the U.S. MT sector is characterized by a high percentage of SMEs

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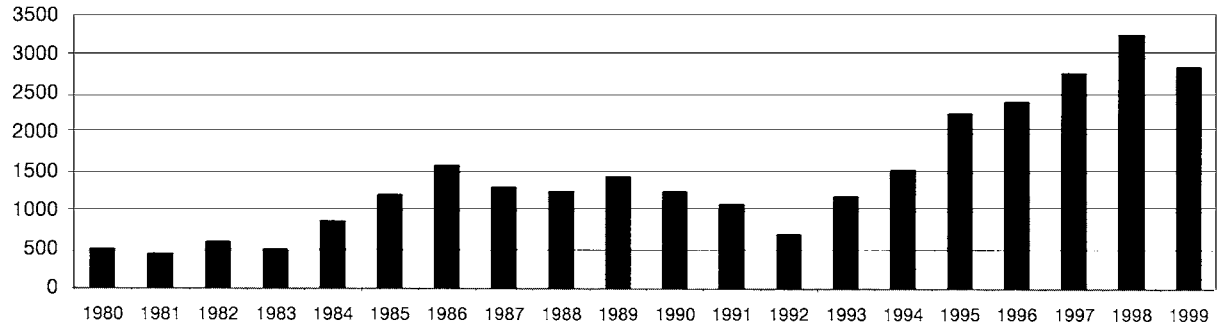
(Finegold et al., 1994), but do these smaller firms have difficulty performing and innovating in a mature industry against larger, well-financed rivals? The relationship between size and innovation itself has provided mixed results (see Acs and Audretsch, 1988; Audretsch and Acs, 1991; Van Dijk et al., 1997) and from an export standpoint there are again ambiguous findings on the impact of firm size (see Bonaccorsi, 1992; Calof, 1994). However, within industries key to the MT sector's success, evidence emerges that often favors larger firms. There are indications that firm size will correlate positively with performance in key metalworking sectors (Harrison et al., 1996). This is joined with earlier findings that size is a factor in Computer-Numerically-Controlled (CNC) MT adoption (Oakey and O'Farrell, 1992; O'Farrell and Oakey, 1992). So, the question remains whether small MT manufacturers can remain viable within the marketplace.

Within this context, there is every indication that smaller firms can adopt flexible technologies (Carlsson et al., 1994). Further, Carlsson and Taymaz (1994) find that SMEs are adopting CNC machine tools as part of a changing division of labor between smaller and larger firms. Moreover, smaller firms may be able to enter and succeed in mature sectors if they focus on specialty markets or narrow focuses that are often missed by larger competitors (Agarwal and Audretsch, 2001). This is a particular strategy that appears to be followed by many domestic MT producers. Keeping these previous studies in mind, one must also ask whether other factors play into small firm competitiveness. Rather than size, there is evidence that performance in a mature industry is related to a firm's overall, long-term strategies, including increased attention to quality control (Williams et al., 1995). None of these findings indicate that smaller MT firms are excluded from taking part in an overall industry recovery.

Framed against this backdrop, the main goal of this paper is to describe the nexus of factors that have enabled the U.S. machine tool industry to achieve the commercial rebound described by Stonecipher (1997). Evidence for the inquiry comes from a sample of 104 MT companies that participated in a postal survey in June of 2000. Supplementary evidence comes from a series of follow-up telephone interviews that were conducted in November/December of 2000. An important finding is that successful U.S. producers in this industry are beginning to resemble their foreign competitors in terms of several basic characteristics, including research and development (R&D) spending, post-sales support, and customized production. On the downside, our evidence suggests that small MT companies have not participated in the revival trend to anything near the same extent as their larger counterparts. Before discussing our results, however, a brief research context is required. Specifically, what are main competitive difficulties that have traditionally confronted U.S. firms in this sector? And, what are the main dimensions of the sector's techno-market recovery?

II. Research context

Firms in the MT industry supply capital goods to the manufacturing sector as a whole. Unlike the various power-driven tools that household consumers might use, MT products are typically large (non-hand-held), very expensive (U.S. trade data exclude machines with unit prices of less than $3,025),[1] and explicitly designed for industrial applications. Examples range from milling and grinding tools to lathes, CNC workstations, lasers, presses, and various other machines that are designed to cut, bend, form, or shape metal (AMT, 2000). Although the U.S. industry is dominated by a handful of large producers, the broader U.S. population consists of small-to-medium-sized enterprises (SMEs) that employ fewer than 50 workers[2] (U.S. Department of Commerce, 2000). Geographically concentrated within the traditional manufacturing belt (i.e. states bordering the Great Lakes), the post-1970 trajectory of the MT industry has generally been negative in terms of jobs, patents, and global market share (see Forrant, 1997). Part of this trajectory can be traced to rising import competition (Nivin, 2000), as well as to a general failure to innovate (Mazzoleni, 1999). Beginning in the late 1970s, Japanese producers acquired a talent for building high-quality machines in large batches (and at low unit costs), prompting a U.S. import surge that continues today (see Figure 1). At the same time, specialty producers from Germany, Italy, and Switzerland were developing sophisticated CNC products for



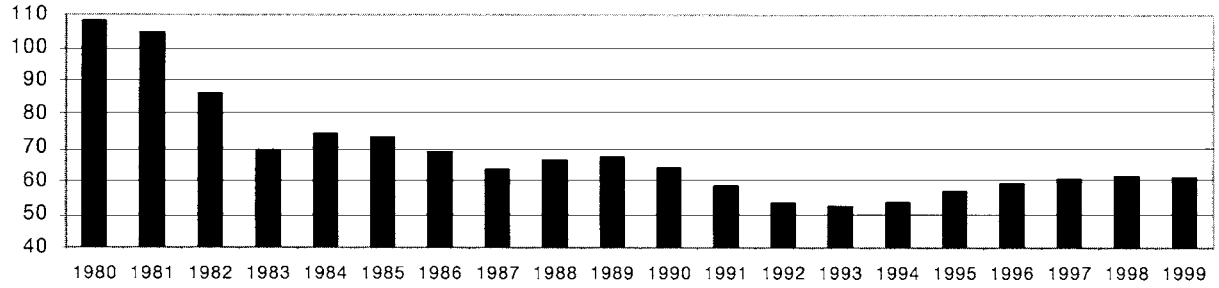
Sources: Association for Manufacturing Technology; U.S. Department of Commerce.

Figure 1. U.S. trade deficit in machine tools (1980–1999) [in millions of $].

the high end of the market, leaving many U.S. producers with stiff competition at both ends of the price spectrum. By 1999, foreign products accounted for almost 60% of U.S. domestic consumption, compared to only 15% in 1980 (U.S. Department of Commerce, 2000).

While the history of the industry's demise has been well documented (Ashburn, 1988; Dertouzos et al., 1989; DiFilippo, 1986; Finegold et al., 1994; Forrant, 1997; Graham, 1993; Nivin, 2000; Robinson, 1996), little attention has been given to its recent resurgence. Part of the industry's rebound can be explained by a renewed focus upon export markets, as well as by a concerted effort toward product improvement (MacPherson, 2000). Despite rising import penetration over the 1990s, U.S. manufacturers of specialized MT products now earn as much as 30% of their annual revenues from foreign customers (AMT, 2000). For an industry that was over 80% dependent upon the home market in the early 1980s, an export-intensity average of 30% in recent years implies a fundamental change in marketing focus (Logan, 1999). Recent evidence suggests that rising export orientation has come as a response to several factors, including intense import pressure (loss of domestic customers), reduced defense contracts, a weaker U.S. dollar, improved access to export finance, and greater competition for local markets. Under these circumstances, it is no surprise that many U.S. companies have come to regard export activity as a strategic counterbalance to hostile domestic conditions. Given that many machine tools have life-cycles that average 20 years or more, the loss of a domestic customer to foreign competition often implies bleak prospects for recapturing that customer within the lifespan of any given MT product.

With this said, it would seem that the increasingly competitive environment facing U.S. firms has spurred efforts toward greater specialization, continuous product innovation, and organizational change. For example, few U.S. producers deliberately backlog their orders these days (a common practice in the 1970s and 1980s); most firms now allocate at least some of their resources toward in-house R&D; all but the very smallest SMEs operate with ISO certification; most U.S. machines can now be delivered with software control systems that reflect the needs of specific clients; major innovations have been introduced across several segments of the industry (e.g. dry-cutting, linear motors); and most producers are now willing to adapt their products to suit the tooling specifications of users (customization). As recently as the 1980s, few U.S. producers were willing to offer any of the above. To an extent, then, some of these changes may explain why MT employment has recently stabilized. After many years of layoffs and plant closures (over 50,000 jobs were lost since 1980), the downward employment curve started to flatten by 1993 (Figure 2). Indeed, some years since 1993 have witnessed modest growth (a rare event for any mature industrial sector these days). The question thus arises: how did the U.S. machine tool industry manage to achieve this? Given the global dominance of Japanese, German, Swiss, and Italian producers, this is clearly an important question. Another question concerns the resiliency of the post-1994



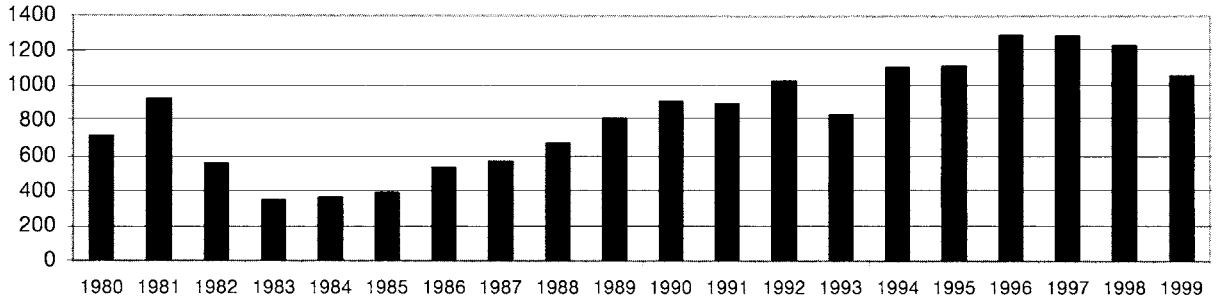
Sources: Association for Manufacturing Technology; U.S. Department of Commerce; U.S. Bureau of the Census.

Figure 2. Total employment in the U.S. machine tool sector (1980–1999) [thousands of jobs].

recovery. More simply, will this recovery continue?

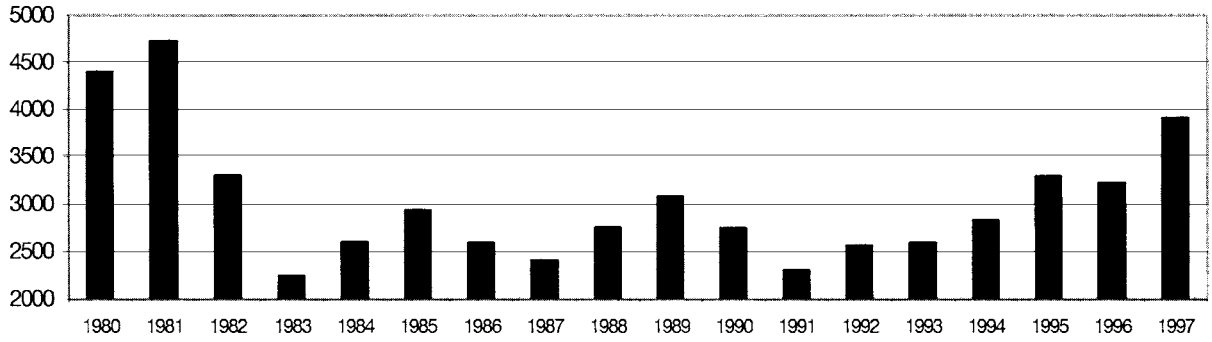
Despite a rising trade deficit in MT products since the late 1970s (see Figure 1), U.S. exports of MT products have been growing steadily since the mid-1980s (Figure 3). With import penetration currently running at more than 60% across most major categories of MT products, it is safe to suggest that the positive employment trend since 1994 owes much to U.S. export activity. Value-added within the U.S. MT sector has also shown an upward trend since 1993 (Figure 4), giving some support to Stonecipher's (1997) assertion that MT producers have been riding a sustained recovery curve over the last few years. Even so, it is clear from Figures 1–4 that a "recovery" has taken place within an environment of rising import penetration (intense foreign competition), and that the only unambiguous indicator of recovery at the industry level is aggregate employment. This said, the U.S. has not experienced seven consecutive years of positive job growth within the MT industry since the 1960s. Overall, Figures 1–4 point to a marked phase of post-1994 growth in terms of employment, exports, and value-added – despite a rising trade deficit in MT products.

Armed with monthly data on shipments, import-export trends, order requests, and various economic growth forecasts, MT industry analysts tend to offer revised outlook statements on a frequent basis. For example, the Asian currency crisis dampened U.S. exports to East Asia over the 1998–1999 period, while a general slowdown in U.S. capital investment over the last 12 months has led to lower output figures relative to previous years (U.S. Department of Commerce, 2000). More fundamentally, however, the short-term outlook for any subsector of the MT industry underscores a critical point that must be emphasized from the outset. Specifically, demand is highly unpredictable, in that MT producers are locked into the purchasing schedules of buyers that are themselves exposed to cyclical demand (e.g. aerospace, automotive, and other durable



Sources: Association for Manufacturing Technology; U.S. Department of Commerce.

Figure 3. U.S. exports of machine tools (1980–1999) [in millions of $].



Sources: Association for Manufacturing Technology; U.S. Department of Commerce.

Figure 4. Value-added in the machine tool industry (1980–1997) [in millions of $].

goods companies). Volatility of this nature means that exports have become increasingly important to U.S. producers, if only because foreign markets provide a cushion against downturns in home demand. At the same time, of course, it should be noted that U.S. producers are generally much smaller than their counterparts from the European Union and Japan (many of whom enjoy high-volume production across multiple MT categories). This implies that few U.S. firms are in a position to serve mass markets (domestic or foreign), and that finding niche-based opportunities is critical.

On this note, the rest of this paper offers a company-level perspective on the competitive prospects of the U.S. MT industry in the 2000s. In seeking answers to the questions posed earlier, a number of expectations guided our initial research design. In terms of commercial problems, for instance, it was expected that a combination of import competition, declining home markets, and shortages of technically proficient workers would represent the main difficulties facing domestic producers. These expectations were gleaned from recent issues of prominent MT trade journals, as well as from academic literature on the problems confronting the industry (e.g. Forrant, 1997; Nivin, 2000). In terms of industrial recovery, moreover, it was anticipated that the main factors responsible for Stonecipher's (1997) optimism would be the exact opposite of those factors that led to the industry's decline in the first place. Thus, for example, it was expected that successful firms would exhibit faster deliveries (reduced backlogging), improved customer involvement and support, stronger export-orientation, and a commitment to continuous product development. Again, a survey of MT trade journals and recent academic literature informed this expectation. A final expectation was that very small SMEs would exhibit a wider array of problems than larger firms. This expectation was informed by the fact that recent rates of market exit have been noticeably higher among small producers (MacPherson, 2000).

III. Survey method and main results

To test these expectations, self-administered questionnaires were distributed to a sample of 284 MT firms in June of 2000. The survey instrument (4 pages in length) was structured to obtain basic information on firm-level R&D activity, employment, export characteristics, competitive problems, recent growth performance, product policy (innovation and design issues), and technical aspects of production (e.g. batch sizes, cycle times, unit cost trends). The sampling frame came from the AMT's 1999 membership directory, which accounts for close to 90% of total employment in the industry. Of the 480 firms represented in this directory, 196 were filtered from the final database (193 were found to be manufacturers of accessories rather than complete machines, 1 was found to be a multi-product firm with only a limited MT focus, while 2 had gone out of business since the 1999 directory was published). Given that our study was designed to capture MT

producers only, the "population" dropped from 480 to 284. After three rounds of contact (i.e. the initial mailing of the survey instrument, a postcard reminder 30 days later, and follow-up telephone solicitations thereafter), a total of 104 valid returns were obtained (giving a final response rate of 36.6%).

To estimate nonresponse bias for the survey, three approaches were adopted. First, difference of means and/or chi-square tests were applied to early versus late participants across several attributes, including employment size, plant status (single versus multiplant), ownership (foreign versus domestic), export-intensity (percentage of sales from export markets), and company 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. While the logic surrounding this approach can be questioned, the fact that no significant contrasts emerged should be mentioned. Our second test involved a comparison of the known characteristics of respondents and nonrespondents. Here, three variables were tested (employment, plant status, and product focus), reflecting data availability. Again, however, no significant contrasts were detected. Finally, we compared the geographic distribution of the target population with the pattern of sample responses across several levels of spatial aggregation. Chi-square tests failed to reveal significant differences between the sample distribution and the target population. In short, we believe that the sample is geographically and structurally representative of the industry as a whole.

IV. Empirical results

A summary of the main characteristics of the sample is shown in Table I. These data reveal that the typical MT company is relatively small (mean employment = 128 workers), well established (there are few new or young firms in the sample), moderately export-oriented (overall sample mean = 14.9%), and R&D-active. Fully 82 (79%) of the survey firms obtain at least some of their sales from foreign export markets (mean export-intensity = 23.8%), while 87 (83%) operate with in-house R&D units (mean R&D-intensity = 5.8%). Over the period 1995–1999, the typical MT producer introduced an average of 3 new products (incrementally improved versions of older products were not considered). For the sample as a whole, new products accounted for roughly 35% of total sales over the 5-year study period. Clearly, then, there is evidence that the industry has recently been developing new types of machines. Finally, the data show that customization is common, in that an average of 36% of total output consists of machines that are adapted and/or modified to suit the needs of specific clients. It should be noted that these data (Table I) are broadly consistent with the more aggregate summaries reported by the AMT for its membership base (AMT, 2000). In other words, it would again appear that our sample resembles the broader population.

TABLE I
Main characteristics of the sample

Characteristics	Mean	Median	Mode
Total employment[a]	128.4	60	20
Export intensity[b]	14.9	10	0
R&D intensity[c]	5.8	5	5
Company age[d]	52.4	45	51
New product count[e]	3.3	2	0
New product share[f]	35.9	30	0
Customization level[g]	36.3	20	0

[a] Total employment (production and nonproduction workers).
[b] Exports as a percentage of total sales.
[c] Research spending as a percentage of total sales.
[d] Number of years in the MT business.
[e] Number of new products introduced over the last five years.
[f] New products (last five years) as a % of current output.
[g] Percentage of output customized for specific clients.

Competitive problems

A synopsis of the main competitive problems facing the survey firms is presented in Table II. Here, respondents were asked to rank the impact of 15 factors along a 5-point scale (ranging from 1 = "not a competitive problem" to 5 = "critical impediment"). Mean index scores per factor are listed in the first column, whereas the second column shows the percentage of respondents that ranked the factors in question as being either serious or critical (items 4 and 5 in the scale). All factors were collated against employment counts using Spearman's rank-order correlations to test

TABLE II
Competitive problems facing the MT industry

Factor	Mean score on index[a]	% seriously affected[b]
Availability of skilled labor	3.56	57.7
Foreign import competition	3.22	47.1
Cyclicality of demand	3.23	39.4
Product liability laws	3.01	33.6
Shrinking local markets	2.64	29.9*
Federal taxes	2.53	23.0*
Domestic competition	2.65	18.2
Local and state tax rates	2.46	18.2
Worker compensation	2.40	14.5
Government regulations	2.39	14.5*
Relocation of customers	2.08	13.5*
U.S. export restrictions	1.99	10.6
Access to export finance	1.98	10.6
Cost of electricity	2.10	9.6
ISO certification	1.89	4.8

[a] Mean score along a five-point scale, ranging from 1 (no problem) to 5 (critical problem).
[b] % of firms indicating that the factor was either serious or critical (items 4 and 5 on the scale).
* Negative Spearman's correlation between total company employment and the competitive problem ($p = 0.05$ or less).

for size effects. The results suggest that firms of all sizes view the availability of skilled labor as being the single most important competitive problem (mean score = 3.56). A total of 60 respondents (57% of the sample) identified shortages of technically trained workers as being either a serious or critical obstacle to competitiveness. Cyclicality of demand (mean score = 3.23) and import competition (mean score = 3.22) emerged as the second and third ranked obstacles, whereas ISO certification turned out to be the least significant issue overall (mean score = 1.89). A fourth factor that warrants brief mention concerns product liability (mean score = 3.01). According to Nivin (2000) and Finegold et al. (1994), many MT companies spend more on product liability insurance than they do on applied R&D. An obvious reason for this is that MT products can cut, crush, deform or fatally injure workers that are not fully trained in the operation of such tools. Not surprisingly, then, the insurance premiums associated with product liability represent irritants that affect the industry as a whole (for examples, see Clevenger, 1999).

While similar impressions can be abstracted from recent issues of popular trade journals such as Manufacturing Engineering or the American Machinist, the data listed in Table II point to a set of size-related issues that are not commonly discussed in such outlets. Specifically, SMEs appear especially susceptible to geographic and/or regulatory factors. Negative and significant ($p \leq 0.05$) Spearman's correlations emerged between company size and two geographic variables (relocation of customers and shrinking local markets). For instance, of the 31 firms that cited shrinking local markets as a serious or critical problem, 26 (83%) employ less than 20 workers. A similar picture emerged for the other geographic variable (relocation of customers). Initial research indicates that these particular problems are overwhelmingly concentrated among firms located in the traditional manufacturing belt that fringes the Great Lakes – an issue that will be addressed in a subsequent paper. Relative to larger firms, moreover, SMEs appear more likely to view federal taxes and/or regulatory conditions as being problematic.

A further point is that few of our respondents appear to be concerned with the problem of dual-use U.S. export restrictions.[3] This is surprising, in that Logan (1999) and several other industry representatives have testified before U.S. Senate Committees on precisely this topic. For example, it has been pointed out that 5-axis CNC machines can be displayed by foreign competitors at Chinese trade shows, whereas comparable U.S. machines are denied entry as a result of U.S. trade legislation.[4] Moreover, the export license process for potential shipments to China has also been cited as an impediment to export success (Suzik, 1999). Given that China represents one of the world's fastest growing markets for sophisticated MT products, and given the AMT's continued opposition to U.S. export controls, the fact that this problem is ranked thirteenth in our 15-factor list of competitive difficulties seems odd (less than 11% of the survey firms identified this factor as being important).

Recall that the index shown in Table II represents an aggregate score for the sample as a whole. In the case of this particular variable, it should be noted that 8 of the larger firms that export on a global basis ranked the dual-use policy as a major obstacle to sales growth. Although the Spearman's

test did not point to a significant size-effect for this variable, the same test revealed an export-intensity effect at $p = 0.061$ (i.e. highly export-dependent firms are more likely to object to export restrictions than their less export-dependent counterparts). On this basis, the low aggregate score for this particular factor should be interpreted with caution.

Factors associated with a commercial recovery

Table III gives summary ratings for those factors that have enhanced the recent commercial performance of the survey firms (in this instance, the procedures used to build Table II were replicated for Table III). A survey of the recent MT trade journals yielded a menu of 16 general factors that are perceived by industry analysts to be important to the recent revival of firms in this sector. Two factors in the list stand out as being sensitive to company size (i.e. improved product quality and technical alliances with other manufacturing firms). In both cases, the Spearman's rank-order correlation is positive ($p \leq 0.05$). Specifically, larger firms are more likely to assign high scores to these factors than SMEs. One possible explanation for the product quality contrast is that larger firms have recently been developing new products at faster rates than their smaller counterparts (discussed later). In terms of technical alliances (strategic collaborations), the size-effect may say something about the potentially limited extent to which SMEs can offer technological advantages to external partners.

TABLE III
Factors in the recent performance of MT firms

Factor	Mean score on index[a]	% agreeing strongly[b]
Improved product qualtiy	4.06	62.5*
Better technical information	3.94	58.6
Shorter cycle times	3.93	56.8
Better customer support	4.07	55.8
Faster delivery speeds	4.08	53.9
Improvementss among suppliers	3.80	51.0
Use of interest	3.84	51.0
Improved manufacturing methods	3.92	51.0
Fewer parts per machine	3.57	48.1
Alliances with other firms	3.57	45.2*
Increased customization	4.10	40.4
Reduced unit costs	3.80	40.1
Growth of R&D spending	3.53	39.4
ISO compliance	3.28	32.7
Better access to export markets	3.28	31.8
Government assistance	2.52	13.4

[a] Mean score along a five-point scale, ranging from 1 (not a factor) to 5 (critical factor).
[b] % of firms indicating that the factor was either very import or critically important (items 4 and 5 on the scale).
* Positive Spearman's correlation between total company employment and the competitive factor ($p = 0.05$ or less).

Leaving size effects aside for now, Table III shows that the highest ranked performance-enhancing factors pertain to customer relations. For example, the single most important item is increased customization (mean score = 4.10), followed by faster product delivery (4.08) and better customer support (4.07). Historically poor performance with regard to these factors goes some way toward explaining why U.S. industrial customers first initiated their switch toward imports in the 1970s. Outside the domain of military procurement, Forrant (1997) notes that few U.S. machine builders were prepared to offer customized products during the most pronounced period of the industry's decline. Further, Nivin (2000) notes that U.S. product quality was substandard during much of this period, while the widespread practice of order backlogging meant that shipments were often delivered late (Robinson, 1996). To an extent, then, Table III implies that firms in the U.S. MT industry have started to address these issues. Significantly, the second column of Table III shows that over 60% of the survey respondents believe that their recent commercial performance has been driven by improved product quality.

Growth characteristics of the surveyed firms

If product quality has indeed improved, and if measures to deliver better customer support have actually been implemented, then one ought to see evidence of this turnaround in terms of company performance. In this regard, Table IV presents a summary of the recent growth characteristics of the survey firms over the 1995–1999 period. The data are ordinally scaled across 6 growth classes (percentage change) and 4 growth dimensions (employment, total sales, market share, and

TABLE IV
Growth characteristic of the sample, 1995–1999 (% of firms by growth class)

Growth class	Negative	Zero	1–5%	5.1–10%	10.5–15%	> 15%
Employment	30.4	18.6	26.5	11.8	4.9	7.8
Sales	19.6	8.8	18.6	22.5	10.8	19.6
Market share	17.9	16.8	26.3	18.9	6.3	13.7
Exports**	9.3	16.3	31.4	20.9	9.3	12.8

* Estimated annual growth rate over 1995–1999.
** Data are for exporting firms only.

exports). In terms of employment, 51% of the survey firms created new jobs over the study period; 71% experienced sales expansion; 65% improved their market share; and 74% of the exporting firms experienced positive export growth. At first blush, then, the survey firms do not appear to belong to a sector that is still in decline. After all, how many U.S. firms in mature sectors actually create new jobs these days? In the case of the MT sample, the proportion is over 50%! And, by weighting this estimate alongside matching estimates from several other sources, the 51% that created new jobs more than counterbalanced the 49% that indicated either job stability or job losses. For an industry that appeared close to extinction less than 10 years ago (see Graham, 1993), it is remarkable that any new jobs have been created at all.

A more detailed picture of the growth characteristics of the survey firms is shown in Table V, which collates the ordinal scores on the growth dimensions across a series of attributes. Spearman's rank-order correlations suggest a set of interesting connections that merit attention. To begin with, recent employment growth correlates positively with company size (larger firms have been growing faster than SMEs). Recent employment growth also correlates positively with R&D-intensity, two measures of product innovation[5] (frequency and share), and export-intensity (all correlations that include exports are for the 82 exporting firms only). A negative correlation can be seen between age of firm and recent employment growth, suggesting stronger job-creation among younger firms (a similar negative correlation emerged between age of firm and recent sales growth). The only variable that does not correlate with employment growth is customization (which is not surprising in light of the fact that most of the survey firms customize at roughly similar levels).

In terms of sales growth, positive correlations again emerged for company size, R&D-intensity, and both measures of innovation. Interestingly, the only attribute that correlates positively across all four growth dimensions is R&D-intensity. It would appear that growth performance is positively associated with R&D spending (expressed as a

TABLE V
Growth rates and selected correlates (Spearman's tests)

Attributes	Growth classes (1995–1999)			
	Employment	Sales	Market share	Exports
Total employment	0.245*	0.313*	0.073	0.144
R&D intensity	0.317*	0.302*	0.308*	0.286*
New product count	0.253*	0.385*	0.185	–0.017
New product share	0.235*	0.262*	0.092	0.154
Customization	0.018	0.068	0.100	0.122
Age of firm	–0.371*	–0.312*	0.162	0.166
Export intensity	0.213*	0.186	0.006	0.490*

* $p = 0.01$ or less.

percentage of total sales). Finally, it should be mentioned that export growth correlates positively with export-intensity, which suggests that foreign sales have been growing fastest among firms that already exhibit high levels of export orientation. Not surprisingly, the four growth dimensions are themselves interconnected (Table VI). Thus, for example, employment growth correlates positively with growth of sales, market share, and exports; growth of sales correlates positively with growth of market share and exports; while growth of market share correlates positively with export growth ($p < 0.01$ in all cases).

Characteristics of exporters versus non-exporters

Thus far, the picture that emerges is distinctly atypical of a mature industry operating at the sunset phase of the product cycle. Instead, it would appear that many MT firms are following an innovation-assisted growth path in which exports figure prominently. On this note, some of the main similarities and differences between exporters and non-exporters are shown in Table VII. Regarding similarities, the results show that both groups exhibit comparable levels of R&D-intensity ($p = 0.96$). At the same time, exporters appear no different from non-exporters in terms of company age ($p = 0.44$) and degree of customization ($p = 0.75$). On the other hand, several significant differences emerged between the two groups. First, exporters are generally much larger than non-exporters ($p = 0.044$). This adds to the debate on the relationship between firm size and exporting. Whereas several very small SMEs are part of the exporting group, there is a tendency for SMEs to be over-represented in the non-exporting category. Second, exporters exhibit significantly higher scores on the two metrics of innovation ($p = 0.05$ or less). Perhaps not surprisingly, recent job growth has been stronger among exporters (this holds true for the industry as a whole, as well as for the current sample).

TABLE VI
Spearman's correlation matrix for the growth scales*

	Employ-ment	Sales	Market share	Exports
Employment	1.000	0.727	0.579	0.543
Sales		1.000	0.635	0.415
Market share			1.000	0.346
Exports				1.000

* All coefficients are significant at $p = 0.01$ or less.

TABLE VII
Characteristics of exporters versus non-exporters (*t*-tests)

Characteristics	Exporters	Non-exporters	*p*
Total employment	148.6	52.8	0.044*
R&D intensity	5.9	5.8	0.960
Company age	53.7	47.8	0.447
New product count	4.0	0.9	0.005*
New product share	39.1	24.0	0.050*
Customization level	35.7	38.5	0.750

* $p = 0.05$ or less.

Given these contrasts, it is worth repeating that SMEs are more likely to suffer from locational disadvantages than their larger counterparts (Table II). Specifically, such firms are vulnerable to local market shrinkage as a result of several factors, including the relocation decisions of former customers, local plant closures (industrial decline), and increased competition from larger establishments (both foreign and domestic). Most of the SMEs that fall into this category are located in close proximity to major automotive and/or metalworking complexes within the traditional manufacturing belt. Although firms of all size categories can be found in the zero or negative performance columns of Table IV, SMEs are conspicuously over-represented. In this regard, it would seem assertions that the U.S. machine tool industry has rebounded aptly describes the position of larger firms that export, but does not fully apply to SMEs that serve local markets.

Characteristics of small versus large MT companies

As far as this particular sample is concerned, the main differences between SMEs and larger producers can be summarized as follows. First, SMEs are generally older than their larger counterparts, and most SMEs are family-owned. Second, most SMEs depend upon local markets, whereas larger firms are significantly more export-oriented. Third, SMEs typically operate with very small batch sizes (< 50 items per run), and most depend

upon a small number of local customers. Fourth, SMEs are disproportionately susceptible to import competition, product liability lawsuits, and customer migration. Here, a conspiracy of geography and firm size would appear to be the root problem. Specifically, SMEs that have recently been losing jobs are concentrated in U.S. manufacturing belt regions that have been losing buyers via customer migration and/or local deindustrialization (e.g. plant closures). On balance, moreover, such SMEs appear to have little interest in export development (discussed later). In sum, the "typical" SME is a dedicated producer that relies heavily upon local rather than national or global customers. While there are several notable exceptions to this (see MacPherson, 2000), we would suggest that SMEs in this particular industry are not especially capable of cultivating export markets and/or non-local customers.

At this juncture, then, one might reasonably ask whether very small SMEs suffer from problems that are linked directly to size-related issues? Alternatively, are other factors at play (e.g. management attitudes, product characteristics, or market focus)? Evidence from other industries suggests that size of firm no longer serves as a good predictor of innovation, international business success, or growth potential (e.g. Bonaccorsi, 1992; Calof, 1994; Oviatt and McDougall, 1994). Framed against this backdrop, the section that follows takes a closer look at the problems confronting small SMEs in this industry. Does firm size really matter?

V. Discussion

Our inquiry was initially motivated by suggestions in the literature that a techno-market recovery had recently taken hold across key segments of the MT industry. Accordingly, our survey instrument asked respondents to state whether or not they believed that such a recovery was underway (both for the industry as a whole, and for the responding firm). On both counts, the vote was 76% "yes" ($n = 79$) and 24% "no" ($n = 25$). Simple 2×2 chi-square tests revealed that negative voters were more likely to be domestically-oriented SMEs experiencing zero growth or worse. In contrast, positive voters were more likely to be exporters experiencing moderate or rapid growth. Thus, we have an optimistic/pessimistic dichotomy within the sample.

To probe the underlying reasons for this split, follow-up telephone interviews were conducted with a subsample of optimists and pessimists (15 from each group). The results point to scale-related differences between the two groups. Rather than reiterate the reasons for optimism (most of which can be gleaned from the summaries presented earlier), the remainder of our paper focuses on the pessimistic group. In this regard, the chief factors responsible for pessimism resemble intensified versions of the various competitive factors listed in Table II. These factors include (in rank order) problems pertaining to the availability and/or retention of skilled workers, recent customer relocations, local industrial decline (loss of regular clients), difficulties associated with long-distance customer support, and competition from larger producers (both domestic and foreign). Although other irritants were uncovered during our interviews, we choose to concentrate only upon the five listed above.

Before talking about the results of these follow-up efforts, however, at least three contextual points should be stressed. First, all 15 of our pessimists are specialty producers of dedicated and/or semi-dedicated equipment. Second, a majority of these firms operate with small batch sizes, short production runs, and a limited number of "regular" (mainly local) customers. In short, we are dealing with a subsample that has evolved in response to the needs of local rather than global clients. Third, product lifespans are typically quite lengthy as far as users are concerned (20 years or more), and these lifespans can be stretched substantially via good maintenance. In other words, our subsample produces durable outputs that last a long time. While these are characteristics that apply to other MT producers (pessimistic or otherwise), the discussion that follows should be interpreted in light of these comments.

On this note, all 15 of our pessimists stated that skilled machinists are scarce (difficult to locate, hire, and retain), expensive (reflecting scarcity), potentially mobile (attractive to other, larger, and less cyclical firms), and rarely proficient across a full spectrum of metalworking tasks (e.g. capable of setting-up jobs on both new and old machines). Finding young workers with the basic skills

required for MT production is a critical problem. This is hardly a new complaint within the MT industry (see Gertler, 1996; Knudsen et al., 1994). Among pessimists, however, the problem is particularly acute, not least because pessimists are typically much smaller than optimists (the latter compete for the same stock of scarce people as the former). The winners in this competition are usually larger firms; the losers are SMEs, many of whom enter a spiral of decline once key workers retire or move to other companies. Significantly, most of our 15 pessimists noted that labor problems are likely to worsen over the near future, if only because retirees are hard to replace. It is probably fair to assert that nothing short of a complete overhaul of the national education/training regime will suffice to alleviate this problem. Although federal and state tax incentives are available to reward firms that operate apprenticeship programs, most of our pessimists noted that these initiatives represent "too little, too late".

A second problem for pessimists concerns customer migration. Of our 15 pessimists, 12 noted that the relocation issue was especially important. Specifically, the task of retaining clients that have relocated is close to impossible without establishing a maintenance facility close to the customer's new location. In practical terms, this option typically entails geographically transplanting part (or all) of a small/family-owned business with local roots to a "foreign" environment. Among pessimists in the SME category, a locational strategy based on customer trailing is not an attractive option from a logistical, cultural, or lifestyle standpoint. In terms of our second-ranked problem, then, SMEs that suffer from customer migration have only 3 basic options: (1) follow the customer; (2) abandon the customer, and seek alternatives within the home area; or (3) attempt to serve the customer from the original home base. Option (2) is the most common strategy among pessimists in this sample. The main problem with this option is that new customers are hard to find.

A third and more general problem concerns local industrial decline (i.e. demand falls as a result of plant closures or the collapse of entire sectors). In Buffalo, for example, SMEs in the MT sector have been negatively affected by the decline of specialty steel production and related forms of customized metalworking. Although the bulk of Buffalo's steel industry disappeared over 20 years ago, the ongoing erosion of the city's remaining metalworking specializations has left many SMEs with a shrinking local market (and few prospects for finding alternatives). In the case of Buffalo, Cleveland, Pittsburgh, and several other traditional manufacturing belt cities, local industrial decline poses a major problem to SMEs in the pessimistic category. Again, there is nothing new about this. Nevertheless, it is disappointing to see evidence of the ripple effects that accompany local or regional trends toward de-industrialization.

This brings us to our fourth problem category. Specifically, how do SMEs that are already afflicted by labor shortages and other locational problems reposition themselves along a growth path? From a theoretical perspective, several answers appear pertinent (e.g. opt for export development, or, at the very least, follow a strategy that emphasizes non-local sales). Alternatively, SMEs in this position could cultivate different markets altogether (e.g. switch from automotive to aerospace). Our subsample of pessimists had some interesting things to say about this wisdom. First, export activity among specialized MT producers requires that engineers or technicians be quickly available to clients as the need arises. Most of our pessimists indicated that foreign support services would stretch existing resources beyond feasible limits. Given that few of these firms felt that they could efficiently serve domestically relocated customers, it is not hard to see why the export option is unpopular among SMEs in this subgroup. Specifically, few of our pessimistic SMEs have the cashflow and/or personnel to sustain long-distance support efforts. With regard to sectoral switching (finding new customers in other sectors), most of our pessimists stated that this is the hardest possible option, in that new learning curves would need to be mastered (easy to suggest, hard to do).

It should also be mentioned that most of the pessimistic SMEs are specialty producers that face strong competition from other MT companies (both foreign and domestic). With new generations of flexible machines entering the market, many of these specialty producers believe that dedicated and/or 100% custom-built tools will eventually be sold in such low quantities that downsizing is

inevitable. To an extent, this is already happening among very small SMEs in this sample. For instance, one SME from Michigan noted that flexible workstations can now perform many of the tasks that were once the preserve of the dedicated/customized producer (these workstations are typically produced by larger firms); another SME from Ohio noted that its customers increasingly require machines that have alternative applications in the event that production processes change in the future. Significantly, 11 of our 15 pessimists indicated that they had become locked into the production of dedicated machines of one sort or another. In almost all of these cases, the common message is that dedicated/customized products will always be required, but that the need for such specialization is waning in light of the growing versatility of competing products (most of which are manufactured by larger companies, especially foreign ones).

Finally, many of our pessimists grumbled about irritants that are common to the industry as a whole, including: (1) the high cost of product liability insurance; (2) the overly complex and time-consuming procedures that accompany export license applications; (3) a general and long-standing lack of federal support for non-defense R&D; and (4) an unwillingness on the part of the government to enforce U.S. trade laws. While we are not in a position to say much about these issues at this stage, there is little doubt that the AMT has taken a serious position with regard to concerns of this ilk. The task remains to separate "general grumbling" of a potentially specious nature from more "serious grumbling" that might require policy action. Given the wide range of political, economic, strategic, and security issues that surround the MT industry (see Logan, 1999), this could turn out to be a challenging task.

VI. Summary and conclusions

The MT industry continues to face a wide array of problems, including acute labor scarcity, cyclical demand, and rising import competition. After nearly three decades of decline, evidence of a commercial recovery began to emerge in the mid-1990s. Data from our survey suggest that this recovery owes much to a combination of new product development, better customer support, and increased export involvement. Close to 80% of the firms that were surveyed believe that the industry has experienced a commercial rebound over the last few years. Over the 5-year study period, most of these "optimists" experienced positive growth in terms of employment, total sales, exports and/or market share. This is atypical of old firms in a mature sector.

The survey results also point to major distinctions between firms that export and those that do not. Specifically, exporters have been creating new jobs at faster rates than non-exporters. Firms in the non-exporting category more typically exhibit zero or negative employment growth (along with stagnant or declining sales). The main reasons for zero or negative growth among non-exporters can be traced to a mix of geographic and structural factors. On the structural side, the market for dedicated and/or wholly customized tools is being eroded by the diffusion of new types of flexible MT products. On the geographic side, most of the firms in the non-exporting category operate with shrinking local markets (caused mainly by customer migration and/or local industrial decline). In the absence of compensatory strategies (e.g. relocation, export development, non-local customer search), it is reasonable to speculate that firms exhibiting zero or negative growth are unlikely to survive for very long. Size effects are in place here, in that domestically oriented firms in the zero or negative growth categories are typically very small SMEs that have been in business for at least 50 years.

None of this should be taken to imply that SMEs can not grow on the basis of innovation and/or export development. After all, some of the fastest growing MT exporters are very small. Many of these firms have adopted new technologies and many have successfully exploited market niches. Rather, the suggestion is that firms in the SME category face a broader range of geographic, technological, and/or competitive problems than their larger counterparts. The advent of flexible tools (among other things) suggests that certain types of SMEs in this industry will continue to downsize for some time. In the event that U.S. and/or global economic growth rates fail to match the almost stellar averages of the 1990s (a distinct possibility as we write), it is conceivable that the international MT industry as a whole may be

headed toward a new round of rationalization, merger activity, or consolidation. The implications of all of this for SMEs are uncertain at this stage.

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Notes

[1] To underscore this point, the U.S. Department of Commerce dismisses all international MT shipments (imports and exports) on products that have unit selling prices of less than $3,025. Thus, it should be noted that international trade data often exclude rebuilt machines, used machines, MT accessories (e.g. drills, spindles, etc.), or new machines valued at less than $3,025 (we know of no convincing explanation that justifies this particular cutoff point, though we can say with confidence that this cutoff point defines all recent trade statistics with regard to U.S. exports and imports of MT products).

[2] There is no universally accepted definition of what constitutes a small-to-medium-sized enterprise (SME). This paper defines such an enterprise as a single-plant manufacturing firm that employs less than 50 workers. This definition accords with the AMT's perception of SME status for the MT industry, as defined by Logan (1999).

[3] Dual-purpose export restrictions are designed to prevent U.S. machine tools from being used by potentially hostile nations for the production of military hardware. These restrictions are officially justified on the grounds that certain types of MT exports represent technology outflows that compromise U.S. security from a foreign production capability perspective. The AMT position on this issue is that these restrictions curtail U.S. export opportunities, and that European or Japanese producers benefit as a result (i.e. competing producers of sophisticated machines are not subject to similar constraints).

[4] In the case of the rapidly growing Chinese market for advanced machine tools, one of Logan's (1999) main concerns is that Chinese producers already have the technological capability to build multi-axis CNC-controlled machines that show very high accuracy (± 3 microns), and that comparable (or better) U.S. machines are being denied an opportunity to compete with Chinese and/or other producers as a result of a U.S. security policy that fails to recognize that the U.S. is not the sole producer of sophisticated CNC products! Though we do not wish to enter this debate on either side of the argument, it should be noted that Chinese firms can buy British, German, Japanese, or Swiss CNC machines without the lengthy export-licensing delays that typically afflict the marketing efforts of U.S. companies (many of whom are not granted export permission at the end of a lengthy application process).

[5] Innovation is defined as the introduction and subsequent commercialization of a new or substantially improved product (incrementally enhanced versions of older products are excluded). The first innovation metric refers to the number of innovations (frequency count over the period 1995–1999). The second metric (share) refers to the proportion of a firm's 1999 sales represented by new products that were developed over the past 5 years (1995–1999). All innovation data were self-reported by the survey firms.

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