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Competitiveness Review; 2005; 15, 1; ProQuest Central
pg. 14

FIRM PERFORMANCE AND THE STRATEGIC FIT OF MANUFACTURING TECHNOLOGY

by Steven W. Congden

EXECUTIVE SUMMARY

Scholars have widely asserted that a firm's manufacturing technologies must be aligned with its competitive strategy. This study tests the existence of such a strategy-technology "fit", determines whether good fit results in better performance, and examines the nature of fit in light of computer controlled or "advanced manufacturing technologies." For a sample of 399 metal machining firms, a strategy-technology alignment was found to exist and relate to higher financial performance. Advanced manufacturing technologies were found to both reinforce and alter conventional thinking about the flexibility-efficiency tradeoff. Specific technologies were found to be uniquely bundled or combined to support specific competitive requirements.

INTRODUCTION

Although it is generally accepted that firms' manufacturing technologies must support strategy, empirical research examining the existence, performance impact, and structural nature of the strategy-technology relationship is limited. This study examines the strategy-technology relationship in the metal machining industry using a sample of 399 firms. It tests for the existence of a fit between the strategies followed by firms and the manufacturing technologies they employ, and the resulting impact of this fit on firm performance. Insights into the nature of this strategy-technology relationship are sought by examining the much publicized impact of computer controlled or "advanced manufacturing technologies". The results demonstrate the existence and importance of a strategy-technology fit, and provide new insights into this relationship with respect to the role of today's computerized technology.

BACKGROUND

Definitions

Because the terms strategy and technology have many different usages and meanings, effectively understanding a research paper and relating it to other work requires clear understanding of how these constructs are being used. Strategy is a complex construct encompassing many different aspects of a firm. Definitions range from plans (e,g., Chandler, 1962) to realized outcomes (Mintzberg, 1978). The appropriate definition to use depends upon the nature of the research questions being addressed. This research investigates the strategy-technology relationship at a level that examines how the characteristics of specific technologies provide or enhance capabilities instrumental to the way firms compete. The strategic relevance of a particular capability provided by a manufacturing technology (e.g., a particular level of precision) depends on the industry context. Consequently, an intra-industry strategy construct capable of capturing sufficient richness is needed to examine this complex relationship.

The strategic group concept of strategy is particularly well suited for this task. In an effort to gain competitive advantage within an industry, a firm positions itself along many strategic dimensions (e.g., product characteristics, target markets, distribution channel, degree of vertical integration, etc.). Strategic Groups are firms who have made similar choices along various dimensions and thus have roughly the same strategy (Porter, 1980). When measured appropriately, this "midrange", intra-industry analysis provides the richness needed to examine the complex relationship between manufacturing technology and strategy (Hatten & Hatten, 1987). Furthermore, grouping firms based upon a number of strategic dimensions appropriately recognizes their interdependencies (Harrigan, 1985).

While manufacturing technology definitions vary from emphasis on pure hardware to the human procedures used to accomplish tasks, this research focuses on hardware. This is consistent with much of the strategic management literature and most of the manufacturing strategy literature. Technology, therefore, will refer to the machinery or equipment employed by the firm to produce its products. More recent computerized manufacturing technologies have come to be referred to as "advanced manufacturing technologies" or AMTs.

The definitions for both strategy and technology will be operationalized in the research design section.

Literature

The idea that manufacturing technology should be aligned with or "fit" one's business strategy has come from both the strategic management and manufacturing strategy perspectives. Strategic management scholars have generally viewed strategy as a gestalt of various scope and resource commitment elements (e.g. Cool & Schendel, 1988). Key to this conception is that the elements or dimensions of strategy should be compatible with and reinforce each another (Porter, 1996). Although many strategy scholars (e.g., Ansoff & Stewert, 1967; Freeman, 1974; Hitt et al., 1998; Miles & Snow, 1978; Miller, 1988; Porter, 1983) have explicitly recognized technology as a critical element in the support of the firm's overall strategy, the level of analysis employed has mostly been very generalized.

The manufacturing strategy literature approaches the necessity of fit between technology and strategy somewhat differently and at a more specific level. The traditional perspective in this literature is that of a tradeoff between efficiency and flexibility (e.g., Abernathy, 1976; Abenathy & Utterback, 1978; Hayes & Wheelwright, 1979). Managers can choose to use general-purpose equipment technologies that allow for greater flexibility to produce a variety of different products or custom product configurations, or they can increase efficiency by using dedicated automation, specialized fixtures, and integrating technologies to produce greater volumes of more standardized products. Over an industry life cycle as products become more standardized, manufacturing technologies generally evolve in the direction of higher levels of automation and integration. A company can choose to lead this evolution to less flexible, more efficient technologies and pursue strategies which produce standardized products at low cost, or it can choose to lag this evolution and offer more customized products (Hayes & Wheelwright 1979).

Other works identify additional dimensions of manufacturing strategy potentially affected by the choice of manufacturing technologies (i.e., low costs, product. quality, dependable delivery promises, short delivery cycles, flexibility to produce new products quickly, flexibility in adjusting to volume changes, low investment, and product consistency). Firms are advised to "focus" on one or a few of these strategic dimensions because a given manufacturing technology is unable to serve the needs of too many dimensions (Hayes & Schmenner, 1978; Hill & Duke-Woolley, 1983; Skinner, 1974, 1984; Stobaugh & Telesio, 1983; Wheelwright, 1978). Recognizing the importance of this limitation, strategic considerations are included in technology choice models (e.g., Cil & Evren, 1998; Kleindorfer & Partovi, 1990; Swamidass, 1987).

More recently, the computerization of manufacturing technologies has shifted the focus to “Advanced Manufacturing Technologies”or “AMTs”. Although AMTs can give greater product flexibility at reasonable levels of efficiency compared to traditional manufacturing technologies, (e.g. Jelinek & Goldhar, 1983), differences in range (Blois, 1985), costs, and configurations suggest that fit with strategy is still needed. Marketing should be matched to and take advantage of the new capabilities of AMTs. (Blois, 1985; Prabhaker et al., 1995; Voss, 1986). As part of one’s manufacturing technology, technology must be matched to a firm’s business level strategy (Gerwin & Kolodny, 1992; Grant et al.,1991; Kotha & Orne, 1989; Sweeney, 1991).

While much of the literature on the fit between AMT and strategy is conceptual or is based on anecdotal evidence, some empirical studies have been done. Several have focused upon strategy-technology alignment (e.g., Schroeder et. al, 1989, Zairi, 1993), but have employed small samples (i.e., 20 or fewer firms) and have been largely exploratory in design. Dean & Snell (1996) examined the fit of AMT and manufacturing strategy in 92 manufacturing firms. They concluded that a product quality strategy strengthened the relationship the AMT-performance relationship while a cost oriented strategy weakened this relationship. No positive impact on firm performance was found for those firms that combined computer controlled technologies with strategies of scope and delivery flexibility. One recent larger sample study by Kotha & Swamidass (2000) surveyed 160 manufacturing firms to test for fit between strategy and AMT. Using a broad definition of AMT, including many information technologies, their study found a link between strategy-technology fit and performance. In addition to finding that AMT use varied by strategy, they subdivided the sample into groups of the top third and lowest third in performance. Better performing (superior profitability) firms following a differentiation strategy were found to use more AMTs while more profitable firms following a cost-leadership strategy did not use AMTs significantly more than traditional technologies.

The contribution of this study is to test the idea of fit on a large sample while also gaining depth of insight into the nature of this fit by looking at a single, highly competitive industry. With this focus, this study can be fairly specific in measuring manufacturing technology (Boyer & Pagell, 2000), both traditional and “advanced.” This type of mid-range study is critical in understanding the impact of technology (Rosenberg, 1982). It enables us to closely examine, and thereby better understand, the precise nature of the strategy-technology relationship, especially with respect to conventional versus advanced manufacturing technologies.

HYPOTHESES

The logical starting point in studying the nature of the fit between strategy and technology is to test for the existence of the assumed fit between the two. This leads to the first hypothesis:

H1: *The manufacturing technologies employed by firms within an industry vary significantly based upon the differences in the firms' competitive strategies.*

If fit between technology and strategy is important, each of the different technologies relevant to an industry should coalesce around the strategy that maximizes its particular advantages. This assumes significantly different technologies are available and some kind of price-performance tradeoff exists between them (e.g., capital costs, or efficiency versus flexibility). Over time, firms that are least able to exploit their manufacturing technology either fail, change strategy, or change manufacturing technology. A pattern of significant technology differences between firms with different strategies would be evidence of this evolution.

Fit can also be validated more directly by the existence of a relationship between firm performance and the interaction of strategy and technology. Some firms might suffer lower performance from misalignment rather than actually go out of business. The question of whether "fit" really makes a difference in performance is perhaps the primary research question with regard to competitive strategy and manufacturing (Kotha & Orne, 1989):

H2: *The goodness of fit between a firm's strategy and its manufacturing technologies will impact its performance.*

While H1 addresses the existence of fit between technology and strategy, and H2 addresses the importance of this fit, both focus at a relatively high level of abstraction, one of overall relationships within the firm. To learn more about the specific nature of this fit, we must examine the relationships between specific dimensions of different strategies and the technologies utilized to support them. We can begin by examining the traditional view regarding a tradeoff between efficiency and flexibility (e.g., Abernathy, 1976; Abernathy & Utterback, 1978). This long accepted relationship generally predates advanced manufacturing technologies. If it still holds, we can expect to find strategies involving stable products (i.e., infrequent design changes, large batch sizes, etc.) to be positively correlated with dedicated technologies and strategies calling for a wide range of more frequently changing products to be negatively correlated with dedicated technologies. Stated as the first part of the third hypothesis:

H3A: *Firms pursuing strategies involving stable products will use dedicated technologies, while firms following strategies involving a wide range of products will not use dedicated technologies.*

The advent of advanced manufacturing technologies may have changed this relationship. Many scholars have speculated on how the flexibility-efficiency tradeoff may be changing (Adler, 1988; Blois, 1985; De Meyer et al., 1989; Goldhar et al., 1991; Jelinek & Goldhar, 1983; Meredith, 1987; Meredith & McTavish, 1992; Thompson & Paris, 1982; Voss, 1986; Wheelwright, 1984). The main assertion is that advanced manufacturing technologies dramatically lower the cost of flexibility. Consequently, it is nearly as efficient to manufacture product variations as it is to manufacture large volumes of standardized products. If this speculation about a change in the flexibility-efficiency tradeoff holds true, one can expect to find firms with strategies involving a wide range of products employing AMTs. Firms that cannot utilize the flexibility of AMTs would not be able to justify the higher purchase costs. This leads to the second part of hypothesis three:

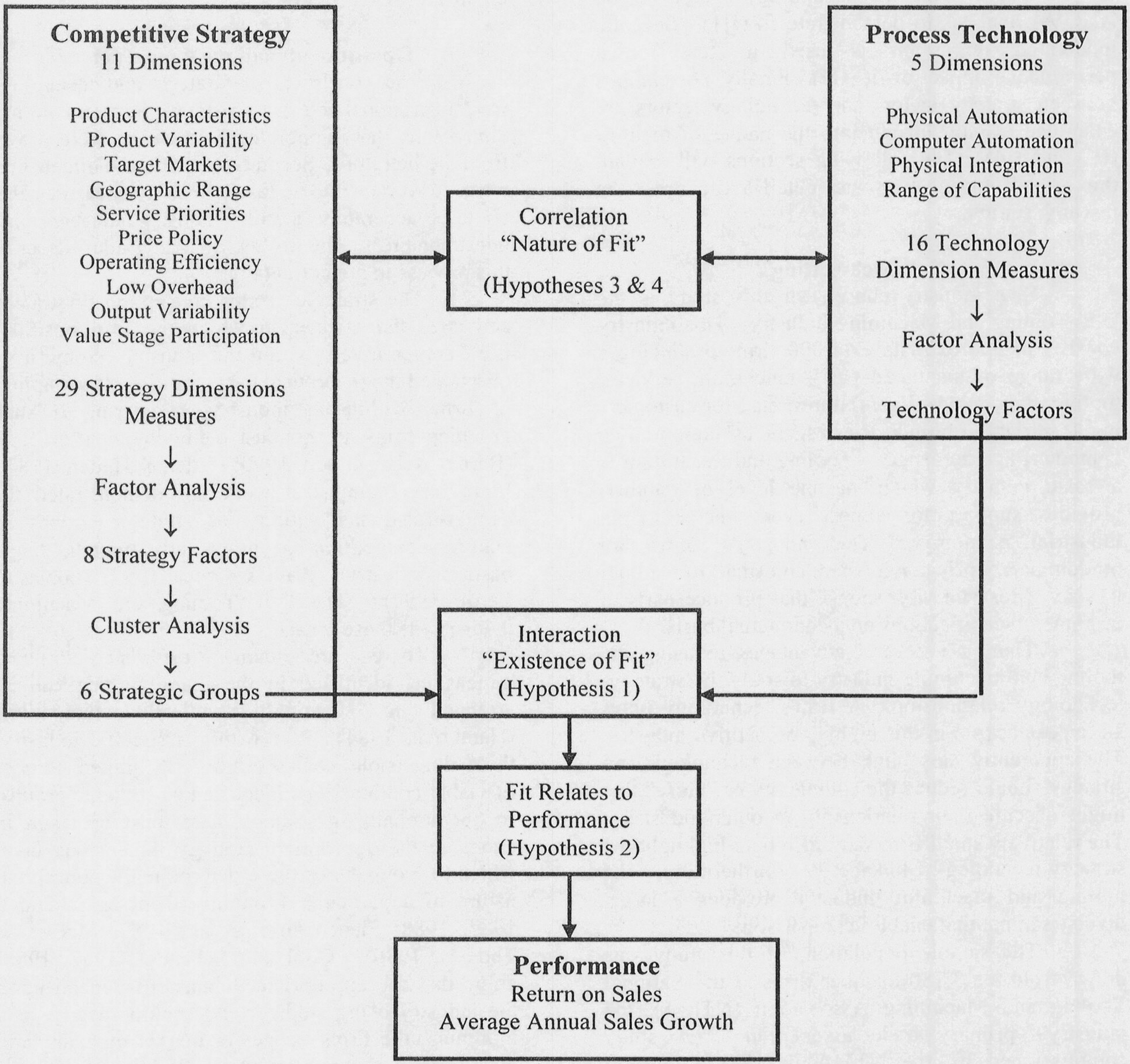
H3B: *Firms pursuing a wide range of products will use more AMTs, while firms with stable products will use fewer AMTs.*

As noted earlier, the manufacturing strategy literature identifies strategic dimensions other than flexibility and efficiency. While the same technology cannot be expected to support every one of these dimensions, a given technology often offers a variety of capabilities, each of which can be used to support different strategic dimensions. Furthermore, a technology seldom provides its full advantage without the support of ancillary technologies (Rogers, 1983, Rosenberg, 1982). Schroeder (1990) found that a specific technology could be used to support different strategies depending upon how the technology was linked with other technologies to provide the desired competitive benefits. AMTs may, perhaps more than traditional technologies, be used to support more than one strategy. A specific computerized machine provides vastly different outcomes based upon the software being used and the ancillary technologies with which it interfaces.

At the same time, a company relies upon a bundle or portfolio of different technologies to support its competitive strategy. A single one-to-one strategy-technology fit is unlikely. Rather, companies following different strategies can be expected to use different bundles of technologies. Some particular technologies may appear in bundles supporting different strategies, while other technologies may be conspicuously absent because they hinder the pursuit of those strategies. Hottenstein & Dean (1992) state that non-alignment of technology and strategy is a risk. At minimum it is a cost without a compensating contribution, at worst it is a hindrance to the rest of the organization. This leads to the fourth hypothesis.

H4: *Firms use combinations of technologies to support their strategies. While some technologies may be used to support more than one strategy, they are combined in different ways to provide different strategic advantages.*

FIGURE 1
Research Design



RESEARCH DESIGN

In broad terms, this study examines the relationship between technology and strategy within industries, and determines whether it significantly affects firm performance. The study's basic design is modeled in Figure 1. First, the constructs of strategy and manufacturing technology are linked to theoretical dimensions. Second, the dimensions are operationalized into industry specific measures. Third, these measures are used to collect, data using a questionnaire. Fourth, the data is factor analyzed to empirically validate the theoretical dimensions. Fifth, the strategy factors are clustered to form groups of firms following like strategies. Sixth, the groups are compared with the technology factors using ANOVA analysis to demonstrate fit (H1). Seventh, moderated regression is used to test for a performance impact of fit (H2). Finally, correlations between strategy factors and technology factors are examined to gain insight into the nature of their fit (H3 and H4). The following sections will explain this manufacturing in greater detail and address the research setting.

Research Setting

The industry chosen for this study is the U.S. Tooling and Machining Industry. This industry consists of approximately 11,000 firms producing a wide range of machined parts, machining services, tooling, dies, molds, jigs, fixtures, etc., for customers in a variety of industries such as automotive, computer, and aerospace. Tooling and machining is a basic industry which, at one level or another, provides support for almost every sector of an industrial economy. The industry's firms are predominately privately owned, and small to medium in size. Most are "job shops" that produce parts to customers' specifications on a contractual basis.

There are several advantages to using the tooling and machining industry to study the strategy-technology relationship. A firm's technology plays an important role in this highly competitive industry. The apparently close link between technology and strategy should reduce the complexity or "noise" that might obscure their relationship in other industries. The relatively small firm sizes also help highlight the strategy-technology linkage. Furthermore, the tooling and machining industry provides a large, diverse sample that enables comparison.

The sample population for this study was drawn from the 3,180 member firms of the National Tooling and Machining Association (NTMA), the industry's primary trade association. (A study commissioned by the NTMA in 1981 found no significant differentiation between NTMA member firms and non-member firms within the industry (NTMA, 1981). The NTMA membership files provided accurate and current data allowing us to both target the questionnaire to the most appropriate individuals within each firm and to focus the mailing on firms fitting the desired profile. For example, this study chose not to survey firms with less than fifteen employees. Previous research in the industry found that data from many of these very small firms is tenuous and idiosyncratic because the impact of a single piece of manufacturing technology, one person, or the relationship with one customer, can be too preponderate (Schroeder et al., 1995). This segmentation reduced the sample population to 1577 firms, with an average and median size of 44 and 29 employees respectively.

Operationalizing the Constructs

The constructs of strategy and technology were operationalized in two steps. First, theoretical dimensions that support each construct were drawn from the literature. Second, each of these dimensions were converted into industry specific measures that could be accurately rated by industry managers on a questionnaire. The following paragraphs describe this process in greater detail.

The strategic groups conception of strategy addresses the manner in which the firm positions itself competitively within the industry. Some have questioned the theoretical basis for discrete groupings of firms within an industry, wondering if such grouping firms are not just methodological artifacts (Barney & Hoskisson, 1990; Hatten & Hatten, 1987). More recent empirical work has demonstrated the demonstrated the validity of strategic groups in mature, competitive, geographically limited, single business industries (Nath & Gruca, 1997; Thomas & Carol, 1994). The U.S. Tooling and Machining industry fits these criteria.

There are many different strategic dimensions identified in the literature that can be arranged in seemingly endless combinations (Hambrick, 1984). Yet within a specific industry, these dimensions coalesce around a limited number of viable combinations identified as strategic groups. In operationalizing strategy, care must be taken in choosing the appropriate strategy dimensions upon which to group, since these determine the conceptual nature of a particular grouping (Cool & Schendel, 1987, 1988; Fiegenbaum, et al., 1987; McGee & Thomas, 1986). Cool and Schendel (1987, 1988) argue that the appropriate dimensions depend upon the industry being studied, and should specify, at a minimum, the firms' scopes or market domains, and their resource commitments. Building from this standard, both Porter's (1980) strategic grouping dimensions from the strategic management literature were integrate with strategic dimensions identified in the manufacturing strategy literature (i.e., Hayes & Schmenner, 1978; Skinner, 1974; Stobaugh & Telesiao, 1983; Swamidass & Newell, 1987; Wheelwright, 1984).

Operationalizing the technology definition follows a similar pattern. The technology literature traditionally characterizes manufacturing technology in terms of "level of automation" and "degree of integration" (Amber & Amber, 1962; Child & Mansfield, 1972; Hickson et al., 1969; Woodward, 1965). Automation substitutes electro-pneumatic-mechanical processing for on-line human inputs. Integration refers to separate processing centers becoming more interconnected. Historically, increasing automation and/or increasing integration resulted in a decrease in the flexibility to produce a wide variety of products. However, AMTs are argued to increase flexibility. These technologies have fundamentally different natures than their predecessors, particularly in their ability to process feedback information and to alter functions based on program changes. This challenges traditional tradeoff rules by enhancing both capabilities and flexibility. Consequently, dimensions of technology should distinguish between both physical and computerized levels of automation and degrees of integration.

Technologies also vary widely in their range of capabilities. Some are very specialized and narrow in application, while others are very versatile. The "range" or the degree of "differentness" in products that a manufacturing technology can accommodate varies in terms of processing requirements and size. For example, computerized machine tools with more directions of machining movement (axes) can make parts that require more complex shapes. Yet, even computer integrated manufacturing systems are very inflexible outside their designed product size range (Blois, 1985). Consequently, the range of capabilities is the fifth technology dimension that was measured. All five technology dimensions are listed in the upper right of the research design model in Figure 1.

The Instrument

A mail questionnaire of industry specific measures derived from the theoretical dimensions was developed. These measures were derived using the authors' industry knowledge gained from prior research and personal industry work experience, as well as, from feedback provided by a panel of industry experts. The panel, consisting of industry experts from the National Tooling and Machining Association and the Massachusetts Small Business Development Center Manufacturing Assistance Program, also provided feedback regarding instrument format, wording, and terminology, and were helpful in providing a pilot test for the instrument. Whenever possible, objective measures were used. Where objective measures were not possible, measures were either in ratio or interval form using seven point Likert scales. The resulting questionnaire included twenty-nine strategy measures and sixteen technology measures. Objective measures of return on sales and average annual sales growth were used to measure performance. Respondents were asked to specify average ROS for the last 3 years and sales figures for the last four years. A copy of the complete questionnaire is available from the authors.

Sampling Procedure

The mailing followed much of Dillman's (1978) "total design method" for achieving high response rates, such as first class postage, typed addresses, self-addressed, postage- paid return envelopes, individually addressed cover letters, etc. The NTMA logo was included on the' questionnaire cover to show their support. The first mailing produced 468 responses; the second mailing a month later drew 208 responses, for a total of 676 responses and a forty-three percent response rate. This response rate compares very favorably with most survey research, and is more than double the twenty percent rate typically achieved with the NTMA's annual survey.

Because the purpose of this study was to examine the linkages between a firm's strategy and it's manufacturing technologies, care had to be taken to ensure a comparison of firms with like manufacturing technologies. Because the survey instrument was designed to assess metal machining technologies, data from firms using a significant amount of other technologies could produce noise in the data. Consequently, only firms with at least eighty percent of their value added derived from metal machining processes were retained. This included firms providing dies, molds, machined parts, and machining services. Including only these firms reduced the relevant sample from 676 to 399 firms. The average firm size of these 399 firms was 53 employees, and the median size was 32.

DATA ANALYSIS AND RESULTS

To assess a firm's overall manufacturing technology, the survey's technology measures were factor analyzed to identify principle underlying dimensions. These empirically derived dimensions were then compared with theoretical dimensions for correspondence. The principal factor method yielded six of sixteen potential factors with eigenvalues above one. A scree plot did not indicate a definitive cut-off point. Promax oblique rotations were then run on the 3,4,5, and 6 factor solutions. A four-factor solution explaining 44.3 percent of the total variance was chosen for theoretical interpretability and parsimony (see Table 1).

The four factors correspond to proposed theoretical dimensions. Factors 3 and 4 correspond with "range of capabilities," and "computerized automation," respectively. Factor 2 appears to encompass both physical automation and physical integration. In theory physical automation and physical integration are rather fixed or "dedicated" to a limited number of particular products, while computerized automation is relatively "flexible" in its ability to support high product variety. Thus Factor 2 was labeled "Dedicated Technology" in contrast to Factor 3 which was labeled "Flexible Automation." Factor 1 has measures that can be interpreted as a form of computerized integration, particularly process integration backward into computerized design and the linking of machines in a computer network. Thus, this factor was labeled "Computer Integration/ Design."

Twenty-nine strategy measures were also principal factor analyzed. Nine factors had eigenvalues above one. Again, no clear cut-off point was revealed by a scree plot. Promax oblique rotations were run on the 7 ,8, and 9 factor solutions to aid selection.

TABLE 1
Technology Factors
(For clarity, factor loadings less than .25 are not shown)

F1 "Computer Integration/Design"				
Stand Alone CAD	.66			
Integrated CAD/CAM	.65			
DNC Network	.58			
F2 "Dedicated Technology"				
Dedicated Material Handling		.66		
Automatic Parts Changing		.58		
Secondary Capabilities		.49		
Product Specific Machine Layouts		.45	-.32	
Custom Machine Tools		.43	.40	
Multi-Spindle Machine Tools	.32	.40		
F3 "Range of Capabilities"				
Machine Tools w/Extra Capabilities			.71	
Broad Size Range Capabilities			.55	
Multi-Axis Machine Tools		.45	.53	
Average Axis of CNC Machine Tools		.48	.41	
F4 "Flexible Automation"				
CNC Machine Tools.				.77
Automatic Tool Changers on CNC				.66
CNC Code Programming Computer	.39			.51
Percent of Total (44.3) Variance:	12.50	11.10	10.80	10.00
Cronbach Alpha Reliability within Factors:	.54	.58	.48	.48

The eight factor solution, which explained 58.3 percent of the total variance, was chosen for interpretability (see Table 2). These strategy factors correspond quite well to the theoretical grouping dimensions previously proposed.

The eight strategy factors were then used to cluster firms into groups with like strategies using Ward's method (Ward, 1963), which minimizes the within cluster or "error" sum of squares. Because it is sensitive to outliers (Milligan, 1980), ten percent of data points which had the lowest estimated probability densities were removed prior to clustering.

Selection of the level, or number of clusters to use, was primarily based on interpretability. As Harrigan notes, "the appropriate number of clusters will be, a trade- off between parsimony and one's need for detail (Harrigan, 1985:61)."

TABLE 2
Strategy Factors
(Factor loadings less than .25 are not shown.)

	STRATEGY FACTORS							
	1	2	3	4	5	6	7	8
F1 "Product Stability"								
% Sales which are repeat orders	.81	.00	.00	.00	.00	.00	.00.	.00
Average batch/lot size (log of)	.81							
Products are large batch/lot size	.77							
Products are repeat, routine	.69						.27	
Customer does design	.61					-.33	-.38	
F2 "Product Precision "								
Products are high precision		.84						
Customers are "High Tech"		.71						
Products are complex		.71						
Close tolerances important		.56						
Average tolerances held		-.49				.37		
F3 "Service"								
Delivery			.75					
Dimensional consistency		.26	.67					
Close customer relations			.53		.35			
Short lead times	-.32		.51					
Verifiable quality assurance	.34		.44					
Accommodate fluctuations in orders			.37		.35		-.35	
F4 "Price Premium"								
Competitive pricing				-.81				
Differentiation (vs. Low Cost)				.71				
Cost plus pricing				.61				
F5 "Value Added"								
Value added from design	-.36				.65			
Value added from assembly					.87			
F6 "Customer Stability"								
Customers are repeat						.76		
Actively seek new customers						-.71		
F7 "Geographic Scope/Proprietary Product"								
Wide geographic range							.76	
Percent products contract						.33	-.55	
F8 "Product Range"								
Products broad in range, different							-.25	.71
Products large in size								.68
Wide variety of products important							-.46	.46
Many customers in number				.31			-.38	.42
Percent of Total (58.3) Variance:	11.6	9.0	8.0	6.4	6.1	5.9	5.9	5.5
Cronbach Alpha Reliability within Factors:	.83	.74	.59	.56	.55	.45	.37	.49

Cluster centroids were examined in detail for the 4, 5, 6, 7, and 8 cluster solutions. A six cluster solution was supported by more pronounced increases in cluster tightness as measured by the mean squared error (Hambrick & Schecter, 1983; Harrigan, 1985), and by differences between cluster centroids using MANOVA (Cool & Schendel, 1987).

To judge the character of each cluster, the mean values of the strategy factors in each cluster (Table 3) were examined in relation with other clusters. The six clusters were judged to correspond to meaningful differences in types of firms observed in previous research and the panel of industry experts. Qualitative descriptions of each cluster are provided in Figure 2. The relationships of the factor means to one another within each cluster seem to result in meaningful wholes. These clusters appear to represent meaningfully different strategic groups.

TABLE 3
Mean Values of Cluster Centroids

	"One-of-a-Kind"	"Hi-Volume Parts"	"Hi-Precision Prospector"	"Service Volume"	"No Frills Volume"	"Opportunist"
Strategy Factor	1	2	3	4	5	6
1. Product Stability	-1.21	1.05	-.13	.33	.31	-.04
2. Precision	.33	.41	.42	.30	-.15	-.79
3. Service	.19	.14	-.19	.71	-.75	.00
4. Price Premium	-.16	-.65	.03	.97	-.56	.27
5. Value Added	.37	-.08	.23	-.02	-.62	.37
6. Customer Stability	.58	.44	-1.12	-.25	.18	-.41
7. Geographic Scope/Proprietary product	.31	.27	-.10	-.07	-.50	-.61
8. Product Range	.43	.31	-.09	-.57	-.70	.86
Number of firms	65	47	29	55	61	44
Average Employment	43	71	45	53	34	42
Percent Contract	100	100	87	90	99	99

FIGURE 2
Strategic Group Descriptions

Group 1: "One-of-a-Kind"

Group 1 represents primarily die and mold makers or firms that machine one-of-a-kind products (mean percentage of products which are dies and molds = 85.7%). What most characterizes this group is low product stability because of the lowest batch sizes and the lowest amount of jobs which are repeat. Customer stability is high, but each mold or die is different, thus the higher than average score on product range. Firms in this group are among the highest in value added, mostly in the form of design. In the larger scheme of things, the firms in this group could be said to have a "one-of-a-kind" strategy.

Group 2: "Hi-Volume Parts"

Unlike Group 1, Group 2 is distinguished by the highest batch sizes and repeat orders. This group is highest in government work and highest in percent products which are machined parts. Their customer base is fairly stable, precision is very high, service is slightly above average, value added is average, but price competition is intense. Firms in this group are generally larger than firms in the other groups. Perhaps these large, high volume firms are very efficient and can afford smaller margins across a high volume of output.

Group 3: "Hi-Precision Prospector"

This group is most distinguished by very low customer stability. Firms in this group produce less than average batch sizes at levels of precision higher than any of the other groups. Their products are often prototype parts, small batches of high precision parts, or special assemblies (firms in this group score highest on value added from assembly). The special nature of such products leads these firms to search quite widely for customers requiring such services.

Group 4: "Service Volume"

Firms in this group provide significantly higher service than any other group. They provide the shortest lead times, dependable deliveries (almost half on a "Just-in-time" basis), verifiable quality assurance ("ship-to- stock"), and accommodate fluctuations in orders second only to Group 6. For this high level of service and moderately high precision, these firms command significantly higher price premiums. This group is second highest in product stability, very similar to Group 5, but not really close to Group 2.

Group 5: "No Frills Volume"

Relative to most groups, this group produces moderately high and repeatable batches. Although lower in production stability, firms in this group are comparable to the "High Volume Parts" strategy (Group 2) in that they produce mostly machined parts (83 percent), many for the government, under conditions of intense price competition. Where they differ is that they provide absolutely no services, no value added, and they stick to a very narrow range of product types at lower than average precision. In essence, no frills.

Group 6: "0pportunist"

The salient characteristic of this group is the very wide product range. As one might expect, this is somewhat reflected in the highest percentage of machining services (113). This group is strictly contract oriented like most of the groups, but is different in that it is the most local in geographic scope. These firms produce the lowest precision and, next to Group 3, highest value added from assembly. Customer stability is low, apparently from doing a wide variety of jobs for a wide variety of customers, where ever opportunities arise. For their trouble, these firms command a slight price premium.

Results

Hypothesis 1 predicts that technology will vary significantly across strategic groups. MANOVA was used to test whether firms' overall manufacturing technology (all technology factors taken together) varies by strategic group. In addition, ANOVA was used to see whether each technology factor taken alone varies across strategic groups. A technology factor taken alone would represent the respective discrete technologies that are part of a firm's overall portfolio of manufacturing technologies.

The results for both analyses are displayed in Table 4. Firms' overall (MANOVA) technology is significantly different across strategic groups at the .0001 level of significance. Three of four technology factors taken individually are also significantly different across groups. Overall, H1 is strongly supported.

TABLE 4
Results of Hypothesis One

MANOVA

Statistic	Value	F	Num DF	Den DF	Pr>F
Wilks' Lambda	.754	4.00	20	900	.001
Hotelling-Lawley Trace	.302	4.00	20	1078	.001

ANOVA

Tech Factor	Num DF	Den DF	F Value	Pr>F
Computer Integration/Design	5	274	6.45	.0001
Dedicated Technology	5	274	1.88	.0975
Range of Capabilities	5	274	3.97	.0017
Flexible Automation	5	274	2.85	.0158

Hypothesis 2 predicts that the relationship between technology and strategy will impact performance. This was tested using moderated regression analysis as outlined by Sharma, Durand, & Gur-Arie (1981). Moderated regression is a linear model which includes an interaction term between the moderator (Technology) and the predictor (Strategy) with respect to the dependent variable (Performance). In this study, "generalized" linear regression is used because strategy is a categorical variable.

When building the regression models, care must be taken to control for extraneous variables that may impact the dependent variable. Consequently, in addition to the main effects of technology and strategy, "Markets" is used as a control variable. The vitality of the industries of a firm's customers can have a direct impact upon both the firm's growth rate and its profitability. Because machine shops tend to focus on serving customers within specific industries, any performance differences uniquely attributable to those industries can and must be controlled for within the models. Therefore, the market variable, based upon customer industry growth rates, is added to compensate for performance due to market differences.

Models 1 and 3 look at the main affects (technology and strategy); Models 2 and 4 add the interaction between the two main affects. All of the models examine firms' overall manufacturing technologies by including all four technology factors:

Model 1: ROS = Markets + Strategy + Technology Factors 1- 4
Model 2: ROS = Markets + Strategy + Technology Factors 1- 4 + Strategy x Technology Factors 1- 4
Model 3: GROWTH = Markets + Strategy + Technology Factors 1- 4
Model 4: GROWTH = Markets + Strategy + Technology Factors 1- 4 + Strategy x Technology Factors 1- 4

With respect to these models, the impact that technology-strategy fit has upon performance is demonstrated with either significant beta coefficients for the interaction terms in the full models, or by significant increases in R^2 when the interaction terms (i.e., as seen in models 2 and 4) are introduced into the main affects models (i.e., models 1 and 3) (Cohen, 1968). The results are displayed in Table 5.

TABLE 5
Results of Hypothesis Two

INDEPENDENT VARIABLES	ROS Model 1 without Interaction	 Model 2 with Interaction	GROWTH Model 3 without Interaction	 Model 4 with Interaction
MARKET	3.84*	5.56*	7.44**	6.06*
STRATEGY	1.58	1.18	0.5	0.61
F1: Computer Integration/Design	0.08	0.94	1.87	1.93
F2: Dedicated Technology	7.72**	9.07**	0.19	0.33
F3: Range of Capabilities	1.11	0.96	0.25	0.01
F4: Flexible Automation	0.10	0.50	4.13*	2.32
Strategy X F1: Comp Int		1.61		1.44
Strategy X F2: Ded Auto		2.29*		1.03
Strategy X F3: Range		1.72		0.30
Strategy X F4: Flex Auto		0.41		1.54
R^2	.0857**	.1966**	.0839*	.1655*
Change in R^2	.1109*		.0816	

* = $p < .05$
** = $p < .01$
*** = $p < .001$

The results show support for the hypothesis that good strategy-technology fit impacts profitability, but not for the hypothesis on growth. As might be expected in an industry substantially dependent on competitive bidding, the growth of customer industries is a significant predictor in all four models. "Dedicated technology" is related to profitability (Models 1 and 2), while "flexible automation" is related to growth (Model 3). The overall explanatory power of all four models is significant; the performance variance explained, 20 and 17 percent, is not trivial given the myriad of elements that impact performance. The important finding, however, comes from the significant increase in explanatory power (delta R^2=.1109) when the interaction of technology and strategy is added to Model 1. The goodness of fit between strategy and technology accounts for a significant ($p<.05$) increase in our ability to explain profitability. Hypothesis H2 is therefore supported. A good fit correlates with improved financial performance (return on sales). Support is not found for fit impacting average annual sales growth.

Hypothesis 3 tests the nature of the strategy-technology relationship by examining the linkages between specific elements of strategy (i.e. factors/dimensions) and the manufacturing technologies employed. It predicts that firms pursuing stable product strategies will use dedicated technologies, while firms pursuing wide product range strategies will not. In addition, firms pursuing wide product range strategies will use more AMTs (assuming such technologies are more flexible) than firms pursuing stable product strategies. This hypothesis was tested by examining correlation coefficients to determine the strength, direction, and significance of relationships amongst these factors.

The results shown in Table 6 support the traditional perspective in hypothesis 3A.

TABLE 6
Results of Hypothesis Three
Pearson Correlation Coefficients
(Probabilities)
306 Observations

		Product Stability	Product Range
Hyp 3A	Dedicated Technologies	.277 (.001)	-.121 (.0339)
Hyp 3B	Flexible Automation	.357 (.0001)	-.055 (.3335)
Hyp 3B	Computer Integration/ Design	-.295 (.0001)	.138 (.0156)

"Dedicated technology" is positively correlated (p<.0001) with "product stability" and negatively correlated (p<.0339) with "product range." H3B, testing the role of computerized technologies, shows an interesting mix of results. As hypothesized, "Computer integration/design" is negatively related (p<.0001) to "product stability" and positively related (p<.0156) to "product range." However, contrary to the hypothesis, no relationship is observed between "wide product range" and "Flexible Automaton." In addition, a positive relationship (p<.0001) is observed between "Flexible Automation" and "product stability," where a negative relationship was hypothesized.

Hypothesis 4 examines the alignment of a firm's competitive strategy dimensions with its specific technologies. H4 predicts that bundles of technology will be assembled in different ways to support different strategy dimensions. The correlations in Table 7 show this perspective is supported. If we disregard the "service" and the "price premium" strategy dimensions because they can be achieved using a wide variety of tactics independent of specific technological capabilities, twenty-four possible strategy-technology correlations remain (6 strategy dimensions X 4 technology factors). Of these possible combinations, 17 correlate significantly (p<.05), and an additional 3 approach significance (p<.10). Rather than a specific one-to-one alignment between strategy and technology factors, we observe a pattern in which firms bundle technology factors to support their specific strategy factors. While a specific technology factor may be used to support several different strategy factors, every strategy factor has a unique bundle of supporting technologies.

TABLE 7
Strategy-Technology Factor Correlations
(306 Observations)

Strategic Dimension	Computer Integration	Dedicated Technology	Range of Capabilities	Flexible Automation
1. Product Stability	-.295 ***	.277 ***	-.042	.357 ***
2. Precision	.207 ***	.105 !	.164 **	.244 ***
3. Service	.024	.083	.066	.108
4. Price Premium	.023	.033	-.090	-.087
5. Value Added	.252 ***	.178 **	.237 ***	.104 !
6. Customer Stability	.107	-.146 **	-.131 *	.031
7. Geographic Scope/ Proprietary Product	.132 *	-.131 *	.027	-.160 **
8. Product Range	.138 *	-.121*	.309 ***	-.055

! = p < .10
* = p < .05
** = p < .01
*** = p < .001

DISCUSSION

Overall, the results of the hypotheses tested support the contentions in this study and improve our understanding of the strategy-technology linkage. The test of hypothesis H1 supports the existence of a fit between strategy and manufacturing technology. There is a significant difference in the technologies used by firms pursuing different strategies.

Taking HI a step further, tests of hypothesis H2 support the contention that a good strategy-technology fit is important to firm profitability (return on sales). When the second order strategy-technology interaction terms are added to the moderated regression model, its overall explanatory power increases significantly. This can be interpreted to mean (Cohen, 1968) that a good fit between strategy and technology can explain significantly more of a firm's profitability than can be explained by strategy and technology alone.

These results are in general agreement with findings by Dean & Snell (1996) and Kotha & Swamidass (2000) that AMT fit with strategy relates to performance. Their studies were also done in metalworking industries, industries most relevant to AMTs.

Differences relate to the samples, strategy, and performance measures. This study focused on a single, albeit broad, industry, the contract tooling and machining industry. The other two studies sampled a wider variety of metalworking firms which renders their results more generalizable. Performance for this study as well as that of Kotha & Swamidass was return on sales and growth, while Dean & Snell use managers' assessments of change in performance relative to their industry on variables such as productivity, lead time, quality, etc. Strategy was also differently defined for each study. Dean & Snell measured manufacturing strategy arriving at strategies of quality, cost orientation, scope flexibility, and delivery flexibility. Kotha & Swamidass used measures to assess the generic business level strategies of low cost and differentiation (Porter, 1980). This study measured business level strategy tailored to the industry in the form of strategic groups. This allowed a richer conception than a two dimensional approach.

Support was not found for the importance of a good strategy-technology fit to a firm's growth rate performance. In hindsight, this may be caused by a strong relationship between growth and technology in the machining industry. With a machine tool's relatively high cost, and its useful life measured in decades, new equipment purchases are often more readily made for reasons of capacity expansion rather than for equipment replacement. Because computer controlled machine tools are relatively new, their purchase is more easily facilitated by growing firms requiring additional capacity. We see evidence of this pattern in the significance between "market" growth and "flexible automation" in Model 3 of Table 5. Consequently, the strong relationship between growth and the purchase of computerized machine tools may mask any relationship between a good strategy-technology fit and a firm's growth rate performance.

Test results for hypotheses three and four provided some of the more unique findings. Hypothesis H3 examined two conventionally assumed relationships. The first, H3A, was the existence of a tradeoff between flexibility and efficiency in technology choices (e.g., Abernathy, 1976). The second, H3B, was the demise of this same view, due to the ability of new computerized technologies to provide both flexibility and efficiency (e.g., Adler, 1988, Jelinek & Goldhar, 1983). The use of dedicated, integrated technologies was found to be strongly correlated with strategies calling for stable products and negatively correlated with strategies involving a wide range of products. This supports the traditional flexibility-efficiency tradeoff (H3A) when using conventional (non-computerized) technologies to support a strategy.

H3B test results were an interesting mix that both supports and contradicts the hypothesis. Opposite from Hypothesis 3B, a strong positive correlation was found between computer controlled machining technologies ("flexible automation") and firms with stable products. No correlation, however, was found between firms with a "wide range of products" and "flexible automation" even though a positive correlation was expected. "Flexible" computer controlled machining technologies were being used less for strategies calling for a wider range of products than by firms that had traditionally used, and are still using, more integrated, dedicated technologies to gain economies with longer production runs. Thus, the demise of the flexibility-efficiency tradeoff in favor of "economies of scope" from using computerized manufacturing technologies (e.g. Jelinek & Goldhar, 1983) did not materialize in the manner hypothesized.

These findings seem to contradict conventional wisdom on AMTs and the findings of Kotha & Swamidass (2000) and Dean & Snell (1996) that the flexibility of AMTs supports a differentiation strategy and does not support a cost orientation strategy. Rather, this study's finding appears to support Jaikumar's (1986) conclusion that firms were tending to adopt AMT's for cost oriented production. However, Jaikumar argued that such adoption was not taking full advantage of AMT's and was thus misguided.

Is the adoption pattern displayed in this study misguided? It appears that these findings can be explained by examining precisely what computerized machining technologies do and do not offer. First, programming computerized machines is not without cost. While this cost is continuing to drop with ongoing advances in user friendly software, there remains a fixed cost. At the same time, there are different types of flexibility. One type is the ability to easily switch back and forth between products that are produced for repeat orders. In this type of situation programming costs occur only once. Simply switching programs makes changing between products relatively inexpensive, and results in lower economic production lot sizes, inventory cuts, and shortened lead times. The types of firms that can most fully exploit these advantages are the same ones that traditionally use highly integrated technologies to gain economies of scale on large production runs.

A second type of flexibility is the ability to make dissimilar products that are not repeat orders. Computerized machine tools do not offer as great an advantage here. Each job must be programmed anew. Consequently, no correlation was found between firms with strategies calling for a wide range of products and the use of computerized machining technologies. However, a different type of computerized technology, "computer integration/design," proved important in supporting this type of flexibility. As hypothesized in H3B, "computer integration/design" was negatively related to "product stability," and positively related to a "broad product range."

There appears to be a key difference in the strategic impact of physical integration and computer integration technologies. While physical integration decreases product variety flexibility, computer integration at least when associated with design, increases the flexibility to produce a wide variety of products. In this way, the technology allows us to do some things that were previously impossible. Such abilities, rather than simply computerizing what is already being done, are perhaps where the fullest impact advanced manufacturing technologies is realized. Overall, hypothesis H3 shows that we must be careful to understand exactly what type of flexibility we gain when using computerized technologies.

Another perspective suggests care on the scope of the sample studied. The production of one-of-a-kind products appears to be a typical form of flexibility and differentiation in this industry. These firms have traditionally used general purpose machine tools. As noted by Jelinek & Golhar (1983), the appropriate batch size for computer controlled machine tools fall in between that of general purpose machine tools and fixed automation. Given the nature of this industry, for many firms, AMT's represents a move toward cost saving automation compared to general purpose machine tools.

The business level strategies of cost leadership and differentiation are generalizations when used cross industry, and thus are "generic" strategic groups (Porter, 1980). When looked at in a particular industry, strategies are more complex and multifaceted than a cross industry generalization. The combination of activities to accomplish these generic strategies in one industry will differ from the combinations used in another industry. Relating this somewhat relativistic strategy construct to actual hardware then becomes potentially problematic. For example, a particular technology such as CNC machine tools may yield great new product flexibility relative to one industry while at the same time being a fairly inflexible technology choice to another industry that by its nature changes products much more frequently. As suggested earlier, time may take care of this particular example as design technologies improve. However, the possibility for strategic misinterpretations with respect to other technologies remains and suggests care in choosing and understanding a sample is very important. One could alleviate this problem by also using generalized technology measures, but the results then would likely be very generalized and important insights lost (Boyer & Pagell, 2000). Relating such results in terms of AMTs might be suspect in that AMTs are generally conceived and spoken of as particular hardware.

Hypothesis H4 provides further insight into the nature of the strategy-technology linkage. We find a rich array of significant strategy-technology linkages. Each strategy is supported by a unique bundle of technologies. A simple one-to-one correspondence between particular technologies and particular strategies does not exist. Rather, the way in which a bundle of technologies is jointly employed to support the dimensions of a firm's strategy appears to be the critical issue in fit. A specific technology factor may support several different strategic dimensions. Yet another technology may support some of the same dimensions, while being counterproductive for others. For example, the "Product Stability" strategy dimension includes "Dedicated Technology" and "Flexible Automation" in its technology bundle. Although the technology bundle of the "Precision" strategy dimensions contains these same two technology dimensions, it also includes the "Range of Capabilities" technology dimension and the "Computer Integration/Design" dimension, which was actually a negative in the "Product Stability" bundle.

Because a particular technology offers a variety of capabilities, it can often be used to support several different strategy dimensions. Furthermore, a technology's fullest value in supporting a strategy comes into play only when combined with other, complementary technologies (Rosenberg, 1982; Schroeder, 1990). There is not a specific one-to-one technology-strategy linkage, but rather an interaction among a bundle or portfolio of interrelated technologies that provides competitive advantage. Consequently, when searching for a strategy-technology fit, we must examine sets of technologies rather than one particular technology.

CONCLUSIONS

This study provides empirical support for theorized relationships, and presents findings that extend the field's knowledge and understanding of these relationships. The often assumed linkage between the strategy followed by a firm and the technologies it employs was supported in a large sample empirical test. Furthermore, the quality of this linkage was shown to relate to financial performance. To date, such empirical support for these ideas has been limited.

Perhaps the most interesting contributions made by this research are in furthering our understanding of the nature of strategy-technology linkages. The findings on the flexibility-efficiency tradeoff in technology choices confirms longstanding assumptions, while clarifying the role computerized technologies play. Surprisingly, computer controlled machining was most frequently used to support the same strategic dimension we generally cede to physically integrated and physically automated technologies, that of long production runs where economies of scale are important. In our sample, computerized machining technologies did not prove to be heavily used for strategies that have been assumed to require more flexible technologies to support more product variety with shorter production runs. While these strategies did exploit computerized design and computer integration technologies, these results show the importance understanding one's sample and being more specific about the capabilities of AMTs. This study showed that "flexibility" will have to be more precisely defined as there are different types. Cross-industry findings will likely be limited in specificity in order to avoid increasing the risk of misinterpretation of what specific technologies mean strategically.

When examining the broader set of strategy-technology relationships, combining a bundle of overlapping technologies appears to be much more important in supporting a strategy than using a specific technology. The manner in which a set of technologies is integrated into a company provides the capabilities required to support specific strategies.

These later findings might be of more interest to managers. That fit impacts firm performance may be more of an academic question as many managers accept this idea intuitively. However, the way a particular AMT fits with strategy is at least industry specific. There are also different types of "flexibility." Because academics often strive for cross industry generalizations, managers must carefully sort through hype that says a particular AMT fits strategy a particular way or is "flexible."

Complicating AMT decisions is the fact that a particular technology offers multiple capabilities and that its over all impact will be determined by how it is combined with other technologies. Managers of small firms must be especially careful, as new technology purchases can be significant dollar expenditures. They must carefully consider the different capabilities of an AMT and determine how certain capabilities will combine with capabilities of other technologies to get the best overall strategic bang for the buck.

One must always take care when generalizing research findings. There are issues of timing, domain, and methodology. Technology, by nature, is complex and situation specific (Rosenberg, 1982). This study certainly supports this. Furthermore, technology is a moving target. With improvements coming from ongoing refinements, ancillary supporting technologies, and new applications, the competitive impact of a technology changes over time (Schroeder, 1990). This research focused upon hard technologies and strategies in the metal machining industry. While this covers a broad and important industry, it does not mean the findings are universal. Their confirmation in other settings is required. Methodologically, this research design involved a mid-range study to explore linkages between specific strategy and technology dimensions. While this method proved appropriate for the scope of the research, it accommodates neither the broad generalizable findings of large cross sectional research nor rich case based findings that could include greater human interaction and context.

This study has taken a step in demonstrating the importance of considering technology as an integrated system of individual "machines" combined and configured to provide the advantages needed to pursue various elements of a firm's strategy. The next step is to broaden this system to include the information and human process technologies that go beyond the hard technologies of the shop floor. With time, competitive advantage will come increasingly from integrating technologies with human processes. Information management that bridges functions within the organization, and spans boundaries to reach suppliers and customers, offers rich opportunities to create competitive advantage.

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