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RELATIONSHIPS BETWEEN A FIRM'S PERFORMANCE AND ITS ALLOCATION OF RESOURCES TO TECHNOLOGY VALUE-CHAIN: AN EXPLORATORY STUDY

by

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ABSTRACT

RELATIONSHIPS BETWEEN A FIRM'S PERFORMANCE AND ITS ALLOCATION OF RESOURCES TO TECHNOLOGY VALUE-CHAIN: AN EXPLORATORY STUDY

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RAMESH R. GEHANI

Advisor: Professor S. P. Sethi

A firm's allocation of resources to its technology competency has been known to have a significant influence on its performance. The technology competency can change the intensity as well as rules of market competition. In many previous studies, the technology competency of a firm was operationalized primarily by the firm's allocation of resources to its research and development capability. This study extended that uni-variable operationalization of technology competency and included resource allocations to other complimentary capabilities in the firm's technology value-chain.

In the tradition of the resource-based view of strategy, this research joined a small group of empirical studies. Relationships between a firm's performance and its allocation of resources were tested. Comparisons were made for firms competing under

different industry structures. These were measured by four-firm concentration factors. We hypothesized and tested that higher performing firms in highly concentrated industries, such as the semiconductors and related devices industry, allocate resources more intensely to their research and development capability. On the other hand, higher performing firms in a less concentrated industry, such as the pharmaceutical preparations industry, gain superior performance by allocating more resources to their market development and selling capability. Firms in the plastics materials and resins industry, with moderate concentration, were tested for their reliance on allocation of their resources to their automation and plant engineering capability. The first two hypotheses were confirmed to hold true, whereas the third hypothesis did not pass. These findings were discussed with results from other studies. Industry structure was seen to have a significant influence on the way firms allocated their resources.

PREFACE

A doctoral dissertation is an organic synthesis of ideas. These ideas come from various sources, and from various directions. Some come directly, others arrive in more subtle ways. For example, by way of inspiration. I am grateful to many people and sources for their guidance, inspiration, encouragement and help. I learn from many sources. It is hard for me to list all of them. Here is my humble salute to all those who inspired me and helped me whenever I was in need of a support.

I would like to express my deep gratitude to Professor S. P. Sethi. He was not only the chair of my dissertation committee, but also a role model, and a mentor. Other members of my committee guided me, and supported me in many different ways. It has been a pleasure knowing and working with Professor Harris Jack Shapiro. First at the Center for Management Development where he provided me a warm support. Later as the chairman of the Department of Management he offered his assistance in many forms. Professors William McCutchen and R. Parthasarthy were great to work with. They often shared their expertise and

provided their deep understanding of the field of strategic management and the management of technology-driven industries.

My special thanks go to Professor Gloria Thomas and Mrs. Molveine 'Mollie' Karan for their much needed empathy and support. At times they provided that extra support needed to help tide over and persist in a long-term endeavor such as this. On a number of occasions I particularly found registrar Vince De Luca at the Graduate Center refreshingly open and generous with his help and support.

Finally, I must acknowledge the value of love and affection that I have received from my family members. My father, who passed away during the course of this stage of my life, and who would have cherished this achievement the most, has provided me with an infinite source of inspiration. I also appreciate the faith that my mother and brother have always put in what I do. My wife Meena, and children Rashmi and Gautam have helped me in many ways to think, and do creative things. I eagerly look forward to the days in near future when we will partner together in bigger and better challenges of life. I dedicate this work to all these people, and the Almighty, who helps me and guides me in many ways.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER - 1

CONCEPTUALIZATION AND NEED FOR THIS RESEARCH TOPIC

This chapter examines the literature on the resource-based view of strategy and develop the need to research relationships between the allocation of resources to the technology value-chain, for firms competing under different industry structures. This research topic was developed to extend our understanding of the technology-based competency, and empirically evaluate the resource-based 'view' of strategy as a testable and 'falsifiable' theory.

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1. TECHNOLOGY, RESOURCE ALLOCATIONS AND FIRM PERFORMANCE.

The allocation of resources by a firm to its technology competency can significantly change intensity of rivalry as well as rules of competition in an industry (Mansfield et al.. 1977; Abernathy, Clark & Kantrow, 1982; Porter, 1986). Globalization of markets since the 1980s has intensified competition for many technology-driven industries and firms in the United States. (Scott, 1984). During this period some major U.S. technology driven firms lost some of their competitiveness and market performance (Harvard Business Review, 1987). The M.I.T. Commission on Industrial Productivity, and many other researchers, have blamed this downfall of firms on their improper allocation of resources to their technology related capabilities. This is the focus of this empirical research study.

The technology related changes and innovations can create or destroy profits, markets, and industries (Frohman, 1985). Porter (1985) reviewed the rise and fall of firms' competitive performances. He observed that of all the decisions that can change the rules of competition, the decision regarding "technological change is one of the most prominent drivers." A firm that integrates technology and its strategy can significantly improve its performance from the exogenous as well as the endogenous technological changes.

To improve a firm's competitive performance, a large number of organizational and policy researchers have urged firms to establish closer links between their technology-related capabilities and their business strategies (Kantrow, 1980; Jelinek & Goldhar, 1983; Porter, 1983; Maidique & Hayes, 1984; McGee & Thomas, 1989; Morone, 1989). The technology competency and innovations help organizations to grow, safeguard, or improve their performances over an extended period of time (Gold, 1983).

Schumpeter called this role of technology a "creative destruction." This dynamic equilibrium develops and provides growth to an industrial economy as a whole, and a technology-driven firm in particular (Schumpeter, 1937). There are two routes to improve a firm's performance.

2. THE TECHNOLOGY COMPETENCY, INDUSTRY AND STRATEGY.

There are two main views of strategies for improving performance of firms competing in a technology-driven industry.

2.1 A Structural View of Strategy.

Porter (1980) provided a structural perspective of strategy for a business firm. He emphasized that the competitive environment of an industry has an influence on the performance of a firm. For example, he pointed out that the intensity of rivalry, market structure and the threat of new entrants, in a particular industry or a strategic group, can influence the profitability of a firm. Technological changes in an industry affect these competitive forces.

The "industrial policy" advocates, supporting the structural view, recommended a federal support and subsidies for the promotion of birth and growth of a technology-driven industry or a firm. They proposed that for firms in the declining or dying industries, the U.S. government should provide assistance or subsidies to rescue them (Scott and Lodge, 1984). This school received inspiration from the phenomenal success of Japan's Ministry of International Trade and Industry (MITI) in providing the growth for many Japanese firms. The critics of industrial policy school, on the other hand, suggested that a government should stay away, and not interfere with the "invisible hand" of the marketplace. They wanted market forces to decide the fate and future of different firms.

2.2 The resource-based view of a firm

This is a more recent perspective, complimenting the structural view of strategy. This resource-based view suggested a shift in emphasis, from the products or services a firm produces, to the resources that firms develop and allocate (Miller, 1996). Wernerfelt (1984: 172) looked at different firms in terms of their resources, and defined them as those tangible and intangible assets which are tied semi-permanently to a firm. These resources provided strength to the firm, extending its capacity to pursue opportunities, and generate additional profits or prevent potential losses. Such resource allocations enhance the firm's ability to earn unusual returns. The allocation of resources to an organization's technology-related capabilities, could move the boundaries as well as the rules of competition in an industry (Porter 1983). The resource-based barriers were defined as partially analogous to the entry barriers (Wernerfelt, 1984: 179).

The "management myopia" school, supporting the resource-based view, proposed that the main cause behind the declining competitiveness of some U.S. industrial organizations was their managers' short-term profit strategy for allocation of their resources (Hayes and Wheelwright, 1984). Subscribers to this school recommended that the focus of the resource allocation strategy should be changed from a short-term profitability to a long-term building of the strategic capabilities and cross-functional competencies of organizations. To do so these managers must allocate more resources to build their firms' long-term technology competency.

Under an intense market competition, a firm's allocation of resources to its technology-related distinctive competencies (Frohman, 1985) has a high impact on the firm's ability to compete. This is particularly true for the technology-driven organizations, which use their technology as both the engine of their growth, and the basis of their business strategy.

Furthermore, The M.I.T. Commission on Industrial Productivity reported that corporate managers in the U.S. firms tend to pursue outdated strategies with short-term time horizons. The U.S. manufacturing firms have substantial technological weaknesses in their abilities to develop and introduce their new products with speed. They do not invest enough of their resources to a flexible production of goods with low cost and high quality. These technology related limitations have led to these firms' poor performances (Berger et. al. 1989). The M.I.T. Commission recommended that the U.S. firms must allocate more resources to cultivate and promote their technological innovation competency. These remarks suggest that the technology-driven firms not only must invest adequate resources to their research and development capability, but also to the other complimentary capabilities in their technology value-chains.

3.0 WHAT CONSTITUTES THE TECHNOLOGY COMPETENCY?

There is a general agreement that the technology-related capabilities and competencies of a firm should be included in any comparative study of variances in the performances of firms across different technology driven industries (Dvir, Segev & Shenhar, 1993; Gillespie & Miletti, 1977). There is, however, a far less agreement as to the meaning and measurement of what constitutes an effective management of technology competency.

Traditionally, most managers and researchers of technology driven organizations, have considered their allocation of resources to research and development (R & D) capability as their operationalization of their technology competency. They consider R & D capability as their major and primary source for defining their technology (Parisi, 1989). The National Science Foundation defined "High-Tech" firms and industries as those firms and industries which spend more than three percent of their sales on their research and development efforts. In 1988, the U.S. industries spent $59.4 billion on corporate R & D. This increased in five years to $83 billion in 1993, with an average increase of 6 percent per year, and an annual increase of 4.2 percent over 1992. (This research study analyzed the allocation of resources by technology driven firms for 1993.) Such allocation of resources to the firm-level R & D capability have helped the U.S. firms gain significant new knowledge and proprietary new technology. This sometimes resulted in patents for the firms. These firms gained a temporary monopoly based on their technological inventions or new knowledge.

3.1 Relationship Between R&D Determined Technology Competency and Performance.

In many previous studies, there was a weak empirical evidence linking a firm's R&D intensity (measured as R&D expense per unit sales) and the firm's superior competitive performance. For example, the macroeconomics studies between allocation of resources to R&D and the competitive performance of a firm (in many industries), have shown a relatively low correlation (about

.20 to .50) between a firm's R&D spending and competitive outputs (McLean & Round, 1978; Comanor & Scherer, 1969). This weak correlation was hard to explain by those who believed that a firm-level technology is defined and determined by a firm's R&D intensity.

Partly this weak correlation can be explained by noting that this relationship was usually generalized over a large number of industrial groups. This may have balanced out firms in more correlated industries with firms in less correlated industries. *Therefore one objective of this study is to empirically investigate the cross-sectional differences in allocations of resources to technology competencies of firms competing in different industries.*

4.0 RELATING TECHNOLOGY COMPETENCY, RESOURCE ALLOCATIONS, AND PERFORMANCE OF A FIRM.

There is a paradox in linking allocations of resources by firms to their technology competency, and their performance. Historically, some technological inventions were produced with very little allocation of resources to their R & D capability. Penicillin was discovered accidentally by Alexander Fleming without allocating much resources. General Electric spent under $200,000 for developing the gas-filled lamp (Galvin, 1959). On the other hand, extensive allocations of resources to the creation of sophisticated products and processes have not always contributed to the birth of a commercially profitable new technology. In this paradoxical relationship lies the key to improving our understanding of strategic management of technology competency.

We postulated in this study that the performance of a firm depends not only on the allocation of resources to R & D capability but also on the firm's commitment of resources to other complimentary capabilities in the firm's technology value-chain.

Let us next consider three case studies to understand and formulate this relationship between allocations of resources, technology competency and performance of a firm. The first case-study considers Xerox, a pioneer innovator of photocopying technology. Xerox gave birth to a new technology-based industry, and performed very well due to the R & D efforts of its founder Chester Carlson. But Xerox was unable to profit from the numerous technological innovations developed by its California based Palo Alto research and development center. The second case-study is an observation by the head of research and development function at I.B.M., a global leader in computer technology. The third case-study is about E.I. Du Pont's allocation of resources to the development of its nylon technology. Nylon is considered to be one of the most successful technological innovations by a modern technology driven organization.

These case-studies helped formulate the need for the research problem in this study.

4.1 Case-Study: Xerox and Unrealized Returns from Technological Innovations.

During the 1970s and the early 1980s, Xerox invested substantial resources to its basic computer technology related research at its California based Palo Alto Research Center (PARC). Researchers at PARC proposed that their management executives in Rochester, New York, support their efforts to pioneer and enter in the personal computer industry. Their allocations of resources to research and development resulted in significant technological discoveries. This included development of an experimental computer language, an easier-to-use computer interface, and basic computer communication technologies. But, Xerox could not successfully transform its successful research discoveries into many marketable products. On the other hand, other companies like Apple Computer, Adobe Systems and Grid Computer built sizable businesses based on the technological innovations pioneered and sponsored by Xerox. These other firms coupled Xerox's technological inventions with their own complimentary technology-related capabilities and were able to commercially exploit and sell new products into major markets developed by them (Markoff, 1989). Thus, for these high performing firms, their capabilities other than R&D played critical role in generating superior returns from their investments in R&D.

4.2 Case Study: I.B.M.'s Experience With Technology

According to Dr. John Armstrong, I.B.M's head of research and development:

"The traditional academic view is that first you do basic research, then applied research, then product development, and then give it to manufacturing. But... the Japanese had been so effective at rapidly translating (their own and others') research into successful commercial products that IBM had been forced to try to (match their practices and) generate new products more quickly" (Markoff, 1989).

This observation by a leading technology driven firm indicates that the technology innovation process does not always begin and end with the R & D capability of a firm. In the case of the Japanese technology leader SONY, the technology innovation process sometimes started with allocating resources to their market development capability. They often licensed the needed research and development capability from outside.

Such anecdotal experiences, frequently observed during the past few decades, indicate the need for a re-examination of the conventional uni-dimensional, and R & D determined management of a firm's technology competency.

Let us next take a detailed look at E.I Du Pont's allocation of resources and success with its development of nylon technology. A study of development and commercialization of nylon technology has been the starting point for many empirical and econometric studies of technological change (Scherer, 1967).

4.3 Case-Study: Management of Nylon Technology at Du Pont

E. I. du Pont allocated significant resources to research, development and innovation of nylon technology for many years. This helped Du Pont commercialize a family of products such as nylon parachute ropes during the World War II, stocking hose substitute for women after the World War II, fabric for uniforms of men and women, carpet yarn for homes, tire cord reinforcement for automobiles, engineering molding powder for plastics, and advanced reinforced materials for industrial applications (Gehani, 1980).

Wallace H. Carothers, a research scientist at Du Pont, was intrigued in 1928 by sticky, messy, and insoluble substances produced during some of his run-away chemical reactions. Most of the other researchers of his time dubbed these products as accidents, and discarded them. Carothers received resources from Du Pont to pursue his basic research interests even during the economic Depression. Such allocations of resources helped him discover nylon polymer's long-chain molecular structure (Gehani, 1985). Until then most of the known synthetic materials were assumed to have small molecular structures (Gehani, 1979). By 1930, and after spending about $50,000, Carothers discovered that nylon polymer could be processed into synthetic fiber form, with some potential commercial uses. Four years later, and after allocating $1 million to research, nylon polymer was synthesized with predictable properties. Thereafter alternate routes for the synthesis of nylon polymer were researched, and the basic properties of nylon were systematically analyzed.

The nylon fiber technology project was then sent to Du Pont's development department, where additional $44 million worth resources were allocated. A test pilot-plant was developed to explore the alternate processing conditions for nylon's production process. This helped Du Pont improve properties of the nylon fiber produced by them in large volumes. Many persons other than researchers and scientists were involved with the design and engineering of nylon's production process. Expensive plant and equipment needed to be fabricated. By then, Du Pont's allocation of resources to their production and manufacturing of nylon "dwarfed the expenditures on R & D"(Scherer, 1984: 5).

Subsequently, Du Pont began allocating more and more resources to the market development of their nylon-based products.. This helped Du Pont educate their buyers in adopting the nylon polymer products to meet their real or latent needs. Thus, the focus of their allocation of resources shifted from building the research and development capabilities in their early stages, to the market development and selling efforts, and building of efficient production plant and equipment facilities.

5. LESSONS FROM CASE STUDIES TO DEFINE RESEARCH TOPIC

These case studies of the management of desk-top computer technology at Xerox, I.B.M.'s mainframe computer technology, and Du Pont's nylon technology provided useful lessons for conceptualizing and formulating the present empirical study of the allocation of resources to a firm's technology based competency.

First, Du Pont's success with nylon technology illustrated that Du Pont's allocation of resources to their nylon technology did not result in one big boost in its performance. Their allocations of resources also did not take place in one sweeping decision of economic rationality. Instead, Du Pont allocated its resources in a series of inter-related steps. Therefore, for a start-up business, driven by one single technology, the allocation of resources must be accumulated over time; and in different capabilities. On the other hand, in a large multi-technology, multi-product firm, their annual resource allocations to R & D and other technology related capabilities must evolve into a steady pattern of resource allocations.

Some researchers studying either management or economics of technology have treated each technological innovation as a "product event." They investigated how an innovation diffused in markets over time. Others have studied technology as a "process flow." They investigated how these discontinuities integrated with the structure and other attributes of an organization over time (Tushman and Nadler, 1986). The resource-based strategic view, used in this study, reflects a firm's ongoing commitment to its technology competency.

Second, the early upstream synthesis of a nylon polymer in research, or development of desktop computer technologies at PARC, required the allocation of relatively low levels of resources.

Subsequent downstream stages of development, and the bulk production of desktop computers or nylon fibers required much larger levels of resource allocations by the respective firms. More resources were needed for the procurement and engineering of the needed plant and equipment. Additional resources were also required for identification and education of potential buyers, and successful commercial selling in major markets.

Thus, we noted that substantial resources were required for the integration of new technology discovered in research, into a commercially viable product that performed satisfactorily and reliably for its buyers. Only then a technology, such as the one embodied in nylon products or desktop computers, developed a commercial potential to sell deep into its markets, and provided superior returns to the investing firm.

These case studies illustrated that in a total technology innovation process, R & D capability, particularly the basic research involved with the creation of new technology and knowledge on which new products and processes are based, accounted for only a small percentage of total resource requirements for the technology competency. Other complimentary capabilities in the firm's total technology value-adding chain played significant roles in deriving superior returns from the investment of resources to the R & D capability.

A firm's returns on the allocation of resources to its technology competency depend on resources allocated to these 'complimentary assets' (Teece, 1986). Here we use Porter's (1985) concept of 'value chain' to distinguish different value-adding activities in the technology competency of a firm.

In this study, we therefore extended our scope of the allocation of resources to R & D capability, and included the allocation of resources to other complimentary technology related capabilities of a firm. All these technology related capabilities of a firm, collectively were called the technology value-chain (TVC) of the firm.

Third, in the early upstream stages of the nylon technology value-chain, relatively low levels of resource allocations to basic research accompanied very high levels of technological uncertainties. However, such allocations of resources helped Du Pont gain useful understanding and knowledge that helped reduce technological uncertainty for the firm for allocating resources in subsequent stages of development, production and market commercialization. These latter stages required significantly higher levels of commitment of resources. But due to relatively high uncertainties in early stages of a technology value-chain, some firms prematurely cut allocation of resources to research capability. Such downstream impact of upstream resource allocations reaffirmed our proposed need for including the allocation of resources to complimentary technology related capabilities.

Fourth, the returns and benefits from Du Pont's allocation of resources to nylon technology spilled over into many other lines of Du Pont's current and future businesses. For example, the development of nylon's fiber forming process started a textile machinery business. Du Pont's nylon synthetic fiber technology also led to 'constructive destruction' of the traditional cotton textile industry. Subsequently, some of the lessons derived from Carothers's research on polymer chemistry gave birth to a series of highly successful technologies based on new synthetic polymers. This included product and process innovations of polyester fiber, acrylic fiber, bullet-proof Aramid fiber, high performing Kevlar tire reinforcement etc. (Gehani. 1985a). Many of these spillovers contributed significantly to Du Pont's market performance and profitability.

Because of these intra-firm spillover effects from allocation of resources to a new technology, this study investigated the allocation of resources to the technology competency of a firm at a firm-wide level (and not 'product event' level, or 'process flow' level mentioned earlier). Thus a firm level performance was related to a firm level allocation of resources to the technology competency.

6.0 DEVELOPING A COMPETENCY PERSPECTIVE FOR TECHNOLOGY.

In this section we develop the topic of this study in the context of the current state of understanding of the resource-based view of strategy. The above case-studies of key successful and unsuccessful management of technological innovations indicated that the current model of using a firm's allocation of resources only to its R & D determined technological competency was unable to explain the firm's performance. There were other complimentary technology-related capabilities of a firm that helped in the 'transformation' of a new technology developed by the firm's R & D capability into commercially successful products. These capabilities together contributed towards the firm's superior performance (Kamien and Schwartz, 1975). Some of the complimentary capabilities cited by other researchers, included a firm's automation and production engineering capability (Ramachandaran, 1986), and a firm's capability for getting close to its customers (Shanklin & Ryans, 1988) etc. However, what is lacking in the currently available empirical studies, is the empirical development of a multi-variable framework for technology competency, that takes into account a firm's allocation of resources to its major technology-related capabilities. And furthermore, to study how these allocations relate to the firm's performance under different industrial structures (Porter, 1985).

The most important purpose behind a firm's allocation of resources is that doing so provides significant value to the investing firm. Barney (1991) and Grant (1991) grouped the resources of a firm into categories such as physical, capital, human, financial, technological, and reputational. Technology related resources of a firm, as illustrated by above case-studies, included proprietary intellectual property owned by a firm, superior factors of production, brand equity created by marketing and selling administration efforts, preferred channels of distribution etc. (Black and Boal, 1994; Miller, 1996). These resources provide utility to a firm by extending the firm's ability to pursue new opportunities and generating additional profits (or prevent losses). For sustainable competitive advantage, researchers also recommended that resources should be rare, hard to imitate, and have no easy substitute (Barney, 1991; Lippman & Rumelt, 1982; Peteraf, 1993).

In an empirical study published in the June 1996 issue of *Academy of Management Journal*, Miller and Shamsie (1996) classified the resources of a firm into two categories. They based this on the barriers to imitability. These categories were the knowledge based resources, and the property based resources. Both these categories represent the technology related resources of a firm. They can not be easily imitated because the competitors either do not know about them, or the firm owns patents, contracts and other property rights to these resources. Miller and Shamsie (1996) also looked at the texture of these two types of resources, and grouped them as discrete or systemic. In the present study we focused on the 'systemic resources' or the firm-wide technology competency of a firm. As per results discussed in Chapter - 5, allocating resources to the different technology related capabilities had different impact on the performance of firms in different industries.

6.1 Developing the Technology Value-Chain Perspective.

Prahalad and Hamel (1990) have defined core-competencies of an organization in the tradition of the resource-based view of the firm (Wernerfelt, 1995). These researchers proposed that "the roots of competitive advantage" of an organization are based on "the portfolio of competencies" of the organization. They pointed out that their activities or "core competencies are about harmonizing streams of technologies, the organization of work, and the delivery of value." The competencies of an organization include its collective learning about organizing the diverse production skills and integrating their multiple streams of technologies available in the firm. These capabilities over-arch an organization across its different businesses. We bundled together the technology related complimentary capabilities of a firm as its technology value-chain.

The present empirical research with the resource-based competency perspective of the technological capabilities of a firm can make significant contributions to the current state of understanding of the resource based view of strategy. We have unfolded the overall technology competency of a firm. Miller and Shamsie (1996: 519) have criticized that the resource based view of strategy was still primarily descriptive. And that it was yet to fully evolve into a testable and 'falsifiable theory.' Only some researchers have reported any empirical results in this direction (Collis, 1991; Henderson & Cockburn, 1994; Montgomery & Wernerfelt, 1988; McGrath, McMillan, & Venkatraman, 1995). The present study hopes to join this small group.

Furthermore, Porter (1991: 108) drew attention to the inward bias of the resource-based view. This view of strategy overlooked the fact that the competitive value of resources can be enhanced or eliminated by changes in the behavior of competitors, by (exogenous) technology, or the buyer needs. Miller and Shamsie (1996) urged that just as the contingency theory related structures and strategies to the contexts in which they are most appropriate for a firm (Burns & Stalker, 1961), so too must the resource based view. It must consider the environmental contexts within which various kinds of resources provide the best contribution to enhancing performance of a firm (Amit & Schoemaker, 1991).

Summary and Plan of Research Work. The main motivation of this empirical research was to fill some of these gaps in the resource-based view of strategy. To do so, this research study was aimed at analyzing the patterns of allocations of resources to the different technology related capabilities in a firm's technology value-chain (TVC). Relationships between the resource allocations and a firm's performance were investigated. These relationships were empirically tested for the U.S. manufacturing firms in three different technology-driven industries with different industry structures. Thus, the resource-based view of strategy was extended to include the influence of external industrial context under which a firm competed. This addressed Porter's (1991), as well as Miller and Shamsie's (1996) criticisms of the current state of understanding of the resource-based view of strategy.

Next, in chapter 2 relevant literature has been reviewed. In chapter 3 the research design and hypotheses for this study are developed and different variables are operationalized. The research methodology and the statistical analyses of relationships are covered in chapter 4. The results of descriptive and inferential statistical analyses are summarized and discussed in chapter 5. Chapter 6 gives the implications for future research, and the limitations of this research study.

CHAPTER - 2

REVIEW OF LITERATURE

In this chapter literature related to the relationships between an organization's allocation of resources to its technology-related capabilities and its performance are examined. This includes the literature on the resource-based view of strategy, and the concepts of strategic choice and strategic fit. The influence of an organization's context, particularly the structure of the industry in which a firm competes, was reviewed. This helped develop a multi-variable technology value-chain framework for a firm's resource allocations to its technology-related competency. This included the impact of resource allocations on a firm's performance in industries with different market structures.

1.0 RESOURCE-BASED VIEW IN STRATEGIC MANAGEMENT

A number of prominent researchers in the strategic management area have recently focused their attention on the way an organization acquires and allocates its limited resources (Petraf, 1993; Mahaoney & Pandian, 1992; Wernerfelt, 1984; Penrose, 1985, 1959; Rubin, 1973 etc.). Ansoff's classical formulation of the concept of strategy was based on an organization's allocation of its resources to generate rents. According to the resource-based view, an organization's strategy for competitive advantage can be viewed as the firm's continuing search for above-normal rents (Porter, 1985). Different firms improve their competitiveness and long-term profitability by their long-term investment in their capabilities (Waddock and Graves, 1989, p 344).

As described in chapter 1, an organization's resources are all those tangible and intangible assets that are tied semi-permanently to the organization (Wernerfelt, 1984, Caves, 1980). These are in the form of a firm's capital allocations in plants and equipments, the labor and human resource skills, the proprietary knowledge of technology, the marketing expertise in understanding their customers' preferences etc.. The resource-based viewers seek and propose that different ways firms deploy their resources to gain above-normal rents. A rent is defined as a firm's return on its resource allocation in excess of its opportunity costs (Bowman, 1974: 47; Tollison, 1982). An organization generates rent not only because it has better or more resources, but also because of its superior practice of allocating those resources appropriately to the various capabilities and competencies (Penrose, 1959: p 54). This study was focused on a firm's allocation of resources to its technology-related competency.

2.0 R&D DETERMINED MANAGEMENT OF TECHNOLOGY FOR RICARDIAN RENTS

A firm's rents are generated in many different ways. The traditional "R&D determined technology" school proposed that the firms seek their Ricardian super-normal rents, R(r). These rents are obtained from "the ownership of a valuable and scarce resource, such as a proprietary patented know-how and unique manufacturing assets." (Ricardo, 1817). The allocation of resources to R&D helps a firm gain exclusive access to scarce innovative capabilities. In the context of the technology value-chain proposed in this study, the Ricardian rents are derived by an organization's allocation of its financial resources to in-house development of the firm's proprietary know-how and new technology. Alternately, a firm can acquire other firms' unique R&D results by licensing, or a transfer-of-technology.

One sub-group of the "strategic content" researchers (including, Hoskisson and Hitt, 1988; Franko, 1989 etc.) studied an organization's commitment of resources to its R&D intensity (R&D$ per unit sales$) and related it to the competitive performance of firms. The knowledge and learning based core-competencies, resulting from investing in a firm's R&D improve as they are applied across an organization (Prahalad and Hamel, 1990). Thus resource-allocation decisions for research and development reflect a firm's commitment to its firm-wide technology competency.

The strategic perspective linking a firm's R&D capability to its performance, has been developed only recently (Lee et al., 1986). For many years, the R&D related empirical studies were devoted only to the functional level operationalization of a production technology (Ansoff & Stewart, 1967). Furthermore, many firms allocated resources to their R & D capability based on their historical trend of resource allocations in the previous few years. Thus investments in R & D capability were increased every year by a fixed percentage of their previous year's R & D budget. The R & D capability was managed in isolation in an organization. There was little integration between the R&D capability and the complimentary technology-related capabilities in other parts of the same organization, particularly in the manufacturing or marketing departments. Thus, many researchers argued that a more intensive allocation of resources (per sales dollar) to the firm's R & D capability (**Endnote #1**) leads to a superior performance.

3.0 AUTOMATION & PRODUCTION ENGINEERING DRIVEN TECHNOLOGY FOR ECONOMIES OF SCALE RENTS.

It has been often observed that some technology-driven organizations decide not to invest in any risky research. These firms instead allocate more of their resources and efforts on upgrading their automation and production facilities for a better plant efficiency or a lower unit cost of production. (These decisions may be influenced by other factors such as the level of maturity of the industry or its technology). Higher economies of scale (Porter, 1980) have helped firms compete with a low cost leadership strategy. These economies are achieved either by offering lower prices to customers, or by gaining higher returns with competitive pricing. This helps a firm improve its performance by gaining more market-share, or by earning higher profits. This strategic choice in allocation of resources helped firms achieve above-normal rents by a more efficient production and engineering capability. These efforts contributed to the economies of scale rents, [r(scale)], obtained by raising high barriers to potential competitors. They also contributed to some firms gaining brand-loyalty due to their high market-shares. (Bain, 1968).

From the technology value-chain perspective proposed in this study, these rents relied on a firm's allocation of its resources towards building its production capability by using its automation and plant engineering (APE) capability. This implied that such firms with high or flexible production plants can generate certain competitive advantages over their rival competitors.

Ramachandaran (1986), Schonberger (1987), Cohen & Zysman (1987), Wheelwright (1984) and others have studied organizations' commitment of resources to enhance their production capabilities through the automation and production-engineering improvements in their plants and equipments. There is, however, a disagreement on the degree of allocation of resources to the different types of production capabilities.

With the advent of highly dynamic competition and increasingly globalized production, the competitive utility of high allocation of resources to traditional fixed automation is being supported by some researchers, and questioned by some other groups of researchers. Schonberger (1987) proposed that all firms should use "frugal manufacturing" capability with focus on incremental improvements in their jigs, fixtures, plants, and equipments. And that they should not allocate their scarce resources heavily on their automated plant and equipment systems. On the other hand, Ramachandaran (1986) has proposed that the "post-industrial manufacturing" demands a flexible automation capability to gain competitive advantage.

Cohen & Zysman (1987, 1987a) distinguished between the "static flexibility" capability and the "dynamic flexibility" capability of a technology-driven organization. The former is an organization's ability to adjust and respond "at any moment" to shifting market conditions. An organization develops "dynamic flexibility," when the organization can also steadily improve its productivity with new production process innovations.

Meyer et. al. (1989) surveyed the literature on the production strategies pursued by the industrial organizations in the U.S.A., Europe and Japan. They concluded that the flexibility of a production process will define the next competitive battle in the world markets. The European and the North American organizations were found still focused on allocating their resources to the traditional (hard) automation capabilities for implementing their cost reduction and quality programs. On the other hand, the Japanese technology managers focused their efforts on balancing trade-offs between a cost efficiency (with fixed automation) and development of flexible capabilities (gained with more costly flexible automation of production plant and equipment). These researchers inferred that the Japanese managers were ahead of their Western counterparts, and that they allocated resources more intensely to building their production flexibility. They thus generated higher value-added production as a result of such allocations of their resources.

Research by Parthasarthy and Sethi (1992) on flexible manufacturing systems, highlighted the competitive impact of economies of scope through a flexible automation and engineering capability. These researchers also made a distinction between flexible automation and fixed automation. Traditionally fixed automation has been used to improve process efficiencies using large production runs and standard product designs. On the other hand, a flexible automation was classified to be the "objective driven by a predetermined criteria." It could also be more "opportunity driven," to respond to emerging market requirements. This required a firm's commitment of resources to the complimentary production engineering capability in its technology value-chain, as proposed in this study.

Adoption of automation, fixed or flexible, has direct impact on the strategy formulation and implementation in an organization (Hayes & Jaykumar, 1988; Goldhar & Jelinek, 1985). These researchers have argued that for a flexible-automation user, "a technology-based approach, as opposed to the current marketing- and finance-based approach is recommended" (Parthasarthy & Sethi, 1992, p 87).

In any case, there is a wide-spread agreement among many practitioners and researchers that production technology, hitherto confined to strategy implementation activities only (Skinner, 1985), needs to be integrated dynamically with the strategic position of the firm (Porter, 1988; Stobaugh & Telesio, 1983). Hayes, Wheelwright, & Clark (1988) have supported a dynamic and multi-dimensional role of technology-related capabilities of an organization in its competitiveness. The exclusively R & D capability determined view of a technology competency pursued by many researchers has overlooked this opportunity.

4.0 MARKET DEVELOPMENT & SELLING DRIVEN SCHUMPETARIAN RENTS

The third strategic choice available to a manager formulating a technology-related strategy, and allocating resources to building the technology competency of a firm, is to gain a Schumpetarian-type entrepreneurial rent. These rents are earned by the creative destruction of current markets, and by meeting their customers' actual or potential requirements [C(r)]. These customer-driven rents are generated by introducing new products based on a firm's intimate understanding of complex market environment (Schumpeter, 1937; Rumelt, 1987).

In terms of the technology value-chain proposed here, Schumpetarian-rents are likely to depend on a firm's allocation of its resources on efforts related to its market development and selling (MDS) capability. In financial statements these investments are covered under the selling and general administration (SGA) expenses.

Many technology-driven organizations operate in fast-changing market environments, and face very volatile market demands. Typically, the technology-driven firms have superior research facilities. But they often fail to achieve much success with their innovative products or technologies in their relevant market (Shanklin & Ryans, 1988). To become competitively effective, these organizations must convert their research efforts into marketable goods or services. They must make adequate investments while keeping in mind the specific needs of the high-tech markets they serve (Bowen et al., 1989). For the long-term growth and competitive survival of an industrial organization (Bart, 1988), the success of their different technological innovations in "diverse" markets is essential. This requires a management commitment and allocation of resources needed to build their market development and selling capability.

Similar approaches have been suggested by other researchers. Roberts (1987) has gone a step beyond conventional R&D determined technological innovation, and has operationalized the management of technology as a sum of invention (that is, creation of new ideas), and exploitation (that is commercialization of these new ideas). Takeuchi & Nonaka (1984), Levitt (1965, 1966), Lilien & Yoon (1990), Berger et al. (1989) and others have suggested that a firm's ability to develop, enter, and diffuse innovative products or processes into relevant markets is a critical determinant of the firm's market performance.

While developing a new market, or selling products in different markets, a firm may allocate its resources on certain value-adding market exploiting activities. Examples include identifying either added-value market gaps or a more effective distribution. A technology-driven firm must identify and commercially exploit unfulfilled customer needs for their many differentiated products (Porter,1980). Alternately, a firm may allocate more resources to launch a mass market education for a deeper and a more profitable diffusion of products into remunerative markets. These efforts are classified here as a managerial commitment to the market development and selling (MDS) capability.

The "High-tech" markets in technology-driven industries have been divided into the "supply- side markets," and the "demand-side markets." In the "supply-side markets," the technological innovations push and create new demand. The "demand side markets," require that the research efforts for a technological innovation must adapt and respond to the changing customer preferences in different maturing markets. In the former case, a firm's market development efforts play an entrepreneurial role for the organization. For the latter case, the market development efforts play a more traditional selling role for the organization. In both the cases, the market development and selling capability of a technology organization should be responsive to its market fluctuations.

The "service orientation" of an industrial organization has been defined (Bowen, Siehl & Schneider, 1989) in terms of its commitment to product innovation (Lele, 1986; Levitt, 1969); and its definition of elements of its product strategy (Buzzell & Gale, 1987; Lele, 1969; Porter, 1980). The organizational efforts for the former include developing product style or design-related features, and promoting them. Activities relating to the latter category involve gaining a competitive advantage by product differentiation, higher quality, and a more value-added service. Thereby, customers' switching costs (Porter, 1980) are kept high.

The research in consumer behavior, dealing with market-diffusion, was extended by Robertson & Gatignon (1986: 1) to a "technological diffusion at organizational level." They derived their propositions from fields other than the consumer behavior (- such as economics and organizational behavior). They postulated that an organization's decision and timing for adoption of a technological innovation depends on: the innovation characteristics and the organizational characteristics. Robertson & Gatignon (1986: 3) argued that a technological innovation must be defined from the perception of its potential adopters. These authors followed Shanklin & Ryans (1982), and used the term technological innovation as synonymous with discontinuous innovation. According to them:

> "An innovation may be (of) high technology from the (producer's) vantage point, but if it is not perceived (such) by customers as (sophisticated) and altering their...function, then it is not of interest in the (technological innovation) context."

Our review of literature indicated that the market development and selling capability in the technology value-chain of a firm can play a critical role in deriving above normal Schumpetarian rents. These are accrued from being close to the firm's relevant customers and markets. In general, the technological innovations involve sophisticated products or complex processes, and therefore their potential adopters may have limited knowledge to evaluate and make decisions regarding their adoption. Typically, technology intensive goods and services are also costly, and involve high switching costs. Thus, education of potential customers of a technological innovation, to help them evaluate and decide for its adoption, is critical (Wilton & Pessemier, 1981). Such efforts improve the process of market exploitation and selling of goods and services in amarkets. This can lead to an early or more voluminous adoption and use of their technological innovations (See Rogers, 1985, for the high adoption but low usage of communication technology.) There may even be some correlation between a firm's R&D intensity and allocation of resource to the firm's market development and selling capability.

The present study, therefore considered a firm's allocation of resources to its market development and selling (MDS) capability, as a critical and complimentary component of that firm's technology value-adding chain. This may, however, be influenced by other external environmental factors, such as the industry structure and the intensity of market rivalry. These issues will be discussed after reviewing the relevant literature linking the technology competency, strategy and performance of firms.

5.0 LITERATURE ON LINKAGE BETWEEN ALLOCATIONS OF RESOURCES TO TECHNOLOGY COMPETENCY AND PERFORMANCE

This section compares the resource-based view of technology competency with our current understanding of the role of technology in the performance of a firm. Many different researchers have used three alternate perspectives for the role of technology competency in the competitive performance of a firm (Ansoff & Stewart, 1967; Freeman, 1974, 1982; Miles & Snow, 1978 etc.) These are summarized in Exhibit 2.1 and briefly reviewed and critiqued next.

Table - 2.1: TECHNOLOGY COMPETENCY AND STRATEGY

Researchers-	Ansoff & & Stewart (1967)	Freeman (1974)	Miles & Snow (1978)
Common Attributes of Firms	Ability to enter emerging markets	Response to external technological changes	Relationship across technologies
Types of Technology Driven Firms	1 First to Market 2 Follow Leader 3 Application Engg 4 Me Too	1 Offensive 2 Defensive 3 Imitative 4 Dependent 5 Traditional 6 Opportunist	1 Defender 2 Prospector 3 Analyzer 4 Reactor
Limitation	Limit firms to emerging industries	During 70s Technologies hybridized	Diffused markets due to mergers & acquisitions

Ansoff & Stewart (1967) have classified different organizations based on the role of their technology-related capabilities, and their ability to enter newly emerging markets. These were markets created by Schumpetarian creative destruction. These researchers classified different organizations as pursuing the "first to market strategy," "follow the leader strategy," "application engineering strategy," or "me too strategy." A simple criticism against this model has been that the authors considered only the organizations in emerging industrial sectors. They overlooked the organizations in growing, maturing, or declining sectors of industries.

Freeman (1974, 1982) treated the role of technology in an organization as an exogenous contextual variable. He classified different technology-driven organizations by their strategic responses to their external technological changes. He proposed six strategic responses. These are organizations with: (1) "the offensive response" strategy, (2) the "defensive response" strategy, (3) the "imitative response" strategy, (4) the "dependent response" strategy, (5) the "traditional response" strategy, and (6) the "opportunist response" strategy. Freeman (1974, 1982) used a wider perspective of the management of technology than that of Ansoff & Stewart (1967). He covered the active performers as well as the non-active performers. A major criticism against the Freeman-model of management of technology competency has been that during the 1970s, many technological innovations were fused together and "hybridized." The hybrid technologies such as "mecha-tronics," "op-tronics," bio-computers etc. emerged during this period. Thus the assumption of a pure external technological innovation as a stimulus to a firm's resource allocation strategies was no more valid. During this period, acquisition of external technological innovations (rather than internal development of R&D capabilities) became far more prevalent than before. In the present study, the acquisitions of technology-related capabilities from outside a firm were included within the scope of the allocation of resources to a firm's technology value-chain.

Miles & Snow (1978) proposed a model in response to the widespread diversification of organizations in either related or unrelated products. They classified the technology-driven organizations based on four different strategies. These are: (1) the "defender strategy," (2) the "prospector strategy," (3) the "analyzer strategy," and (4) the "reactor strategy." These business-level technology-related strategies were anchored in the population ecology theory. This classification was based on an organization's aggressiveness in a relevant product-market sector.

However, the merger and acquisition activity of the 1980s diffused many sectoral boundaries in industries. It was, therefore, not easy anymore to clearly define the "prospector" organizations from the "defender" organizations. The increased turbulence in the global competition also enhanced uncertainty for the "analyzer" organization, and limited the utility of delayed responses by the "reactor" organizations.

5.1 A Criticism of Business Level Technology Strategy: Lack of Empirical Linkage

The technology - strategy paradigms proposed by Ansoff & Stewart (1967), Freeman (1974) and Miles and Snow (1978) have been criticized by Miller (1988). He argued that they were "subjective and can not be empirically validated." These models were anchored in the individual researchers' experiences, and did not link the technology strategy of a firm with its performance.

Miller (1988) provided an alternate taxonomic model, which characterized the operations of a firm by the extent of measurable work-flow automation and integration.

In the present research study, Miller's (1988) work-flow based technology competency is operationalized through a firm's resource commitment to its automation and plant engineering capability in its technology value chain. The work-flow automation is one of the three capabilities in our research model for the technology value-chain of an organization. Thus the present research study took into account the Miller (1988) criticisms, and offered a more comprehensive multi-capability view of a firm's technology strategy. This study also provided a framework to integrate the above-mentioned paradigms proposed for different technology - strategy relationships.

5.1 The Resource-Based View of Technology Value-Chain as Firm Level Technology Competency

The resource-based view of strategic management assumes that the competencies and allocations of resources in organizations may differ across different firms within an industry. And that resource allocations are different in different firms in different industries (Barney, 1991; Nelson, 1991; Williams, 1992). Firms differ in their access to scarce resources, and in their allocations of these resources. They also vary in their efficiency of usage of their resources. These factors determine how well a firm is able to produce, innovate or create new technology, and satisfy different customers' needs. These technology-related capabilities are generally shared across different businesses within an organization (Prahalad and Hamel, 1990). They represent a firm-level competency.

The concept of relatedness between different capabilities of an organization is important for firm level study of strategy (Porter, 1985; Teece, 1980; Rumelt, 1974; and others). Many competitors differ in the ways they exploit their organization-wide synergies in the areas of production and marketing capabilities (Ansoff 1965: 81). Rumelt (1974: 17) noted that the most relatedness between businesses within an organization was either the production-relatedness through common production facilities in vertical integration, or the market-relatedness through common markets and distribution systems. The production relatedness and automation competency helps to reduce costs, and enhance profitability (Davis et al., 1992). The market relatedness helps in enhancing a firm's product differentiation and ability to introduce new products in the markets. These organization-wide attributes of relatedness were represented in this study as the different capabilities in a firm's technology value-chain.

The role of technology competency in the performance of an organization spans across the organization's different functional capabilities (Maidique and Frevola, 1988). These researchers proposed that the role of technology competency in an organization goes beyond the mere production and R&D capabilities of the firm. Hence the need for a multi-variable operationalization of the technology competency of a firm as the technology value-chain of the firm.

Other technology related capabilities of a firm, such as selection and sourcing of technology, firm's technology development management, and competitive positioning of a firm may also be considered. These expectations, though conceptually comprehensive, are difficult to operationalize across many organizations in different industrial sectors. All these studies suggested that the impact of technology related capabilities (and particularly the allocation of resources to them) in the technology value-chain of an organization, span beyond the performance of one business-unit in an organization. One can therefore assume that the allocation of resources to technology-related capabilities in different business-units will reflect a corporate management's commitment towards the role of technology competency in improving an organization's performance.

6.0 STRATEGIC CHOICE PERSPECTIVE: SUPERIOR PERFORMANCE VIA ALTERNATE RESOURCE ALLOCATIONS TO TECHNOLOGY VALUE-CHAIN CAPABILITIES

Another purpose of this study was to focus on a firm's strategic choice in the allocation of its resources to different complimentary capabilities in its technology value-chain. And relate the strategic choice of resource allocations in different capabilities to the performance of a firm.

The perspective of a "distinctive competence" gives a firm a competitive edge over its rivals (Lippman & Rumelt, 1982; Hitt &

Ireland, 1985; Barney, 1986a, 1986b; Ghemawat, 1986; Reed & DeFillippi, 1990). "Organization is a nexus or bundle of specialized resources that are deployed (most effectively) to create a privileged market position" (Lado et al., 1992; Rumelt, 1984, 1987; Wernerfelt, 1984). And that "firm-specific competencies are potential rent-yielding strategic assets." Their pattern of resource allocations, therefore, is a key source of a firm's competitive advantage. In this study, a firm's distinctive competencies in its technology value-chain, as manifested by its deployment of resources in complimentary technology-related capabilities, were investigated with respect to the "strategic choice" perspective. This is in the tradition of Child (1972) and others (Bourgeoise, 1984; Weick, 1979; Smircich & Stubbart, 1985).

7.0 STRATEGIC FIT AND RESOURCE ALLOCATIONS TO TECHNOLOGY VALUE-CHAIN

The concept of strategic "fit" relates to how well the different value-adding competencies (Hitt & Ireland, 1985; Barney, 1986a, 1986b) of an organization match with its external environmental, and internal organizational characteristics (Miller, 1992;

Venkatraman, 1989; Ginnsberg & Venkatraman, 1985; Venkatraman & Camillus, 1984; Miller, 1992; Hoffman et al., 1992). The fit between an organization's commitment of its resources, and the organization's competitive competence in a product-market domain has been investigated by Wernerfelt (1984) and others.

The concept of "strategic fit" is rooted in the population ecology model, and follows the tradition of contingency theory (Aldrich, 1979). Miller (1992: 159) pointed out that the "organizations must attain fit, both with their external environments, and among their organizational elements of their structure and process." Pioneers of the field of strategy, such as Andrews (1971) and Chandler (1962), have proposed the "matching" or "aligning" of an organization's resources with external environmental opportunities and threats. We already discussed how internal organizational characteristics such as the R & D capability, and the complimentary capabilities in the firm's technology value-chain, are related. Together they represent the firm's distinctive technology competency. The next sections focuses on the literature related to a firm's fit with external environmental factors.

7.1 Strategic Group Membership By Industry and Type of Technology

The earlier research studies of resource allocations in firms, such as the Profit Impact of Market Share study (Buzzell and Gale, 1987), generalized their observations and conclusions for different firms across a very broad range of different industries. They based their studies on a database of participating firms "with products ranging from candy to capital goods." Services such as the financial services, and firms having wide spread markets in "North America, Europe and elsewhere" were included in the same research sample.

The "strategic group" school of researchers has proposed that the organizational capabilities are influenced to a great extent by the firm's membership in a particular industry (Hatten and Schendel, 1977; Huff, 1982). For example, Hatten and Schendel (1977) noted that the "attention to homogeneity" in an industry revealed the information that would otherwise be obfuscated. They also argued that the identification of strategic groups can help in the evaluation of different strategies, and in checking their usefulness in specific competitive market situations (Hatten et al., 1978, p 592). It has been stressed that there is a "commonality among the organizations" belonging to an industry (Huff, 1982).

These studies proposed that the managers in firms belonging to a particular industry or its segment, tend to view and interpret their internal and external environmental changes in a similar manner. Huff (1982) recalled that the different small car manufacturers' reaction to oil shock in 1973-74; the different household appliance makers' response to low cost imports in 1970s; and the different commercial airline operators' expansion of their capacity in late 1960s, were similar actions influenced by their respective strategic group memberships.

In the present study we studied the resource allocations in firms within and across three different technology-driven industries.

7.2 Industrial Concentration & Resource Allocations To Technology Value-Chain

Another issue related to the influence of strategic group membership, is whether or not the structure of an industry influences the way an organization allocates its resources to its technology value-chain. An important attribute of an industrial structure is industry concentration. Industry concentration measures the intensity of rivalry. It distinguishes an industry that is highly fragmented with intense rivalry, from an industry that is controlled by a few dominating competitors.

For instance, researchers and managers alike wish to know if the dominating firms invest more or less intensely in their research & development efforts. If an organization has a monopolistic power and can earn high monopolistic rents, would it invest more resources to its market development efforts, or less? Or, is it that the dominant firms are driven by higher investments that help build their technology-related capabilities, and enable them increase their barriers to new entrants further. And, thus they either sustain or even promote their market dominance. Thus, there was a need to empirically establish the impact of an industry's structure on a firm's pattern of resource allocations to its technology value-chain.

8.0 A CAVEAT ON STRATEGIC PROCESS PERSPECTIVE OF TECHNOLOGY COMPETENCY

Finally, before we end our review of the relevant literature, we must note that the allocation of resources to a firm's technology value-chain, and the firm's distinctive competencies, are linked via complex, multi-variate relationships with its organizational processes (Kantrow, 1980; Abernathy & Utterback, 1980). The allocation of a firm's resources, researched in this study, may be classified as belonging to the "strategic content school".

We could have alternately pursued the "strategic process school" and focused our attention on the strategic process by which a technology innovation strategy is developed, executed and exploited. This is classified as the "strategy formation" by Mintzberg (1990). In technology related studies, these were classified as the 'product and process views' of management of technological innovation.

The management of technology competency, more specifically the task level process technology, has been studied by many organizational scientists. They have investigated the influence that a task technology exercises on an organization's structure. A technology is viewed by them as task-interdependence at a departmental level (Thompson, 1974). Woodward (1965) combined the resultant task rigidity and automation into a "technical complexity" variable. Woodward (1965), Thompson (1967) and Perrow (1970) argued that the task technology influenced the structural complexity, the use of controls, the integrative devices, and the centralization of authority. Pugh, Hickson et al. (1968, 1969) measured a technology as a task/work flow integration, or the extent to which a work-flow is automated, interdependent, and adaptable to flexible purposes.

An important process aspect is the influence of the degree of formality of planning and the culture of an organization on its technological innovativeness. The technological competency of an organization depends to a great extent on many factors other than the formal procedures and structures within an organization. An example is when an organization encourages its front-line employees, far away from the upper echelons of an organization, to take risks. These have a direct influence on the technological innovativeness of that organization. For example, in a personal visit to I.B.M.'s research and development facility, managers shared that they noticed that their employees' "buy-in" for Total Quality Management had a significant influence on their contributions to any team-based attempts to improve the firm's technological innovativeness, and overall performance.

The process perspective of the technology competency of a firm, such as concurrent product development and the time-based management of technology, have been investigated and presented by this author elsewhere (Gehani, 1991; Gehani, 1992). In the present study, the focus is on the strategic content perspective. This was empirically investigated using the resource-based view of strategy.

Endnote #1: Some researchers, such as Johnson (1984), Mansfield et. al. (1982), have divided the overall process of research and development effort into further sub-processes. Such sub-processes included: (i) the scientific or fundamental research for generating new knowledge, (ii) the applied research for developing technological innovations for products or processes; and (iii) the market or service development. They were able to do so because of their proprietary access to the organizations they were investigating. Such a distinction in sub-processes involved in the technology competency of an organization was difficult to operationalize from the empirical data obtained from secondary sources of information. Therefore, in this study, R&D related efforts of an organization were considered a single capability. The R&D capability is distinct from the automation and plant engineering capability, and the market development and selling capability of the same organization. All these three capabilities constituted the technology value-chain, representing the technology competency of that organization.

CHAPTER - 3

RESEARCH MODEL, HYPOTHESES AND OPERATIONALIZATION OF VARIABLES

This chapter has developed the research model and the hypotheses used in this study. These are based on the literature review discussed in the previous chapter. Operationalization of independent and dependent variables used in this research is also discussed. This is derived from the review of previous empirical studies.

1.0 RESEARCH MODEL

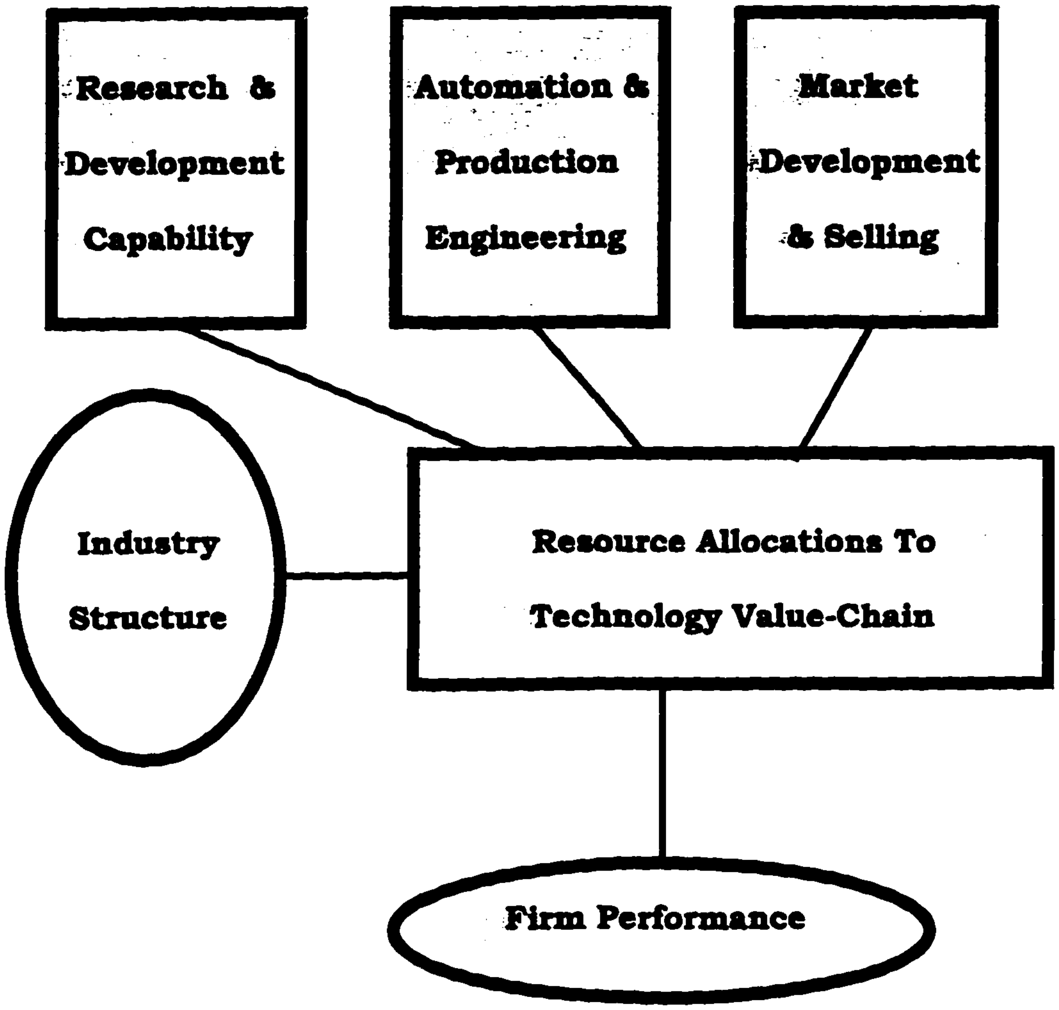
Based on the review of relevant literature in chapter 2, following research proposition can be postulated:

Performance of a firm in technology-driven industries is related to its allocation of resources to the different technology-related capabilities in its technology value-chain. The allocation of resources varies with the structure of the industry in which a firm competes.

This research proposition is represented by the research model shown in Figure 3.1. In this research model a firm's technology competency was unbundled into three capabilities in the firm's technology value-chain. These three components were a firm's allocation of resources to (1) the research and development (R & D) capability, (2) the automation and plant engineering (APE) capability, and (3) the market development and selling (MDS) capability.

Previous research studies have indicated that a firm's technology competency extends beyond its research and development capability. Teece (1986) proposed that to generate profits from a technological innovation requires successful commercialization of the firm's technological innovations. The successful commercialization of a technological innovation required that know-how generated by research and development capability of a firm was utilized in conjunction with many other complimentary assets of the firm. These complimentary assets were classified by Teece (1986) into the buyer complimentarities and the supplier complimentarities.

Figure - 3.1 RESEARCH MODEL FOR THIS STUDY



In this study, inclusion of resource allocations in the complimentary capabilities of a firm, such as the production process related capability and the market development and selling capability, provided an extended conceptualization of a firm's technology value-chain. Together with the research and development capability, these three capabilities help a firm deliver value to its customers.

The allocation of resources to the technology value-chain of a firm is influenced by the structure of the industry in which the firm competes. These relationships are hypothesized in the next section.

2.0 HYPOTHESES

In chapter 2 the U.S. economy was noted to be composed of mostly oligopolistic industries. These industries have been characterized by their concentration measures. The economic theory and much empirical experience indicate that industry characteristics, such as the concentration and the intensity of rivalry, influence performances of different firms. The degree of industry concentration is considered to be one of the most important external environmental factors influencing a firm's performance.

In a highly concentrated industry, a few firms control a large share of the total market demand. Some researchers have postulated that the firms in a concentrated industry behave interdependently (Baldwin, 1987). These firms influence each other's decisions regarding allocation of resources to their research and development capability, the production outputs, and their prices. The last two factors contribute to the level of performance of a firm. Based on this reasoning, the following hypothesis can be proposed.

Hypothesis -1:

In an industry with high concentration, the high performing firms allocate their resources more intensely to their research and development capabilities, compared to the low performing firms.

Where, *industry concentration is measured by a 4-firm concentration ratio; a high concentration implies higher than 50 percent 4-firm concentration; performance is measured by profit, and* *the resource allocations to research and development capability is based on net annual sales. (The operationalization of these variables is discussed in detail in a later section in this chapter).*

On the other hand, **in an industry with low concentration**, many rival firms compete with each other in a market, where market forces define how firms behave. Some researchers postulated that these firms had little discretionary power over their managerial decisions regarding allocation of resources to their research and development capabilities and other efforts. The market, rather than choices of competing firms, defined their decisions regarding requirements of resources. In such firms, it was postulated that the firms allocating more resources to their market development and selling capability, perform better. Allocation of resources to a firm's market development and selling capability, through efforts such as advertising and promotion, helped these firms raise their barriers to entry for potential new entrants. This also helped these firms differentiate their products from those of their rivals.

Based on this reasoning, grounded in different theories, the following hypothesis required to be tested:

Hypothesis - 2:

In an industry with low concentration, the high performing firms allocate their resources more intensely to their market development and selling capability, compared to the low performing firms.

Where, *the allocation of resources to a firm's market development and selling capability is measured by the selling & general administration expenses reported in financial statements and submitted to the Securities & Exchange Commission (SEC). The other variables can be measured in the same manner as in the case of Hypothesis-1.*

The firms in **industries with moderate concentration**, as in relatively more mature industries (such as the plastics & synthetics materials), compete with other firms based on their production economies of scale. In such industries, the high economies of scale, and the experience curve advantages, force new entrants to allocate more resources to their production plant and equipment engineering capabilities. Therefore,

Hypothesis - 3:

In an industry with moderate concentration, the firms with higher performance allocate their resources more intensely to their automation and production engineering capability, compared to the low performance firms.

Where, *the intensity of resource allocation to automation and production engineering capability of a firm is derived from the net property and plant equipment expenses reported in the firm's financial statements submitted to the Securities and Exchange Commission. Other variables are measured in the same manner as in Hypothesis -1.*

Next section discusses how the different research variables used in this study were operationalized.

3.0 OPERATIONALIZATION OF VARIABLES

3.1 External Environment

Defining an Industry

In this research study, relationships between allocation of resources by different firms and their performances were investigated in different industries. The U.S. Government uses a standard industrial classification system (SIC) to classify different industries. The manufacturing sector has been sub-divided into 20 two-digit SIC major groups. These are also subdivided into 452 four-digit industries. For example, the chemicals and allied product firms are classified under the major SIC group 28. Within that major group, firms which manufacture industrial organic chemicals are assigned SIC Group 281. The manufacturing firms in plastics materials and resins industry are assigned a four-digit SIC code of 2821. Concentration of an industry is almost always measured in the U.S. with a three-digit SIC group or a four-digit industry (Baldwin, 1987: 151). In this research, an industry was defined based on a four-digit SIC classification of an industry (INDUS). This helped in defining different technology groups, and the firms competing directly with each other.

Industry Concentration

Once an industry was defined, we needed to operationalize a measure of that industry's market structure. An industry structure is usually operationalized by that industry's concentration (INDCON). The U.S. Government uses concentration ratio, or proportion of total value of a product accounted for by either four, or eight, or 20, or 50 largest manufacturers in a three-digit SIC group and a four-digit SIC industry. However, to assure confidentiality, a four-firm concentration (referred to as CR4) is the finest breakdown of information about industry that is available in public domain (Baldwin, 1987: 151).

Most economics and organizational researchers use CR4. This selection assumes that the four largest firms in an industry constitute an oligopolistic group, which exercises collective market power. The current theory postulates that the share of market held by the 20 or 50 largest firms is of little relevance to the state of market competition in a particular industry (Baldwin, 1987: 152).

Many researchers have selected either a CR4 of 50 percent, or a CR8 of 70 percent, as the two threshold limits for a 'high' concentration in an industry (Bain, 1951; Mann, 1966). For example, Harrigan (1981), in her studies on relationship between exit barriers and industrial structures operationalized industrial concentration measured by CR4 and CR8 measures. In the present study, a four-firm concentration factor (CR4) was calculated for each industry group. This was obtained by sorting and adding the net sales of the largest four firms in the industry (defined by a four-digit SIC code), and dividing the sum by the total sum of net sales in that industry.

3.2 Dependent Variable: Measures of Performance

An organization may have multiple strategic objectives for improving performance. Firms improve their performances as a result of selective allocations of their resources. Different organizations seek to make effective allocations of resources either to gain a competitive growth, or a higher profit margin, or to improve productivity.

The allocations of resources to different capabilities in the technology value-chain of a firm help achieve its performance objectives. However, a portfolio of technology related capabilities that helps to produce commercially successful technological innovations takes time. Firms may require up to 3 or 4 years to debug, and diffuse their technological products or processes satisfactorily into their markets at commercially viable levels (Gold, 1983). We earlier postulated that many large organizations have a stable pattern of allocation of resources reflecting their commitment to their technology competency. Typically, organizations with short-term orientations tend to evaluate their allocations of resources to complimentary competencies in technology value-chain, with conventional accounting criterion. A common accounting practice is to determine the net present value of expected future returns. These are discounted at an annual 15 to 20 per cent rate. Such short-term performance criteria overlook long-term impact of a firm's allocations of resources. For instance, the technology related resource allocations may help an organization build its distinctive competencies in the long-run. These help a firm learn, and gain their competitive advantage with highly differentiated products, higher customer satisfaction and loyalty, and therefore higher profitability (Gold & Boylan, 1975).

Often a firm's performance is empirically measured by profitability (Davis, Robinson, Pearce & Park, 1992). Performance has been assessed by researchers by using return on investments (ROI), return on assets (ROA), or return on equity (Venkatraman and Ramanujam, 1986). Profitability based measures assess how efficiently an organization is able to transform its inputs into its outputs. For investment market, a common derivative of profitability measure is the average earnings per share (EPS). Gomez-Mejia (1992) also used other stock performance measures, such as the average return on common stock, and the average annual percent change in a firm's market value.

In this research study, performance of a firm was measured by firm level profit. Performance was operationalized by two profitability (PROFT) measures. These were: net income to sales ratio in a fiscal period (NETINC), and gross profit margin to sales in a fiscal period (GRPRF).

3.3 Independent Variables: Allocations of Resources to Technology Value-Chain

In this research study, the traditional uni-variate technology competency, defined by R&D, was extended, to a multi-parametric definition of a firm's technology value-chain. This extended model was based on the premise that the technology value-chain is composed of three complimentary capabilities. Operationalization of these capabilities is discussed next.

3.3.1 Resource Allocations to Research & Development Capability

Many firms generate or acquire innovative technological knowledge through allocation of resources to their research and development capability, coupled with their technology acquisition capability.

Such technology driven organizations invest resources in their in-house R&D capability to develop their tacit knowledge base, their core technologies, or their distinctive technological competencies. These help them sustain their high performance and competitive advantages (Teece, 1986). According to Hambrick et al. (1983), "expenditures on R&D constitute an important form of non-price competition in technologically active industries."

Hoskisson and Hitt (1988), Franko (1989) and others have investigated relationship between a firm's R&D intensity (R&D per unit sales) and competitive performance.

A number of researchers have operationalized technological competency of an organization by a firm's commitment of its own resources to research & development efforts (Miller, 1988; Graves, 1988; Govindarajan, 1988). Graves (1988) used R & D intensity based on the data reported by publicly held firms on Form 10K to the Securities Exchange Commission (S.E.C.). He also used R & D expenditure per employee, in constant 1967 dollars. Govindarajan (1988) used R & D intensity based on annual sales, to operationalize Porter's (1980) competitive strategy. Miller (1989) operationalized technological innovation by calculating five year average expenditures for a firm's R & D efforts, and new product development & commercialization. These were calculated as percentages of sales. He combined the two values so obtained, to determine his "strategic content dimension." In the present study, these two variables were retained as two separate components capturing the complimentary capabilities in technology value-chain of an organization.

Furthermore, sometimes organizations decide that instead of investing resources on in-house risky R&D capability, they can acquire proven technological "knowledge" generated by other organizations. The external sources of such know-how may be a competitor, a university, or a federally supported research laboratory. By acquiring new technology in this manner, it is quite likely that an organization in a technology-driven industry, may allocate less resources to its in-house research and development capability. They may even fall below the 3 percent level defined by the National Science Foundation (National Science Foundation, 1978,1981). And still attain a superior performance. Such acquisitions were included in this research study in the firm level allocation of resources to R&D capability. Hill & Snell (1988) measured a firm's emphasis on technology competency by R&D investment per employee, instead of the R&D investment to sales ratio used by others.

While considering the overall R&D capability of an organization, different economists have distinguished between a firm's allocation of its own private resources, from the firm's use of public subsidies provided by government to do federally supported research (Bhattacharya & Mookherjee, 1986). In the present research study only allocations of organization's own resources, as reported by it to the Securities Exchange Commission (S.E.C.) were taken into account.

Based on these observations, the present cross-sectional study, used a linear scale with current dollar values, to calculate R & D resource intensity of a firm (R&D) based on its annual sales for 1993. These values were reported to S.E.C.

3.3.2 Resource Allocations to Automation & Production Engineering Capability.

This is based on an organization's allocation of resources to incorporation and execution of its innovative technological ideas into its production and engineering capabilities. This was operationalized through automation, plant and equipment engineering (APE) capability.

Some researchers operationalized an organization's commitment to develop production process capability, by measuring their managers' "perceived automation". For a 7-point Likert Scale response, they asked the question: "How automated is the technology of your operations?" (Endnote #2). On the other hand Collins et al. (1988) employed relative change in "automaticity" of a plant's manufacturing equipment over a period of eight years. They used Amber & Amber (1962) automaticity scale which "indicates the extent to which machines replace human energy" etc.

In the present research study, an organization's commitment to manufacturing capability was measured by the organization's allocation of resources to its automation, plant and engineering capability. This was operationalized by the annual net plant and equipment expenditure of a firm divided by its net sales for the same period. Values used for such resource allocations were the ones reported by each industrial organization to S.E.C. for the year 1993.

3.3.3 Resource Allocations to Market Development and Selling Capability

This is based on allocations of resources by a firm to its market development and selling capability. This helps firms profitably commercialize technologically innovative ideas generated by research and development. These technological ideas are embodied in products or processes offered to customers.

The organization's commitment to market development and diffusion of its technological innovations, showed the widest diversity in terms of the ways by which researchers operationalized this variable (Miller, 1988; Miller et al. 1988; Varadarajan, 1985; Kim & Lim, 1988). Varadarajan (1985) referred to the product innovation and distribution components of marketing mix as significant competitive strategy variables. Kim & Lim (1988) used managerial response to the organization's capabilities in the areas of product differentiation, new product development, extension of market channel, advertising, market differentiation, image building etc.

Quantitatively, some researchers operationalized market development and diffusion of technological innovation as a five-year average expenditure on new product development and commercialization expenses. These were either calculated as a percentage of sales (Miller et al., 1988) or, as percentage of sales spent on costs of initiating and implementing product-market innovations each year (Miller, 1988).

In the present study, allocation of resources to market development and selling capability was operationalized by calculating selling and general administration expenses. These were calculated as percentages of current year's net sales, and were based on values reported by an organization to S.E.C. on Form 10K.

3.3.4 Strategic Choice in Technology Resource Allocation Strategy Based on Total Technology Value-Chain

Strategic choice of an organization is based on its options in the pattern of allocation of resources to all its technology related capabilities that it chooses. A firm exercises a strategic choice in allocating its resources to building either research and development capability, or automation and production engineering capability, or market development capability. How a firm chooses this decision for allocating resources to one technology related capability over allocating its resources to another technology related capability, was the subject of investigation in this empirical research.

Summary. In this chapter, first a research model, and then hypotheses based on that model were developed. Various independent variables, dependent variables, and external environmental variables were operationalized for this research study. In the next chapter 4, research methodology and statistical analysis used for this study are explained. Research sub-population, data sources, and descriptive and inferential statistical analysis employed in this research study will be discussed.

Endnote #2:

A vigorous enforcement of U.S. Patent System is expected to discourage a larger number of U.S. firms taking advantage of the already developed technological innovations from their U.S. or foreign competitors (Johnson, 1984).

CHAPTER 4

RESEARCH METHODOLOGY & ANALYSIS

This chapter discusses how a sub-population of technology driven industries was selected for this research study. To avoid any distortions in results due to the effect of firm size, the research sub-population was restricted to medium-to-large sized publicly held firms. Various data sources used in this study are described. The statistical analyses used in this study, including descriptive and inferential analysis, are discussed with comments on multicolinearity and heteroscedasticity.

1.0 RESEARCH SUB-POPULATION

In chapters 2 and 3, the relevant literature was reviewed to define different relationships. Relationships were hypothesized for a firm's performance as related to its strategy for allocating resources to the complimentary capabilities in its technology value-chain..

These relationships were empirically investigated in this research study for a sub-population of medium to large firms in three technology driven U.S. manufacturing industries. These are: the semiconductors and related devices industry, the pharmaceutical preparations industry, and the plastics materials & synthetic resins industry. First, a brief description of how the research sub-population for this empirical study was selected.

1.1 Technology-Driven Industries in the Research Sub-Population

The National Science Foundation (NSF) has defined a technology driven organization or industry, based on the allocation of resources by the firm to its research & development efforts (NSF, 1981). According to NSF, a technology driven industry is one which spends at least 3 percent of its sales revenue on its R&D efforts. Prior to this research study, a preliminary empirical research study showed that the average ratio of allocation of resources to R & D to net sales, for firms in different technology driven industries, varied from a low of 4.0% in the plastics materials & resins industry, to a high of 9.5% in the pharmaceutical preparations industry (Gehani and Sethi, 1989). Technology driven industries and firms are characterized by rapid changes in products, processes, or services. Management of such organizations is similar in that they must continually create, develop, apply, and commercialize their technological innovations. They must also quickly adapt to competitive changes in their technologies. Based on these observations, NSF identified five groups of U.S. industries that met their criteria for technology driven industries. These groups of technology driven industries are:

1. Aircraft & missiles manufacturing industry group;
2. Electronic & communications equipment industry group;
3. Scientific and professional instruments industry group;
4. Chemicals and synthetics industry group,
5. Pharmaceutical preparations industry group.

1.2 Criterion for Excluding Certain Industry Groups From This Research

From the technology driven groups of industries listed above, the aircraft and missiles manufacturing industry group relies heavily on defense contracts from the U.S. government. Firms in these industries are therefore likely to pursue very different performance criteria. These criteria may be determined by government and public policy rather than market competition and business strategy. This was confirmed by a preliminary statistical analysis of firms in this industry group. Therefore this industry group, consisting of aircraft and missile manufacturing firms, was excluded from the present research study.

The consumer electronics and communications equipment industry group was noted to be dominated by foreign-owned manufacturers. Their allocation of resources for technology related capabilities are biased by this difference. Scientific and professional instruments industry group included a large number of small and micro-sized entrepreneurial organizations. Many of them operated as suppliers to large manufacturing firms. Their strategies for resource allocations were likely to be markedly different from the strategies for large manufacturing firms. Firms in the machine tools industry group operated the same way. These groups of industries were therefore excluded from this research study.

1.3 Criterion for Selecting Industry Groups in Research Sub-Population

Each of the remaining technology driven industry groups consisted of firms with diverse technologies. For an operationalization of strategic groups (consisting of firms competing directly with each other) we used an additional criterion for selection. Technology driven industries for this research study were selected based on primary four digit S.I.C. code of each industrial organization. The selected industries and corresponding S.I.C. codes for industries in the research sub-population of this study are given below.

1. Semiconductors & Related Devices Industry	3674
2. 2. Pharmaceutical Preparations Industry	2834
3. Plastics Materials & Synthetic Resins Industry	2821

1.4 A Brief Description of Selected Technology Driven Industries

The Semiconductors and related devices industry, defined by a primary SIC code of 3674, includes manufacturers of semiconductors and related solid-state devices. They make semiconductor diodes and stacks, such as rectifiers, integrated microcircuits, transistors, solar cells, and light-sensing and emitting semiconductor or solid-state devices. Different semiconductors and related devices have unique electronic characteristics, and usually act as brains or controllers in the electronic apparatus in which they are used. These devices are used to manufacture electronic many different goods, such as computers, home appliances, missiles and toys. This industry excludes manufacturing activities related to either integration of semiconductors, or the machines that are used to produce semiconductors.

The Pharmaceutical preparations industry, characterized by a primary 4-digit S.I.C.code 2834, includes firms primarily involved in manufacturing, or processing of drugs in the pharmaceutical preparations needed for either human or veterinary use. The majority of their products are finished in the form of tablets, capsules, vials, ointments, powders, solutions, suspensions, intended for final consumption. This industry produces products that can be classified into two important categories: ethical drugs primarily promoted to the dental, medical, or veterinary professions, and over-the-counter (OTC) drugs promoted more directly to the public. Worldwide, most ethical drugs are paid for indirectly by patient-consumers through third-party payers such as health insurance providers or government. Ethical drugs can be further categorized according to their in-patent or out-of-patent status. In-patent drugs have higher profit margins, but require high research and development and market development expenses. Many industry analysts have noted that high R&D costs in this industry must be recovered over the short duration of their exclusive patents. This is done by world-wide market development and selling efforts. For firms in this industry, patenting proprietary research and development and marketing are two primary routes to maximization of profits.

The **Plastics Materials and Synthetic Resin Industry**, defined by primary SIC code of 2821, includes firms primarily engaged in manufacturing various synthetic resins and plastics that are processed by other industries into sheets, rods, films and other products. Plastic materials are made of giant polymer molecules, with thousands of repeating molecular units. Two main classes of plastics are thermoplastics (such as polyethylene, PVC, etc.) and thermosets (such as epoxies), with the former accounting for the bulk of the industry output. They differ in their thermal properties. In general, some of the large volume commodity resins are manufactured by large, integrated companies. As some segments of the industry matured and became more competitive, prices of plastics fell, but their usage penetrated a number of metal, glass, and wood material markets.

Firms in these three industries with different industry structures were analyzed for cross-sectional comparisons of their performance and resource allocations to different technology-related capabilities. [See Endnote #3).

1.5 Publicly Held Firms

Some empirical research studies have indicated variations in resource allocation strategies due to variances in external control and the ownership characteristics of firms. To avoid these distortions, only publicly held industrial firms have been included in this research study.

1.6 Size Effect

In this research study, size of a firm was operationalized by its annual net sales. Earlier studies, including firms with very wide range of sizes (from very large organizations to micro-sized organizations), have shown distortions due to wide differences in their organizational structures. To compensate for such large variances, these studies used logarithmic transformation of firm size by net sales or number of employees (Meyer & Goes, 1988). In the present study, the research sub-population was selected by fixing a lower bound of $150 million net sales of an organization in 1993. This is equivalent to about $100 million net sales in 1990 dollars. Setting such a reference point for firm size is a standard practice in empirical studies in economics and financial management. The minimum size of firms thus selected was smaller than the smallest firm listed in Fortune 500 list but was larger than the smallest firm in the annual Business Week 1000 list. This criterion takes care of size related distortions. This criterion was also used because of our research focus on industry concentration. The industry sub-groups thus defined account for more than 90 percent of net sales or total assets in their respective industries. (See Chapter-5 for the number of firms in each industry and distribution of their descriptive statistics).

Because of commonly observed organizational size effects, the present research study also used normalized resource intensity values for unit dollar sales (that is resource allocations per unit sales) rather than using absolute or real dollar values of allocated resources.

2. DATA SOURCES

A large amount of data was needed to study resource allocation strategies in medium to large firms in different technology driven industries and then to relate these strategies to their performances. The needed information was collected first from data reported in Compustat electronic on-line database for publicly held organizations. Reliability of this information is fairly high because the data is based on information that publicly held organizations are mandated to report periodically to the Securities & Exchange Commission (S.E.C.). This information was supplemented with review and verification of information provided on federally mandated forms such as 10K, 10Q Reports and Proxy Forms for publicly owned firms. In some cases, information was verified by calling corporate offices of the firms directly. The data thus collected was matched for consistency with information in lists compiled by business publications. These secondary sources of information were chosen over alternate means of more direct collection of primary information by surveys. It was hoped that this approach will help relate and extend findings from this research study with other research studies based on secondary sources.

3.0 DATA ANALYSIS

The primary purpose of this research was to conduct exploratory research to empirically test and evaluate the current and new constructs for resource allocation strategies in technology-driven industries. The statistical analyses used in this study are focused on empirical investigation of relationships between resource allocations and firm-level performance. The research approach in this study was derived from resource-based view of strategic management.

3.1 Sample Statistics

As discussed earlier, this study was based on a sub-population of three technology driven industries with different industry structures. We therefore did not investigate "sample" statistics, or the sample-to-population validities for relationships. This would have been needed if we were generalizing sample conclusions over all low and high technology industries. On the contrary, one of the primary propositions of this study was that membership of a firm in a technology-based industry has a significant influence on its allocation of resources to complimentary capabilities in its technology value-chain.

3.2 Descriptive Statistics

A number of routines for descriptive statistical analyses provided in SPSS software package were utilized to assess and define the distinguishing characteristics of industries and firms included in this research study. This included mean, standard deviation, minimum, maximum, and sum for each variable used in this study. Descriptive statistics were obtained for the data variables as well as the variables derived from the data variables. These were then related to hypotheses postulated for this research study. The SPSS software package is a standard statistical package used for empirical research in business management and organizational studies of comparable scope. This was followed by use of inferential statistics. Firms in each industry were analyzed to estimate differences in resource allocations in industries with different concentrations. The variances of independent and dependent variables were analyzed, and investigated for significance of their differences.

3.3 Inferential Statistics

A number of different statistical techniques were used to test the hypotheses developed in this research study. These included correlation matrix analysis (at different levels of significance) for relationships between resource allocations and performance. A Three-way analysis of variance and analysis of covariance was used across resource allocations of firms in three complimentary capabilities in their technology value chain. Multivariate t-tests in MANOVA and multiple regression analysis were used to evaluate the effect on profits explained by resource allocations. Discriminant analysis helped compare relationships for high performing and low performing firms. A correlation matrix was developed to study the strategic choice set of hypotheses. Results of these and other analyses are explained and discussed in the next chapter.

3.4 Heteroscedasticity and Multi-colinearity in Analyses

Researchers conducting econometric studies using longitudinal data over extended periods, or cross-sectional studies across very diverse industries in the overall economy, are generally concerned with heteroscedasticity and multicolinearity effects. These effects bias the conclusions one can draw from these analyses. Heteroscedasticity may be observed when assumption of constant variance of the disturbances being investigated is violated. Particularly when the variances of the unexplained disturbances in dependent variables tend to increase or decrease nonlinearly with increasing values of the regressor variables. The problem of heteroscedasticity is more acute in cross-sectional data for industries spanning from agricultural, services to manufacturing sectors. For example, homoscedasticity can be generally safely assumed in studies based on aggressive time-series data, or a cross-sectional study with narrow distributions of values for different independent and dependent variables used.

In the present research study an attempt was made to check if SPSS had a statistical analysis routine to assess and report results for heteroscedasticity in the data set. One could have then reported the result of a measure of heteroscedasticity. But SPSS software does not have such a standard routine. Instead, as is a common practice used by researchers carrying out empirical investigations, we redefined our variables to attest to linearity assumption. The linearity of variances was improved by normalizing the variables used in this research. The normalized values of performance, over a mean performance value in an industry, varied over a narrow linear range. Similarly intensities of resource allocations [such as R & D intensity, market development and selling intensity etc.] were derived and used to take care of incidence of heteroscedasticity in data.

Multicolinearity was evaluated more directly in this research study. Statistical procedures such as multivariate analysis of variance and covariance (MANOVA and MANCOVA) analyzed effect of multicolinearity using one or more independent variables against two or more dependent variables. Discriminant analyses also provided detailed statistical results in variances across individual and paired variables. Wherever applicable, full statistical output reports were generated and reviewed, to detect any bias due to effects such as heteroscedasticity and multicolinearity. To the best of our understanding of these results, the research analyses used in this research study were free from any significant influences of these effects.

Endnote # 3:

After selecting firms using pre-specified criteria, their business operations were carefully reviewed. As a result of this examination, minor apriori additions were made in the selection criterion for defining an industry. It was noted that in the Plastics Materials & Synthetic Resins Industry, Dow Chemical, Eastman Chemical, Rohm & Haas, Union Carbide etc. are classified under primary SIC of 2821. On the other hand, their competitors, Monsanto, Ethyl Corp. Hoechst Celanese, are classified under a primary SIC of 2824. In some cases, such as Monsanto, the next significant business SIC was 2821. Thus the Plastics, Materials & Synthetic Resins industry was defined by combining them together.

Chapter - 5

EXPLORATORY RESULTS AND DISCUSSION

This chapter reports results obtained from statistical analyses of data for operationalized variables. Analyses in this exploratory study were based on the hypotheses proposed earlier in chapter 3. Results are summarized in exhibits presented at the end of this chapter. These are discussed in order to draw inferences.

In chapters 2 and 3, structure-based and resource-based literature sets were reviewed to develop research hypotheses for this study. Based on these, independent and dependent variables were operationalized. In the previous chapter 4, statistical analyses used in this research study were described. Tables 5.1 to 5.10, presented at the end of this chapter, provide summaries of the results of this exploratory research. Descriptive statistics and then inferential analyses are next discussed.

1.0 SIZE OF RESEARCH SUB-POPULATION

Table 5.1 indicates the number of firms in the sub-population of this research study. Three technology driven industries with different degrees of industry concentration were selected. These were the semiconductors & related devices industry, the pharmaceutical preparations industry, and the plastics materials & synthetic resins industry.

As explained earlier, these industries were defined by their primary 4-digit SIC codes, public ownership, and a size larger than $150 million net sales in 1993. The numbers of firms in these industries were: 23 in the semiconductors & related devices industry, 22 in pharmaceutical preparations industry, and 15 in the plastics materials and resins industry. Together there were 60 medium to large firms in this research sub-population. This is a large sub-population compared to many other empirical studies investigating similar research scope. For example, Mansfield's pioneering econometric studies on technology, done during the 1970s at the University of Pennsylvania were based only on ten businesses and three firms.

The National Science Foundation classifies industries as technology-driven industries based on the intensity of their allocation of resources to research and development. Average intensities of allocation of resources to R&D were over 14% for firms in pharmaceutical preparations industry, over 11% for firms in semiconductors and related devices industry and about 4% for firms in plastics materials and synthetic resins industry. All three industries in this research study exceeded the threshold limit set by the National Science Foundation. They are considered technology-driven industries.

2.0 SIGNIFICANCE OF RESEARCH SUB-POPULATION

Table 5.2 gives a summary of values of total assets, net sales, gross profits, and allocations of resources to three technology-related capabilities: the research and development, the automation plant & equipment, and the market development & selling capabilities. For each of these variables, the values of total values, means, and standard deviations are given for each technology driven industry in the research sub-population.

The three technology-driven industries combined together accounted for $192,672 million in total assets, and $192,735 million in net sales. Of this total, the pharmaceutical preparations industry accounted for the highest share of $93.9 billion net sales, or 48.7%. The semiconductor and related devices industry accounted for $45.2 billion net sales, or 23.5 % share in the research sub-population. The rest of the 27.8% of net sales of the sub-population was accounted by the plastics materials and synthetics industry.

The three technology-driven industries together accounted for $17,785 million worth research and development investments. This amounted to about 21.5% of $83 billion in resources allocated to research and development by all publicly traded U.S. firms in the same year.

The three technology-driven industries in the research sub-population also accounted for about $96.7 billion in gross profit, about $75.2 billion in automation, plant & equipment investments, and about $47.5 billion in market development and selling efforts. These were significantly large fractions of the total U.S. economy. For example, in April 1994, Fortune reported that for the Fortune 500 list, total net sales were $2,370 billion, total assets were $2,676 billion, and net profits were $62.6 billion for the previous year. These values indicated that the sub-population of this research study accounted for a significant size of total industrial sales and profits in the U.S. industry, and large share of the high-technology industries.

Individual firms in each technology driven industry were sorted by their net sales in Figures 5.3, 5.4, and 5.5. These exhibits show the distributions of firm size in the three technology-driven industries. They illustrate the different degrees of concentration in these different technology-driven industries. In the case of the semiconductors and related devices industry, the three largest firms (Motorola, Texas Instruments and Intel) dominated the industry. This group of large firms was followed by a number of much smaller firms. On the other hand, the pharmaceutical preparations industry, illustrated in Figure 5.4, showed a gradual decline in size. Size declined from large firms such as Bristal Meyers, Merck, Baxter International, etc., to Syntax, about 15th in size by net sales in this industry. The plastics materials and synthetic resins industry showed a distribution of firms by net sales that fell somewhat between the highly concentrated distribution of the semiconductors and related devices industry and the much less concentrated pharmaceutical preparations industry. The size distribution and concentration of industries are discussed next.

3.0 CONCENTRATION IN TECHNOLOGY DRIVEN INDUSTRIES

We discussed earlier that industry structure is usually measured by four firm concentration factors. This varied in this research study from a high concentration in the semiconductors and related devices industry to a low concentration in pharmaceutical preparations industry. Table 5.6 gives four concentration index factors (CR1, CR2, CR4, and CR8) for the three technology driven industries under investigation in this study. These concentration factors were calculated based on shares of the one largest firm, the two largest firms, the four largest firms, and the eight largest firms in each of the three industries respectively. These are commonly used measures of industry concentration, the CR4 index being used in most of the empirical research studies.

The semiconductors and related devices industry had a CR4 value of 80.24%, based on a four-digit primary SIC code. This was a very high industry concentration compared to the 50% threshold limit for CR4 index commonly used by researchers for highly concentrated industries. On the other hand, the pharmaceutical preparations industry had a much lower concentration, with a CR4 value of 42.34%. The plastics materials and synthetic resins industry had a medium to high concentration, with a CR4 value of 69.95%, falling in between the other two technology driven industries. It was not as low as we had originally anticipated.

A closer examination of values of CR8 concentration factor index (based on 8-firm concentration values) indicated that CR8 made it harder to distinguish differences in the concentrations of the semiconductors and related devices industry, and the plastics materials & synthetic resins industry. For the two industries, CR8 values converged to about 90% concentration. On the other hand, CR4 values for the semiconductors and related devices industry and the plastics materials & synthetics were clearly distinguishable at 80.24% and 69.95% respectively.

4.0 PATTERNS OF AVERAGE RESOURCE ALLOCATIONS IN DIFFERENT TECHNOLOGY DRIVEN INDUSTRIES

Table 5.7 gives the pattern of average resource allocation intensities for firms in each technology driven industry. Their pattern of resource allocations included the intensities of allocations of resources by each firm in current dollars to its technology value chain comprising of research & development capability (R&D), automation plant & equipment capability (APE), and market development & selling capability (MDS). Total and mean amounts of resource allocations were presented earlier in Table 5.2.

4.1 Research & Development Capability

On average, a firm in the semiconductors & related devices industry, with very high CR4 concentration, allocated $205 million to research and development. This was comparable, but lower than $242 million allocated on average to research & development by firms in plastics materials & synthetic resins industry. Firms in the pharmaceutical preparations industry with a low CR4 concentration, on average allocated $481 million to research and development. For firms in the highly dynamic semiconductor industry, we expected a far higher extent of allocation of resources to R&D, compared to firms in other less concentrated industries.

When adjusted for constant net sales, the average resource allocation intensities to research and development capability were 14.39% for the pharmaceutical preparations industry, 11.19% for the semiconductors & related devices industry, and only 3.98% for the plastics materials and synthetics industry. One partial explanation of these results is that only a few firms in the semiconductors & related devices industry carried out most of the research and development effort in that industry. A large number of other firms in this technology-driven industry leveraged their own technologies based on the technologies developed elsewhere (i.e., by their larger rivals). Firms such as Texas Instruments willingly licensed their technologies to others. An alternate explanation could be that much of the allocation of resources to R&D competency in the semiconductor & related devices industry may have been subsidized by the U.S. Department of Defense or other agencies in the U.S. government. Such funding, not included in our analysis, could depress the mean values of resource allocations to research and development mentioned earlier.

4.2 Resource Allocations to Complimentary Market Development & Selling Capability

Firms in the pharmaceutical preparations industry (with a low concentration index) allocated on average $1,345 million resources to market development and selling capability. This was much higher than the corresponding resource allocations to market development & selling capability of $386 million in the highly concentrated semiconductors and related devices industry, and $537 million for the plastics materials & synthetics industry.

When controlled for the size of a firm, the resource allocation intensities for market development and selling capability was the highest (at 33.77%) among firms in the low concentration pharmaceutical preparations industry. This is almost twice as much as the 18.86% for the highly concentrated semiconductors & related industry. This compares to a low concentration of 12.61% for firms in the plastics materials & synthetics industry.

In a low concentration industry, marketplace plays a more significant role than the competitors' actions. In a high concentration oligopolistic industry, different firms' actions are far more interdependent. Firms in the pharmaceutical preparations industry must also quickly recover their high intensity of resource allocations to research and development by investing in complimentary market development and selling capabilities.

4.3. Mean Resource Allocations to Automation & Plant Capability

Firms in the highly concentrated semiconductors and related industry allocated the least amount of resources, on average $713 million, to this complimentary capability in their technology value-chain. The corresponding average resource allocations to automation and plant equipment capability were $1,492 million for firms in the low concentration pharmaceutical preparations industry, and the highest of $1,678 million for firms in the plastics materials and synthetics industry.

When controlled for firm size, the average intensity of resource allocation by firms to this complimentary capability in their technology value-chain was the highest (at 42.13%) for the plastics materials & synthetics industry, and the lowest (at 32.43%) for firms in the highly concentrated semiconductors & related industry. In the low concentrated pharmaceutical preparations industry, the intensity of allocation of resources to this complimentary capability was an intermediate value of 38.14%.

These descriptive statistical results generally supported our hypothesized understanding of resource allocations to complimentary capabilities in technology value chains of firms in technology driven industries. Above results confirmed that firms in different technology-driven industries pursue strategies with different patterns of the allocation of resources to their technology value-chains. On average, firms in the pharmaceuticals preparations industry, with low degree of industry concentration, allocated the highest resource intensities to build their complimentary market development and selling capabilities. This was pursued side by side with their high intensity of resource allocations to their research and development capability. On the other hand, firms in the plastics materials and synthetics industries showed a very different resource allocation strategy. These firms, on average, had the highest resource allocation intensity for automation plant and equipment capability. They had the lowest resource allocation intensity for research and development, and market development and selling capabilities.

The hypothesized relationships between the resource allocation and the performance of firms, however, must next be tested for firm-to-firm variations in each technology-driven industries.

5.0 RELATIONSHIPS BETWEEN RESOURCE ALLOCATIONS TO TECHNOLOGY VALUE-CHAIN AND PERFORMANCES OF FIRMS

Tables 5.8 and 5.9 show the results of a correlation matrix analysis and a stepwise multiple regression analysis, described in chapter 4. Correlation coefficients summarized in Table 5.8 confirmed that for firms in the semiconductor and related devices industry, a moderately high significant relationship prevailed between gross profit of firms and their resource allocation intensities to research and development capability. The correlation coefficient was 0.4906 at a 2-tailed significance level less than or equal to a chance probability of 0.05 (or 0.95 significance level). For firms in this industry, which had a very high degree of industry concentration, performance measured by gross profit did not show any other significant relationship with a firm's allocation of resources to other complimentary capabilities in technology value-chain. When performance of firms was measured by net income, no significant correlation was observed with resource allocation intensities.

For firms in the pharmaceutical preparations industry with a low degree of industry concentration, a very strong correlation was observed between the performance of firms measured by gross profit, and their intensities of resource allocation to market development and selling capability. The correlation coefficient was 0.5996 at a two-tailed significance level (of 0.99) corresponding to chance probability of less than or equal to 0.01. Beside this strong co-relationship, a fairly strong correlation coefficient of 0.5045 was also observed between gross profit and intensities of resource allocations to their research and development capability for these firms.

This result empirically confirmed what other researchers had qualitatively speculated (as discussed in previous chapter) for firms in the pharmaceuticals preparations industry. That pharmaceutical firms try to maximize their profitability by two routes: patenting of proprietary know-how produced by their research and development capability and widespread market development and penetration. This research study provided specific empirical evidence for such conjectures. It may be noted that when performance was measured by net income, however, no such significant correlation effects were observed.

Finally, in the case of firms in the plastics materials and synthetics industry, similar significant correlations were obtained between gross profit performance and the intensity of resource allocations to market development and selling as well as research and development capability. We note that for firms in the plastics materials and synthetic resins industry, even though the mean intensities of resource allocations to research and development capability and complimentary market development and selling capability were the lowest, the performance of firms in plastics industry improved with higher allocations of resources to these two technology value-chain capabilities. On the other hand, even though mean intensity of resource allocation to automation plant and equipment capability was the highest for firms in the plastics materials and synthetics industry, their performances did not improve significantly with increase in their intensities of allocation of resources to this complimentary capability.

In Exhibit 5.9, a stepwise multiple regression was used to identify the most significant regressors for the performance of firms measured by gross profit. In the case of firms in the semiconductors and related devices industry, only intensity of resource allocation to research and development was entered to give a moderately significant relationship. The gross profit performance of firms in this industry was explained by the expression, GRPRF = 28.075 + 1.213 [R&D], with a multiple R value of 0.4906, and a moderate significance F value corresponding to a chance probability of 0.0239.

For firms in the pharmaceutical preparations industry, a similar stepwise multiple regression produced the expression: GRPRF = 31.040 + 1.042 [MDS]. This regression expression had a higher multiple R value of 0.6329, and a much stronger significance F value of 0.0016. As postulated earlier, in the pharmaceuticals preparations industry with low degree of industry concentration, profit performance of firms was more significantly regressed by resource allocations to market development and selling capability instead of resource allocations to research and development, observed in the case of firms in the highly concentrated semiconductors and related devices industry.

Finally, in the case of firms in the plastics materials and synthetics industry, performance measured by gross performance was explained by the step-1 regression equation: GRPRF = 10.587 + 3.583 [R&D], explaining a very high variance of gross performance, with multiple R of 0.8775, and a very high significance F value of 0.0002. Thus, even though the mean intensity of allocation of resources to research and development was relatively low in the case of plastics firms (out of the three technology driven industries), their profit performance improved with increase in allocation of resources to research and development. Furthermore, unlike in the case of the other two technology driven industries, for firms in the plastics materials and synthetics industry with a moderate degree of industry concentration, a second regressing variable, resource allocation intensity to market development and selling capability, was added in step-2 of the stepwise multiple regression procedure. These two variables, together explained most of the variance of gross profit performance of these firms with a significance F chance probability of close to 0.0000 (or a significance better than 0.9999).

So far we reported aggregate results of relationships tested for each technology-driven industry. Next we tested the postulated hypotheses, discriminating resource allocation patterns in high performing and low performing firms.

6.0 TESTING OF HYPOTHESES

With the above mentioned results of descriptive statistics and some inferential analyses, we gained some insights into the resource allocation patterns of firms in technology-driven industries. We were next ready to test the hypotheses postulated in chapter 3. To test these hypotheses, discriminant analyses were employed to test and discriminate between high performing and low performing technology-driven firms. To do this, values of intensities of resource allocations to three technology value-chain capabilities and performances of individual firms were calculated relative to their respective means. Thus for example, two groups of high performing and low performing firms were formed. Results of

SPSS Discriminant analysis are summarized in Table 5.10 and will be discussed next.

Hypothesis - 1 postulated that in an industry with a high concentration (such as the semiconductor and related devices industry with a very high CR4 concentration of 80.24%), the high performing firms allocate resources more intensely to their research and development intensity, compared to low performing firms.

The results summarized in Table 5.10 show that this hypothesis passed with a very high significance level. High performing firms had a mean intensity of allocation of resources of 14.126% (with standard deviation of 4.371) for research and development capability. This was significantly higher than the mean intensity of resource allocation to research and development capability of 8.527% (with standard deviation of 3.588) for low performing firms, in the same semiconductors and related devices industry.

It was interesting to note that intensities of allocations of resources to complimentary market development and selling capability, or automation plant and equipment capability did not discriminate significantly between high performing and low performing firms.

Hypothesis 2 postulated that in an industry with low concentration (such as the pharmaceuticals preparations industry, with four-firm concentration factor of 42.34%), the high performing firms allocate resources more intensely to market development and selling capability, compared to the low performing firms.

The summary of results in Table 5.10 show that this hypothesis also passed, with a moderate significance level corresponding to a chance probability of 0.0492. High performing firms in the pharmaceutical preparations industry had mean resource allocation intensity of 36.648% (with standard deviation of 6.489) for market development and selling capability compared to a corresponding mean of only 28.906% (with standard deviation of 10.985) for low performing firms in this industry.

Furthermore, for firms in the pharmaceutical preparations industry, intensities of resources allocated to other capabilities in technology value chain (such as research and development capability or automation and plant equipment capability) did not discriminate between the high performing pharmaceutical firms and low performing pharmaceutical firms. We also noted that the total industry-wide mean and the mean of resource allocation intensity to research and development capability for high performing firms in the pharmaceuticals preparations industry were higher than the corresponding values for the firms in semiconductors and related devices industry.

Finally, in hypothesis 3 we postulated that an industry with moderate concentration (in the present study we used plastics materials and synthetics industry with a four-firm concentration factor of 69.95%), high performing firms allocate resources more intensely to this automation and plant engineering capability compared to low performing firms.

The results summarized in Table 5.10 show that this hypothesis failed to hold true. The high performing firms and low performing firms in the plastics materials and synthetics resins industry did not discriminate based on their intensities of resource allocations to the automation, plant, and equipment capability. On the contrary, the low performing firms in the plastics materials and synthetics industry had a higher mean intensity of 49.129%

(and standard deviation of 20.649), compared to a lower mean intensity of 43.480% (and a standard deviation of 12.226) for the high performing firms in the same industry. It seemed that a higher capital intensity, represented by more intense allocation of resources to automation, plant, and equipment capability, dampened the profit performance of firms in this industry with moderate concentration. This anomaly has been discussed in a later section.

Furthermore, high performing and low performing firms in the plastics materials and synthetics industry, discriminated based on their intensities of the allocation of resources to research and development capability, as well as the complimentary market development and selling capability. This discriminating effect seemed like a hybrid of the discriminating effects observed for firms in the semiconductors and related devices industry and pharmaceuticals preparations industry.

Like firms in the semiconductors and related devices industry, high performing firms in the plastics materials and synthetic resins industry invested more intensely in their research and development capabilities (with a mean of 5.248% and standard deviation of 2.542, compared to a mean of only 2.707% and standard deviation of 1.227 in low performing firms). This discrimination held at a significance level corresponding to a chance probability of 0.0520. Furthermore, like firms in the pharmaceutical preparations industry, high performing firms in the plastics materials and synthetic resins industry invested more intensely in their market development and selling capability (a mean of 18.477% and standard deviation of 3.982 for the former, compared to a mean of 7.580% and standard deviation of 3.148 for the latter). Firms in the plastics industry showed a 'mixed effect' rather than the 'different effect' postulated by Hypothesis 3.

7.0 DISCUSSION OF RESULTS

Results reported earlier clearly demonstrated that for firms in technology-driven industries, the allocation of resources to technology competency played a significant role in their profit performance. Furthermore, technology competency of such firms must be extended beyond their research and development capability to a technology value-chain. The allocation of resources to the complimentary capabilities in technology value-chain (such as market development and selling capability and automation and plant engineering capability) must be included in the operationalization of technology competency of firms in technology-driven industries.

It was observed that in the highly concentrated industries, such as the semiconductors and related devices industry, higher performing firms allocated their resources more intensely to their research and development capability. The dominating firms in oligopolistic markets compete inter-dependently and sought Ricardian rents with unique and proprietary knowledge based resources. In industries with low concentrations, higher performing firms relied on allocating resources more intensely to their market development and selling capability. This helped these firms learn more about their customers' changing preferences. Knowledge thus gained corresponds to Miller and Shamsie's (1996) knowledge based resources for gaining sustainable advantage.

On the other hand firms in industries with moderate concentration, such as in plastics materials and synthetic resins, invested higher resources, on average, to their automation and plant engineering capability, than firms in either low concentration or very high concentration industries. Such allocations of resources did not have a significant impact on the profit performance of these firms. This resulted in failed hypothesis 3, but confirmed the observations made by the MIT Commission on Industrial Productivity. The Commission noted that U.S. managers tend to pursue a short-term strategy, and do not allocate sufficient resources to building long-term manufacturing or flexible process capabilities of their firms.

In another study, the Boston-based Strategic Planning Institute, in a detailed empirical research of their subscribing firms, reported that a high capital intensity can upset the (profitability) apple-cart of a firm (Buzzell and Gale, 1987: 135). They noted that capital investment to sales intensity and return on investments were negatively related. They tested the relationship between increase in capital intensity and profit margins on sales. But their returns on sales also declined with increased capital investment.

Table 5.11 shows results of a discriminant function analysis carried out by individual resource allocation variables. This table confirms the results of previous table 5.11 by a stepwise discriminant function analysis. Low values of the F statistic discontinued the computation of percent classification by the selected disciminant function.

The results confirm our hypothesis for firms in the semiconductors & related devices industry. Their resource allocation to research and development discriminated between high performance and low performance. In the case of the hypothesis for the pharmaceuticals preparations industry, resource allocation to market development and selling discriminated the most between high performing and low performing firms and classified over 78% of the firms correctly. But resource allocation to research and development also explained a smaller but substantial fraction of the performance-based classification. However, for the plastics materials and synthetics resins industry, the results did not agree with our hypothesis. In fact, as stated earlier, for none of the three technology-driven industries, allocation of resources to automation and plant equipment helped classify the firms correctly by their performance. In all the three industry cases, the level of the F statistic was so insufficient that SPSS discontinued further computation from that point onwards. Instead, allocation of resources to market development and selling seemed to play a significant role in correctly classifying high performing and low performing firms in the plastics materials & synthetics industry.

Table 5.11 shows the results of a second series of discriminant function analysis. This was performed by individual resource allocation variables. This table confirmed the results of previous table 5.10 obtained by step-wise discriminant function analysis. In some instances, low values of F statistic discontinue the computation of percent classification by the selected discriminant function.

The results confirmed our hypothesis for firms in the semiconductors & related devices industry. Their resource allocation to research and development discriminated between high performance and low performance. In the case of hypothesis for the pharmaceuticals preparations industry, resource allocation to market development and selling discriminated the most between the high performing and the low performing firms. This classified over 78% of the firms correctly. But resource allocation to research and development also explained a smaller but substantial fraction of the performance-based classification.

For the plastics materials and synthetics resins industry, the results did not agree with our hypothesis. We had postulated that resource allocations to automation and plant equipment competency discriminates high performing firms from low performing firms in this industry. In fact, as stated earlier, for none of the three technology driven industries, firms' allocation of resources to automation and plant equipment helped classify the firms correctly by their performance. In all the three industries, the level of the F statistic was not sufficient for SPSS to continue further computation. Instead, allocation of resources to market development and selling had a more significant role in correctly classifying high performing and low performing firms in the plastics materials & synthetics industry.

In summary, this empirical research highlighted the significance and impact of complimentary capabilities in the technology value-chain of a firm competing in technology-driven industries. These complimentary capabilities in the technology value-chain augmented the impact of the allocation of resources to research and development capability on profit performance of technology-driven firms. The significance of allocation of resources to different capabilities in the technology value-chain of a firm varied from one industry to another depending on their concentration and intensity of rivalry. Limitations of this research study and implications for future research are discussed in chapter 6.

TABLE - 5.1

RESEARCH SUB-POPULATION FOR STUDY OF RESOURCE ALLOCATION STRATEGIES IN TECHNOLOGY-DRIVEN INDUSTRIES

Industry	SIC	n
1 Semiconductors & Related Devices	3674	23
2 Pharmaceutical Preparations	2834	22
3 Plastics Materials & Synthetic Resins	2821	15
	Total N =	60

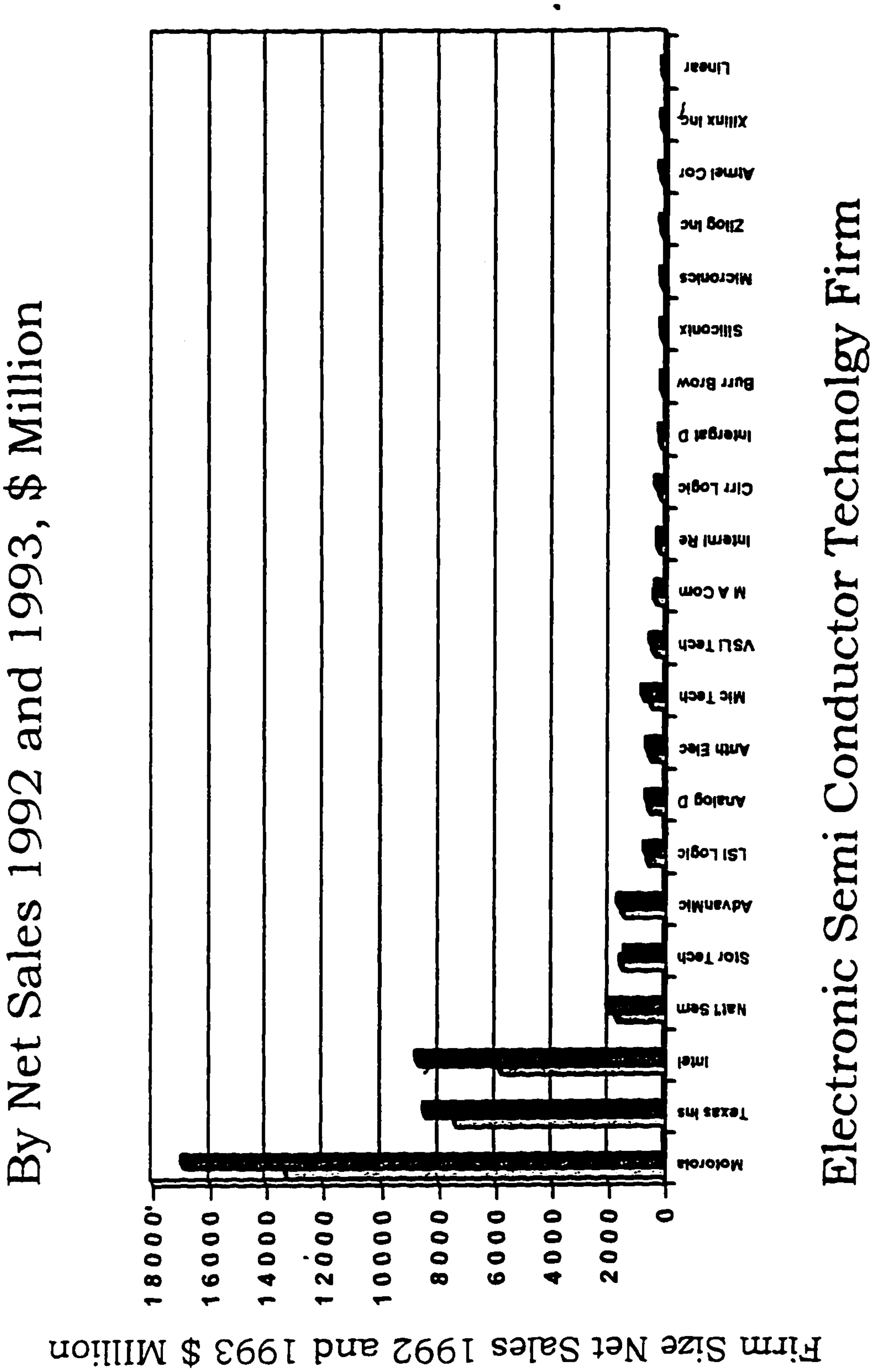
TABLE 5.2

SIZE AND SIGNIFICANCE OF RESEARCH SUB-POPULATION

			SRD	PP	PMS
1.	Total Assets:				
	Total	$M	41,511	113,428	37,733
	Average	$M	1,887	4,932	2,516
	Std. Dev.		3,655	4,940	2,790
2.	Net Sales:				
	Total	$M	45,215	93,918	53,610
	Average	$M	2,055	4,083	3,574
	Std. Dev.		4,119	3,707	4,661
3.	Gross Profit				
	Total	$M	18,573	62,338	15,822
	Average	$M	844	2,710	1,055
	Std. Dev.		1,765	2.515	1,586
4.	Research & Development				
	Total	$M	4,308	10,572	2,905
	Average	$M	205	481	242
	Std. Dev.		380	373	373
5.	Automation Plant & Equipment				
	Total	$M	15,681	34,318	25,168
	Average	$M	713	1,492	1,678
	Std. Dev.		1,418	1,405	2,223
6.	Market Development & Selling				
	Total	$M	8,480	30,923	8,049
	Average	$M	386	1,345	537
	Std. Dev.		848	1,214	799

Note:
SRD: semiconductors and related devices industry,
PP: pharmaceutical preparations industry;
PMS: plastics materials and synthetic resins industry.

FIGURE 5.3


By Net Sales 1992 and 1993, $ Million
Electronic Semi Conductor Technolgy Firm
Firm Size Net Sales 1992 and 1993 $ Million
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Motorola
Texas Ins
Intel
Nat'l Sem
Slor Tech
AdvanMic
LSI Logic
Analog D
Anth Elec
Mic Tech
VSLI Tech
M A Com
Internl Re
Cirr Logic
Intergal D
Burr Brow
Siliconix
Micronics
Zilog Inc
Atmel Cor
Xilinx Inc
Linear

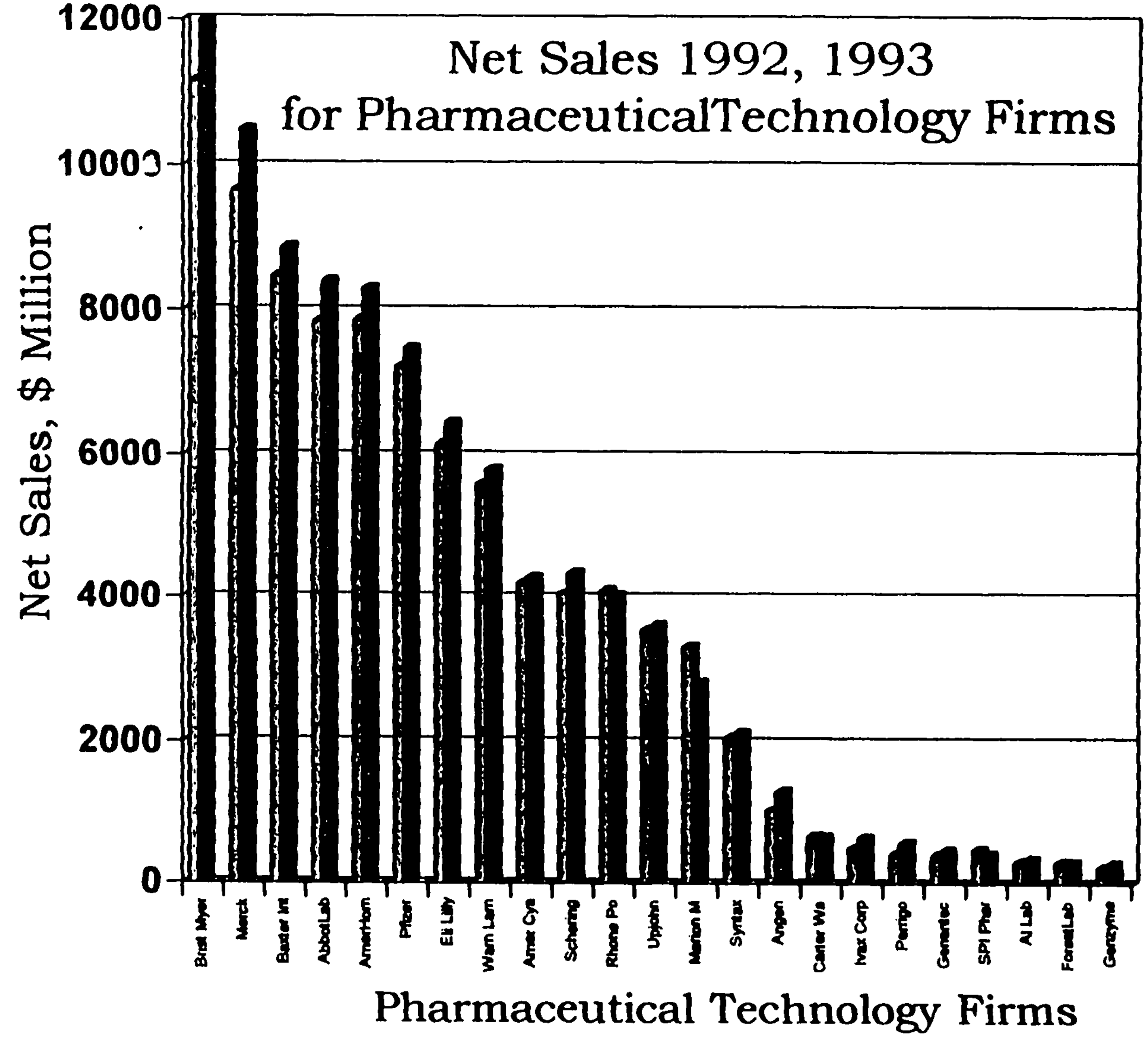

Net Sales 1992, 1993
for PharmaceuticalTechnology Firms
Net Sales, $ Million
12000
10000
8000
6000
4000
2000
0
Brstl Myer
Merck
Baxter Int
AbbotLab
AmerHom
Pfizer
Eli Lilly
Warn Lam
Amer Cya
Schering
Rhone Po
Upjohn
Marion M
Syntax
Amgen
Carter Wa
Ivax Corp
Perrigo
Genentec
SPI Phar
Al Lab
ForestLab
Genzyme
Pharmaceutical Technology Firms

FIGURE 5.4

FIGURE 5.5

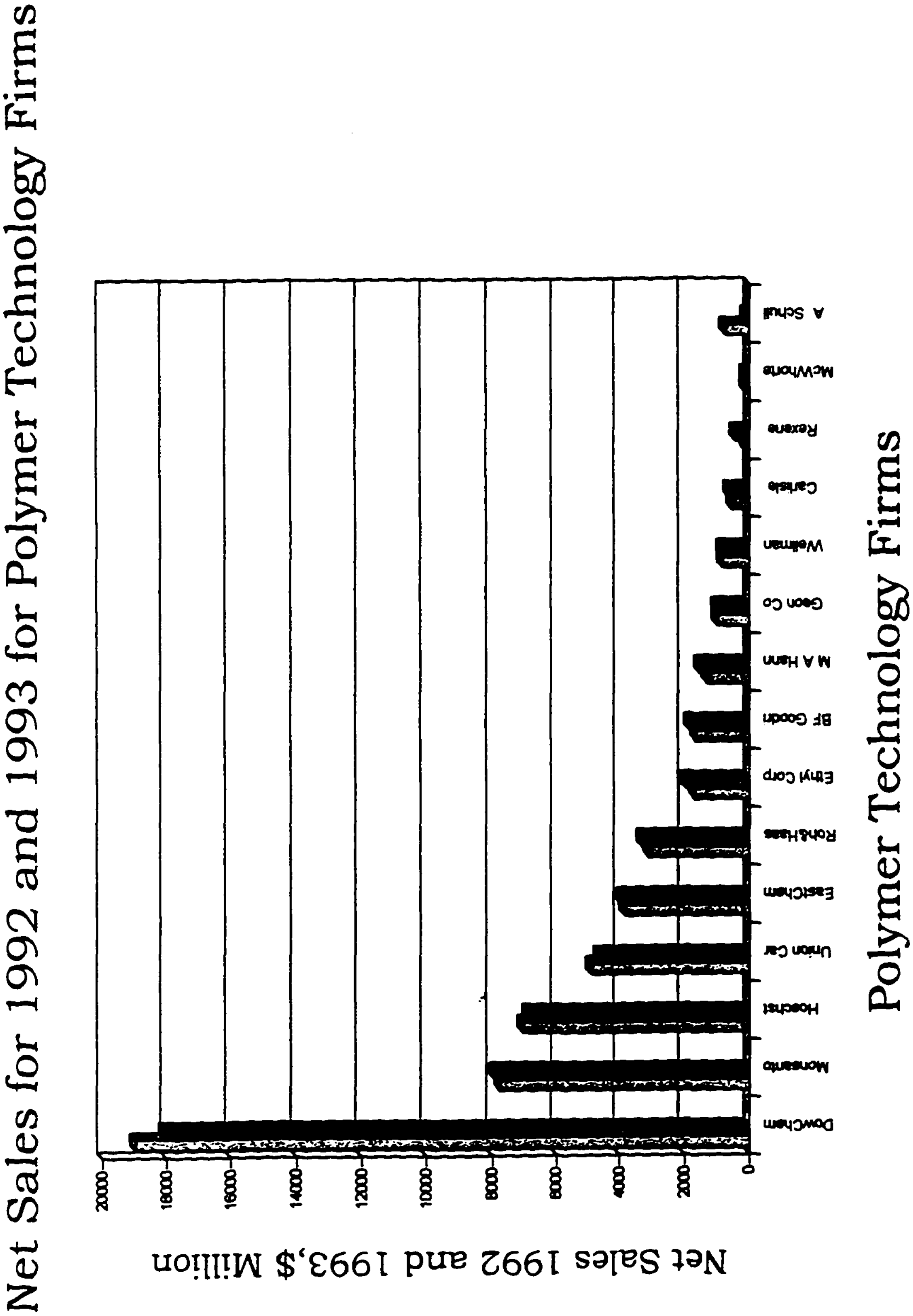

Net Sales for 1992 and 1993 for Polymer Technology Firms
Net Sales 1992 and 1993,$ Million
Polymer Technology Firms
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
DowChem
Monsanto
Hoechst
Union Car
EastChem
Ethyl Corp
Geon Co
Wellman
Carlisle
Rexene
A Schull

TABLE 5.6

CONCENTRATION FACTORS FOR TECHNOLOGY DRIVEN INDUSTRIES

Concentration Factor		SRD	PP	PMS
One-firm	CR1	37.52%	12.76%	33.69%
Two-firm	CR2	56.37%	23.94%	48.43%
Four-firm	CR4	80.24%	42.34%	69.95%
Eight-firm	CR8	90.42%	72.19%	90.33%

SRD: Semiconductors & Related Devices Industry
PP: Pharmaceutical Preparations Industry
PMS: Plastics Materials & Synthetic Resins Industry

TABLE 5.7

PATTERNS OF RESOURCE ALLOCATION INTENSITIES IN TECHNOLOGY VALUE-CHAINS IN DIFFERENT INDUSTRIES

	SRD	PP	PMS
1. Four-firm Concentration	80.24%	42.34%	69.95%
2. Research & Development			
Average	11.19	14.39	3.98
Standard Deviation	4.82	13.63	2.32
3. Automation Plant & Equipment			
Average	32.43	38.14	42.13
Standard Deviation	15.83	20.18	18.75
4. Market Development & Selling			
Average	18.86	33.77	12.61
Standard Deviation	6.52	8.79	6.00

SRD: Semiconductors & Related Devices Industry
PP: Pharmaceutical Preparations Industry
PMS: Plastics Materials & Synthetic Resins Industry

TABLE 5.8

CORRELATION COEFFICIENTS FOR RELATIONSHIPS BETWEEN RESOURCE ALLOCATIONS AND PERFORMANCES OF FIRMS IN TECHNOLOGY - DRIVEN INDUSTRIES

	1 R&D	2 APE	3 MDS	4 GRPRF	5 NETINC
A. Semiconductors & Related Devices Industry					
1. R&D	1.0000				
2. APE	0.1453	1.0000			
3. MDS	-0.0044	0.0708	1.0000		
4. GRPRF	0.4906*	0.2494	0.1540	1.0000	
5. NETINC	0.0716	0.0868	-0.4604*	0.7158**	1.0000
B. Pharmaceutical Preparations Industry					
1. R&D	1.0000				
2. APE	0.8713**	1.0000			
3. MDS	0.3331	0.0937	1.0000		
4. GRPRF	0.5045*	0.3571	0.5996**	1.0000	
5. NETINC	0.0055	-0.1001	-0.0357	0.4263*	1.0000
C. Plastics Materials & Synthetic Resins Industry					
1. R&D	1.0000				
2. APE	0.1556	1.0000			
3. MDS	0.6272*	-0.0489	1.0000		
4. GRPRF	0.8775**	0.0992	0.8305**	1.0000	
5. NETINC	0.2686	-0.4671	0.4931	0.4604	1.0000

R&D : Research and development intensity
APE : Automation, Plant & Equipment intensity
MDS: Market development and selling intensity
GRPRF: Gross profit intensity
NETINC: Net Income intensity
* - Significance LE .05; ** - Significance LE .01

TABLE 5.9

RESULTS OF STEPWISE MULTIPLE REGRESSION ANALYSIS OF PERFORMANCE OF FIRMS AND THEIR RESOURCE ALLOCATION INTENSITIES

	R	Sig. F
1. Semiconductor and Related Devices Industry		
Step-1 GRPRF = 28.075 + 1.213 [R&D]	0.4906	0.0239
2. Pharmaceutical Preparations Industry		
Step-1 GRPRF = 31.040 + 1.042 [MDS]	0.6329	0.0016
3. Plastics Materials & Synthetic Resins Industry		
Step-1 GRPRF = 10.587 + 3.583 [R&D]	0.8775	0.0002
Step-2 GRPRF = 6.678 + 0.663 [MDS] + 2.391 [R&D]	0.9494	0.0000

TABLE 5.10

RESOURCE ALLOCATIONS AND PERFORMANCE OF FIRMS

		R&D	APE	MDS
1. Semiconductors & Related Devices Industry				
High Performing	**- mean**	14.126	33.552	19.277
	- std. dev.	4.371	15.550	5.784
Low Performing	**- mean**	8.527	34.106	19.120
	- std. dev.	3.588	14.700	7.362
Total	**- mean**	11.193	33.843	19.195
	- std. dev.	4.821	14.729	6.493
Wilks' Lambda		0.6469	0.9996	0.9998
F-Statistic		10.37	0.0070	0.0029
Significance		0.0045	0.9340	0.9572
2. Pharmaceutical Preparations Industry				
High Performing	**- mean**	16.947	41.278	36.648
	- std. dev.	14.526	22.140	6.489
Low Performing	**- mean**	9.910	33.048	28.906
	- std. dev.	11.392	17.858	10.985
Total	**- mean**	14.388	38.285	33.833
	- std. dev.	13.634	20.644	8.990
Wilks' Lambda		0.9354	0.9615	0.8202
F-Statistic		1.381	0.8014	4.384
Significance		0.2538	0.3813	0.0492
3. Plastics Materials & Synthetic Resins Industry				
High Performing	**- mean**	5.248	43.480	18.477
	- std. dev.	2.542	12.226	3.982
Low Performing	**- mean**	2.707	49.129	7.580
	- std. dev.	1.227	20.649	3.148
Total	**- mean**	3.977	46.304	13.029
	- std. dev.	2.320	16.446	6.640
Wilks' Lambda		0.6728	0.9678	0.2656
F-Statistic		4.863	0.332	27.65
Significance		0.0520	0.5770	0.0004

TABLE 5.11

RESULTS OF DISCRIMINANT FUNCTION ANALYSIS: PERFORMANCE OF FIRMS BY RESOURCE ALLOCATIONS

INDUSTRY AND RESOURCE	n	Wilks's Lambda	F	Percent Classified
1. Semiconductors & Related Devices Industry				
Research & deve.	21	0.6469*	10.37	76.19%
Auto. plant & equip.	22	0.9956	0.088	n.s.
Market dev. & selling	22	0.9965	0.070	n.s.
2. Pharmaceutical Preparations Industry				
Research & deve.	22	0.9354*	1.381	59.09
Auto. plant & equip.	22	0.9615	0.801	n.s.
Market dev. & selling	23	0.8260*	4.425	78.26
3. Plastics Materials & Synthetic Resins Industry				
Research & deve.	12	0.6728	4.863	66.67
Auto. plant & equip.	15	0.9963	0.048	n.s.
Market dev. & selling	15	0.3170	28.01	100.0

NOTE:

n.s.: F level or tolerance not sufficient for computation.

CHAPTER 6

IMPLICATIONS FOR FUTURE RESEARCH AND LIMITATIONS OF THIS STUDY

This chapter discusses some ways by which the current research can be extended further. It also points out the underlying limitations of this research study.

This research study identified a number of findings that facilitated a better understanding of strategic management of firms in technology-driven industries.

1. In the past, managers and researchers limited their attention to the allocations of resources by firms to their research and development capability. Findings from this study illustrate how the allocation of resources to research and development capabilities must be complimented with the allocation of resources to complimentary capabilities in the technology value-adding chain of such firms.

2. In the past, researchers generalized the significance of the allocation of resources to research and development (or other capabilities) on performance to many different industries. Findings

from this research illustrated that different industries are characterized by their different concentrations. And therefore, firms in different technology driven industries must carefully exercise their strategic choices in allocating resources to different capabilities in their technology value-chain.

3. We found that there was a fit between the external environment, operationalized by industry structure and concentration, and resource allocation strategies. We confirmed and demonstrated how the resource-based view can be extended to include the influence of the contextual environment on the effectiveness of resources in gaining superior performance.

4. We empirically supported the qualitative conjectures of previous researchers that knowledge based resources (as in research and development capability and market development and selling capability) have different impact on performance than the property based resources, as in automation, plant and equipment capability.

5. We must caution that no causality must be inferred from the cross-sectional investigation of allocation of resources in firms in different industries. Thus, one can not interpret from this study

or from the literature whether the organization's allocation of resources to its research & development efforts results in improved performance. Or conversely, one can not interpret from this study that the improved performance of an organization leads to higher resource allocations to research & development capability. Even if a strong correlation was observed between the two, one could not imply causality. We have to "revert to some form of longitudinal theory and perhaps common sense, and not the statistics, to determine which came first" (Parisi, 1989). In a different preliminary study, we used the means for over two years for the allocations of resources and performances of firms, as used by other researchers. But this contributed more noise in the analysis, rather than making the relationships more clear.

6. In a cross-sectional study, the temporal lag for effects of resource allocations on performance of an organization can not be captured. This requires a longitudinal research design. In a future research study longitudinal effects can be explored by introducing time lags, or by using time series.

7. In this study, the technology-driven industries and the directly competing firms were defined by a four digit primary SIC

code for firms. These firms are, however, diversified with multiple technologies. A more detailed five digit SIC code (based on products), may provide finer texture of investigation, eliminating the effect of diversification on profit performance of firms. This will require a proprietary access and the permission of relevant firms.

8. This study used a 'strategic content ' approach. Some of the process issues in the management of technological innovations can be better understood by using in-situ process investigations and proprietary access into the investigated firms. Some of the process-related issues in concurrent product development and the time-based management of technology have been presented elsewhere.

9. Ideally the "content view" of role and significance of technology resource allocation strategies on competitive performance of a firm (investigated in this study) should be supplemented with a 'process view' of technology selection and innovation assessment processes. This would help integrate the technological core and the administrative sheath involved in management of a technology-driven organization. The relationship between these two still remains to be empirically investigated. This

may be best accomplished by a more focused sample population or by case studies of a few firms with the active participation of the strategic decision-makers involved.

10. Overall, this empirical research study tested the resource-based view of strategy and extended it by introducing the influence of industry structure on resources.

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