ECONOMIC PERFORMANCE OF PRODUCT AND PROCESS FIRMS

FOCUS AND DIVERSIFICATION IN THE AUTOMOTIVE SUPPLIER INDUSTRY

by Patrick P. Steinemann

Dipl. nat. ETH (1996), Swiss Federal Institute of Technology, Zurich, Switzerland

Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Technology, Management and Policy
at the
Massachusetts Institute of Technology

June 2000

Signature of Author ....
Technology, Management and Policy Program
Engineering Systems Division
April 24, 2000

Certified by ....
John B. Heywood
Sun Jae Professor of Mechanical Engineering
Thesis Supervisor

Certified by ....
Donald R. Lessard
Epoch Foundation Professor of International Management
Sloan School of Management

Certified by ....
Richard de Neufville
Professor of Civil and Environmental Engineering

Certified by ....
Frank R. Field III
Senior Research Engineer, Center for Technology, Policy, and Industrial Development

Accepted by ....
Daniel E. Hastings
Professor of Engineering Systems & Aeronautics and Astronautics
Co-Director, Technology and Policy Program

ECONOMIC PERFORMANCE OF PRODUCT AND PROCESS FIRMS

FOCUS AND DIVERSIFICATION IN THE AUTOMOTIVE SUPPLIER INDUSTRY

by Patrick P. Steinemann

Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Technology, Management and Policy

ABSTRACT

This dissertation refines the understanding of economic performance of firms, using data and practical insights from the automotive supplier industry. Firms in this industry are characterized as either product or process firms, reflecting the importance of technological capabilities in manufacturing industries. Specialized capabilities in product markets define product firms, whereas capabilities in materials processing and manufacturing technologies define process firms. A measure of technological coherence is introduced, which expresses the relatedness of capabilities of a firm. The measure is based on a concentration index and a hierarchical classification of products and processes in the automotive supplier industry.

Using this measure of coherence, analysis shows that firms with stronger coherence are able to better exploit corporate synergies and therefore achieve superior economic performance. That is, firms focusing on a specialized and related set of capabilities are able to outperform less coherent firms. Analysis further reveals a significant difference in performance between product and process firms. Product firms in the automotive supplier industry exhibit negative returns to scale, whereas process firms exhibit positive returns to scale. These differences are attributed to the underlying corporate logic of product and process firms, supported with studies of value creation in corporate acquisitions and interviews with corporate executives.

The findings have implications for strategic choices of firms, such as choosing between product and process focus, and choosing between focus and diversification. The dissertation contributes to strategic management theory with a framework of product and process firms that is based on a technological view of the firm, and with a measure of technological coherence that facilitates empirical research of corporate coherence.

Thesis Supervisor: John B. Heywood
Title: Sun Jae Professor of Mechanical Engineering

ACKNOWLEDGEMENTS

I would like to express the most sincere thanks to my advisors for their extraordinary sympathy and encouragement. I have benefited continuously from their wisdom, and am grateful for their intellectual contributions and advice.

The International Motor Vehicle Program at MIT is gratefully acknowledged for supporting this research, and Merrill Lynch International, London, for providing access to financial databases. My first year at MIT was supported by scholarship contributions from ABB Management AG, the Avina Foundation, and the Rotary Club Foundation, Switzerland.

My initial interest in the automotive industry was supported by Professor Daniel Roos. During my first two years at MIT, Michael Hesse of DaimlerChrysler and Brad Bates of Ford Motor Company provided crucial support for a case study on fuel cell technology that I carried out at the two companies. In my third year, I spent an internship in the Mergers & Acquisitions department of Merrill Lynch International, London, which has sparked my interests in finance, thanks to Henrik Aslaksen, David Melvin, Piero Novelli, and Dimitrios Stratikopoulos.

I wish to thank my good friend Sebastian Fixson and my colleagues at the Materials Systems Laboratory at MIT for many valuable discussions. Carlos Martinez Vela has always been an inspiration to me, and has become a true friend over the time we spent together at MIT.

My thanks also go to my brother Samuel, and Helen, Lisbeth and Felix, from whom I have received a great deal of support. Finally, I wish to thank my parents, Anita and Peter, who were always supportive and provided thoughtful advice and guidance. At heart, my thanks go to Regula for her encouragement, patience and bringing joy to my life.

CONTENTS

FIGURES

TABLES

ACRONYMS

CNC	Computer numerically-controlled machining
JIT	Just-in-time manufacturing
OEM	Original equipment manufacturer
R&D	Research and development
ROA	Return on assets
ROIC	Return on invested capital
ROS	Return on sales
SEC	Securities Exchange Commission
SG&A	Sales, general and administrative expenses
SIC	Standard Industrial Classification

INTRODUCTION

"Strategy is about combining activities."
(Porter, 1996)

"Which activities should the entrepreneur combine?"
(Rumelt, 1984)

This dissertation seeks to improve our understanding of the economic performance of firms and its link with the concept of corporate coherence, using data and practical insights from the automotive supplier industry. The argument made in this dissertation is that technological capabilities of firms are key to understanding corporate coherence and explaining the link with superior firm performance. As a working definition, coherence is defined as the alignment or fit of capabilities such that a firm can obtain synergies.

Using empirical insights from the automotive supplier industry, the dissertation introduces a framework of product and process firms that reflects the importance of technological capabilities in manufacturing industries. Product firms are defined through capabilities in product markets, whereas process firms are defined through capabilities in materials processing and manufacturing operations. It is argued that product and process firms are based on a different corporate logic, which has implications for the performance of such firms. It is demonstrated that that superior firm performance is the result of strong coherence of technological capabilities along product and process dimensions. In other words, firms that focus on a specialized and related set of capabilities are able to outperform more diversified, incoherent firms. The findings have implications for strategic choices of firms, such as choosing between product and process models, and between focus and diversification.

For readers interested in the theoretical aspects of strategic management, the dissertation introduces a new framework of the firm and attempts to make a contribution to the discussion of corporate coherence, strategy and economic performance. For managers and readers familiar with the automotive industry, the dissertation offers new insights into the nature and dynamics of firms in this industry.

What are the sources of corporate synergy?

Explaining the source of corporate coherence, or corporate synergy, is one of the fundamental issues that defines the field of strategy and the practice of management (Rumelt, Schendel, and Teece, 1995; Teece et al., 1994). The following two examples of firms in the automotive supplier industry illustrate the importance of corporate coherence and the link with firm performance and corporate strategy. PPG Industries is a company that is characterized through its diversified business activities as a supplier of coatings, fiber glass, flat and fabricated glass and chemicals. PPG Industries' largest customer is the automotive industry, but the company also serves the industrial, packaging, construction, aircraft, electronics, and other markets. How does PPG Industries successfully compete in multiple industries?

Autoliv is a company that is focused entirely on the production of automotive airbag and occupant safety systems. The company was one of early pioneers of airbag technology and today has grown into a leading global supplier of airbags, seat belts, steering wheels, and complete automotive safety systems. The coherence of Autoliv as a company focused on the automotive industry is apparently based on different principles than the diversified business of PPG Industries. How does Autoliv successfully compete within a single industry?

Theory on strategic management offers different views of successful firm strategies and the sources of competitive advantage of firms. The dominant paradigm in the field of strategy is the framework developed by Porter (1980). In this model, the level of competition or profit potential of an industry is seen as the result of five industrial forces: entry barriers, rivalry among firms, bargaining power of buyers and suppliers, and the threat of substitute products. In Porter's framework, firm performance is the result of industry competition, and opportunities and threats imposed by the industry define successful strategies potentially available to a firm. A firm's coherence is not a central issue in Porter's initial framework[1], because firm performance is viewed as a result of forces imposed on a firm by the industry in which it competes.

[1] Porter's later works (1985; 1996) acknowledge the existence of competence and are discussed further below.

Porter's view of competitive advantage differs fundamentally from another framework in strategic management theory, the resource-based view of the firm (Wernerfelt, 1984; Rumelt, 1984; Prahalad and Hamel, 1990). Resource-based theory argues that firm-specific assets or resources represent the economic foundation of firms. Successful firms achieve superior performance because of their unique competence, because of what they are 'good at'. This view emphasizes the importance of firm capabilities in the form of organizational, functional and technological skills embodied in a firm.

PPG Industries Inc.	
Coatings	Products include protective and decorative finishes for the automotive, appliances, industrial equipment and packaging markets; aluminum extrusions and coils for architectural uses; and other industrial and consumer products
Glass	Products include flat glass, fabricated glass and continuous-strand fiber glass for the automotive, construction, aircraft, furniture, marine and electronics markets
Chemicals	Products include chlor-alkali and specialty chemicals for the chemical processing, rubber and plastics, paper, minerals and metals, and water treatment industries

Autoliv Inc.	
Automotive occupant safety restraint systems	Products include passenger and airbag protection systems, seat belts, steering wheels, and complete safety systems for the automotive industry

Table 1: Business activities of PPG Industries and Autoliv

The resource-based view was found of great use in explaining the link between corporate coherence and economic performance. Superior economic performance is seen as the result of fit, or coherence among business activities. The rationale for combining business activities in a single firm therefore lies in sharing corporate resources and capabilities. In the presence of such sharing, the firm as a whole is expected to achieve better performance than the sum of its separate businesses, a concept known as economies of scope (Teece, 1982). Explaining the sources of corporate synergy therefore allows us to better understand the competitive advantage of firms and the determinants of superior firm performance.

The contribution of this dissertation is first, that it explains corporate coherence as a result of economies of scope among technological capabilities of firms by introducing a framework of product and process capabilities. Autoliv is able to achieve superior performance through a focus on a single product line and synergies among distinct product-related capabilities for developing and manufacturing airbags. PPG Industries achieves superior performance through its specialized knowledge and operating synergies among several related processes. Second, the dissertation introduces a numerical measure for expressing coherence, or relatedness of capabilities in firms. Third, this measure of coherence is used to establish an explicit link between the coherence of product and process firms, and superior firm performance.

Chapter 1: Overview of the automotive component industry

The first chapter starts with an introduction into the research subject, the automotive supplier, or automotive component industry. This industry provides an interesting case for studying the link between coherence of firms. Automotive component manufacturing is a diversified industry ranging from semi-finished products and materials, such as metals, plastics, textiles and glass, to complete assemblies of drivetrain, engine, interiors, and electronics. In such a diversified industry, the question of corporate coherence and the sources of corporate synergy is particularly pronounced.

A highly competitive global manufacturing industry, the automobile manufacturing industry has been a subject of research for decades[2]. Chapter 1 presents a summary of the most important characteristics and trends for readers unfamiliar with the industry, including a discussion of the industry structure, and a summary of the principles of lean manufacturing, extended supply contracts, technological innovation, globalization, and industry consolidation.

Chapter 2: Product and process firms: A technology-based view of the firm

The second chapter focuses on the argument made in this dissertation that corporate coherence can be understood in terms of the technological capabilities of firms, and that technology-based coherence provides a basis for the competitive advantage of firms.

[2] See for example Chandler (1962) for a historical perspective, or Clark and Fujimoto (1991) and Womack et al. (1991) for in-depth industry studies.

This is demonstrated with data and anecdotal evidence from the automotive component industry. By exploring technological aspects of firms in greater detail than strategy research commonly employs, the dissertation aims at providing a technological explanation of the concept of coherence, and its consequence for economic firm performance.

Chapter 2 introduces a framework of product and process firms. Firms with specialized capabilities in product markets are defined as product firms, whereas process firms are defined through capabilities in materials processing and manufacturing operations. This expression of technological capabilities in either product or process dimensions represents a simplified but insightful framework that is carried through the remaining chapters of the dissertation.

The chapter presents characteristic differences between product and process firms, which have implications for corporate synergies and economic performance of such firms. Product firms with strong capabilities in distinct products place a high emphasis on product differentiation through investments in design, product development and marketing. Autoliv represents a typical product firm that is focused on distinct capabilities and technological knowledge relating to a narrow set of products. Other examples of product firms include producers of automotive seats, interiors, engine components, braking and suspension systems.

In contrast, process firms are focused on specific materials processing or manufacturing technologies and often produce more generic, and broadly applicable products. This enables process firms to achieve greater efficiency in their manufacturing operations and the flexibility of selling their products in multiple markets. PPG Industries is a typical process firm focused on superior process skills and management in high-volume coatings and glass processing facilities, which provide the basis for corporate synergies despite the fact that PPG is represented in a diversified set of product markets. Additional examples of process firms are companies focused on metal processing, rubber and plastics processing, glass fabrication, and other process technologies.

Chapter 3: Corporate synergy and firm boundaries

In a more fundamental economic debate, the question of firm coherence points to the question of firm boundaries, which is discussed in Chapter 3. Firm boundaries are determined by the question of make-or-buy. In the historical essay on the nature of the firm, Coase (1937) points out that there is a fundamental distinction between firms and markets. Firms displace markets where activities can be combined more efficiently inside a firm than in the open market. The boundaries of a firm are therefore determined by the ways in which business activities can effectively be combined inside the firm. Williamson (1975) pointed to the existence of transaction costs in explaining why certain economic transactions are taking place in the open market, while others are more efficiently dealt with inside a firm. Several other theories have expanded on the idea of firm boundaries, such as agency theory (Berle and Means, 1932; Jensen and Meckling, 1976), and evolutionary theories of the firm (Nelson and Winter, 1982).

Of particular interest for strategic management is the insight into firm boundaries that can be gained from understanding corporate coherence. What are the typical firm boundaries of product and process firms, and what do firm boundaries indicate about the sources of coherence in these firms? The answer to these questions is important for the analysis of corporate coherence and economic firm performance in Chapter 5. Furthermore, firm boundaries relate directly to a central topic of research in strategic management that deals with the issue of corporate focus versus diversification. In what directions should a firm expand its capabilities, and what businesses should a firm compete in?

Chapter 4: The definition of industry

The discussion of firm boundaries also leads to the definition of an industry. Industry boundaries are traditionally seen as the limits between product markets. This concept of industries as separable groups of firms according to product markets does not fit well with process firms. The strength of a process firm is its manufacturing capability, and a process firm is likely to diversify its products across a range of industries. PPG Industries is represented in diversified product markets as a result of its focus on process capabilities. Individual product markets are therefore not a meaningful indicator of PPG Industries' capabilities.

Chapter 4 presents an alternative definition of industry that includes both product and process dimensions. The concept of product and process industries is then applied to the automotive industry, and discussed in the context of empirical research on industry relatedness.

Chapter 5: Economic performance of product and process firms

The theoretical strategy frameworks of Porter (1980) and the resource-based view of the firm provide different viewpoints of the sources of competitive advantage of firms. In line with the theory of industrial organization economics, Porter (1980) argues that the determinants of competitive advantage, or superior firm performance are represented by industry forces and by the position of firms relative to these forces, see Figure 1. Alternatively, the resource-based view seeks to explain superior performance as a result of firm-specific assets and capabilities, and the coherence among business activities.

Research in strategic management suggests that there is a positive correlation of corporate coherence with firm performance, and that firms with coherent business activities are able to achieve greater competitive advantage (Rumelt, Schendel, and Teece, 1995; Teece et al., 1994; Porter, 1985). But this research makes little reference to technological capabilities as the sources of coherence, despite the widely noted importance of technological capabilities in manufacturing industries (Clark and Fujimoto, 1991; Hayes, Wheelwright, and Clark, 1988; Hayes, Pisano, and Upton, 1996; Womack, Jones, and Roos, 1991). In addition, empirical research often considers only the product dimension, and ignores the existence of process capabilities.

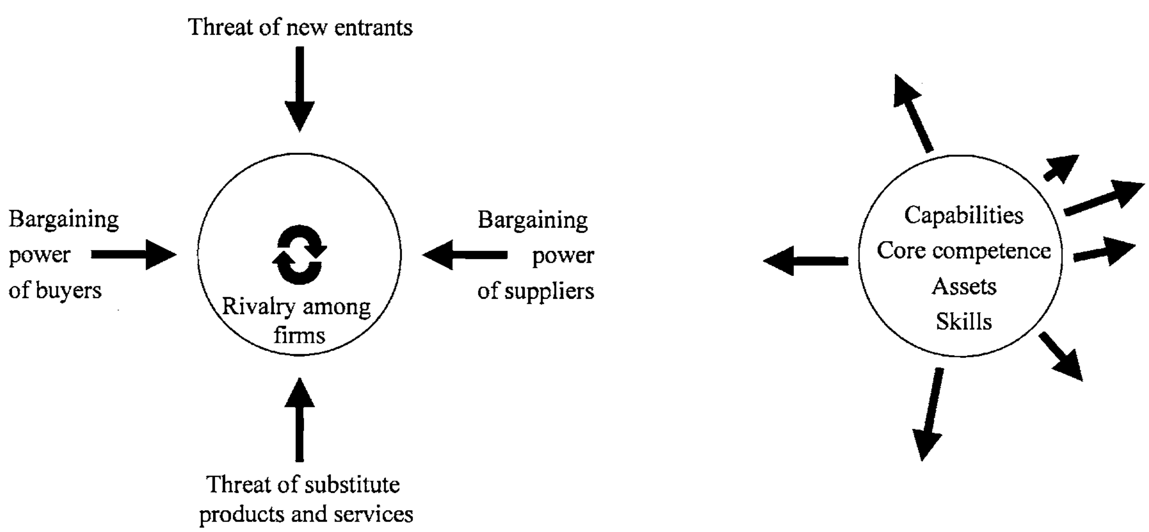


Figure 1: Performance drivers in Porter (1980)'s view of the firm (left) and the resource-based view of the firm (right)

The dissertation attempts to contribute to this debate through the analysis of firms within the framework of product and process firms. Do product firms perform differently than process firms? Does corporate coherence correlate with performance? What can be said about performance drivers of product and process firms? Chapter 5 introduces an empirical measure of technological coherence, which expresses the relatedness of capabilities of a firm. The measure is based on a concentration index and a hierarchical classification of products and processes in the automotive supplier industry. Using this measure of coherence, it is demonstrated that firms with stronger coherence among either product or process capabilities are able to better exploit corporate synergies and therefore achieve superior economic performance. Significant differences in performance between product and process firms are also found regarding the size of firms.

Chapter 6: Value creation through acquisitions

Chapter 6 presents an alternative test of the link between corporate coherence and superior firm performance in an analysis of corporate acquisitions of automotive supplier firms. The analysis adds causality to the hypothesis that coherence of technological capabilities is a key determinant of firm performance. It is shown that related-diversifying firms achieve higher performance than unrelated diversifiers.

In the literature, research on corporate diversification has attempted to establish a link between diversification and economic firm performance. This research has produced an extensive literature in the areas of industrial organization economics, financial economics, and organization theory by analyzing why firms diversify, whether focused firms outperform diversified firms, in which directions firms diversify, and whether the predominant mode of diversification is through internal development or through acquisition. But despite extensive empirical and theoretical work on this topic, the impact of diversification on economic firm performance remains uncertain. A large number of studies point to the finding that focused firms outperform diversified firms (Rumelt, 1974; Montgomery, 1985; Palepu, 1985; Wernerfelt and Montgomery, 1988; see Montgomery, 1985 for a contrary view), although most studies do not attempt to establish a causal negative link between diversification and performance. Other studies refine the findings by demonstrating that firms pursuing a related diversification strategy outperform firms pursuing diversification into unrelated business activities (see Palich, Cardinal, and Miller, 2000 for an overview). In the literature on financial economics, studies found a negative correlation between diversification and financial firm valuation (Lang and Stulz, 1994; Berger and Ofek, 1995), and between diversifying acquisition strategies and stock returns (Kaplan and Weisbach, 1992; Berger and Ofek, 1996; Comment and Jarrell, 1995; Servaes, 1991).

Most of these empirical studies define diversification in terms of product market presence. The framework of product and process firms introduced in Chapter 2 argues that the analysis of firms in the product dimension ignores the existence of process firms with capabilities in manufacturing and materials processes. The analysis of corporate acquisitions in Chapter 6 takes into account both product and process dimensions.

Chapter 7: Reflections on theory and evidence

The final chapter provides additional reflections on the framework of product and process firms, and presents feedback obtained from interviews with senior executives in the automotive industry. The goal of these interviews was to validate the major ideas developed in this dissertation, and to obtain comments that either confirm or disagree with the results.

Chapter 1

OVERVIEW OF THE AUTOMOTIVE COMPONENT INDUSTRY

The main research subject of this study is the automotive component industry. This chapter summarizes the most important characteristics and trends for readers unfamiliar with the industry. This includes a discussion of the automotive industry structure, the distinction between original equipment manufacturers and component suppliers, and a summary of principles of lean manufacturing, extended supply contracts, technological innovation, globalization, and industry consolidation.

1.1 AUTOMOTIVE INDUSTRY STRUCTURE

The automobile industry is typically described as a tiered industry, see Figure 2. Tier 3 companies are defined as suppliers to Tier 2 companies, and Tier 2 companies are suppliers to Tier 1 companies, which sell their products to the automobile assembler, the actual manufacturer of automobile original equipment (OEM). Lower tier suppliers are typically involved in raw materials processing, and manufacturing of individual components, while higher tier suppliers are involved in the production of component subsystems, such as shock absorbers, brake disks, steering wheels, and complete systems, such as transmissions, seats or instrument panels. Automobile manufacturers and assemblers are the actual producers of automobiles, but also provide a range of related business functions including product development, in-house manufacturing of key components, marketing, distribution, dealership and aftermarket customer services.

1.2 AUTOMOBILE MANUFACTURING AND ASSEMBLY (OEM)

The automobile OEM industry is a highly concentrated industry. The ten largest global companies represent more than 80% of the global automobile production[3]. Historically, the largest automobile producers emerged out of national conglomerates with activities in many industrial sectors, including the automobile, truck, aircraft, aerospace and defense, railway, and industrial equipment industries. Most manufacturers have made a transition to become pure automobile producers and have reduced unrelated activities. Some of the remaining diversified industrial manufacturers are General Motors, DaimlerChrysler, Fiat, and the Korean automobile manufacturers.

The automobile industry is a typical cyclical, durable goods industry. Consumer demand for automobiles depends largely on general economic conditions, the cost of purchasing and operating vehicles, and the cost of consumer credit. Industry revenues can vary substantially within cycles of five to ten years. As a highly capital-intensive industry, the percentage of fixed costs are relatively high, and changes in earnings can result from relatively small changes in volumes sold. Consequently, corporate expense management, capacity planning and labor relations are some of the most critical issues for managing an automobile company[4]. Most automobile producers are subject to union labor contracts, and strikes can adversely affect the economic performance of the entire automotive supply chain.

Figure 3 illustrates this cyclical nature of industry sales and profitability, and the close match between profitability in the supplier and automotive OEM industry. The negative spike in profitability around 1979/80 is due to threats of bankruptcy at the Chrysler Corporation after the company experienced a period of decreasing market share and decline in profitability. Chrysler emerged from bankruptcy due to a government bail-out and a fundamental reorganization that included trimming operations, closing unprofitable plants, and persuading labor unions to accept changes to the traditional labor contracts (Levin, 1995). This period of transition paved the way for Chrysler to adopt Japanese lean manufacturing practices and later become one of the most profitable automobile producers, culminating in the company's merger into DaimlerChrysler in 1998.

---

[3] This includes General Motors, Ford, Toyota, Volkswagen, DaimlerChrysler, Fiat, Nissan, Honda, PSA Peugeot-Citroen, and Renault (Automotive News, 1999).

[4] According to Shimokawa (1995), worldwide utilization of OEM production capacity was at a record low of 72% in 1998.

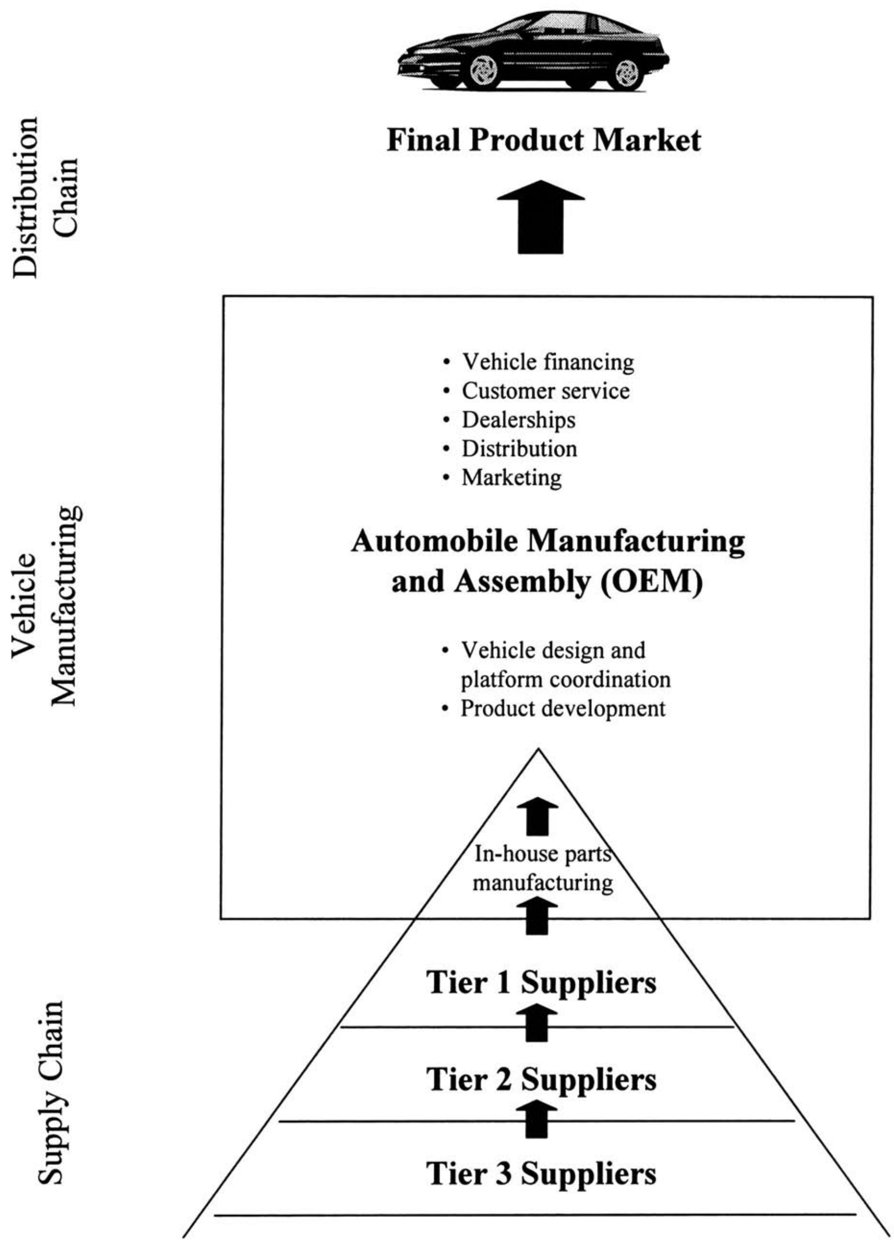
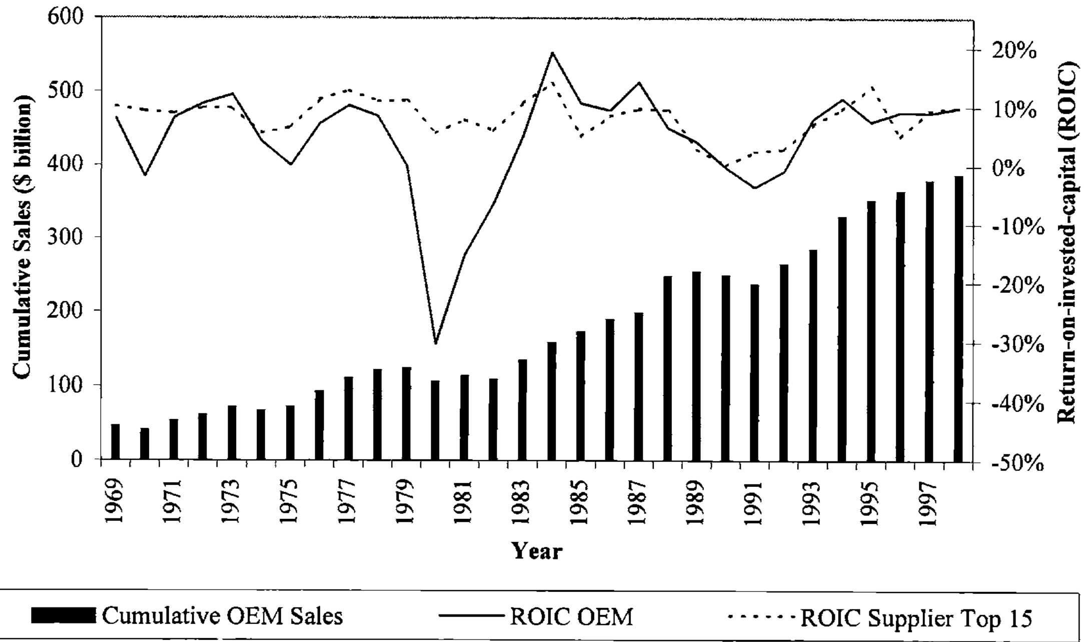


Figure 2: Traditional view of the automotive industry structure

Lean manufacturing and the extended enterprise

One of the most fundamental recent transformations of the automobile industry occurred with the spread of Japanese lean manufacturing practices to American and European automobile producers (Womack, Jones, and Roos, 1991; Fujimoto, 1999). Lean manufacturing, also known as the *Toyota Production System*, has revolutionized many aspects of the automobile industry, and has led to worldwide improvement in operational efficiency, product quality and a reduction of the cycle time for developing new car models.



OEM includes cumulative global sales and average ROIC of the following companies: General Motors, Ford Motor, Chrysler (pro-forma for 1998), American Motors (until 1986).

Supplier Top15 includes the 15 largest automotive Tier 1 suppliers (in 1998) in the United States: Arvin Industries, Borg-Warner, Collins & Aikman, Coltec Industries, Dana, Eagle-Picher, Eaton, Echlin, Federal-Mogul, Johnson Controls, Lear, Mark IV, Mascotech, Meritor, Standard Products.

Figure 3: Cyclical nature of the automotive industry

The practice of lean manufacturing involves a set of principles focused on continuously cutting waste from the production processes with the goal of manufacturing an increasing variety of products while continually decreasing costs. Core elements of lean manufacturing[5] are *just-in-time* manufacturing (JIT), mechanisms for productivity improvement, flexible production, total quality control (*kaizen*), supplier involvement in product development, and the heavyweight product management system. At the center of the automobile production process is the method of cellular manufacturing, which targets the production of all products at the exact same cycle time. This is done through the

[5] For more details, see Fujimoto, 1999; Cusumano, 1985; and Clark and Fujimoto, 1991.

adoption of a just-in-time "pull" system focused at reducing overproduction, inventory, and manufacturing cycle time, combined with the effort to minimize defective parts and increase product quality (*jidoka*)[6]. In comparison with traditional mass production methods for automobiles, lean manufacturing practices have led to significant performance advantages in terms of productivity and quality (MacDuffie, 1991; Krafcik and Macduffie, 1989).

In the United States, automobile producers began to adopt lean manufacturing practices following the success of Japanese competitors in the 1980s and early 1990s. Throughout this period, Chrysler has transformed itself to become the leanest car producer in the United States. Over the years, Chrysler has developed an *extended enterprise* approach that emphasizes lean production, intensive cooperation with suppliers in product development, and reduced vertical integration (Scott, 1994). According to a recent extensive survey of automobile assembly plants, the manufacturing performance gap between United States and Japanese producers has closed significantly, and European producers are approaching Japanese productivity and quality levels (MacDuffie and Pil, 1999).

In-house automotive parts manufacturing

Automobile producers manufacture certain key automotive components in-house, and obtain the remaining components from competitive sourcing in the supplier industry, see Table 2. Automotive parts that are critical components of an automobile from the point of view of product design and development, are manufactured in-house by OEMs. This typically includes metal stampings, engines, transmissions, electronic parts, and glass fabrication. Other components are purchased from suppliers. The split of component manufacturing between OEM and suppliers is even more distinct with Japanese producers. Dyer, Cho, and Chu (1998) observe that suppliers that are close associates of Japanese OEMs produce higher-value components such as engine parts and transmissions, while more loosely associated suppliers tend to make commodity-type products such as tires, belts and spark plugs.

Some OEMs have drastically reduced their reliance on in-house component manufacturing and divested internal auto parts divisions in a move towards a more competitive sourcing process for automotive components. Chrysler, in its transition to become a lean manufacturer, drastically reduced the number of its suppliers in order to

[6] For more details, see Womack, Jones, and Roos, 1991; Kilpatrick, 1997; Irani, 1999; Shimokawa,

reduce procurement costs and concentrate business on preferred suppliers[7]. Most recently, General Motors and Ford Motor joined this trend in attempts to spin off of their internal automotive parts division as independent companies. General Motor's automotive parts and systems division, Delphi Automotive, is now one of the largest independent component suppliers worldwide with sales of $21 billion (in 1998). Ford Motor has announced it will soon divest its automotive components division, Visteon. With this outsourcing trend, automobile production has become a focused activity based around vehicle assembly, product development, and design and marketing as the remaining core competencies of an OEM. Downstream, automobile manufacturers are integrated into the distribution chain to varying degrees. Most manufacturers operate dealership franchises, and own a financial services division providing leasing, financing and insurance services to vehicle purchasers.

Parts manufactured by OEM in-house	**Parts manufactured by suppliers**
• Engines • Cylinder heads • Automatic transmissions • Body panels • Electronic components	• Engine components, pistons • Steering and suspension parts • Brake parts • Wire harness • Seats • Exterior and interior trim • Exhaust components • Radiators • Batteries • Tires

Based on Fine and Whitney (1996) and Dyer et al. (1998).

Table 2: Automotive components typically manufactured by OEMs and by suppliers

---

Jürgens, and Fujimoto, 1997.

7 Chrysler Corporation annual reports state that the company used 972 suppliers of productive materials in 1997, compared to 1,380 in 1993. The annual reports do not specify a definition of what a supplier is, but it can be assumed that this represents individual establishments from which components are procured, and not firms as legal or financial entities

Globalization

Globalization of the automobile industry forces significant changes on the industry, as manufacturers are consolidating various elements of the supply chain in particular locations worldwide to simultaneously meet cost-cutting and market-seeking objectives[8]. Manufacturers are driven globally to benefit from low-cost manufacturing locations and to achieve greater economies of scale with the deployment of global vehicle platforms (*world car platforms)* that allow increased model flexibility and adaptation to local consumer preferences. At the same time, manufacturers seek to establish a competitive supply chain in local markets worldwide by establishing enterprise functions and supply chain structures that go beyond simply moving assembly plants overseas.

In the growing role for suppliers to take on responsibilities in manufacturing, logistics, and product development, OEMs are requiring their largest suppliers to co-locate their facilities with global OEM production. This has resulted in the emergence of global suppliers with global capabilities for coordinating and manufacturing components. Globalization in the supplier industry is therefore not only driven by the need for more responsiveness and just-in-time delivery of components, but also through a more complex interaction of assembly locations, the changing role of suppliers, including development responsibilities, and local government policies (Lynch, 1999).

Technological innovation

Technological innovation has become an increasingly important driver of competition in the automobile industry and an important factor for product differentiation[9]. Technological change is mainly the result of shifts in consumer preference, increasing product regulation and liability, and globalization of markets. Consumers are driving technological innovation through increasingly sophisticated demands concerning purchase price, performance, safety features, comfort and accessories of automobiles. These preferences provide substantial incentives for automobile and component manufacturers to develop new products. Stringent regulatory requirements act as a driver of technological innovation in the areas of exhaust emission control, fuel economy, and safety. Globalization affects product development and technology through the need for product modularization and standardization, and the need to evaluate outsourcing of

---

8 For more details, see Lynch, 1999; Sturgeon and Florida, 1997; Lynch, 1998.

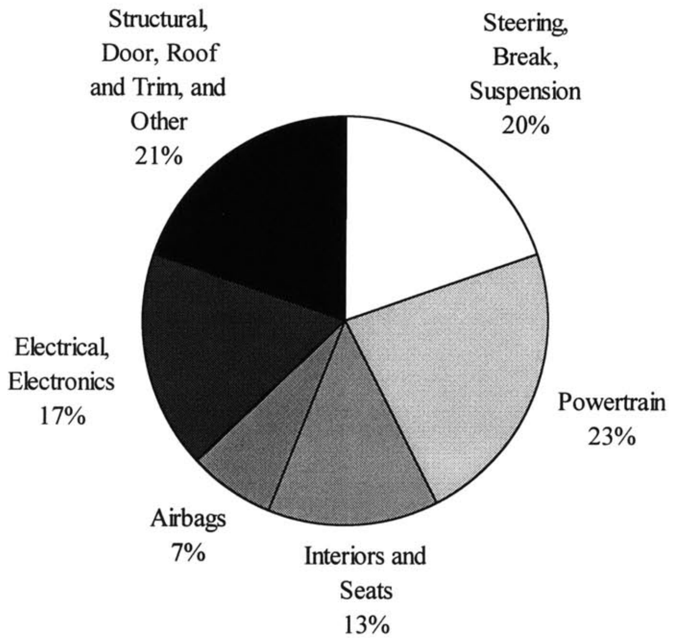
9 An extensive literature describes the importance of innovation and product development in the automotive industry, see for example Altshuler, 1984; Womack, Jones, and Roos, 1991; Clark and Fujimoto, 1991; Cusumano and Nobeoka, 1998.

R&D functions and implement closer cooperation with suppliers in product development. Several automobile producers have established technical centers and satellite R&D divisions in their largest foreign markets, alongside with globalizing their manufacturing base.

Areas of recent technological advances concerning the automobile include the areas of electronics, advanced powertrain technologies, and safety systems. Increasing electronics integration enables more sophisticated vehicle features and higher integration of mechanical and electrical functions within the automobile. Recent electronic innovations include advanced emission and engine control systems, airbag sensors and controls, drive-by-wire, integrated data transmission systems, keyless entry, and navigation and entertainment systems. Advanced powertrain technologies and engine management systems target varying consumer preferences and government regulations concerning the development of alternative propulsion systems, such as electric, hybrid, fuel cell, and alternative fuel vehicles. Innovation in automotive safety targets the protection of occupants through crash detection systems, adaptive belt restraints, multiple airbags, and collision avoidance systems.

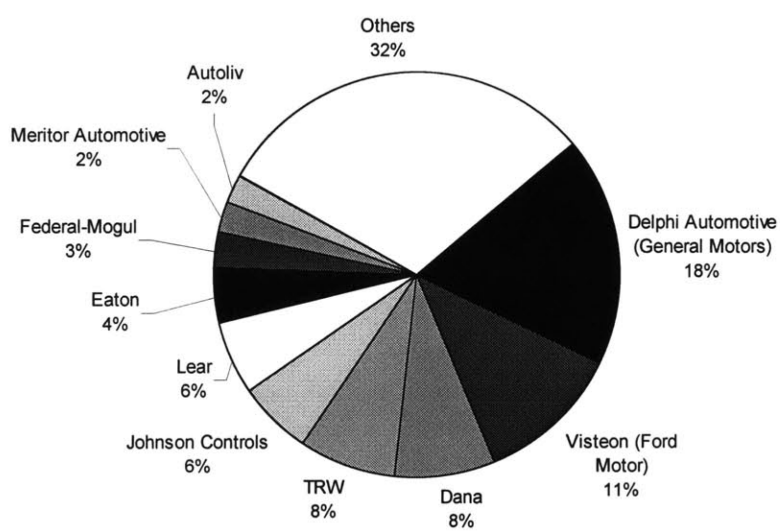
1.3 AUTOMOTIVE COMPONENT MANUFACTURING

The automotive component industry encompasses companies that are suppliers of material, automotive parts and subassemblies to the automobile OEMs and lower tier suppliers. The automotive supplier industry is very fragmented and diverse, and combines various manufacturing industries producing materials and components as diverse as steel bars, textiles, glass, internal combustion engines, pumps, electronics and semiconductors. Figure 4 and Figure 5 show the market share of this industry by components and by producers. The typical firm size of automotive component manufacturers ranges from $200 million to $10 billion, which is considerably smaller than the size of automobile OEMs.



Based on the data set AUTO_COMP Segments. Includes U.S. registered companies only. Numbers represent averages of year 1993-98, total market size is $120 billion (1993-98).

Figure 4: Automotive component industry, market share by components



Based on data set AUTO_COMP and Ford annual report. Includes U.S. registered companies only, excludes Chrysler in-house parts production. Numbers represent year 1998, total market size is $150 (in 1998).

Figure 5: Automotive component industry, market share by producers

Many suppliers not only serve the OEM market, but also sell their products in the aftermarket. The automotive aftermarket is perceived as offering opportunities for higher profit margins, but also more complex requirements for managing logistics in the aftermarket distribution chain. Only very few component manufacturers are integrated with activities in automobile assembly, Magna International being one of the exceptions.

Automotive suppliers broadly follow the trends of automobile producers, including the transformation to lean manufacturing practices, globalization, and greater emphasis on technological innovation[10]. Over the last decade, the automotive component industry has experienced accelerated consolidation as suppliers seek to achieve operating synergies through strategic business combinations, complementary technologies, stronger OEM relationships, and globalization.

Cooperation with OEMs in product development

Suppliers are generally awarded specific contracts for supplying components to automobile producers in a competitive bidding process. The Tier 1 supplier process for automobile platform contracts is initiated when the OEM seeks requests for quotations at least three to six years before anticipated vehicle production. Based on these quotations, OEMs select and work with a supplier on specific component design and development projects related to a platform program. In this process, the OEM evaluates the supplier's performance and its ability to meet the specific production and service requirements. The OEM will then develop a proposed production timetable and source business with the supplier based on contracts, purchase orders or other firm commitments. Large contracts typically cover component supply for a portion of an automobile manufacturer's production of a particular model rather than the supply of a specific quantity of components.

Numerous research studies of the supply chain point to an increasing role of suppliers in vehicle design and assembly processes as OEMs source more fully-engineered, integrated systems and become less vertically integrated[11]. Chrysler in the United States, and Japanese manufacturers have established the model of an *extended enterprise* with close cooperation of first tier suppliers. Research suggest that the increased responsibility of

[10] For detailed studies on the structural changes in the automotive supplier industry, see for example Shimokawa (1995); Lamming (1989); Dyer et al. (1998); and Ealey, Robertson, and Sinclair (1996).

[11] See Monteverde and Teece, 1982; Clark and Fujimoto, 1991; Cusumano and Nobeoka, 1998; Dyer and Ouchi, 1993; Dyer, 1994; Dyer, Cho, and Chu, 1998; MacDuffie and Helper, 1997; Helper, 1997; Sako and Helper, 1995; Liker et al., 1996; Takeishi, 1998; for an overview of the literature, see Takeishi and Cusumano, 1995.

suppliers in technological developments provides benefits for both the supplier and the OEM in terms of increased product development performance. Critical views suggest that the shift in responsibilities may have consequences for manufacturer's reliance on suppliers in providing fundamental technological knowledge in the future (Fine and Whitney, 1996).

Components, modules and systems

As OEMs move towards sourcing a larger portion of vehicle parts from suppliers, they have favored purchasing more fully engineered, integrated systems and modules rather than individual components (Baldwin and Clark, 1997; Sako and Warburton, 1999). The distinction between modules and systems is expressed in the following definition from an industry document:

> "*Modules* are groups of component parts arranged in close physical proximity to each other within a vehicle, which are often assembled by the supplier and shipped to the vehicle manufacturer for installation in a vehicle as a unit. Modular instrument panels, cockpit modules and door modules are examples."
>
> "*Systems* and *subsystems* are groups of component parts located throughout the vehicle which operate together to provide a specific vehicle function. Braking systems, electrical systems and steering systems are examples."
>
> Delphi Automotive Systems Corporation, 1999, p. 65.

By offering systems and modules rather than individual components, Tier 1 suppliers assume many of the design, engineering, research and development and assembly functions traditionally performed by OEMs. In addition, suppliers often provide local assembly of systems and modules near the location of the OEM assembly line. This process allows OEMs to simplify the vehicle design and assembly processes, and to realize cost savings by reducing in-house assembly functions and eliminating the need for significant inventory levels.

Chapter 2

PRODUCT AND PROCESS FIRMS: A TECHNOLOGY-BASED VIEW OF THE FIRM

One of the fundamental issues in the field of strategic management is the question of corporate coherence or synergy, and the link with economic firm performance (Rumelt, Schendel, and Teece, 1995; Teece et al., 1994). Research in strategic management suggests that there is a positive correlation of corporate coherence with firm performance, and that firms with coherent business activities are able to achieve greater competitive advantage (Rumelt, Schendel, and Teece, 1995; Teece et al., 1994; Porter, 1985). Firms with stronger coherence among businesses are able to better exploit their capabilities and corporate synergies, and therefore achieve greater competitive advantage. Understanding the sources of corporate coherence therefore provides a better understanding of the sources of competitive advantage and the determinants of superior firm performance. However, most empirical research makes little reference to technological capabilities as the sources of corporate coherence, despite the widely noted importance of technological capabilities in manufacturing industries (Clark and Fujimoto, 1991; Hayes, Wheelwright, and Clark, 1988; Hayes, Pisano, and Upton, 1996; Womack, Jones, and Roos, 1991).

The argument made in this dissertation is that technological capabilities of firms are key to understanding corporate coherence of firms, and explaining the link with superior economic performance – in the case of the automotive component industry. This chapter introduces a framework that expresses technological capabilities of firms in two basic dimensions, the product and process dimension. According to this technology-based view of the firm, coherent capabilities in product and process dimensions provide the basis for competitive advantage of firms through synergies and economies of scope among business activities.

The automotive component industry is a diversified industry that intersects with several related industries, including materials processing, industrial equipment, aircraft, and electronics industries. Figure 6 illustrates this diversity of automotive components and related industries. What are coherent sets of products and processes in this industry?

What are the sources of corporate synergies among diversified firms in this industry? How do technological capabilities translate into superior performance?

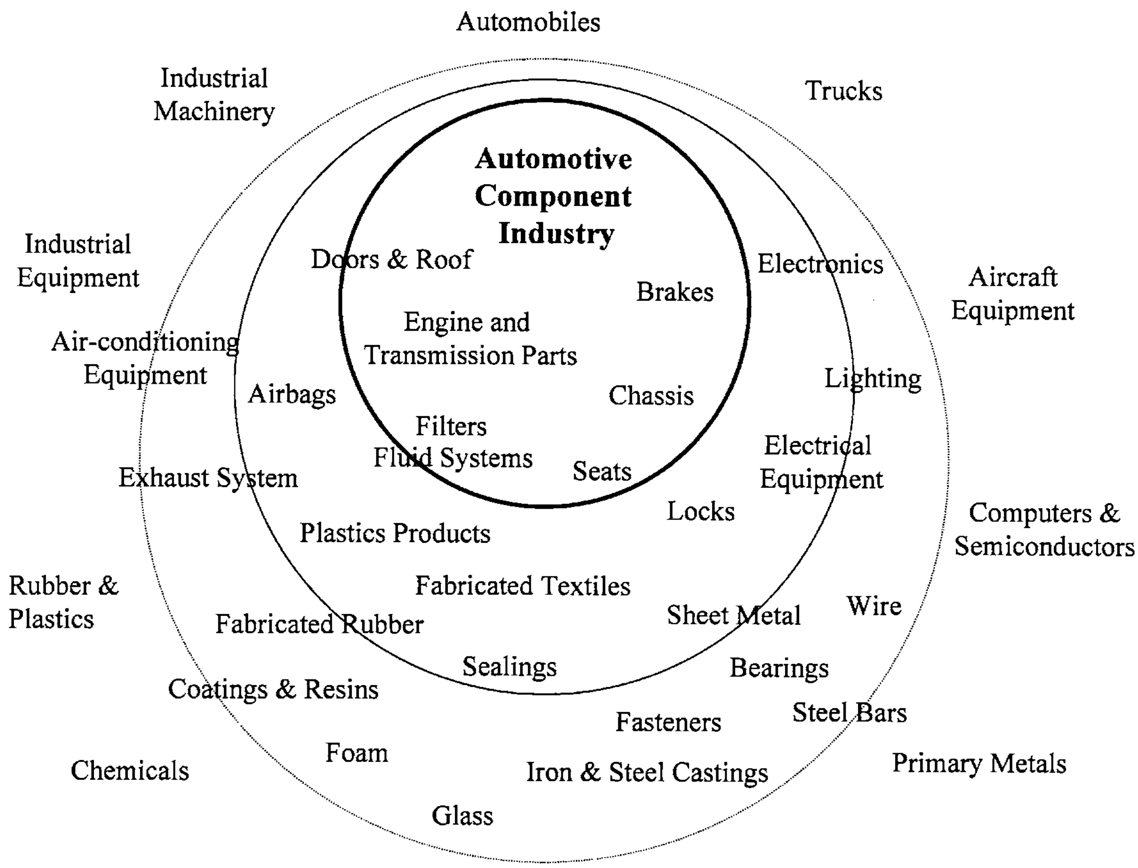


Figure 6: Illustration of automotive components and related industries

Section 2.1 introduces the reader to established theories of competitive advantage and economic firm performance, the strategy framework of Porter (1980) and the alternative view provided by the resource-based theory of the firm (Wernerfelt, 1984), and the literature on technological capabilities in the context of manufacturing industries. The framework of product and process firms is presented in section 2.2. Section 2.3 presents examples of typical product and process firms in the automotive component industry, and section 2.4 describes the corporate logic and characteristics of product and process firms.

2.1 TECHNOLOGICAL CAPABILITIES IN THE STRATEGY LITERATURE

2.1.1 THEORIES OF ECONOMIC FIRM PERFORMANCE

The impact of corporate strategy on the economic performance of firms has been the subject of extensive research dating back to Chandler (1962) and Andrews (1971). The dominant theory of modern strategic management was developed by Porter (1980), who formulated a framework of strategy based on the logic of industrial organization economics (see Schmalensee and Willig, 1989). Firm performance is seen as the result of five industry forces: rivalry among existing firms, entry barriers, threat of substitute products, bargaining power of buyers, and bargaining power of suppliers. According to Porter, firms can increase their competitive advantage through two generic strategies, cost leadership and product differentiation. The paradigm underlying Porter (1980) is known as the Structure-Conduct-Performance paradigm of industrial organization economics, which postulates that market structure determines the conduct of business, which in turn influences firm's performance outcomes. The goal of a firm's competitive strategy is therefore first to choose attractive industries, and products and services to offer, and second to steer the firm into a favorable market position. The fundamental strategic choices of a firm in Porter's framework are consequently defined by the opportunities and threats imposed by the industry. A firm's competence and coherence is not a central issue in Porter's initial framework of strategy, because performance is viewed as a result of forces imposed on a firm by the industry in which it competes[12]. Numerous industry studies provide broad empirical evidence supporting Porter's theory, with particular strength about the effect of monopolistic behavior and market power.

An alternative framework of strategic management, the resource-based view of the firm, claims that firm-specific resources represent the source of economic performance of firms[13]. These resources, or capabilities, allow firms to achieve superior competence, as an expression of what firms "are good at". The resource-based view emphasizes the importance of managerial capabilities, and organizational, functional, and technological skills embodied in a firm, rather than the external forces of industrial competition in

[12] See for example the critique of industrial organization economics by Teece et al. (1994) stating that it neither explains coherence nor disputes its existence. Porter's later works (1985; 1996) acknowledge the existence of competence, but Porter says that strategies based on competence bear "the risk of becoming inward looking" Porter, 1980, p. xvi.

[13] The intellectual roots of the resource-based view are found in Penrose, 1959, and Andrews, 1971, with seminal articles by Wernerfelt, 1984; Rumelt, 1984; and Barney, 1991.

Porter's framework. Numerous empirical and theoretical studies further defined the concept of resources to include "tangible and intangible assets" (Wernerfelt, 1984), or more generally, "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness," (Barney, 1991, p. 101). An important element of firm resources is that these cannot be readily purchased in the open markets, and rather, must be developed by the "rare, imperfectly imitable, and non-substitutable resources" already controlled by a firm (Dierickx, Cool, and Barney, 1989). Other authors have used different names to describe firm resources. Prahalad and Hamel refer to them as core competencies that are "valuable, difficult to imitate", and represent the "collective learning of a firm" (Prahalad and Hamel, 1990; Prahalad and Hamel, 1994). Leonard-Barton (1992) defines core competence as the "knowledge set that distinguishes and provides competitive advantage" for the firm, and distinguishes between resources that provide advantage and those that provide disadvantage through rigidity and inertia.

An interesting practical application of the resource-based view in the context of the automobile industry is given by the lean manufacturing methods of Japanese automobile producers (Womack, Jones, and Roos, 1991). The resource-based view explains such competitive advantage with the ability of knowledge assets, in particular the joint improvement of manufacturing flexibility and cost reduction (Hayes and Pisano, 1996). Porter's framework was unable able to explain the success of individual Japanese companies introducing lean manufacturing, because it assumes that firms perform equally well under the same environmental constraints, and because operational effectiveness is a basic condition of industrial economics (Porter, 1996).

Other economic theories have examined the determinants of industry and firm performance. The literature on technological innovation explains superior firm performance as a result of economic rents that are due to appropriability and first-mover advantages. Based on the work of Schumpeter (1942), firm competition is viewed as a result of the struggle to innovate. In this framework, technological capabilities are not viewed as skills or competencies in a causal link with firm performance, but rather as a result of historical firm evolution and learning-by-doing[14] (Rumelt, Schendel, and Teece, 1991).

[14] In economic terms, Schumpeterian or entrepreneurial rents are short-term rents earned by innovators. The focus of this dissertation is on Ricardian rents, which are due to valuable factors that are scarce, see also Collis and Montgomery, 1997.

Financial economics has contributed to the discussion of firm performance in the context of corporate diversification strategies. Based on the hypothesis of efficient capital markets (Fama, 1970; 1991), a large number of empirical studies have investigated the link between the diversification of multi-product firms and financial firm valuation, with recommendations for corporate acquisition and expansion strategies. Theoretical foundations of financial studies of diversification are found in the agency theory of Jensen and Meckling (1976), which is concerned with the governance structure of firms, and distinguishes between the separation of ownership and control in a firm (Grossman and Hart, 1986, Hart and Moore, 1990). Financial perspectives on firm performance provide a valuable framework for strategic management, but are limited for providing detailed managerial advice and strategic recommendations in firm or industry-specific settings.

2.1.2 THE CONCEPTS OF COHERENCE, SYNERGY, AND ECONOMIES OF SCOPE

Resource-based theory argues that competitive advantage relies upon economies of scope. Economies of scope exist when the cost of joint production $C(y_i)$ of all outputs y_i of a firm is less than the sum of costs for producing each output separately (Teece, 1982).

$$\Sigma C(y_i) < \Sigma C(y_1) + \Sigma C(y_2) + \ldots \Sigma C(y_n) \quad (1)$$

Synergy is another word for economies of scope[15]. In the resource-based view of the firm, superior economic performance is seen as an expression of positive economies of scope resulting from the coherence of a firm's resources, or capabilities. The rationale for combining business activities in a single firm therefore lies in sharing capabilities, for which the firm as a whole is expected to achieve better performance than the sum of its separate businesses. Economies of scope, and the concept of coherence, are therefore key to understanding performance of firms and the sources of corporate synergy. Knowledge about corporate coherence also provides answers to the question what type of growth and

[15] Definition of synergy in the Encyclopaedia Britannica: "interaction of discrete agencies (as industrial firms), … or conditions such that the total effect is greater than the sum of the individual effects." See also the comment made by Porter, 1985, that "it is no surprise that what is meant by synergy has been vague. Synergy has most often been described in terms that suggest that what was meant was intangible interrelationships – transference of skills or expertise in management from one business unit to another."

expansion firms are likely to follow. This insight has implications for strategic choices of firms, such as choosing between focus or diversification.

Coherence of technological capabilities is defined here as the alignment or relatedness of technological capabilities such that a firm can obtain synergies. These technological capabilities are potentially complementary to other corporate dimensions, such as organizational capabilities, and routines.

2.1.3 TECHNOLOGICAL CAPABILITIES IN MANUFACTURING FIRMS

The main argument of this dissertation is that technological capabilities of firms are key to understanding corporate coherence. The importance of technological capabilities in the context of manufacturing industries has been noted by a stream of research on manufacturing strategy that seems to be disconnected from the traditional corporate strategy literature[16]. Most of those who write on the subject of manufacturing strategy point out the role of fundamental cost drivers underlying different manufacturing systems and their influence on competitive advantage (Clark and Fujimoto, 1991; Hayes, Wheelwright, and Clark, 1988; Hayes and Pisano, 1996; Hayes, Pisano, and Upton, 1996; Womack, Jones, and Roos, 1991). The discussion of capabilities and strategic choices in manufacturing can be traced back to Skinner (1974)'s prominent article on *'The focused factory'*, in which he suggests that competitive advantage is linked to the issue of coherence in manufacturing firms. According to Skinner, the choice of strategy based on manufacturing has to be the "result of a comprehensive analysis of the company's resources, strengths and weaknesses."

The dominant strategy framework established by Porter (1980) only makes sporadic reference to technology, and its antecedents in economic theory even dismiss the argument that technology matters for the coherence of firms (Williamson, 1975, p. 49 and 83). Later publications by Porter broaden the framework and mention the importance of technology in support of the two generic firm strategies, cost leadership and differentiation. Porter also acknowledges the idea of complementary products as drivers of competitive advantage (Porter, 1985; 1996).

---

[16] Hayes and Pisano (1996) note: "The concept of 'manufacturing strategy' is still, in human terms, barely past adolescence … It has been undergoing continual growth and elaboration throughout its short life, as it tested itself against the real world and as that world evolved. Today it is facing perhaps the greatest challenge in its short history, as it finds itself in the crossfire of debates about core aspects of its two parent disciplines: manufacturing management and competitive strategy."

In the strategy framework of the resource-based view of the firm, the importance of technological capabilities has been noted by numerous authors. In the original definition of firm resources, Wernerfelt (1984) mentions tangible and intangible assets such as "in-house knowledge of technology, machine capacity, production experience, and efficient procedures." The importance of "knowledge assets and R&D capabilities" is mentioned by Helfat (1997) and Leonard-Barton (1992). Teece, Pisano and Shuen (1997) mention the specific "coordination and integration skills" of Japanese automobile manufacturers. Prahalad and Hamel (1990) called firm capabilities "core competencies," and make reference to technological skills in product development, production, and the integration of multiple technologies in a firm's strategy. According to Prahalad and Hamel (1990), core competence "provides potential access to a wide variety of markets; makes a significant contribution to the perceived customers benefits of the end products; and is difficult for competitors to imitate."

Early literature in the resource-based tradition remains broad in the interpretation of technological capabilities and has been noted for its difficulty in operationalizing the concept of capabilities (Silverman, 1998; Robins and Wiersema, 1995). More recent publications have offered more specific insights and support for the hypothesis that technological capabilities provide sources of corporate coherence and competitive advantage. Silverman (1998) establishes measures of technological resources based on firms' patent portfolio, and St. John and Harrison (1999) identify a detailed list of capabilities in manufacturing industries that makes reference to product and process science and technology.

Milgrom and Roberts (1990; 1995) analyze systems of complementary functions and activities in modern manufacturing, applying the mathematics of supermodularity theory. Their economic model assumes a manufacturing system with strong complementarities, such as simultaneous production flexibility and breadth of product line. The authors conclude that changes in the system can only improve overall performance if these changes involves a coherent bundle of responses instead of individual improvements. The example of Japanese lean manufacturers is mentioned as an example in support of Milgrom and Robert's theorem. The Japanese automobile industry achieved superior performance in manufacturing through the evolution of a *coherent* set of manufacturing practices, known as lean manufacturing (Womack, Jones, and Roos, 1991). For Western producers copying Japanese manufacturing practices, a half-way move to becoming a lean manufacturer would not result in overall performance improvements, in fact such a move may even have negative payoffs. Corporate coherence in this example is a typical expression of synergies between the choice of technology, capital investments and operating systems.

> "The cluster of characteristics that are often found in manufacturing firms that are technologically advanced ... is a result of the adoption by profit-maximizing firms of a coherent business strategy that exploits complementarities." Milgrom and Roberts, 1990.

In summary, the importance of technological capabilities for firm performance is acknowledged by several authors in the strategy literature, yet empirical research is rare and the treatment of technology appears to be disconnected from the managerial literature on manufacturing (represented by Clark and Fujimoto, 1991; Hayes, Wheelwright, and Clark, 1988; Hayes and Pisano, 1996; Hayes, Pisano, and Upton, 1996; Womack, Jones, and Roos, 1991). It appears as if one of Skinner's earliest titles has kept much of its relevance: "Manufacturing – Missing link in corporate strategy" (Skinner, 1969). The remainder of this chapter is aimed at probing deeper into the importance of technological capabilities for superior firm performance, in the case of the automotive supplier industry.

2.1.4 PRODUCT AND PROCESS DIMENSIONS

In discussions of manufacturing industries and technological capabilities, a fundamental distinction is often made between products and processes, in the context of organizational structures, manufacturing operations, and technological innovation. Following is a brief discussion of the literature that provided input to the idea of a framework of product and process firms. The framework is introduced in section 2.2.

Early concepts of product and process distinction in organizational structures are found in Chandler (1962), where the idea emerges from a discussion of organizational structure of General Motors and other industrial enterprises. Chandler uses the term *divisions* for organizations along product lines, and *departments* for process-oriented or functional organizations in the so-called multidivisional form (M-form) of organization. Still today, the product division is the most common form of organization and is particularly pronounced in diversified firms and industrial conglomerates. Interest in the process or functional organization has been revitalized with the efforts of "business reengineering" (Hammer and Champy, 1994; Hammer and Stanton, 1999), and a recent theoretical paper on process-based organizations is found in Rotemberg (1999). Hammer and Stanton (1999) point out that many companies that have combined related activities into a process-oriented organization by grouping core processes rather than products, are better able to coordinate similar tasks. In many cases, such firms achieve superior performance through process standardization, lower overhead costs, and simplified interaction with suppliers and customers. Owens Corning, a company that supplies glass fibers, adhesives and coatings to the automobile industry, is one of the examples of a process organization in Hammer and Stanton (1999).

The distinction between product and process concepts is also presented in Hayes and Wheelwright (1979a; 1979b) in the context of manufacturing operations, and in Hayes, Wheelwright, and Clark (1988, p. 119) in terms of authority and control in manufacturing organizations. Hayes et al. (1988) distinguish between a product / market-focused organization and a technology / production-process-focused organization. The product / market-focused organization separates product groups into divisions that are highly decentralized. As a result, this organization is more responsive to market needs and more flexible when introducing new products. In contrast, the process-focused organization separates manufacturing plants according to process stages. Process organizations are able to better exploit economies of scale, but require more complex management structures with less flexibility.

The extensive literature on the management of technology also points to the importance of product and process dimensions, albeit in a different sense (see Abernathy and Utterback, 1978). In studies of the automobile industry, the role of product development for superior performance has been pointed out by several studies (Clark and Fujimoto, 1991; Womack, Jones, and Roos, 1991; MacDuffie, Sethuraman, and Fisher, 1996). Key performance parameters in automotive product development are development lead time, product quality and productivity, which have been shown by Clark and Fujimoto (1991) to depend critically on superior capabilities in integrated engineering problem solving, manufacturing efficiency (JIT and lean manufacturing paradigm), and the heavyweight product manager (Hayes, Wheelwright, and Clark, 1988, Ch. 11). The role of process development figures less prominently in the literature, but is mentioned in Pisano (1997), and Nishiguchi and Ikeda (1996). Process development is not only important in industries with complex process technologies, and for a continued reduction of manufacturing costs, but also in support of efficient and high-quality launches of new products (Pisano, 1997). Nishiguchi and Ikeda (1996), in a detailed study of a Japanese automotive piston and a brake supplier, find that incremental process innovation of the two firms greatly contributes to improvements of overall productivity and flexibility in the automotive supplier-manufacturer relationship.

In a historic study of the Asian automobile industry, Odaka (1983, p. 384-389) makes an interesting comment about the historical evolution of automotive component manufacturers in Japan. Odaka (1983) observes that most firms were at one time specialized in either products or processes, however, most firms have later adopted specialization by product in favor of specialization by process. According to the author, product specialized firms have the advantage of easier quality control, less burden in production control, and shorter lead times, whereas specialization by process allows for higher economies of scale in production.

2.2 FRAMEWORK OF PRODUCT AND PROCESS FIRMS

The framework presented in this section expresses technological capabilities of firms in the automotive component industry in two dimensions, products and processes. This technology-based view of the firm provides the basis for an alternative explanation of firm coherence, and the link between technological capabilities of firms and superior economic performance. The framework thus presents a firm model in the context of corporate strategy research, but contributes to the existing literature by emphasizing the importance of technological capabilities.

The distinction of product and process firms is based on capabilities or competence in two dimensions. Product firms are defined through capabilities and skills relating to individual products or product lines, while process firms are defined through capabilities in specific manufacturing processes. Figure 7 illustrates the conceptual difference between product and process firms in the automotive component industry. The definition of products relates to individual components and complex systems, such as engine, brakes, and seating systems. Examples of processes include metal machining, casting, injection molding of plastics, and glass processing.

Product-based firms are often organized along individual product lines, as an organizational consequence of their technological capabilities and focus of business activities on distinct product markets. Examples of product firms in the automotive component industry are Dana, TRW, and Gentex, as shown in Figure 8. These firms manufacture highly differentiated and complex automotive products such as entire suspension and chassis systems (Dana), engine components, airbags and electronics (TRW), and specialized products such as opto-electric rearview mirrors (Gentex). As a consequence of the focus on differentiated products, product firms often secure the intellectual property of their highly engineered products through patents and trademarks, and continually investment in research and product development. Complementary assets in marketing and sales serve to maintain the distinct product capabilities.

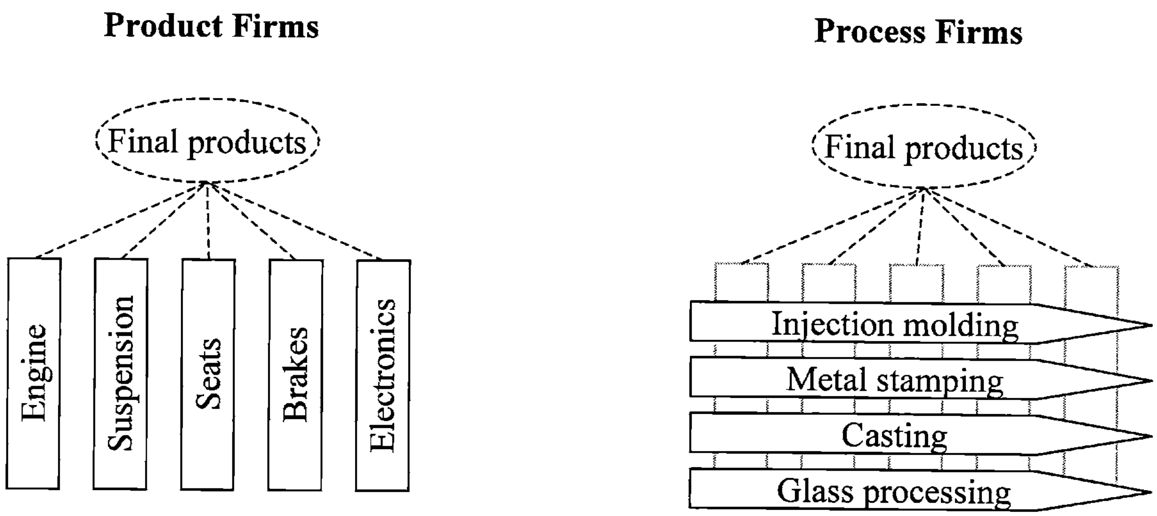
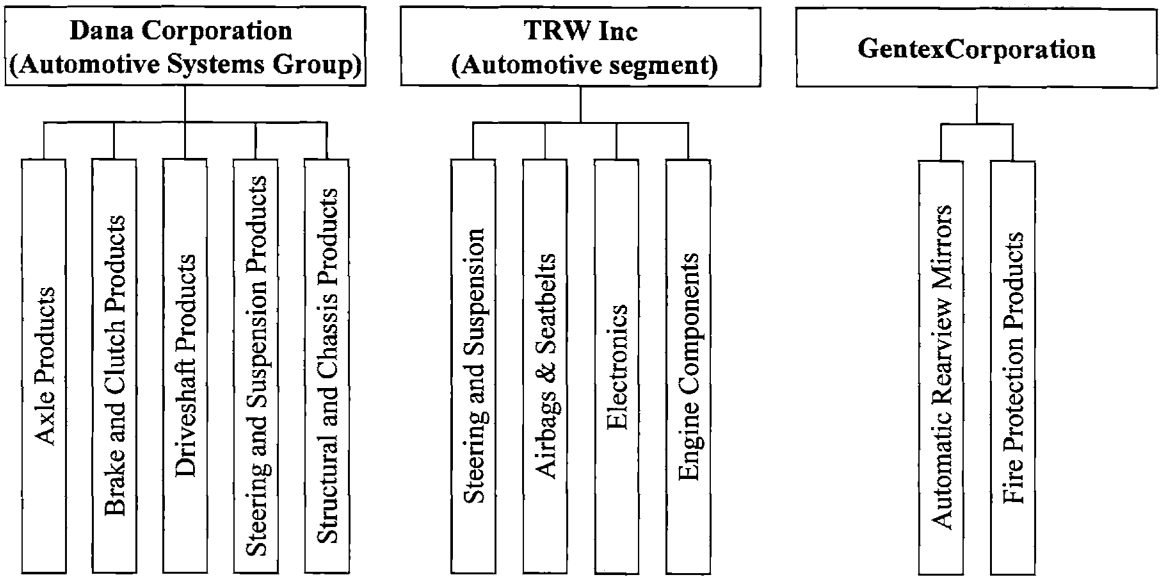


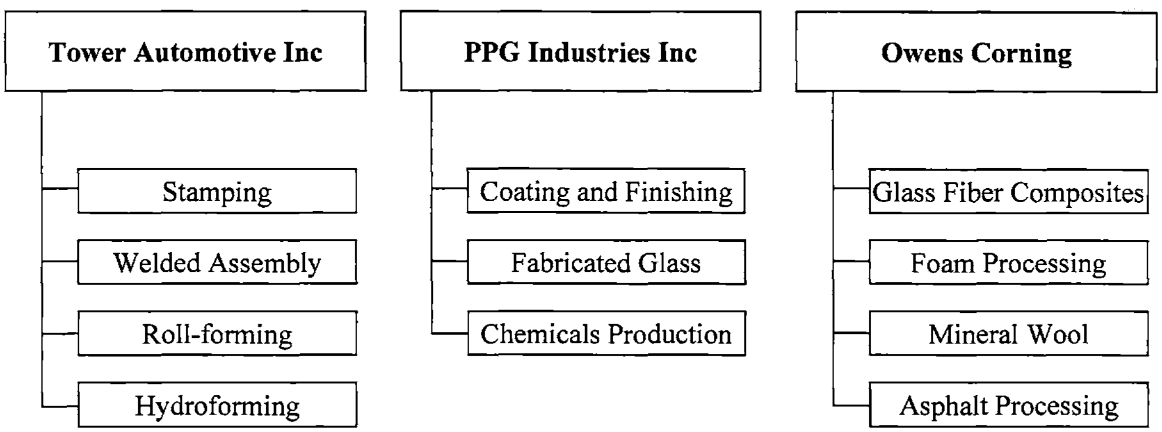
Figure 7: Framework of product and process firms

In contrast, the process firm has distinct capabilities and skills relating to specific manufacturing processes or material process technologies. Process firms are often organized along specific manufacturing operations instead of dedicated product lines. Examples of process firms in the automotive component industry are PPG Industries, Owens Corning, and Tower Automotive, as shown in Figure 9. Their products are typically semi-finished or material-based products such as glass fiber composites, coatings, and foam (PPG and Owens Corning), and processed metals such as stampings and roll-formed or hydroformed components (Tower Automotive). In the automotive industry, process firms tend to represent lower tiered suppliers. Due to the generic nature of their products, process firms are not confined to the market for automotive components, and instead often supply customers in a range of industries. The focus of process firms on manufacturing and materials processing means that these firms engage in continuous development and improvement of process efficiency, capacity utilization, and reduction of inventory levels. Section 2.3 discusses four examples of product and process-based firms in more detail.



(Source: Company annual reports)

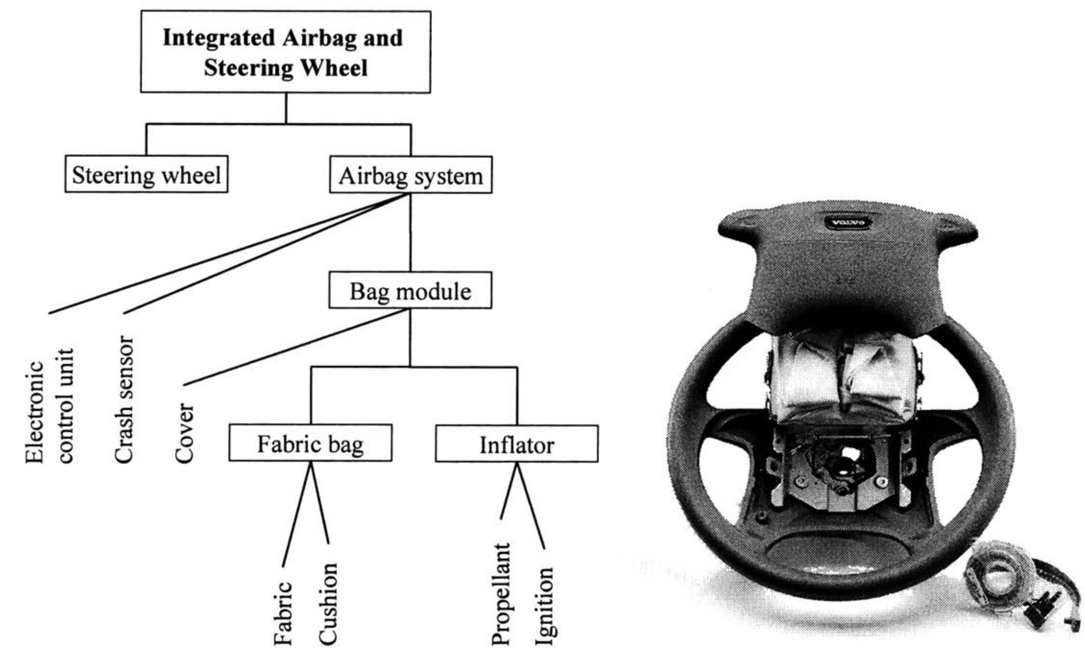
Figure 8: Organizational examples of product-based firms



(Source: Company annual reports)

Figure 9: Organizational examples of process-based firms

How does coherence arise from product capabilities? Figure 10 demonstrates how synergies can be created from the combination of technological capabilities in products. Automotive airbags consist of several different components including an airbag inflator, crash sensor, electronic control unit, and a fabric bag, which in the case of driver-airbags is mounted into a housing located in the steering wheel of the automobile. Potential synergy can be created through the integration of airbag and steering wheel into a unit developed and manufactured by a single company. An integrated design of airbag and steering wheel not only offers potential cost savings in product development and design, but also allows for additional functionality, quality control, compliance with regulatory standards, as well as reduced assembly and inventory requirements compared with the separate development and manufacturing of airbags and steering wheels. As a result of this synergy potential, driver airbags are increasingly being integrated into the steering wheel. Several airbag manufacturers in the United States have purchased steering wheel manufacturing facilities in the years following rapid expansion of the airbag market during the 1990s[17].



(Picture adopted from Autoliv, 2000b)

Figure 10: Illustration of a coherent product line (integrated airbag and steering wheel)

In the dimension of processes, there are similar synergies that point to the importance of process-based capabilities as a source of corporate coherence. Figure 11 shows the example of reinforced plastics. Reinforced plastics, or composites, have become one of

[17] Breed acquired Custom Trim and USS; TRW acquired MST and Magna International's airbag and steering wheel operations; Autoliv acquired Isodelta.

the most important classes of engineered materials in automotive and aircraft applications, offering improved strength and stiffness compared to the mechanical properties of plastics (Kalpakjian, 1995, p. 242). The process of manufacturing composites consists of a molding process of fibers in a plastic matrix. Because the properties of reinforced plastics greatly depend on the processing conditions, the proper control of the manufacturing process is important for part quality. The cost of molding equipment generally depends on the rated capacity of the mold, the clamping force, and the cost for dies. Because of the high cost of dies, high-volume production is required to efficiently amortize equipment costs. Companies specialized in manufacturing reinforced plastics therefore are tempted to maximize capacity utilization. A common strategy is to produce composites for a diverse range of applications that are not limited to automotive components. Reinforced plastics have wide applications in aircraft, piping, electronics, automotive, boats, and sporting goods. Firms with the capability of manufacturing reinforced plastics are likely to take advantage of this broadening of product applications to benefit from synergies in equipment capacity utilization, raw material purchase, as well as engineering knowledge offered by such expansion of product applications.

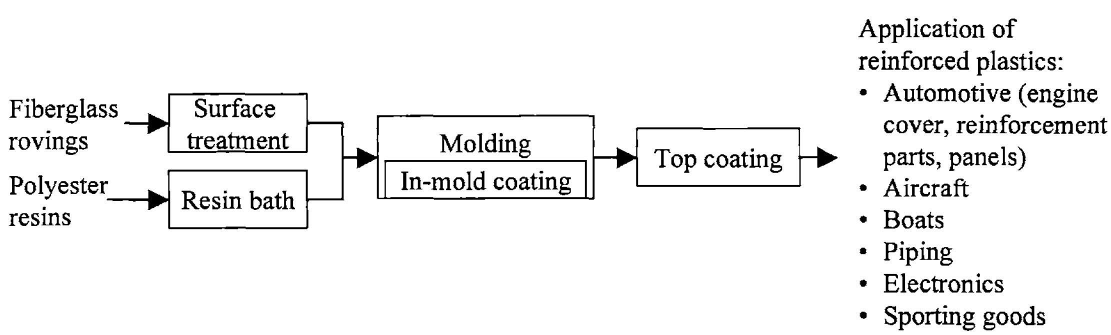


Figure 11: Illustration of a coherent manufacturing process (reinforced plastics)

The examples of integrated airbag and steering wheels, and reinforced plastics point to the importance of technological capabilities for corporate coherence, and illustrate the difference between the synergy mechanisms of product and process firms. For product firms, the synergies arise from highly specialized engineering and design capabilities in distinct product lines, and from savings in assembly and logistics. For process firms, synergies arise from specialized manufacturing skills and process operations, and increased capacity utilization through a broadening of potential product applications.

2.2.1 PRODUCT AND PROCESS CLASSIFICATION

For the purpose of empirical research, a hierarchical classification of products and processes was developed, see Figure 12 and Figure 13. Such a classification allows for the identification of product and process capabilities of individual firms in the automotive component industry, and facilitates the construction of an empirical measure of corporate coherence. This dissertation uses the classification to categorize products or processes of firms in the automotive supplier industry as part of the empirical analysis in Chapter 5 (see appendix 8.3 for a list of all categorized firms and data sets). Chapter 5 introduces a measure of corporate coherence that is based on a concentration index of capabilities within the hierarchical classification of products and processes. This measure is used to test for the effect of corporate coherence on firm performance.

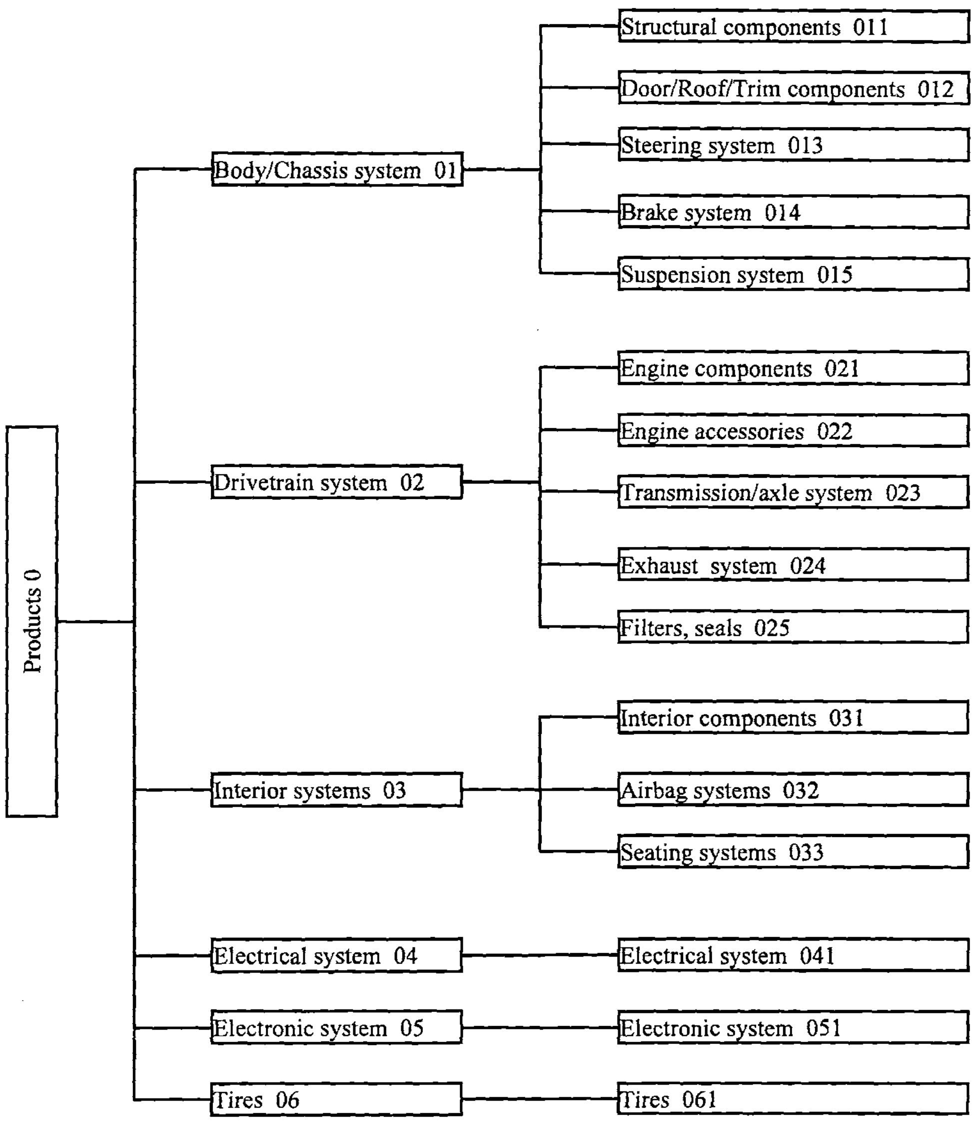
The classification scheme shown in Figure 12 and Figure 13 was created on the basis of criteria involving technological interrelationships of products and processes (see appendix 8.2 for the complete classification). Two products are related if they are placed in the same branches of the classification tree. Relatedness of products was defined on the basis of similarities in product functionality, scientific and technological knowledge requirement, and engineering and design considerations (see appendix 8.2 for detailed criteria). Relatedness of processes was defined on the basis of similarities of materials, equipment and manufacturing methods. Technical and engineering literature on automotive components served as a guideline for establishing the classification scheme[18]. For validation purposes, the classification was presented to two experts in the field of automotive products and processes.

There are obviously multiple methods for arriving at a classification scheme. Alternative classification schemes are used for empirical research in the management literature, however, many alternative methodologies have been noted for deficiencies. A common classification used in the strategic management literature is the Standard Industrial Classification (SIC). The SIC system was initially constructed to facilitate macroeconomic research and would inappropriate for the analysis of firm-specific capabilities. The SIC system lacks consistency (Rumelt, 1974; Silverman, 1998) and is constructed on the basis of product markets, with limited reference to the capabilities of process firms. Therefore an attempt was made to create a classification that would better

[18] Heywood, 1988; Society of Automotive Engineers, 1997a, 1998; Kalpakjian, 1997, 1995; Altmann, 1991; Haldenwanger and Vollrath, 1994; Ravnitzky, 1996; Maxwell, 1994; Ostermann and Woodward, 1993; Seiffert and Walzer, 1984; Shimokawa, Jürgens, and Fujimoto, 1997; Fenton, 1998; Barton, 1996; Society of Automotive Engineers, 1997b; Lechner, Naunheimer, and Ryborz, 1999.

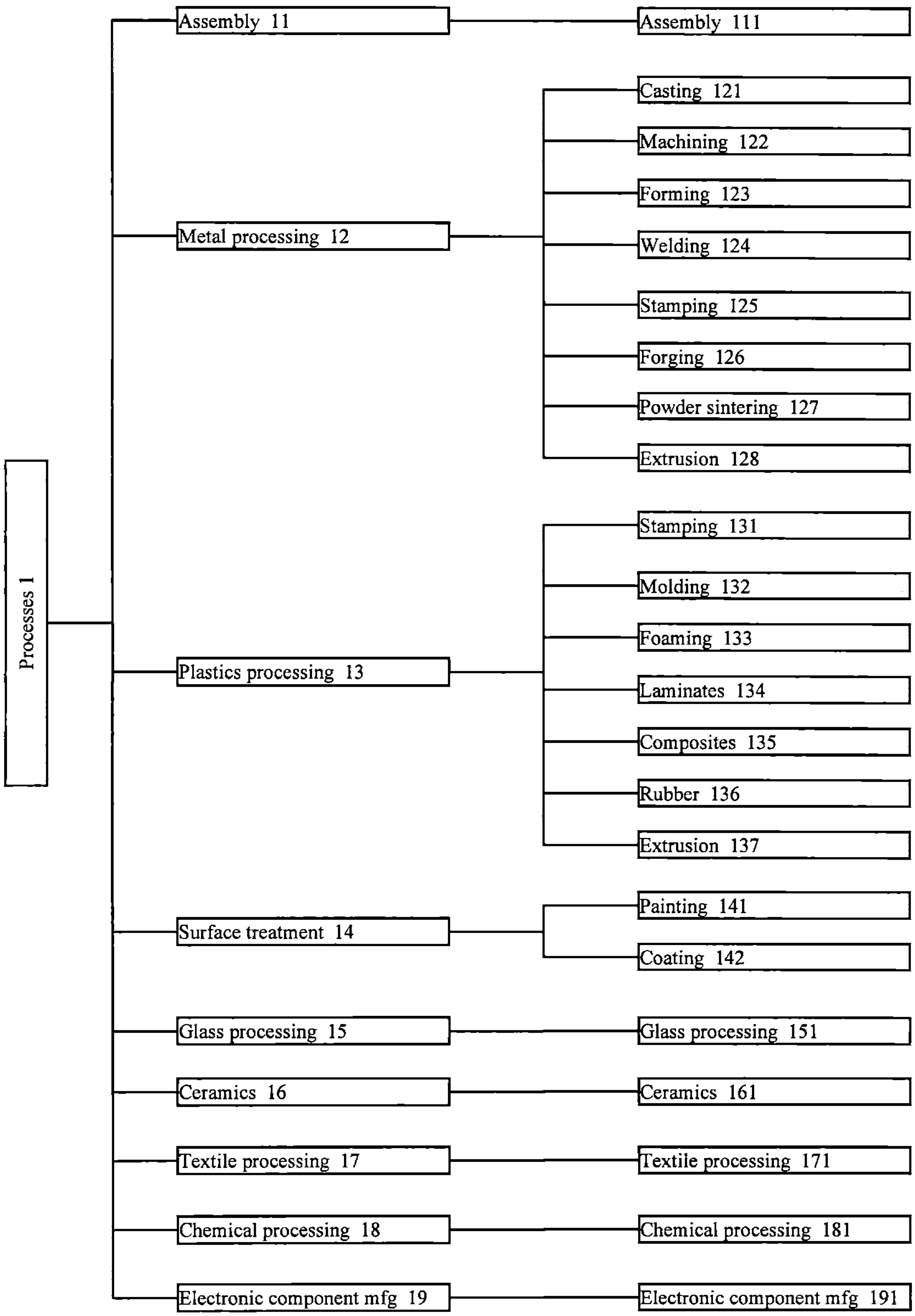
reflect the technological interrelationship of products and processes in the automotive component industry. To validate the results of the empirical analysis in Chapter 5, the US patent classification is used as an alternative classification scheme of product capabilities. However, patents only partially represent the technological capabilities of firms in the automotive supplier industry (several firms do not own any patents), and may not be a meaningful indicator for the capabilities of process firms.

The next section presents four firm examples that further illustrate and empirically ground the framework of product and process firms.



Only first two hierarchy levels are shown. For details, see appendix 8.2.1

Figure 12: Product classification



Only first two hierarchy levels are shown. For details, see appendix 8.2.2

Figure 13: Process classification

2.3 EXAMPLES OF PRODUCT AND PROCESS FIRMS

2.3.1 PRODUCT FIRM: DANA CORPORATION, AUTOMOTIVE SYSTEMS GROUP

The Automotive Systems segment of Dana Corporation is a typical product-based organization focused on capabilities in distinct product lines. The group manufactures axles and driveshafts, chassis and structural components, transfer cases, and brakes for the light truck and passenger car markets. Dana's Automotive Systems segment has become a leading global supplier of complete modules and systems to major automobile manufacturers. The ability to develop complete systems in addition to individual components allows the company to benefit from synergies in product development and manufacturing, and increases the chances of being awarded a single-source supply contract with an automobile manufacturer.

An example of the company's specialized product capabilities is reflected in its innovative Rolling Chassis™ module. The module integrates more than two hundred individual components and includes the frame, front and rear axles, driveshaft, suspension, steering gear, brakes, fuel tank, wiring harness, fluid lines, wheels and tires manufactured and assembled as a total system solution.

As a typical product firm, Dana's core competence is reflected by its ability to constantly introduce new product generations through ongoing efforts in engineering, research and development. Dana has acquired substantial technical expertise and full-service engineering capabilities that support the strong identities of its products in the market. The numerous trademarks of Dana's Automotive Systems segment are widely recognized in the automotive OEM and aftermarket, enabling the company to market its products on the basis of product quality, performance, and reliability.

2.3.2 PRODUCT FIRM: GENTEX CORP

Gentex is another example of a firm with distinct product capabilities. The company develops and manufactures automatic-dimming interior rearview mirrors for automobiles using electro-optic technology. The company was founded to manufacture residential smoke detectors, a product line that has since evolved into a more sophisticated group of fire protection products for commercial applications. Later, Gentex introduced automatic rearview mirrors that are sold mainly to General Motors and have become standard equipment on several of GM's luxury vehicle models.

A typical example of a product firm, Gentex is focused on a single product line, automatic rearview mirrors. The company targets solely the automotive market, and has an estimated worldwide market share of over 85% in this product market (source: company annual reports). The company continuously invests in its technical capabilities and owns several patents protecting its technology. With a gross profit margin of around 40% and operating margins of up to 30%, the company is one of the most profitable small companies in the automotive component industry.

2.3.3 PROCESS FIRM: TOWER AUTOMOTIVE INC

In contrast, Tower Automotive is a process-based company that is focused on manufacturing processes in the production of a broad array of generic products, such as stamped and welded assemblies. These parts use various grades and thickness of steel including hot and cold rolled, galvanized, stainless and aluminized steel. Tower Automotive's expertise in manufacturing covers stamping, roll-forming, hydroforming, and associated coating operations. The company owns a large amount of progressive and transfer presses for the production of stamped parts. Assembly operations are performed on either dedicated welding/fastening machines or on flexible-cell robotic lines for units with lower volume production runs.

As a process firm, the proportion of fixed assets such as plant and equipment to total assets is very high compared to other less process-oriented companies. Maximum capacity utilization and careful management of working capital are critical for achieving profitable operations. This includes detailed planning of manufacturing engineering personnel, maintenance and upgrading of existing manufacturing equipment, and investment in new equipment. Another characteristic feature of Tower Automotive as a process-based company is the high share of raw materials, mainly steel, among its purchased inputs. In 1996, raw material costs represented approximately 53% of Tower's revenues (source: company annual report).

In recent years, Tower Automotive has grown rapidly through acquisitions in the highly fragmented market for automotive structural parts. Through such acquisitions, the company has moved away from being a typical process firm by expanding into specific product lines of chassis and suspension components. In the course of this expansion, the company has also built up more engineering and product development capabilities.

2.3.4 PROCESS FIRM: PPG INDUSTRIES INC

PPG Industries is another firm involved in materials processing. PPG Industries has three business segments: coatings, glass, and chemicals. The coatings business involves the production of protective finishes and coatings for use in a range of applications in the automotive, appliances, industrial equipment, packaging, architectural, and consumer goods industries. The glass segment is a major producer of flat, fabricated and fiber glass for use in the automotive, construction, aircraft, marine and electronics industries, and the chemicals segment is a major producer of chlor-alkali and specialty chemicals. This broad diversification of market presence is typical for the generic products of material or process-based firms. Capabilities focused on a single process, for example glass production, allow the company to expand beyond a single market such as automotive, and sell its generic products into a more diversified set of markets. PPG benefits from this market diversification through potentially increased capacity utilization and through a reduced impact of demand fluctuations for a particular product line or geographic area.

PPG's percentage of plant and equipment to total assets is much larger compared to product firms (50% for PPG Industries, compared to 27% for Gentex; source company annual reports). PPG's production facilities are large-scale facilities with typical sales of $100 million per plant. Effective management of raw materials is important to PPG's continued operations, and the company is significantly dependent on the price of raw materials, because it constitutes a large portion of its operating costs. Most raw materials are therefore purchased with long term supply arrangements. As a company focused on processes, PPG's ownership of product-related patents are insignificant, but the company does constantly invest in improving its process knowledge, and operates test facilities for new products.

2.4 CHARACTERISTICS OF PRODUCT AND PROCESS FIRMS

The following section introduces criteria for defining product and process firms, and distinguishing between the two firm models. Product firms are defined as firms with distinct technological capabilities and skills relating to individual products or product lines. Process firms are defined as firms with distinct technological capabilities and skills relating to specific manufacturing processes or materials processing.

The discussion of product and process firms in this chapter indicated that firms based on products and processes follow a different corporate logic and have distinct characteristic features. Table 3 lists the characteristics of product and process firms that follow from the underlying definition of the framework and are an expression of the exclusive focus on products and processes. The definition and characteristics listed in Table 3 are used as criteria in the categorization of firms into product and process, which is carried out as part of the empirical analysis in Chapter 5. A statistical test of equality was performed to verify that such a categorization results in observable differences between product and process firms (see section 5.2.5). Empirical observations and accounting numbers are used to support the existence of differences between product and process firms. However, accounting numbers can only partially reflect the true value proposition of a firm, and should be taken as an indication rather than a cause of such differences.

Definition, primary criteria	
Product firm Firm has distinct capabilities relating to individual products or product lines	**Process firm** Firm has distinct capabilities relating to specific manufacturing processes or materials processing
Secondary criteria	
Firm is organized along individual product lines	Firm is organized along manufacturing processes
Products are highly differentiated, specialized, or complex	Products are generic, semi-finished, or material-based
Firm is engaged in research and product development, and the protection of intellectual property relating to products	Firm is engaged in on-going process development and improvements, and occasional protection of intellectual property relating to processes or materials
Products are sold primarily to customers in the automotive industry	Products are sold to a broad range of customers in different industries
Pre-manufactured parts represent a large percentage of purchased inputs	Raw materials represent a large percentage of purchased inputs

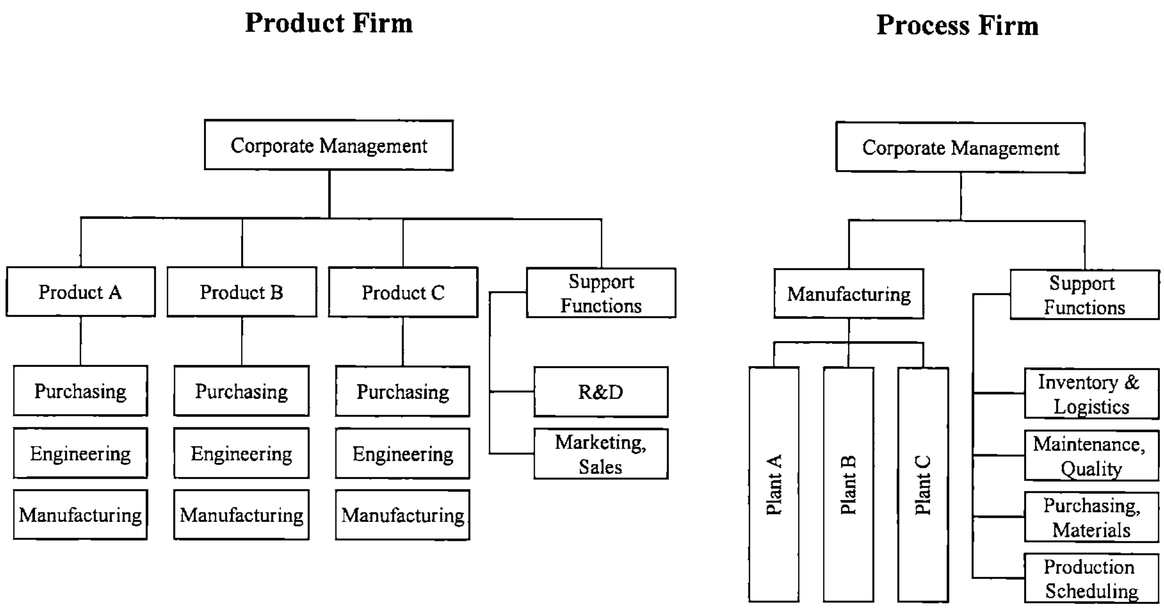
Table 3: Definition and criteria of product and process firms

The differences between product and process firms suggest how underlying technological capabilities and coherence of firms affect their corporate strategies and performance outcomes. These aspects are discussed in the remaining sections of this chapter, supported with insights from the literature. The distinct technological capabilities of product and process firms require different organizational capabilities and routines (section 2.4.1). Strategies of product differentiation and mechanisms affecting the cost and expense structure of firms are critical for product firms, whereas strategies affecting the asset structure and capacity utilization are critical for process firms (section 2.4.2 and 2.4.3). Differences in technology development, and market diversification are elaborated in section 2.4.4 and 2.4.5, and section 2.4.6 discusses the exclusiveness of the two firm models.

2.4.1 ORGANIZATIONAL STRUCTURE

The distinct capabilites of product and process firms require different organizational capabilities and routines. Typical organizational structures of product and process firms based on the study of manufacturing organizations in Hayes and Wheelwright (1988) are shown in Figure 14. Product-based organizations tend to be organized along separate product lines, with limited cross-divisional support functions. This makes product-based organizations highly decentralized, and responsive to the market needs of individual product lines. Product-specific manufacturing plants are highly specialized and require flexibility and innovativeness rather than tight cost planning and control. Corporate-level management staff usually makes decisions about capital investment, technology, product development, and special services such as information technology.

Process-based organizations, according to Hayes and Wheelwright (1988), are more centralized and organized along manufacturing plants or process stages. Central support functions provide services such as purchasing of raw materials, production scheduling, quality control, and inventory and logistics management. The sharing of corporate services offers significant savings in administrative costs, inventory levels, and standardization across process plants[19]. Manufacturing plants tend to be tightly controlled cost centers, and are not dedicated to individual product lines, which allows for company-wide maximization of capacity utilization and equilibration of demand fluctuations. Corporate management in process firms makes decision about large capital expenditures, capacity allocation and use, material flows, and technological changes. Because decision-making responsibility is more concentrated, hierarchies in the process firm involve multiple decision layers, and render the company less flexible but more efficient in operational performance.



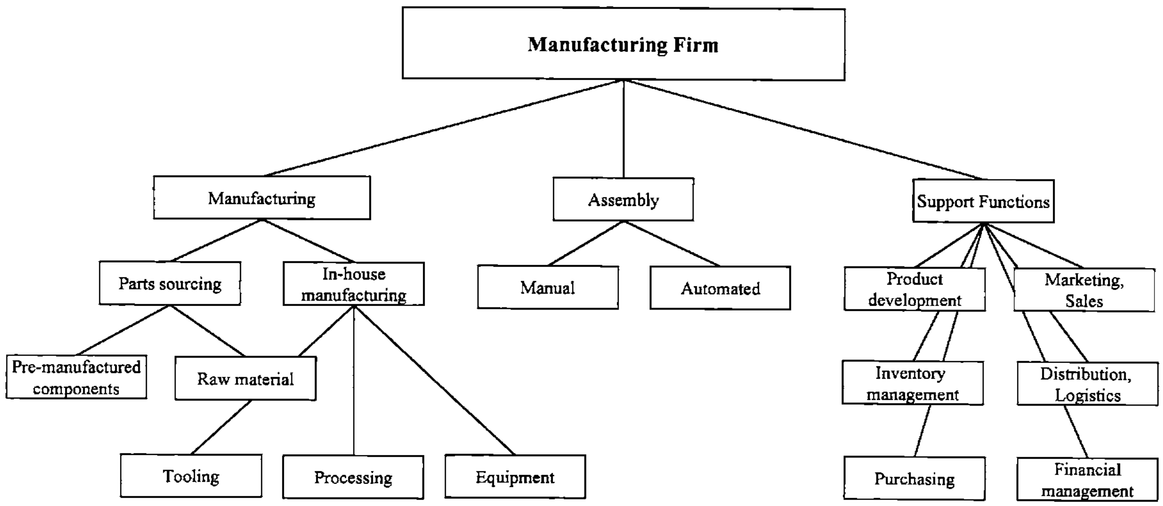
Figures are derived from the market-and-product-focused, and technology-and-production-process-focused organizations presented in Hayes and Wheelwright (1988, p. 118).

Figure 14: Organizational structure of product and process firms

2.4.2 COST AND REVENUE MANAGEMENT

Figure 15 shows the typical accounting positions of manufacturing firms that are used in the following discussions of cost and asset management of product and process firms. The accounting positions include purchasing, marketing and sales, and other administrative activities, engineering and product development, and in-house manufacturing and assembly operations.

[19] According to Hammer and Stanton (1999), Owens Corning in its efforts to streamline the organization according to processes, was able to achieve a "50% increase in inventory turns, a 20% reduction in administrative costs, and millions of dollars in logistics savings."



Adopted from Kaplan and Cooper, 1998, and Ulrich and Eppinger, 1995.

Figure 15: General cost structure of manufacturing firms

The organizational structure and attentional focus of product firms suggests that these firms spend more resources on cost and revenue related expenditures, whereas the importance of managing assets is more important for process firms (see section 2.4.3).

The focus of product firms on product-related activities consequently results in higher expenditures for research and development (R&D), marketing and sales, and administrative overhead (SG&A) compared to process firms. This is empirically confirmed in Table 4, which shows differences in accounting figures between product and process firms, based on ten-year averages of automotive suppliers in the United States (see Appendix 8.3 and 8.4 for details). Statistical tests of equality shown in Table 4 reject the null hypothesis that the means and medians of variables are equal for product and process firms.

Product firms spend on average almost three times the amount on research and development, and 50% more on corporate overhead compared to process firms. This confirms the importance of expense management for product firms, because product-based organizations tend to involve decentralized, and duplicate administrative functions in each product line (see Figure 14). In contrast, process firms spend relatively more on material inputs and capital outlays for manufacturing equipment than for product firms, and therefore comparatively less on administrative expenditures.

	Product-based Firms	Process-based Firms	Tests of Equality (p-values) Mean	Median
Cost and Revenue Management				
SG&A Expenditure (% of Sales)	15.1%	9.6%	*(0.000)*	*(0.000)*
R&D Expenditure (% of Sales)	3.5%	1.3%	*(0.000)*	*(0.000)*
Asset Management				
Machinery and Equipment (% of Assets)	22%	32%	*(0.000)*	*(0.000)*
Capital Expenditure (% of Sales)	5.5%	6.7%	*(0.011)*	*(0.000)*
Inventory Turnover	8.7	11.0	*(0.000)*	*(0.000)*

Numbers represent 46 companies (data set AUTO_COMP), averaged over ten years (1988-97).

Table 4: Characteristic differences in cost, revenue, and asset management between product and process firms

2.4.3 ASSET MANAGEMENT

The technological capability of process firms indicates a greater importance of efficient management of physical assets such as by plant, machinery and equipment. This involves plant capacity, capital expenditures, depreciation of machinery and equipment, and inventory and logistics management. As Table 4 confirms, the capital intensity of process firms is indeed much higher than for product firms (higher percentage of machinery and equipment, and capital expenditure). Interestingly, inventory turnover is higher for process firms, which may reflect the superior process capabilities, but may also be an artifact of the different meanings of inventory for finished components (product firms) and semi-products goods and materials (process firms). There is also a striking difference between small and large process firms. Inventory turnover is about 30% higher for process firms with sales of more than $300 million compared to smaller firms (same data as Table 4). The persistent focus of process firms on efficient management of assets suggests the presence of significant returns to scale for process firms.

In comparison, product firms are less intensive in physical assets, which is confirmed in the accounting figures of Table 4. However, product firms have a larger part of their assets represented by intangibles not reported in conventional accounting figures. Such intangibles may include intellectual property and brand names relating to specific product capabilities.

2.4.4 TECHNOLOGY DEVELOPMENT

Product and process firms engage differently in technology development. Product firms maintain their capabilities through investments in research and development, resulting in more differentiated products. Process firms maintain their capabilities through continuous process development and improvement, which typically results in cost reductions rather than increased differentiation of products.

Table 4 confirms the greater importance of research and development expenditure for product firms. However, the accounting definitions of R&D expenses may distort the figures in Table 4, because expenditures for process development may not fall under the accounting definition of R&D. This may give the misleading impression that process firms do not engage in technology development. In practice, however, process development is very important to the process firm, in the form of improving manufacturing efficiency, cycle time, standardization, and inventory management.

2.4.5 MARKET DIVERSIFICATION

Product and process firms differ in the degree of market diversification. Product-based firms typically focus on key customers for which the product has been developed and engineered. In the automotive component industry, automobile manufacturers require close involvement of their largest suppliers in the design and engineering of new product developments. The resulting accumulation of application-specific knowledge limits the possibility for market diversification of product firms. Supplier firms would need to completely redesign their products in order to be able to diversify into markets other than automotive.

In contrast, the generic nature of products from process-based firms means that such products are typically sold in various markets. Consequently, sales of process firms tend to be more diversified across markets relative to product firms. The example of PPG Industries in section 2.3.4 illustrates the highly diversified market presence of a process firm as the result of efforts to maximize capacity utilization through a broadening of potential product applications.

2.4.6 EXCLUSIVENESS OF PRODUCT AND PROCESS FOCUS

Products and processes are inevitably related because every product is manufactured on the basis of a process, and every process generates a product. Are product and process focus exclusive dimensions of a firm's capabilities? The discussion of product and process firms in this chapter indicated that firms based on products and processes follow a very different corporate logic, which suggests that the two firm types are exclusive models. Hayes, Wheelwright and Clark (1988, p. 122) argue that "it is obvious that these polar examples of manufacturing organizations – product focus and process focus – place fundamentally different demands on both line and staff organizations," and "therefore, the choice of manufacturing-organization structure should essentially be a choice *between* them: either a product focus or a process focus."

In the automotive supplier industry, the product and process focus are quite distinct, and only few examples were found to be ambiguous between product and process focus (see footnote 34, p. 95). Hybrid forms of product/process focus may exist in large firms that have acquired capabilities in a large number of products and processes over a long time. In these cases, the analysis would have to focus on a unit smaller than the firm, for example individual business units or plants, in order to distinguish between product and process focus. Although the empirical tests and data in this dissertation do not allow for a formal test, it is hypothesized that a combination of product and process focus in a single firm has a negative effect on economic performance in the automotive component industry, as a consequence of the exclusive corporate logic of product and process firms.

2.5 SUMMARY

This chapter presents a framework that expresses technological capabilities of firms in the automotive supplier industry along product and process dimensions. The remaining chapters elaborate how this technology-based view of firms helps define coherence of firms in this industry, and how firms achieve superior performance through coherence among either product or process capabilities. A central contribution of the framework is that it highlights the importance of technological capabilities, an argument that has been noted by numerous authors in the literature on manufacturing strategy, but has not been thoroughly examined by the strategy literature.

Coherence, or synergies of a firm, is one of the fundamental issues in the field of strategy. Explaining corporate coherence helps understand what combination of activities within a firm provide a source of competitive advantage. Existing theories of the firm explain competitive advantage as a result of competition and firm's position in the market (Porter, 1980; industrial organization theory), or as a result of distinct capabilities, skills and resources of a firm (resource-based view of the firm). While coherence is not a central issue in Porter's framework, it is instrumental to the resource-based view in explaining the source of competitive advantage. This chapter builds on these two theoretical principles, and seeks to explain coherence in the dimensions of products and processes of firms in the automotive supplier industry.

Coherence in the product dimension is the result of firm-specific capabilities in specific product lines, such as for example engine components, brakes or seating systems. The integration of airbag and steering wheel is presented as an example of how technological capabilities in related products translate into coherence. Synergies resulting from highly specialized engineering and design capabilities are seen as the main sources of coherence in product firms. Coherence in the process dimension is the result of skills and operational synergies in materials and manufacturing processes, such as metal machining, casting, plastics, and glass processing. Coherent process firms can achieve operational synergies through a broadening of potential product applications and increased capacity utilization. The fundamental differences between product and process firms suggest that the two types of firms are based on a different corporate logic, and that corporate coherence affects performance of product and process firms differently. It is hypothesized that performance of product firms depends mainly on strategies affecting the cost and revenue aspects of the firm, while performance of process firms is influenced by strategies affecting the asset structure and capacity utilization of the firm.

The framework of product and process firms is by no means a comprehensive theory of the firm, but it represents an initial formulation of a framework based on a set of constructs and general mechanisms linking these constructs. The simplicity of the product and process framework is both a virtue and a weakness. An advantage is that it explains basic characteristics of firms and provides a simple construct for empirical research, and its disadvantage lies in its relatively simple state of development and generality. The contribution of the model is to demonstrate that coherence is a function of technological capabilities in the dimension of products and processes, and to derive and evaluate implications of this framework for firm performance and corporate strategy.

An interesting aspect of the framework of product and process firms is that it is able to reunite certain features of the product market positioning view of Porter (1980) with the resource-based view in strategic management theory. Porter's framework of competitive strategies and market positioning translates specifically to the product firm, while the strategic recommendations of the resource-based view with an emphasis on assets and diversification translates to the process firm. In this sense, the framework of product and process firms offers a combination of certain aspects of the two theories.

Chapter 3

CORPORATE SYNERGY AND FIRM BOUNDARIES

One of the fundamental issues in industrial economics and strategy is the nature of the firm (Coase, 1937; Williamson, 1975). Why are there firms? What defines the boundaries of firms? In the historical essay on the nature of the firm, Coase (1937) points out that there is a fundamental distinction between firms and markets. Firms displace markets where activities can be combined more efficiently inside a firm than in the open market. The boundaries of firms are therefore determined by the ways in which business activities can effectively be combined inside a firm, in other words by the mechanisms of corporate coherence.

The following chapter builds on this theoretical concept of firm boundaries and attempts to demonstrate how the concept of coherence in product and process dimensions developed in the preceding chapter provides useful insights into the boundaries of product and process firms. Firm boundaries are defined here in terms of both the limits to vertical integration as well as lateral integration of firms[20]. The chapter begins with a review of the literature on the nature of the firm in section 3.1, and a more in-depth discussion of the concept of corporate coherence and firm boundaries in the literature. The second part of this chapter, section 3.2, presents an empirical look at the boundaries of automotive component firms based on an analysis of coherence in the dimensions of products and processes.

[20] For a definition of vertical and lateral integration, see for example Porter (1980, 1985). Vertical integration is the combination of "successive stages of production" in a business (Porter, 1980, p. 9). An example of vertical integration in the automotive industry is the combination of in-house component manufacturing and automobile assembly in a single company (Monteverde and Teece, 1982). Lateral or horizontal integration is the combination of activities in separate markets in a single company (Porter, 1985, p. 364).

3.1 THEORIES OF THE FIRM

The neoclassical economic theory assumes that firms are profit maximizing entities in competitive markets with no transaction costs. Many extensions of the neoclassical theory have added extensions or exceptions to the basic axioms in new economic fields (Rumelt, Schendel, and Teece, 1991).

According to Williamson (1975), the boundaries of firms and markets are determined by the nature of transaction costs. Transaction cost economics assumes that transactions between firms are inefficient because of incomplete contracts due to asset specificity, opportunism, and bounded rationality of actors. The distinction between firms and markets is fundamentally considered a question of efficiency in internal organization. Firms are the preferred form of organization where activities can be combined more efficiently inside a firm, and open markets are more efficient where such internal synergies are absent. According to Williamson, market transaction of goods and services are the predominant form of exchange when transactions are frequent, certain, and not relying on specific assets. Vice versa, transactions take place within firms in the presence of asset specificity, uncertainty, and low frequency of exchange. In a prominent example involving the automotive industry, this theory translates into the question whether an automobile manufacturer or a supplier should own a specific production equipment for automotive parts (see Klein, Crawford, and Armen, 1978, 1988). The short answer provided by theory is that the automobile manufacturer should integrate the equipment in-house if the specificity of the asset is very high and can only be applied to a specific model production. In reverse, the supplier should own the equipment if it is non-specific. Grossman and Hart (1986) extend the aspect of asset specificity in transactions into a theory of property rights, arguing more specifically when transactions should be carried out within firms or within the market, based on the presumption that a firm is identified with the assets that its owners control.

Agency theory (Berle and Means, 1932; Jensen and Meckling, 1976) is concerned with the governance structure of firms and the optimal form of enforceable contracts of corporate control, which transaction cost theory assumes as always remaining incomplete. Agency theory indirectly provides answers to the question about firm boundaries by explaining mechanisms and effects of different forms of corporate control, and aspects of inefficiencies in capital markets. According to Jensen (1986)'s *free cash flow* hypothesis, managers of firms with large free cash flows inappropriately divert this capital towards investments at below the cost of capital due to interest conflicts between owners and managers. This managerial behavior at the expense of firm value maximization explains why profitable firms that have run out of good investment opportunities are more likely to engage in unrelated, value-destroying firm diversification. Jensen's perspective provides an explanation for the existence of laterally diversified, corporate conglomerates, and the boom of unrelated corporate diversification in the 1960s.

Other economic theories of less relevance to the question of firm boundaries are only briefly mentioned here. Game theoretic industrial organization theory provides explanations for irreversible investments by firms. The evolutionary theory of the firm (Nelson and Winter, 1982) and Schumpeterian theories of technological innovation (Schumpeter, 1942) explain the existence and boundaries of firms as the causal result of historical paths, and the evolution of capabilities and organizational routines.

Recent articles offer new ways of looking at the boundaries of the firm. Bolton and Scharfstein (1998) argue for an integrated theory of transaction cost economics and agency theory. Holmstrom and Roberts (1998) argue that the question why firms exist has become too narrowly focused on the role of asset specificity and the hold-up problem in transaction cost and property rights theory. Quoting the example of close cooperation between Japanese automakers and suppliers, Holmstrom and Roberts argue that firm boundaries reflect much more than just investment incentives provided by ownership alone. The examples of long-term, close interaction of Japanese automakers with a small number of independent suppliers, or the high mutual dependence of Nucor Steel, a company which has outsourced all procurement of steel scrap to one supplier, show that the question of firm boundaries also encompasses relational contracts, such as the possibility for market monitoring, and issues of technical and organizational knowledge transfer. Gibbons (1998) confirms that such relational contracts between firms, based on mutual understanding, are important alternative organizational forms explaining the boundaries of the firm.

3.1.1 COHERENCE AND FIRM BOUNDARIES

Chapter 2 presented different theoretical viewpoints in the literature on firms and economic performance, and presented arguments that the concept of corporate coherence, or synergy, is key to understanding performance of firms. Coherence also has important implications for firm boundaries, in both vertical and lateral dimensions.

Neoclassical economic theory has difficulty in explaining lateral integration, or corporate scope. In the standard industrial organization theory, firms are seen as producers of single products, and efficiency gains in production are seen as a result primarily from the achievement of scale economies, and vertical integration. The existence of multiproduct firms cannot be explained in neoclassical theory because there are no compelling arguments for firms to adopt a multiproduct structure in a world of zero transaction costs (Teece, 1982). Neither can financial economic theory explain the existence of multiproduct firms under the assumption of efficient capital markets (Fama, 1970, 1991). The idea that multiproduct firms can reduce systematic risk if the cash flows of its single-product units are imperfectly correlated (see Lewellen, 1971), is invalid under the assumption of efficient capital markets. The efficient market theory argues that investors could always hold a portfolio of single-product firms that duplicates the multiproduct firm, but achieves risk reduction more efficiently through the open market.

In an extension of the neoclassical economic theory, Porter (1980) presents clear concepts of vertical integration of firms, but remains vague about lateral integration in his initial framework of corporate strategy[21]. Vertical integration can serve the strategic goals of a company through economies of scale of various business activities, such as joint production, sales, purchasing, and other areas. But vertical integration has both benefits and costs, which often concern the trade-off of economies of scale and minimum efficient scale of operations. Lateral integration, or multiproduct firms have no particular justification in Porter's framework. Because the economic market for products is viewed as the driver for corporate economic performance, firms are basically identified through their position in product markets and the entry barriers into these markets.

The resource-based view of the firm is able to explain corporate coherence and the existence of multiproduct firms more comprehensively. The resource-based view defines firms as a bundle of coherent tangible and intangible assets, which can be a source of competitive advantage in multiple product markets. According to the resource-based view, coherence of firms is therefore not based on product markets, but rather on a firm's resources. In one of the first resource-based explanations for multiproduct firms, Teece (1982) argues that firms diversify their product basis in order to avoid the high transactions costs associated with purchasing or trading specialized assets in the market. Following the Schumpeterian perspective (Schumpeter, 1942), competition is viewed as a process that is "dynamic, involving uncertainty, struggle, and disequilibrium," Teece (1982). This dynamic competition enables firms to accumulate specialized knowledge

[21] Business interrelationship as a concept of coherence is introduced only later by Porter, 1985, see discussion further below.

through research and development, and learning, and apply it to a constantly changing market environment (see also Teece, Pisano, and Shuen, 1997).

> "A firm's competence is a set of differentiated technological skills, complementary assets, and organizational routines and capacities that provide the basis for a firm's competitive capacities in one or more businesses... It isn't product specific. The presence of such competencies open possibilities for multiproduct activity." Teece et al., 1994:18).

According to Teece et al. (1994), the actual incentive to become a multiproduct firm is seen in the desire to use excess physical and human capacity, such as for example the productive capacity of idling machinery or engineering workforce. If the excess capacity cannot easily be divested, the firm has a clear incentive to use its available excess productive capacity and distinctive capabilities to become active in markets outside the traditional line of business. The central element of coherent, multiproduct firms are therefore underlying organizational and technological capabilities.

The concept of corporate coherence as the basis of lateral integration is further expanded in numerous papers, of which only the most important proponents are summarized here. Teece et al. (1994; 1997) argue that the boundaries of the firm can be understood in terms of enterprise learning, path dependencies, technological opportunities, the nature of the selection environment, and the firm's position in complementary assets[22]. Teece et al. (1994) conclude that corporate competitiveness is based on a firm's competencies:

> "In our view, the competitive strength of a particular corporation is a function of its underlying technical and organizational competencies. The existence of organizational competencies explains why plant and equipment produces more when owned by one company rather than another. The value of Tobin's Q – the difference between the market value of a firm's securities and the replacement cost of its assets – may reflect the presence of their technical and organizational competencies." Teece et al., 1994, p. 19.

Porter (1985, 1996) introduces the concept of fit among business activities that unites certain features of the product market positioning view (Porter, 1980) with the resource-based view. In these works, Porter redefines a firm as a collection of activities that support the firm's value chain and reflect its history and strategy. The importance of interrelationship among business units is emphasized, and coherence of a firm is no longer viewed as restricted to single product markets, but instead encompasses dimensions of vertical, geographic, and industry scope, within which firms can be coherent. Porter (1996) extends this broader view of firm coherence to mean fit among

[22] Complementary assets includes "distribution systems, manufacturing plant and equipment, and complementary technologies. Complementary assets typically lie downstream from product-process

activities. Such fit enhances a firm's uniqueness and competitive advantage, and includes consistency, reinforcement, and optimization among sets of activities.

The idea of complementarity among business activities has been extended in a separate stream of literature on the economics of complementary systems and the theory of supermodularity (Milgrom and Roberts, 1990; Milgrom and Roberts, 1995; Ichniowski et al., 1995; Athey and Stern, 1998; Topkis, 1998). With a particular focus on firm organization and modern manufacturing, Milgrom and Roberts (1990, 1995) describe manufacturing firms as a cluster of complementary activities, including the functions of marketing, logistics, engineering and manufacturing. The highly mathematical theory of supermodularity states that only coordinated changes among all activities allow firms to improve performance, and efficiency improvements in only one dimension of the activities may even worsen overall performance. Lean manufacturing methods of Japanese automobile producers are often quoted as an example for the application of this theorem. Firms can only improve performance, if they adopt all aspects of a lean manufacturing system (simultaneous adoption of short production runs, flexibility of production equipment, broad product line, skilled workers, cross-functional development teams, low inventories, and trust-based relationship with suppliers; see Womack, Jones, and Roos, 1991 and related literature on lean manufacturing).

3.2 CORPORATE SYNERGY AND FIRM BOUNDARIES OF PRODUCT- AND PROCESS-BASED FIRMS

The following section illustrates how the concept of coherence in product and process firms provides useful insights in the boundaries of firms in the automotive component industry. This empirical look at firms further strengthens the concept of coherence in the framework of product and process firms presented in Chapter 2, and links it with the question of firm boundaries. What are the sources of corporate synergies and coherence? What are the implications of corporate coherence on the boundaries of firms in this industry, in both dimensions of vertical and lateral integration?

Four examples of firms are chosen to discuss the concept of coherence and firm boundaries, see Figure 16. Autoliv is an example of a product firm with strong coherence

development in the value-added chain" Teece et al., 1994. The concept of complementary assets was originally applied to technological innovation, Teece, 1986.

in a single product line, whereas Tenneco is a product firm with little coherence among its diverse business activities. Autocam is a process firm exhibiting strong coherence focusing on a narrow set of manufacturing processes, and GenCorp is a process firm with diversified manufacturing processes and little coherence.

	Coherent	**Incoherent**
Product	Autoliv Inc	Tenneco Inc. (Tenneco Automotive)
Process	Autocam Inc	Gencorp Inc.

Figure 16: Examples of coherent and incoherent firms

A summary is presented in section 3.3. Based on the four examples, it is found that firm boundaries are well-defined for coherent firms, and less defined for incoherent firms. Furthermore, product firms have clear firm boundaries delimiting the firm's product portfolio and therefore tend to be vertically integrated, whereas process firms tend to be laterally integrated with clear firm boundaries delimiting upstream and downstream integration.

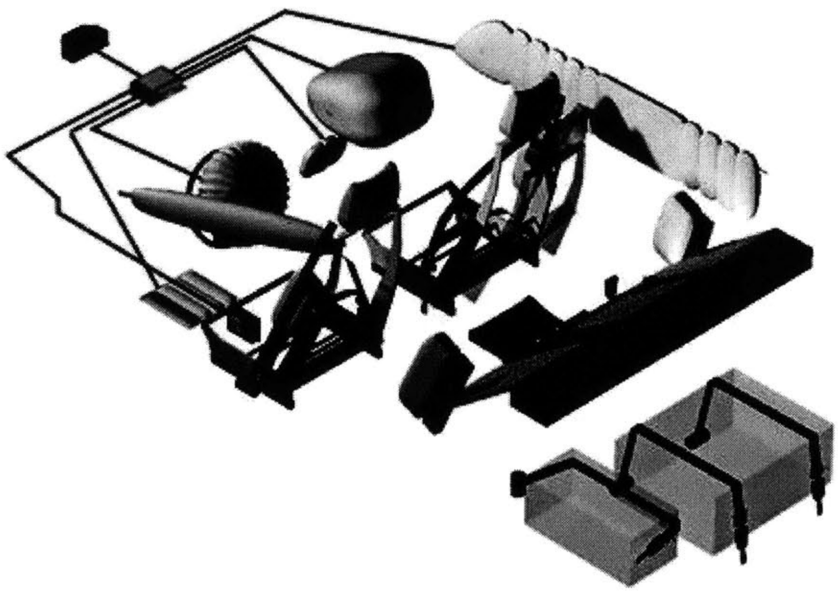
3.2.1 COHERENT, PRODUCT-BASED FIRM: AUTOLIV INC.

Autoliv Inc. is a product-based firm with strong corporate coherence in a single product line. The company is one of the world's leading suppliers of automotive occupant safety restraint systems. The predecessor company, AAB of Sweden, started manufacturing seat belts in 1956, and gradually expanded its product lines to include seatbelt pretensioners, frontal airbags, side-impact airbags, steering wheels and seat sub-systems. In 1998, the company merged with Morton International's airbag and inflator division, which pioneered airbag technology in 1968 and has also grown into a leading producer of airbag modules and inflators. Autoliv's sales after the merger exceeded $3 billion, approximately two thirds of which consists of airbags and associated products and one third of seat belts. Autoliv's products fall within a single industry segment or product line, integrated car passenger protection systems, which the company supplies to the large car manufacturers.

Autoliv's source of corporate synergy lies mainly within its highly specialized technological knowledge and innovative capacity in developing and manufacturing automotive safety systems. Since its inception, the company has been very focused, and has developed a considerable amount of proprietary technology relating to its product line. Autoliv employs about 10% of its work force in 14 technical and research centers. The company's research and development division develops its own tests and trials, and collects occupant collision data from its crash labs. Through this extensive scientific and technical know-how, Autoliv achieves considerable synergies in product development for its line of similar products. Autoliv's key competitive strategies further enhance coherence among its product development activities by continuously improving its product portfolio. The resulting complexity and specialization of Autoliv's competence is illustrated in Figure 17.

Autoliv's manufacturing system shows aspects of coherence in its integrated manufacturing and assembly facilities that are a result of the focus on a single product line. Most of the 64 production facilities are specialized in the manufacturing of individual components such as seat belts, textile airbags, inflators or cushions. A company-wide just-in-time delivery system has been designed to accommodate the specific requirements of each customer, resulting in low levels of inventory and rapid delivery service. The assembly operations are not generally constrained by capacity considerations, which is typical for product-based companies. Most of the assembly factories can make sufficient space available to accommodate additional production lines, and adjust capacity in response to changes in demand within a few weeks.

Corporate synergy can also be found in Autoliv's quality management system. Autoliv's products face extremely high reliability requirements, because they are subject to stringent government regulation. In order to meet these requirements, as well as high customer quality demands, the company has been operating a zero-defect-rate system that is based upon preventive principles involving the measurement of a number of quality indicators. Autoliv's preferred customer status with OEMs is also a result of its narrow product focus that reinforces the company's coherence. Automobile manufacturers increasingly demand standardized automotive safety systems at highest quality worldwide. But the narrow product focus of Autoliv and the resulting small customer base also acts against Autoliv because of the strong purchasing power of automobile manufacturers. As a result of this pricing pressure, unit prices of airbag systems and seat belts are expected to continue to decline in the future, and the future profitability of Autoliv will depend upon the company's ability to continue to reduce unit costs simultaneously with achieving technological improvements in its products.



(Picture adopted from Autoliv, 2000a)

Components shown include collision warning systems, near-zone sensors, electronic control unit, inflatable carpet and tubular structure, steering wheel, driver, knee, and passenger airbag, inflatable curtain, anti-whiplash seat, seat frames, belt-in-seat, integrated child seat, safety rear seat structure, seat belt beam, trunk belt, seat belt systems, thorax bags, and side-impact satellite.

Figure 17: Autoliv's focus on technical specialization in automotive safety systems

The firm boundaries of Autoliv are a result of its product focus and strong coherence. As a consequence of the highly specialized technological focus, Autoliv is focused on the narrow product line of automotive safety systems. Autoliv's growth is therefore limited by the market for this product line. Vertically, the company has increased backward integration of its production activities in attempts to lower production costs, as well as improve quality by increasing internal control of material flows. This gives Autoliv more control of the integrated production phases, which may be vulnerable to supply interruptions of a single pre-manufactured component. Supply delays in the just-in-time system could result in Autoliv's customers having to halt their own production processes, which might result in the customer seeking recuperation for consequential losses incurred due to production stops, besides Autoliv's own loss of income.

Sources of coherence, corporate synergies
• Highly specialized technological knowledge and innovative capacity in a single product line, automotive safety systems, with synergies in research, product development, engineering and testing • Customer-oriented logistics system (JIT) • Quality and reliability management (zero-defect-rate system) • Preferred customer status through high product differentiation and integrated product offerings

Firm boundaries determined by	
Vertically	• High degree of vertical integration • Integration with OEMs in product development • Joint ventures with specialized firms
Horizontally	• Activities focused on a narrow product line • Firm size and growth limited by size of the market for automotive safety products

Table 5: Coherent product firm: Autoliv Inc

Autoliv's firm boundaries are also vertically integrated through attempts of the company to expand its technological knowledge in technological cooperations. Frequently, the development of a new generation of airbag products is done in cooperation with vehicle manufacturers. Autoliv also has technical cooperation with its suppliers, for example in the development of new inflator propellants. An important element of Autoliv's strategy has been to establish joint ventures with specialized firms to gain access to knowledge and intellectual property of new safety products. For example, the company cooperates with the high-tech company Celsius for the development of an adaptive cruise control system using Celsius' radar technology.

3.2.2 INCOHERENT, PRODUCT-BASED FIRM: TENNECO INC. (TENNECO AUTOMOTIVE)

Tenneco Inc is a product-based firm that grew out of a highly diversified industrial conglomerate with businesses in multiple, incoherent product markets. Originally named the Tennessee Gas Pipeline Company, Tenneco has recently transformed itself into separate, more focused companies, but still remains a rather incoherent company, see Figure 18. The conglomerate company once had major businesses in natural gas transportation and marketing (Tenneco Energy), automotive exhaust systems and ride control products (Tenneco Automotive), packaging materials and containers for consumer and commercial markets (Tenneco Packaging), ship construction (Newport News Shipbuilding), and farm and construction equipment (Case Corporation, spin-off in 1994). The original conglomerate provided little source for corporate synergy, and most businesses were subsequently spun off.

Of interest for the discussion of coherence in the automotive component industry is the role of Tenneco Automotive in the conglomerate. Tenneco Automotive is a leading automotive component manufacturer serving both the automotive OEM and aftermarket in two product lines, automotive exhaust and ride control systems. The exhaust product line includes mufflers, catalytic converters, tubular exhaust manifolds, pipes, exhaust accessories and electronic noise cancellation products. The ride control product line includes shock absorbers and struts, electronically adjustable suspension systems, vibration control components, bushings, springs and modular assemblies.

Tenneco Automotive shared little or no synergies with the other business segments of the original Tenneco Inc. The only shared support that the subsidiary obtained from headquarters was an administrative service program and data processing center, Tenneco Business Services, which provided assistance to all Tenneco affiliates. Even within Tenneco Automotive, coherence among the automotive component products is limited. The two product lines of exhaust and ride control systems concern two distinctly different product lines that share little technological synergy, and can be developed and manufactured independently without synergetic losses.

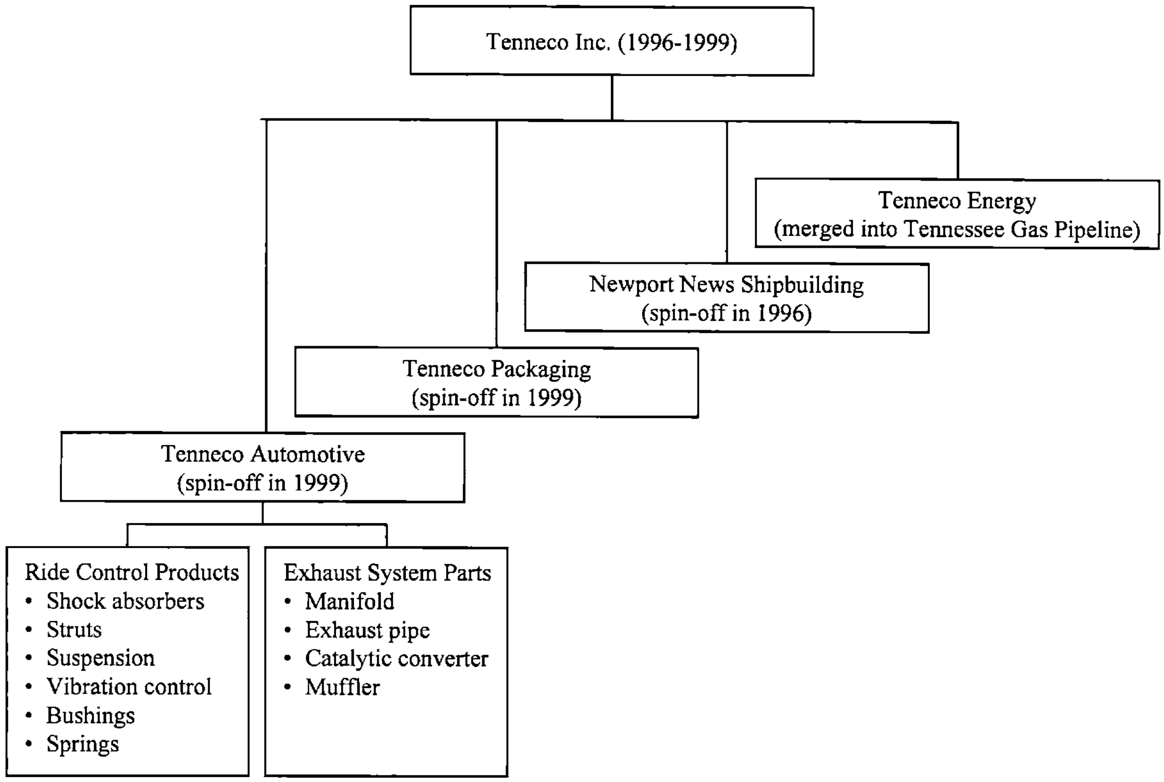


Figure 18: Diversification and spin-off of Tenneco's business activities (1996-1999)

Both automotive product lines were grown through acquisition rather than internal growth, which may explain their relative separation. Tenneco entered the exhaust product line in 1967 with the acquisition of Walker Manufacturing Company, and with the acquisition of Heinrich Gillet GmbH & Co. in 1994, became one of Europe's leading exhaust suppliers. The ride control product line was added in 1977 with the acquisition of Monroe Auto Equipment, and the company further acquired the Pullman Company with its Clevite division, a leading manufacturer of elastomeric vibration control components, in 1996. Through acquisitions, Tenneco Automotive aims at capitalizing on its brand names by incorporating newly acquired product lines within the existing product families, Walker exhaust products and Monroe ride control products. Tenneco Automotive's brand strength is a major asset of the company and one of its few sources of corporate coherence. A second source of coherence is its sales and marketing system. Both product lines take advantage of a dedicated sales and consumer brand marketing force. Coherence in manufacturing seems limited. All manufacturing facilities are separated for the two product lines, which comes as a result of the company's acquisition strategy. Walker operates 44 manufacturing facilities, and Monroe operates 21 facilities, which Tenneco never attempted to integrate.

Within each product line of Tenneco Automotive, coherence exists mainly in technical dimensions. Automotive exhaust systems require precise engineering of the manifold, pipe, catalytic converter and muffler. The engineering capabilities include predictive design tools, advanced prototyping processes and testing procedures. These capabilities have resulted in innovative product solutions such as adaptive dampening systems, and electronically adjustable suspensions.

Sources of coherence, corporate synergies
• Little coherence of Tenneco Automotive with other business segments, except administrative services provided by headquarters and Tenneco Business Services • Coherence among the two automotive product lines, exhaust and ride control products, is limited to: - Similar sales and marketing systems - Strong brand names in automotive aftermarket (Monroe and Walker) - Technical complementarities within product lines - Long-standing business relationships with OEM customers worldwide

Firm boundaries determined by	
Vertically	• Limited vertical integration • Cooperation with OEMs in product development • Manufacturing joint ventures in emerging markets • Mix of direct sales to retailers, warehouse distribution, and sales to OEMs
Horizontally	• Horizontally diversified through separate product lines • Growth through acquisitions into related markets for automotive OEM and aftermarket products

Table 6: Incoherent product firm: Tenneco Automotive

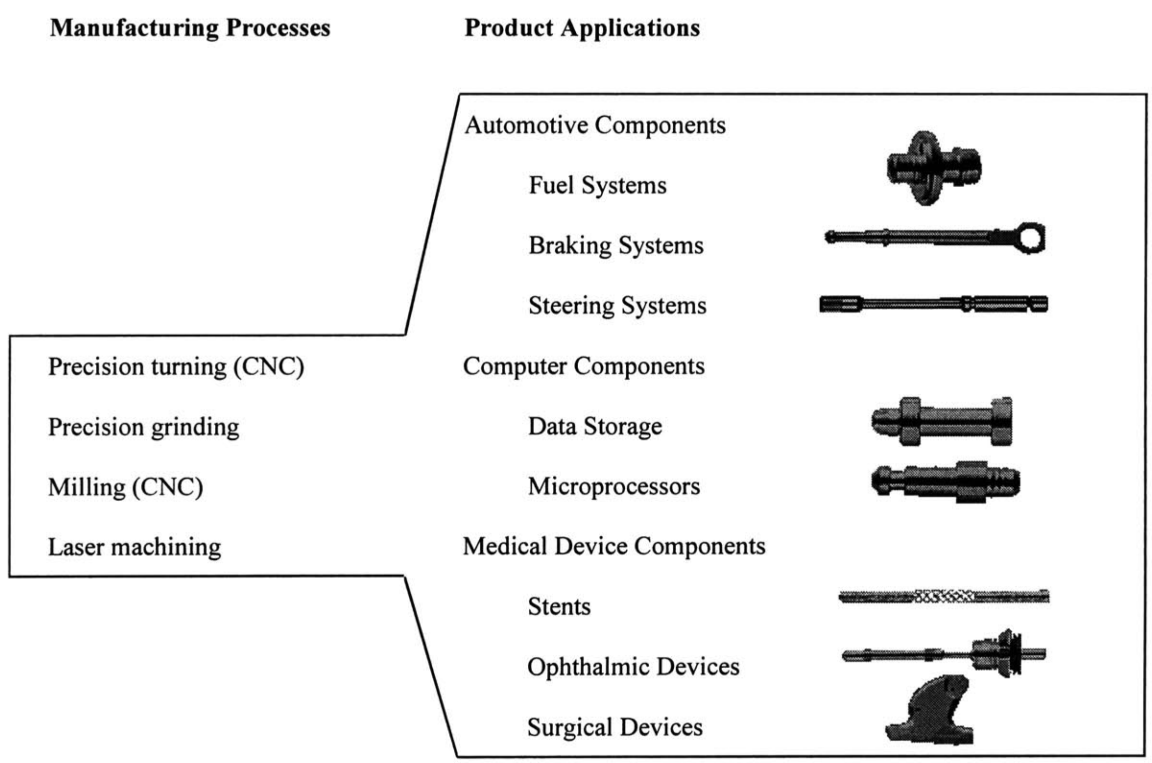
The firm boundaries of Tenneco Automotive are rather undefined, which reflects the limited coherence among its product and technological capabilities, and its diversification and acquisition strategy. Tenneco Automotive has two separated product lines with only limited vertical integration with vehicle manufacturers. The company cooperates with OEMs in the product development stage of its technologically more sophisticated products. Long-standing business relationships with many of its OEM customers worldwide allows Tenneco Automotive to achieve higher supplier status. In the automotive aftermarket, Tenneco Automotive is integrated into the distribution chain, but employs different approaches to reach the end customer, including the traditional three-step distribution system (warehouse distributors, jobbers and installers), direct sales to retailers, and sales to programmed marketing groups. Geographically, Tenneco Automotive attempts to broaden its presence, and has therefore invested in local manufacturing joint ventures to establish a presence in emerging markets, such as India and China.

Tenneco Automotive's strategic goals include further growth in its ability to provide full-system automotive products and continued international expansion. The corporate history of Tenneco Inc has shown that there was little coherence among the old conglomerate, which led to the spin-off of many business segments. Coherence is also limited between the two separate business lines of Tenneco Automotive. A split of the exhaust and ride control product lines of Tenneco Automotive would therefore be a conceivable future strategy for the company.

3.2.3 COHERENT, PROCESS-BASED FIRM: AUTOCAM INC.

Autocam Inc. is a process-based firm with strong coherence among its manufacturing operations. Autocam is a small, but rapidly growing company with sales of $179 million (in 1999) that designs and manufactures close-tolerance, specialty metal-alloy components sold to the automotive, computer and medical device industries. These components are used primarily in gasoline and diesel fuel lines, power steering and braking systems, and in devices for surgical procedures. Autocam's manufacturing involves machining of metals from bar stock using multi-spindle, cam-driven turning machines and centerless grinders. Parts are then deburred, cleaned, and in some cases, plated or heat-treated at outsourced locations, packaged and shipped directly to the customer. Autocam's uniform production equipment includes high-precision, automatic turning machines, and computer numerically-controlled (CNC) turning, milling and grinding machines.

The biggest source of Autocam's corporate synergies lies in the company's focus on a set of specialized manufacturing processes. Through this manufacturing capability, the company is able to simultaneously offer high-precision and high-volume production. As a typical process firm, Autocam has a narrow process focus, but a broad customer and product basis, as illustrated in Figure 19. Autocam initially focused on manufacturing automotive components, and subsequently expanded into the component market for medical devices and computers using the same specialized manufacturing capabilities. The company's strategy remains to continue to expand its customer base by applying its core competence in high-precision machining to product applications in other industries. The focus on a limited set manufacturing processes also allowed the company to implement standardized, company-wide cost reduction and quality control programs.



(Pictures adopted from Autocam, 2000)

Figure 19: Process capabilities and product applications of Autocam

Sources of coherence, corporate synergies
• Specialized manufacturing processes capable of high-precision, high-volume production • Transfer of manufacturing skills from automotive products to medical devices and computer applications • Aggressive cost reduction program in manufacturing • Statistical process controls and quality control program

Firm boundaries determined by	
Vertically	• Limited vertical integration, typically short-term supply contracts or blanket purchase orders • Cooperation with customers for the development of new products, new specifications
Horizontally	• Diversified customer basis in the markets for automotive components, medical devices, and computer components

Table 7: Coherent process firm: Autocam Inc

As a result of Autocam's coherence and narrow process focus, its firm boundaries are delimited in the vertical direction. The company is not vertically integrated, and supplies its customers with short-term supply contracts. Orders are typically awarded as blanket purchase orders from automotive customers in a bidding process based on component specifications submitted by the customer. Occasionally, Autocam builds relationships with R&D units of customers for the development of new products in the medical device industry. Suppliers of Autocam are generally not dedicated, except for the supply of specialty alloys, and Autocam's customers allow for the pass-through of certain raw material price fluctuations.

In horizontal dimensions, Autocam is very diversified with product applications in the markets for automotive components, medical devices, and computer components. This is a result of its specialized capabilities on a narrow set of manufacturing processes applied to a very broad range of product applications.

3.2.4 INCOHERENT, PROCESS-BASED FIRM: GENCORP INC.

GenCorp Inc. is a process-based company that has diversified into a conglomerate based on polymer science and engineering. The coherence among GenCorp's business activities is very limited, and its firm boundaries are consequently less rigid in both vertical and horizontal dimensions. GenCorp was formerly the General Tire & Rubber Company until it was transformed into a holding company in 1984, with subsequent divestiture of its tire business, General Tire. Since then, GenCorp's main competence is still centered around polymer processing, but the company has grown much more diverse. Operations are grouped into three business segments. The aerospace and defense segment manufactures liquid and solid rocket propulsion systems, defense electronics and fine chemicals. The automotive segment produces extruded and molded rubber products for vehicle bodies and window sealings sold to automotive OEMs and supplier, and the appliance market. The polymer products segment produces diverse products including vinyl-coated fabrics, vinyl and paper laminates, plastic films, wallcoverings, roofing systems, tennis balls, racquetballs and specialty latices. The subsequent discussion will focus on coherence in the automotive business segment.

There is no apparent source of coherence between the automotive business segment and other GenCorp businesses, with the exception of headquarter services and the sharing of basic research services in polymer science and engineering. The parent company operates a Technology Center that supports research for new products and processes, and leverages technological competencies in cross-cutting disciplines such as adhesives, coatings, graphics and information technology, materials selection, and engineering analysis for new products. But the Automotive division and the Polymer Products division also operate their own product and process development centers. The weak coherence between Polymer Products and Automotive is apparent from the complete separation of manufacturing facilities, and sales, marketing, design and engineering functions. The separation occurs despite overlaps in certain targeted markets. For example, the Polymer Products division produces in-mold coatings, gaskets, seals, and trim for the automotive industry, serving some of the same customers as the Automotive division. The limited coherence of GenCorp finally led the company to spin off its Polymer Products businesses into a separate company in 1999.

Even within the Automotive division, the company operates two separate units with little coherence. The Reinforced Plastic business produces custom molding of reinforced plastic components for automotive body panels, and the Vibration Control business produces molded rubber products including bushings, engine mounts and suspension assemblies for automotive customers. Both of these businesses require little sharing of engineering and process knowledge.

Sources of coherence, corporate synergies
• Very limited coherence among the parent corporation as a result of process diversification among the business units. • Weak coherence between related process activities, such as the automotive plastics extrusion business and the polymer products division, even though they both serve the automotive market, among others • Coherence between automotive business and polymer products division is limited to: - Experience and technical capabilities in polymer science and engineering shared through development centers (Corporate Technology Center)

Firm boundaries determined by	
Vertically	• Aspects of vertical integration in material supply and processing, and distribution • Integration into distribution chain varies widely depending on the nature of the products and the industry or market served, with products being sold either directly or through distributors
Horizontally	• Horizontal diversification with a presence in various markets, but spin-off of business divisions with weak corporate coherence • Continued growth through acquisitions into related process activities and markets • Strategic alliances to broaden geographical presence (Europe, Asia)

Table 8: Incoherent process firm: GenCorp Inc

As an incoherent firm, GenCorp has loose firm boundaries, exhibiting both aspects of vertical integration into material supply and distribution chains, and lateral integration into diversified product markets. GenCorp has historically been vertically integrated into the material supply chain as a company involved in rubber and polymer processing. In the distribution chain, GenCorp's vertical integration varies widely with the product and market served. Products are either sold directly or through distributors.

In horizontal dimensions, GenCorp is broadly diversified, and as a result of its process focus, has a presence in diversified product markets. In the past, business divisions with weak corporate coherence were spun off. The overall limited coherence of the company suggests that further corporate expansion may also result in additional spin-off of business units that have became too incoherent with the rest of the company.

Geographically, the company uses strategic alliances to broaden its presence in new markets in Europe and Asia. The company created a strategic alliance with German automotive supplier Henniges, which produces high-quality vehicle sealing systems, encapsulated glass and molded rubber parts for major European customers. In the future, GenCorp attempts to expand its activities by further diversifying its product lines, expand its process capabilities across several market segments, and expanding its global presence.

3.3 SUMMARY

This chapter discussed the issue of corporate coherence and firm boundaries, using the framework of product and process firms developed in Chapter 2. Firm boundaries denote the limits of firm integration in vertical and horizontal dimensions. Neoclassical economic theory explains firm boundaries as a result of the efficiency consideration whether economic contracts, or business activities, can be carried out more efficiently inside a firm or in the open market. Firm boundaries are therefore an expression of the limits to efficient combination of business activities within a firm, which in previous chapters has been described as the concept of firm coherence, or synergy. Coherence is the central argument in the resource-based theory for explaining horizontal integration. According to this theory, horizontally integrated, or diversified firms utilize firm-specific capabilities to expand their businesses. Neoclassical economics and the work of Porter (1980) provide little explanation for horizontal diversification of firms, but present extensive arguments and empirical research regarding vertical integration of firms.

Firm boundaries are then discussed in an empirical look at four firms in the automotive supplier industry using the framework of product and process firms. These four examples indicate the following link between the concept of coherence and firm boundaries, see Figure 20. The first observation is that firm boundaries are well-defined for coherent firms, but less pronounced or inconsistent for incoherent firms. This supports the hypothesis that corporate coherence provides insights for firm boundaries. The second observation is that product firms tend to be vertically integrated, while process firms tend to be laterally integrated. Mechanisms of vertical integration of product firms include integration of material supply, long term contracts with suppliers, cooperation in product development with automobile manufacturers, and integration into the distribution chain. Horizontal integration of process firms is expressed in the broadly diversified customer base and market presence, and frequent acquisitions into related process activities. These patterns of vertical and horizontal integration are the result of distinct technological capabilities of product and process firms that were outlined in Chapter 2. The observations on firm boundaries of product and process firms are consistent with the strategy theories of Porter (1980), and the resource-based theory, respectively, but offer a more detailed and explicit explanation of firm boundaries derived from technological capabilities of firms.

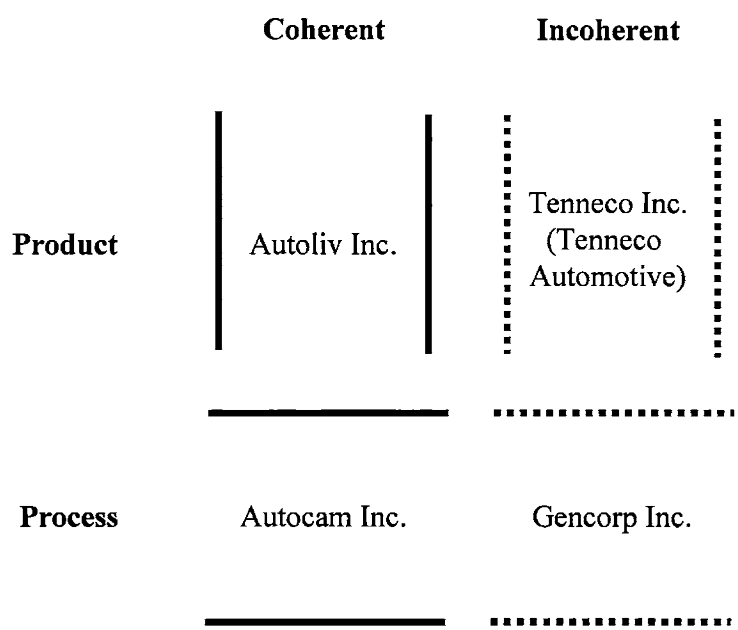


Figure 20: Firm boundaries of coherent and incoherent firms

Chapter 4

THE DEFINITION OF INDUSTRY

Industry is defined in the Encyclopaedia Britannica as "a group of productive enterprises or organizations that produce or supply goods, services, or sources of income." If industry is defined as groups of organizations, along which principles do we group them, products or processes? In economics and strategy, industry boundaries are traditionally seen as the limits between product markets. The definition of industry on the basis of product markets has serious deficiencies for explaining coherence and firm boundaries of process-based firms.

A suggested extension of the definition of industry includes both product and process dimension, as discussed in section 4.1.1. In such a definition, process and product industries are defined as groups of firms that consist of coherent product and process firms. A practical application of product and process dimensions to the automotive industry is discussed in section 4.1.2. Implications for empirical research on industry relatedness are discussed in section 4.2, which proposes a methodology similar to the classification of products and processes in the automotive industry for measuring industry relatedness.

The automotive component industry is an interesting example for demonstrating the difficulty of drawing industry boundaries. Figure 6 in Chapter 2 illustrates that industry boundaries based on a product perspective are ambivalent where products represent generic or undifferentiated components. For example, a firm producing plastic products can be represented in several product markets besides automotive components, and in fact may derive considerable competitive advantage from being diversified into a variety of product markets. Even specialized products may not be associated with a single product market without ambiguity, such as seats, air conditioning equipment, or diesel engines. Such products are not only sold in the market for automotive components, but also in the market for industrial equipment (air conditioning), and other transportation equipment markets (seats for railway, marine, aircraft; diesel engines for truck, bus, power generation, construction, mining, marine markets).

4.1 CONCEPTS OF INDUSTRY

The concept of industries as separable groups of firms is based on traditional economic theory in industrial organization, and hence provides a framework that accommodates product-based firms, but does not fit well with process-based firms that are often diversified into several product markets. Porter (1980, p. 5) defines industry as "the group of firms producing products that are close substitutes for each other." The term *product* is used by Porter in a generic sense as the expression of a firm's output, including products and services. Firms are therefore viewed as a bundle of products, which is difficult to reconcile with the concept of process-based firms. The strength of a process firm is hidden in its manufacturing capabilities, and a process-based firm is likely to be diversified in its products across a range of product markets. For example, PPG Industries is a process firm selling its products simultaneously in the markets for automobiles, construction, aircraft, electronics, and chemicals. In fact, PPG Industries' diverse market presence is the result of its focus on process capabilities rather than the focus on product markets. This concept of firm capabilities irrespective of product market position is central to the theory of corporate strategy in the resource-based view of the firm, as reflected by Collis, 1996:

> "...the relatedness of businesses in a corporate portfolio should have little to do with product market relatedness and much to do with how those businesses leverage the unique resources of the corporation." Collis, 1996, p. 122.

In Porter 1980's alternative framework of strategy, such coherence only exists in the dimension of products, but in his later works, Porter (1985) points out the importance of interrelationship among businesses, which indicates an acknowledgement of coherence beyond product markets:

> "Interrelationships among segments and business units create possibilities for broader industry definitions. A useful working industry definition should encompass all segments for which segment interrelationships are very strong. Segments where interrelationships with other segments are weak may sometimes be separate industries from a strategic viewpoint. Related industries linked by strong interrelationships may in strategic terms be a single industry." Porter, 1985, p.272

4.1.1 PRODUCT AND PROCESS INDUSTRIES

A definition of industry that mitigates the problem of industry delineation extends the definition to include both product and process dimensions, as shown in Figure 21. In such a definition, product industries are defined as groups of coherent firms based on technological capabilities in products, and process industries are defined as groups of coherent activities in the process dimension. Product and process industries are the expression of coherence in the dimension of products and processes that delimit economies of scope in these two dimensions.

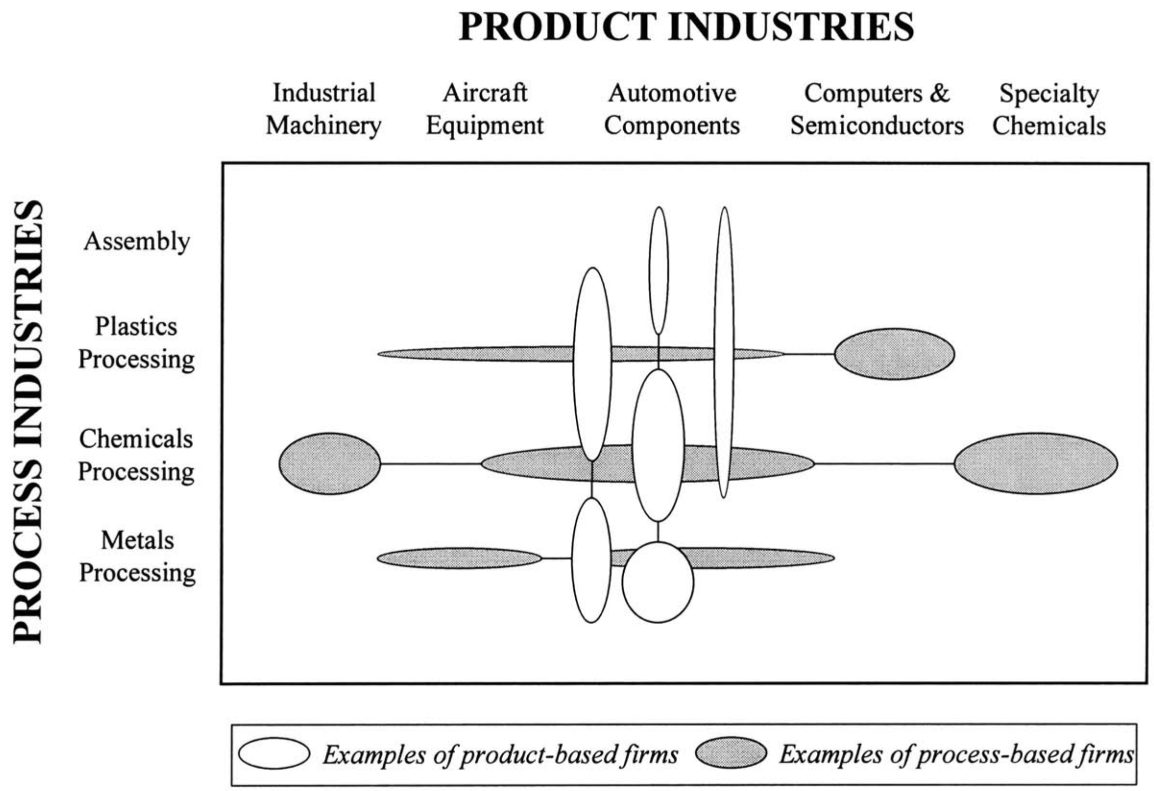


Figure 21: Suggested concept of industries in product and process dimensions

The next section illustrates how the definition of industry in product and process dimensions applies to the automotive industry, and what insight can be gained from such a perspective.

4.1.2 AN ALTERNATIVE VIEW OF THE VALUE CHAIN OF AUTOMOBILE PRODUCTION

A traditional view of the automotive industry was presented in Figure 1 of Chapter 1. In this view, the automotive industry consists of the supply chain, automobile manufacturing and assembly (OEM), and the distribution chain. Such a view of the automotive industry does not accommodate process-related industry features. An alternative view of the automotive industry that includes both product and process dimensions is shown in Figure 22. Such a view of the automotive industry comes closer to describing the complete chain of value-adding activities surrounding the OEM activity of automobile production. The recent works of Porter underline the fundamental role of analyzing complete value chains in identifying sources of competitive advantage in an industry (Porter, 1985, p. 33; Porter, 1996).

In the automotive industry, considerable value is added not only in the product dimension, but also in the process dimension. In the supply chain, product firms add value along the production of components such as drivetrain, powertrain, and electronics; and process firms add value along the manufacturing and processing of metals, plastics, and other materials. Value-adding activities in both product and process dimensions are also found around the assembly activities of OEMs. Product-related activities concern vehicle design and development, and manufacturing of key automotive components by the OEM. Logistics, distribution, quality control, and information technology represent business activities that are process-related in the sense that competence in these services can be leveraged across unrelated markets. Nationwide logistics networks and providers, for example, serve not just automobile manufacturers, but a diversified range of customers[23]. Another example of business services with process characteristics is electronic commerce between businesses (business-to-business e-commerce) for the purchase of supplies and materials. Such service may be offered more competitively by information technology companies that are specialized in e-commerce, rather than by automobile producers seeking to acquire such specialization.

In the automotive distribution chain, product-related value activities are found in dealerships and repair shops, which are closely linked to the actual product, the automobile. Services that are more generic, such as vehicle financing services, represent value activities with typical process characteristics, available across markets. For example, General Motors Acceptance Corporation provides a broad range of financial services that are not bound to the automobile market, including consumer vehicle financing, full-service leasing and fleet leasing, dealer financing, extended service contracts, residential and commercial mortgage services, and vehicle and homeowners insurance.

[23] For example, General Electric provides business services for diverse customers through its subsidiaries GE Supply and GE Industrial Systems, which include on-site inventory management, distribution solutions, factory automation, and production equipment leases.

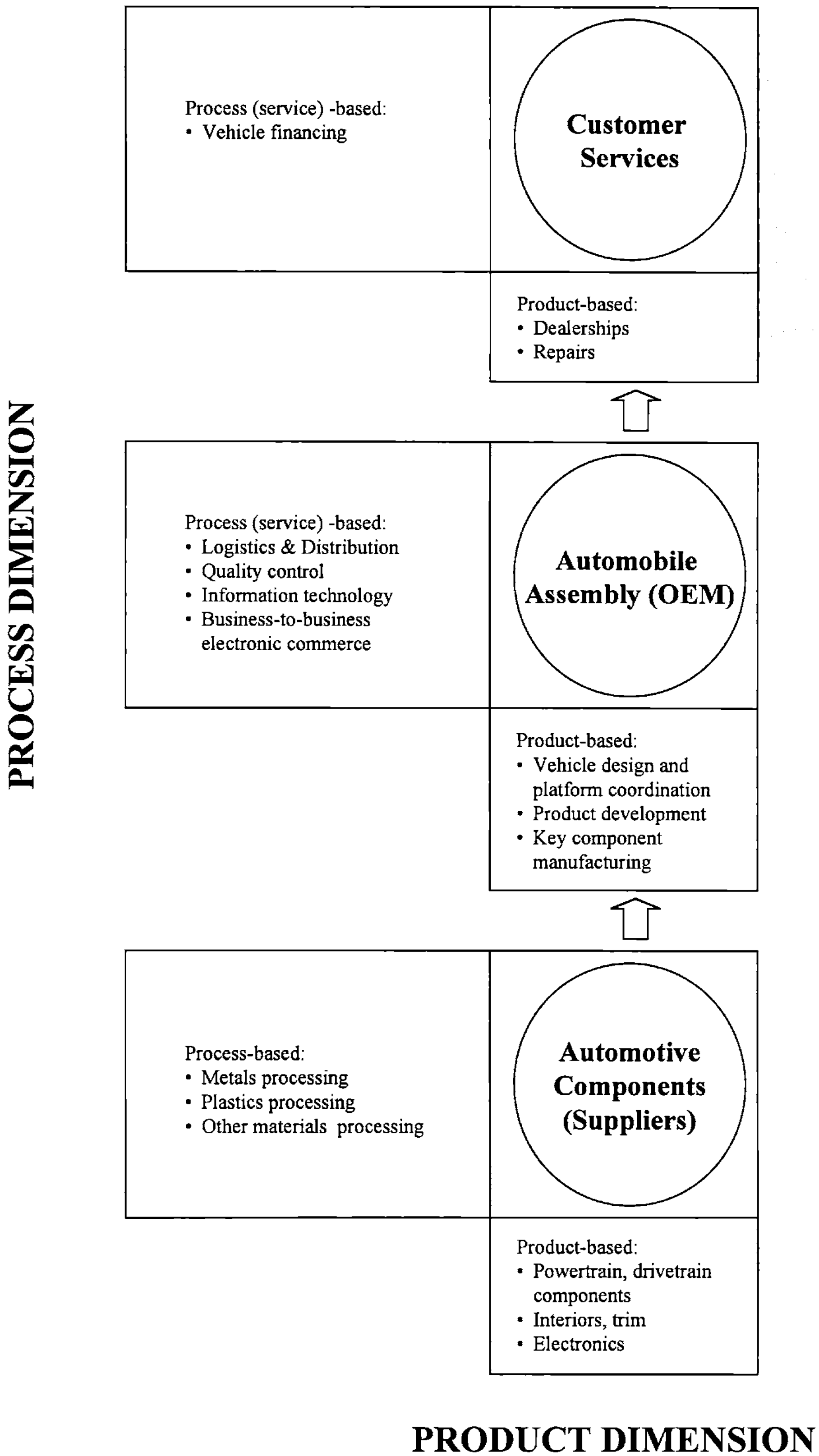


Figure 22: Value chain of the automotive industry in product and process dimensions

4.2 MEASURING INDUSTRY RELATEDNESS

The definition of industry has important implications for empirical research. A great deal of research has been carried out on the measurement of relatedness between industries. Virtually all of this research has focused on relatedness in product markets, ignoring the relevance of the process dimension.

In the strategy literature, numerous measures have been suggested for measuring industry relatedness and diversification of firms (Rumelt, 1974; Berry, 1975; Palepu, 1985). Most of these measures are based on a classification system of industries that contains information about the distance, or relatedness, between industries. The Standard Industrial Classification (SIC) is one of the most widely used systems, but it has been noted for its deficiencies[24]. The system was initially constructed to facilitate macroeconomic research, yet it is frequently used in strategic management research.

From the discussion in this chapter, it becomes obvious that a measure of industry relatedness that is focused on product markets, such as the SIC system, lacks consistency and validity as a measure of corporate coherence and industry relatedness, because product market measures of relatedness make no reference of the sort of capabilities that process firms have. This has also been noted among others by Robins and Wiersema (1995) and Silverman (1998). For example in the automotive industry, the SIC system assumes that producers of seats, air conditioning equipment, and diesel engines each belong to industry groups that are separate form the industry of automotive components (Motor Vehicle Parts & Accessories, SIC code 3714). Automotive seat manufacturers are part of the product class of Public Building and Related Furniture (code 2513), which shares little relatedness with automotive components. Producers of automotive air conditioning equipment and internal combustion engines are also placed in unrelated industry groups (Air, Heat, and Conditioning Equipment, code 5075; Engines & Turbines, code 3510), which does not reflect the close relatedness of certain firms in these product groups with the automotive industry. A closer look at the SIC system indicates that the classification does include sporadic, but inconsistent reference to process capabilities. For example, firms involved in machining of metal parts for automotive components can be found in as many as three different categories: automotive components (Motor Vehicle Parts & Accessories, code 3714), metals processing (Primary Metal Industries, code 3300, which also includes foundries and smelters) and fabricated

[24] For example, the SIC system assumes that each industry is equidistant from all others (Silverman, 1998); see also Rumelt (1974, p. 49) for a criticism of the SIC system.

products (Fabricated Metal, code 3400, which also includes metal cans, tools, metal structures, stampings, arms, valves, springs, etc.).

The SIC industry definition of business services are similarly ambivalent due to the lack of distinction between product and process-related capabilities. For example, Dana Corporation, a large automotive component manufacturer, has a Lease Financing segment that offers financing services in the form of specialized lease transactions and customized equipment financing programs for customers of its Vehicular and Industrial business segment. Do these activities define Dana's Lease Financing segment as a business represented in the market of Non-depository Credit Institutions (SIC code 6172), or are Dana's lease financing programs more related to the activities of its Vehicular and Industrial business segment? In the historical perspective, Dana's Lease Financing segment was created in 1980 to provide value-added services to existing customers, and the business has since grown into a leading diversified finance and leasing company active in financial services for industry, real estate, and retail customers. Dana's Lease Financing business was intentionally created to provide synergies with its existing business activities, which would support a classification related to the automotive industry. Since the segment has diversified into a leading finance and leasing company, the synergies with existing businesses may have faded and now provide only limited coherence, in which case a classification as a financial institution may be more appropriate.

Attempts to improve the deficiency of the SIC system have been made by various authors, but empirical research with alternatives to the SIC system remain data-intensive and cumbersome, because the key concept of capabilities resists direct measurement in many cases. Scherer (1982) estimated inter-industry similarity using patent filings and R&D flows between industry groups. Gollop and Monahan (1991) proposed a manufacturing diversification index based on the dissimilarities of productive inputs and outputs of a firm. Silverman (1996, 1998) and Mowery, Oxley, and Silverman (1998) define industry relatedness on the basis of technological capabilities through a concordance of SIC and patent classifications. Robins and Wiersema (1995) use indirect indicators of firm assets and business portfolio relatedness to explain variability in corporate financial performance. The area of measuring industry relatedness warrants further research.

The classification of products and processes in the automotive industry (see section 2.2.1 and appendix 8.2) offers an alternative method for measuring industry relatedness. Because this classification includes both product and process dimensions, it is capable of expressing relatedness of both product and process firms or industries. Such a classification could be adopted for measuring industry relatedness in the general economy.

4.3 SUMMARY

The framework of product and process firms offers a new perspective of looking at the definition of industry. The traditional definition of industry as product markets is insufficient in explaining many aspects of process-based firms, and therefore has deficiencies for explaining coherence and firm boundaries. A more useful definition of industry expresses coherent business activities along both product and process dimensions. In such a definition of industry, product industries are defined as groups of coherent business activities based on products capabilities, and process industries are defined as groups of coherent businesses in the process dimension.

The implications of this extended definition of industry are discussed in the context of automotive industry. The complete chain of value-adding activities around automobile production not only includes product-related business activities, but also involves important activities in process- or service-related businesses. The importance of these process and service businesses in the value chain of automobile production is ignored if industry boundaries are regarded as limits between product markets.

The distinction of product and process industries potentially applies to other industries, and provides a useful framework for analyzing industry relatedness. What is regarded as the industry of computers & semiconductors also has product and process dimensions. Manufacturers of semiconductor chips are process-oriented firms, while manufacturers of specific computer hardware and peripherals are application-specific, product-oriented firms. In the software industry, developers of operating systems share similarities with process firms, while developers of application-specific software share similarities with product firms. Similar distinctions of product and process dimensions could be made for many other industries, chemicals, pharmaceuticals, and even the service industries.

Implications for empirical research are elaborated in the second part of this chapter. Product-based measures of industry relatedness, such as the Standard Industrial Classification system, often ignore the process dimension. The classification of automotive component related products and processes based on technological capabilities (see section 2.2.1) offers an improved, alternative method for measuring coherence of firms, and industry relatedness. In general, such a classification could also be developed for other industries, which would require the systematic development of a methodology to classify firm capabilities.

Chapter 5

ECONOMIC PERFORMANCE OF PRODUCT AND PROCESS FIRMS

The preceding chapters presented a framework of product and process firms in the automotive supplier industry with the objective of applying this framework to the analysis of corporate coherence and economic performance of firms. This chapter establishes a formal link of corporate coherence with firm performance in an econometric regression analysis. Such a link seeks to confirm the source of superior performance and competitive advantage of product and process firms. In Chapter 2, it was argued that product firms achieve superior performance through coherent product capabilities and synergies among product-related activities. Process firms achieve superior performance as a result of operational synergies, and a focus on materials and manufacturing processes.

The first two hypotheses in the econometric analysis are aimed at testing the performance difference between product and process firms in the automotive supplier industry. Do product firms outperform process firms? What can be said about performance drivers of product and process firms? The findings reveal significant differences between product and process firms. Large, process-based firms achieve consistently higher performance than large product-based firms, but the opposite is true for small companies, where product-based firms outperform process-based firms by a wide margin. These results confirm the hypothesis that the performance of process firms is based on operational synergies, and therefore exhibits considerable returns to scale. For product firms, the interpretation is less indicative, but points to the negative influence of product diversification of large product firms.

The third hypothesis tests the correlation of coherence and firm performance, using the classification scheme of products and processes and measure of coherence developed for this analysis. The results confirm that firms with stronger coherence are able to better exploit corporate synergies and therefore achieve superior performance. These empirical findings contribute to the conceptual discussion of corporate coherence as a source of competitive advantage and determinant of superior firm performance.

The analysis uses data from more than two hundred public, automotive supplier companies in the United States, over a period of ten years. Two levels of analysis are considered, firms and individual firm segments. The econometric method includes generalized least squares regression, in which a set of independent and control variables is regressed on a measure of economic performance as the dependent variable.

5.1 HYPOTHESES

The first two hypotheses concern the difference in economic performance between product and process firms. Economic performance is expected to differ between the two types of firms, given the distinct underlying capabilities that result in different cost structures and operating principles of product and process firms. Hypothesis H1 represents a reference test, comparing the performance of product and process firms.

H1: The economic performance differs for product and process firms, controlling for size and other known determinants of firm performance.

Product and process firms are distinctly different firm models as a result of the underlying technological capabilities. It was shown in section 2.4 that the two firm types have characteristic differences in cost and asset structure that affect the economic performance of such firms. Product firms have on average relatively large expenditures for administrative, marketing and sales, and research expenditures. Process firms, on the other hand, are characterized by more efficient management of physical assets, and a greater asset intensity of fixed assets, such as plants, machinery and equipment, as part of total assets. These differences between product and process firms suggest that the determinants of performance, firm size in particular, act differently for the two types of firms. Greater returns to scale are expected for process firms.

H2: The effect of firm size on economic firm performance differs for product and process firms. Process firms exhibit greater returns to scale.

The third hypothesis tests the explicit correlation between coherence and firm performance. Based on the discussion of corporate coherence as a source of competitive advantage, it is hypothesized that coherence of product and process capabilities is positively correlated with economic firm performance. Coherence is measured with a concentration index of products and processes in the hierarchical classification developed for this dissertation. Based on this measure, firms focusing on a specialized and related set of capabilities are more coherent than firms with diversified capabilities. It is hypothesized that coherent firms perform better as a result of synergies and economies of scope derived from technological capabilities.

H3: *Coherence among the capabilities of product firms, and coherence among the capabilities of process firms, is positively correlated with economic firm performance.*

5.2 ECONOMETRIC PROCEDURE AND DEFINITIONS

The hypotheses are tested in generalized least square regressions involving a measure of economic firm performance and a set of independent and control variables. The analysis uses data from public companies registered in the United States[25], for reasons of data availability and comparable accounting standards. The analysis is applied to both firm-level data as well as firm segment data, as the unit of analysis. Segment-level data offers more uniform measurement of product and process capabilities, but data for several control variables is only available at the firm level[26]. Firms are defined as public business enterprises reporting to the Securities Exchange Commission (SEC). Firm segments are defined as operating units of a firm according to the definition used by the Financial Accounting Standards Board. Operations are defined as business activities of a firm that earn revenues and incur expenses.

> "Operating segments are components of an enterprise about which separate financial information is available that is evaluated regularly by the chief operating decision maker in deciding how to

[25] This also excludes foreign companies with ADRs (American Depositary Receipts) on the New York Stock Exchange.

[26] Many variables and external factors could be included as control variables, however, the choice of control variables does not influence the result as long as omitted variables are uncorrelated with the independent variables.

allocate resources and in assessing performance." Financial Accounting Standards Board, Summary of Statement No. 131. Disclosures about Segments of an Enterprise and Related Information. Issued 6/1997.

The following sections provide further details about data sources, variables, and econometric issues.

5.2.1 INDUSTRY DEFINITION AND DATA SOURCES

The subject of the analysis, the automotive component industry, needs to be carefully defined in order to minimize the influence of external factors in the analysis, such as industry cycle, industry growth, and investment risk[27]. The automotive component industry is defined as firms primarily engaged in manufacturing of semi-finished and finished automotive components. The definition excludes suppliers of raw materials, tool manufacturers, suppliers of instrumentation and computer services, testing services, software developers, pure R&D companies, pure manufacturers of components for trucks and other transportation equipment, and pure automotive aftermarket firms.

The most recent decade was chosen as the time period for the analysis. This period covers approximately one full economic cycle of the automotive industry (Figure 3). Reporting requirements for financial disclosures of business segment information has changed in 1998, and therefore the ten-year period from 1988 to 1997 was chosen to exclude the effect of these reporting changes[28].

Data on products and processes of firms was taken from company annual reports (10-K) filed with the Securities Exchange Commission (SEC). Financial data was taken from COMPUSTAT™. To include as many firms as possible in the analysis, a broad list containing over 650 firm names was compiled from multiple sources[29], and this list was then narrowed down to meet the criteria of the industry definition.

The following data sets were created (see appendix 8.3 for a detailed list of firms). AUTO_COMP represents the main data set used to perform the econometric analysis. A

---

[27] The investment beta (S&P500) of firms in the automotive component industry is within small bands (average beta is 0.8 with a standard deviation of 0.4).

[28] As of 1998, Financial Accounting Standards Board (FASB) statement No. 131 requires that segment financial information be reported on a basis consistent with a company's internal reporting used for evaluating segment performance and allocating resources based on the management reporting approach.

[29] Firms in COMPUSTAT with at least one business segment representing SIC code 3714 (Motor Vehicle Parts & Accessories) and/or business segments having an automotive manufacturer as primary business segment customer; firms listed in the 1998 Market Data Book of Automotive News, and firms listed in the Automotive Engineering International 8th Annual Product Sourcing Guide, North America (1999).

firm or firm segment was included in AUTO_COMP, if sales to the automobile industry represented at least 80% of total sales or, for companies that sell to closely related industries such as aftermarket or truck manufacturers, at least 50% of total sales. Data was excluded for years in which a firm had less than $50 million in sales, and for firm segments with less than $20 million in sales. The AUTO_COMP data set covers more than 600 segment-years, after dropping invalid or missing observations, and covers approximately $120 billion of annual sales. According to other sources, the size of the automotive component industry in the United States is about $150-$250 billion, depending on how far lower tier suppliers are included. The largest bias in the selection of companies probably originates from the exclusion of private and international companies, subsidiaries of automobile manufacturers, and raw materials suppliers (see Appendix 8.3.7).

A special case concerns the automotive parts divisions of automobile manufacturers, which were not included in the analysis. General Motors' automotive parts division is believed to be the world's largest automotive component manufacturer. This division, Delphi Automotive, has been quoted as a separate public company only since 1998. Ford Motor does not publish separate financial information for its component division (Visteon). Chrysler has divested most of its component manufacturing operations and does not publish separate financial information for the remaining component division.

A second, more broadly defined data set was created to test whether the results from AUTO_COMP also hold for a broader set of companies that not only manufacture automotive components, but also more general industrial components. Also, because the AUTO_COMP data set only covers companies with at least 50-80% sales to the automotive industry, typical process-based firms may not fall under this definition. The data set INDUSTRIAL_COMP therefore includes firms and firm segments, respectively, that have sales of at least 20% to the automotive industry.

Two more data sets were created as a reference to the automotive component industry. The data set OEM contains all major automobile manufacturers publicly registered in the United States, including ADRs[30]. The data set STEEL_ALU contains major U.S. suppliers of steel and aluminum to the automotive industry.

Table 9 summarizes all data sets and lists the number of valid firm-years and segment-years. The table indicates an average operating margin for the automotive component manufacturing industry of around 8%, almost double the level of automobile manufacturers whose long term profitability is around 5%. Producers of steel and aluminum achieve operating margins that are almost as high as those of automotive component suppliers.

The data sets are sufficiently large to achieve statistically robust results. The coverage could be enlarged to include more firms and a longer time period, but this would also increase the influence of undesirable external effects and economic conditions.

Firm-segment level data sets (1988-1997)	**Operating Margin (Return-on-Sales) Mean**	**Median**	**Firms**	**Segments**	**Segment-Years**
AUTO_COMP Segment	8.4%	7.8%	92	131	633
INDUSTRIAL_COMP Segment	8.6%	8.2%	135	193	1068

Firm level data sets (1988-1997)	**Operating Margin (Return-on-Sales) Mean**	**Median**	**Firms**	**Firm-Years**
OEM	4.6%	4.5%	9	89
AUTO_COMP	8.2%	7.7%	46	276
INDUSTRIAL_COMP	8.6%	7.9%	99	791
STEEL_ALU	7.1%	6.4%	26	223

Table 9: Summary of data sets

5.2.2 DEPENDENT VARIABLES

The preferred measure of firm performance is economic earnings, that is, sustainable free cash flows that a firm generates without impairing the productive capacity of the firm. However in practice, only accounting earnings are known, which are affected by several

[30] Ford, General Motors, Chrysler, DaimlerChrysler (Daimler-Benz pre-1998), Volvo, Fiat, Nissan, Toyota, Honda.

conventions and may deviate from sustainable economic earnings throughout the business cycle. Accounting earnings, as defined by the Generally Accepted Accounting Principles (GAAP) in the United States, are affected by taxes, the need for risk adjustment, conventions of asset valuation such as inventories[31] and the way capital investments are recognized over time as depreciation expenses, and accounting rules for research and development expenses. The pitfalls of using accounting rates of return are further discussed in Fisher and McGowan (1983) (see also Lindenberg and Ross, 1981; Meckling and Jensen, 1986; Kaplan and Ruback, 1995; and Copeland, Koller, and Murrin, 1994). Multiple measures of firm performance were therefore used in the analysis, see Table 10 (Appendix 8.4.1 lists the COMPUSTAT™ data types used to construct the variables).

Return-on-invested-capital (ROIC) would be a preferred performance measure that closely approximates economic returns (Copeland, Koller, and Murrin, 1994; Palepu, Healy, and Bernard, 2000; Hayes, Wheelwright, and Clark, 1988, p. 375). Return-on-invested-capital is defined as income divided by the sum of firm equity and outstanding debt, and measures the total financial returns of a company that are available to owners of equity and debt claims. However, return-on-invested-capital is only available for firms as a whole and not for individual segments. In addition, the use of net income to calculate ROIC reflects earnings that include the effect of non-operating or financing activities, such as taxes, minority interest and other factors which are not of primary interest for this analysis.

An alternative performance measures is operating return-on-assets (ROA), defined as operating profits divided by assets at book value. Operating return-on-assets is a frequently used performance measure in strategic management research (used for example by Chatterjee and Wernerfelt, 1991; Rumelt, 1991; and McGahan and Porter, 1997). Return-on-assets reflects earnings of manufacturing firms better because it uses operating profits, rather than reported profits (net income). However, ROA is not an optimal performance measure due to the accounting definition of assets, especially in an analysis of product-based firms. Product firms are expected to have a higher share of intangible assets through higher investments in research and development than process firms. Because certain intangible assets are not recorded as accounting assets, ROA of product-based firm may be upward biased. An alternative accounting measure, return-

[31] The book value of assets contains a certain bias for manufacturing firms, if it is not adjusted for different inventory valuation methods. LIFO inventory has lower reported profits and lower balance sheet value than FIFO inventory, see Bodie, Kane, and Marcus, 1996, p. 582.

on-net-assets (RONA, operating profit divided by fixed assets including plant and equipment) would make this problem even worse.

Return-on-sales (ROS) is an alternative measure of firm performance (used for example used by Markides and Williamson, 1994; and Delios and Beamish, 1999). The problem with this measure is that sales may not reflect the underlying productive capacity of a firm and therefore may bias the results. A decomposition of return-on-assets into return-on-sales and asset turnover illustrates this point.

$$\frac{Operating\ Profit}{Assets} = \frac{OperatingProfit}{Sales} * \frac{Sales}{Assets} \tag{2}$$

$$ROA = ROS * ASST\_TRN \tag{3}$$

where ROA is return-on-assets, ROS is return-on-sales, and ASST_TRN is asset turnover. Two firms with the same return-on-assets may have different capital intensity, meaning that a firm with low return-on-sales may achieve the same return-on-asset through higher asset turnover. Therefore, comparing return-on-sales between firms is only meaningful in evaluations if these firms have similar asset turnover or capital intensity. For the data sets used here, a statistical test of equality between the two data sets strongly suggests that asset turnover is similar[32].

A fourth measure, market-to-book ratio, expresses firm value rather than current performance of firms. It better reflects the long term value of a firm and its ability to generate cash flows in the future. However, market value is only available for firms as a whole, and not for firm segments. Market-to-book ratio is calculated as the market value of a firm divided by the book value of its assets. The market value of a firm reflects the capitalized value of future profitability expected by shareholders of the firm, and thus better reflects the long term value of a firm compared to annual accounting rates of return. Market-to-book ratio is a simplified version of Tobin's Q, which is frequently used in economic research. Tobin's Q is the ratio of market value of a firm to the replacement value of its assets (used for example in the studies of Lindenberg and Ross, 1981; Smirlock et al., 1984; Lang and Stulz, 1994; Montgomery and Wernerfelt, 1988; and Wernerfelt and Montgomery, 1988).

[32] Anova F-statistic 0.66, n = 806, p = 0.42, data set AUTO_COMP. The mean asset turnover is 1.5.

Dependent variable	Abbreviation	Definition	Available at firm-level	Available at segment-level
Return-on-Sales (= operating profit margin)	ROS	Operating Income After Deprec. (MM$) / Sales (Net) (MM$)	Yes	Yes
Return-on-Assets	ROA	Operating Income After Deprec. (MM$) / Total Assets (MM$)	Yes	Yes
Return-on-Invested Capital	ROIC	Income Before Extraordinary Items (MM$) / (Total Common Equity (MM$) + Debt due in One Year (MM$) + Total Long-Term Debt (MM$))	Yes	No
Market-to-Book ratio	MTB	(Market capitalization + Book Value) / Book Value = (Common Shares Outstanding (MM) * Closing Share Price Fiscal Year ($) + Total Assets (MM$) - Total Common Equity (MM$) - Deferred Taxes (Balance Sheet) (MM$)) / Total Assets (MM$)	Yes	No

Table 10: Dependent variable definitions

5.2.3 INDEPENDENT VARIABLES

Table 11 lists independent variables used in the analysis. Firms were coded into product and process firms based on the criteria listed in Table 3 and the classification scheme of section 2.2.1. Each firm was then assigned a dummy variable, PROCESS, which takes on the value of 1 for process-based firms and 0 for product-based firms. Data subsets including only product or only process firms are labeled *Product-based* or *Process-based.*

A measure of technological coherence is used to express the relatedness of capabilities of a firm for testing of hypothesis H3. This measure is based on a concentration index of capabilities and the classification of products and processes introduced in section 2.2.1. This hierarchical classification scheme expresses technological relatedness of products and processes in the automotive supplier industry, and is one of the main contributions of this dissertation, facilitating empirical research of corporate coherence. The classification includes both product and process dimensions, and therefore avoids deficiencies of alternative measures such as the Standard Industrial Classification system, which is constructed on the basis of product markets and which makes only limited reference to the capabilities of process firms.

The concentration of product and process capabilities of a firm within the classification scheme is expresses with two alternative measures, the Herfindahl index of concentration and the entropy index. The Herfindahl index of concentration is based on Berry (1975):

Herfindahl concentration ΣS_i^2 (4)

where S_i represents the number of firm capabilities i of a firm to the total number of capabilities in the classification scheme (at the second hierarchy level). The entropy index (Palepu, 1985) provides an alternative measure used, and expresses incoherence, or diversification of a firm:

Entropy index $\Sigma S_i * ln (S_i)$ (5)

The Herfindahl concentration ratio is bound between zero (diversified capabilities) and unity (concentrated capabilities), and the entropy index between infinity (infinitely diversified capabilities) and zero (concentrated capabilities). The assessment of capability fractions S_i was evaluated on the basis of product and process information about firms according to the classification scheme presented in section 2.2.1 (see appendix 8.2 for details). A firm was considered capable in a certain product or process, if it reported a product or process as part of the public information filed with regulators. The measure therefore relies on self-reporting of products and processes by firms according to regulatory guidelines, and therefore may represent a source of reporting bias. However, it can be assumed that a mentioning of products and processes in a regulatory document indicates that the company derives considerable sales from such products, which is assumed to correlate with underlying firm capabilities. To eliminate the reporting bias, U.S. patent classification was used as an alternative classification for measuring technological capabilities. However, it has to be considered that the automotive component industry is not a research-intensive industry where patents represent a major source of competitiveness[33]. Patents may not be a meaningful indicator of the capabilities of process firms, and have only been used to validate the hypothesis for product firms. Patent coherence is measured as the Herfindahl concentration ratio of the 3-digit U.S. classification of patents of a firm. The first three digits of the patent classification indicate the major class in which a patent falls. This is used as a basic indicator for the scientific and technological capabilities of a firm.

[33] Based on companies' own assessment in 10-K reports. See also Cohen, Nelson, and Walsh, 2000.

Independent variable	Abbreviation	Definition	Available at firm-level	Available at segment-level
Product/Process dummy	PROCESS	Dummy for process-based firm (versus product-based firm)	Yes	Yes
Product coherence	PROD_COH	Herfindahl concentration ratio of products, based on product classification scheme at 2nd hierarchy level	n/a	Yes
Process coherence	PROC_COH	Herfindahl concentration ratio of processes, based on process classification scheme at 2nd hierarchy level	n/a	Yes
Product dispersion	PROD_DISP	Entropy measure of product dispersion based on product classification scheme at 2nd hierarchy level	n/a	Yes
Process dispersion	PROC_DISP	Entropy measure of process dispersion based on process classification scheme at 2nd hierarchy level	n/a	Yes
Product patent coherence	PATENT_COH	Herfindahl concentration ratio of 10 year patent stock, based on 3-digit US patent classification (for product firms only)	Yes	No

Table 11: Independent variable definitions

5.2.4 CONTROL VARIABLES

Table 12 lists control variables used in the analysis. Sales are used as a proxy for the size of a firm, and are taken as natural logarithms to better approximate a normal distribution for this variable. Logarithmic sales are used by numerous other studies to control for the effect of firm size. The regression coefficient on firm size is expected to be positive, if returns to scale are present. Other variables that are expected to influence firm performance and for which data exists, are capital expenditure, customer concentration, segment diversification, and geographic diversification. Capital expenditure are expected to be positively correlated with performance, assuming that successful firms re-invest higher percentages of cash flow into plant and equipment to maintain high performance. To correct for heteroscedasticity in the data, a dummy for above-average capital expenditure is used (average capital expenditure in the automotive supplier industry is approximately 5%). Research and development expenditures would represent another desirable control variable, but it is not available for many firms in the data set, and was therefore not included.

According to standard economic theory, industry concentration negatively impacts performance. To reflect this effect in the automotive supplier industry, a measure of customer concentration was chosen. Customer concentration is calculated as the Herfindahl concentration ratio of sales to the three largest buyers of automotive components in the United States, General Motors, Ford and (Daimler)Chrysler. Other customers are ignored in the evaluation of this control variable. The assumptions behind the customer concentration variable are that firms with sales to only one automobile manufacturer are more dependent than firms, which have their sales evenly distributed among the three manufacturers. The regression coefficient of this variable is therefore expected to correlate negatively with economic firm performance.

Measures of business segment and geographical diversification are included as control variables for firm-level data to account for these effects on firm performance. Segment diversification is expected to be negatively correlated with performance according to the broad literature on corporate diversification and firm performance (see Montgomery and Wernerfelt, 1988; Chatterjee and Wernerfelt, 1991; Lang and Stulz, 1994). Arguments for both positive and negative correlation of geographic diversification with firm performance are found in studies on globalization of the automobile industry (Lynch, 1999; Sturgeon and Florida, 1997; Lynch, 1998). Diversification of business segments and geographic sales is measured as the Herfindahl diversification of these activities:

$$\text{Herfindahl diversification} \qquad 1 - \Sigma S_i^2 \qquad (6)$$

with S_i representing the share of a firm's sales in business (or geographical) segment i.

Control variable	Abbreviation	Definition	Available at firm-level	Available at segment-level
Sales	SALES	Sales (Net) (MM$)	Yes	Yes
Capital expenditure % of Sales	CAPEX	Capital Expenditures (SCF) (MM$) / Sales (Net) (MM$)	Yes	Yes
Above average capital expenditure	CAPEX5	Dummy if Capital Expenditure is at least 5% of Sales	Yes	Yes
Customer concentration ratio	CUSTCONC	Herfindahl concentration ratio of Sales to General Motors, Ford and Chrysler	No	Yes
Segment diversification	DIV_SEG	Herfindahl diversification ratio of Sales in industry segments with different 1-digit SIC codes (different 2-digit codes for manufacturing SIC codes 3300-3999)	Yes	No
Geographic diversification	DIV_GEO	Herfindahl diversification ratio of Sales in the three Large Existing Markets (North America, Japan/Asia, Europe)	Yes	No

Table 12: Control variable definitions

5.2.5 ECONOMETRIC ISSUES

The focus of the analysis on a single industry, automotive components, reduces the bias due to omitted variables. There are countless potential variables that may impact firm performance, but only a very limited number of variables is considered for this analysis. However, the choice of control variables does not influence the result, as long as omitted variables are uncorrelated with the independent variables. Uncorrelated omitted variables only reduce the explanatory power of the model[34].

Heteroskedasticity in the data is a concern in the regression of annual performance data. The use of panel data (data over time and across firms) allows to increase statistical confidence and to apply econometric corrections. Cross-sectional heteroskedasticity is addressed by applying weighted least squares in the regression analysis using cross-sectional variance (σ_i^2) estimated from a first-stage pooled ordinary least squares regression. White standard errors and covariances are included as additional corrections for heteroskedasticity in all regression models. The descriptive statistics and correlations of all variables used in the analysis are listed in Appendix 8.5 and 8.6 (tables are generated by pooling the panel data, and therefore reveal considerably higher heteroskedasticity than the cross-sectional data used in the analysis). The correlation tables show that independent variables have low correlation with dependent variables. The only pooled correlations higher than 0.5 are between firm size and DIV_SEG, and firm size and DIV_GEO.

Table 13 shows the effect of different control variables and regression specifications. The coefficient for PROCESS is negative and statistically significant in all models (1a) through (1d), and the coefficients of control variables are as expected. Firm size is a slightly negative factor for performance, above-average capital expenditure is positive, above-average R&D expenditure is positive (but significantly reduces the number of observations due to missing data), customer concentration is negative, and serial correlation is strongly positive. Model (1d) almost completely explains the variance in the independent variables (high R^2) due to the loss of many degrees of freedom through the correction for first-order serial correlation. This model is over-specified because of competing effects between autocorrelation and control variables. Model (1c) contains most control variables and is chosen as the preferred model for subsequent regressions.

---

[34] Explanatory power is expressed by the R^2 statistic, which is defined as the fraction of variance of the dependent variable explained by the independent variables. R^2 therefore expresses the success of regression in predicting the values of the dependent variable. A possibility to reduce the effect of omitted variables is by correcting for first-order serial correlation in the data.

Model specification	(1a)		(1b)		(1c)		(1d)	
Dependent variable	ROS		ROS		ROS		ROS	
Data set	AUTO_COMP Segment		AUTO_COMP Segment		AUTO_COMP Segment		AUTO_COMP Segment	
Sample	1988:1997		1988:1997		1988:1997		1988:1997	
C	0.081	*(0.00)*	0.093	*(0.00)*	0.091	*(0.00)*	0.131	*(0.00)*
PROCESS	-0.011	*(0.00)*	-0.015	*(0.00)*	-0.008	*(0.00)*	-0.056	*(0.00)*
LOG(SALES)	0.000	*(0.96)*	-0.005	*(0.00)*	-0.001	*(0.07)*	-0.003	*(0.07)*
CAPEX5	0.008	*(0.00)*	0.032	*(0.00)*	0.007	*(0.00)*	0.001	*(0.04)*
R_D1			0.011	*(0.00)*				
CUSTCONC					-0.035	*(0.00)*	-0.058	*(0.00)*
AR(1)							0.893	*(0.00)*
R^2	0.786		0.915		0.800		1.000	
R^2 unweighted	0.013		0.093		0.015		0.634	
S.E. of regression	0.054		0.060		0.054		0.034	
Durbin-Watson stat	0.692		0.781		0.698			
Mean dependent var	0.137		0.168		0.138			
S.D. dependent var	0.117		0.202		0.119			
Regression F-statistic	770		536		624			
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	10		10		10		10	
Number of cross-sections	91		35		91		88	
Total panel observations	632		205		628		534	
Heterosked. corrections	White		White		White		White	

(p-values in parentheses)

Table 13: Test of control variable effects (Return-on-sales, segment-level data)

A final comment concerns the bias of data. The separation of firms into product and process firms may represent a potential source of bias in the data. For most firms, however, the categorization seems straight-forward, and only a few companies were found to be ambiguous[35]. The inclusion of these companies in either product or process data set only marginally affects the coefficient results. Statistical tests of equality between variables of product and process firms are shown in Table 14. The test of equality rejects the null hypothesis of parameter equality between the two types of firms

[35] These include Excel Industries, JPE, Methode Electronics, Newcor, Noble International, Standard Products, and Superior Industries.

for all variables, except for asset turnover, sales growth and sales contribution of acquisitions.

Variable	Product-based Firms		Process-based Firms		Tests of Equality (p-values)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean (t-test)	Median (Chi-sq. test)
ROA	0.120	*0.09*	0.113	*0.07*	*(0.023)*	*(0.627)*
ROS	0.083	*0.06*	0.082	*0.05*	*(0.000)*	*(0.048)*
MTB	1.650	*1.20*	1.469	*0.64*	*(0.000)*	*(0.000)*
ATO	1.521	*0.46*	1.475	*0.39*	*(0.416)*	*(0.559)*
FIX_ATO	7.687	*2.60*	5.138	*2.37*	*(0.000)*	*(0.000)*
LOG(SALES)	6.242	*1.29*	5.394	*0.96*	*(0.000)*	*(0.000)*
SALES_GR	0.168	*0.21*	0.120	*0.23*	*(0.534)*	*(0.719)*
INVTURN	8.743	*6.39*	10.099	*5.90*	*(0.000)*	*(0.000)*
R_D	0.035	*0.03*	0.013	*0.02*	*(0.000)*	*(0.000)*
R_D1	0.855	*0.35*	0.405	*0.49*		
CAPEX	0.055	*0.04*	0.067	*0.04*	*(0.011)*	*(0.000)*
CAPEX5	0.430	*0.50*	0.566	*0.50*		
DIV_SEG	0.035	*0.09*	0.013	*0.06*	*(0.000)*	*(0.000)*
DIV_GEO	0.388	*0.31*	0.198	*0.24*	*(0.000)*	*(0.000)*
ACQ_S	0.085	*0.37*	0.040	*0.12*	*(0.598)*	*(0.876)*
ACQ_I	-0.004	*0.03*	0.000	*0.01*	*(0.099)*	*(0.167)*
PPE	0.215	*0.06*	0.321	*0.08*	*(0.000)*	*(0.000)*
SG_A	0.151	*0.08*	0.096	*0.05*	*(0.000)*	*(0.000)*
GROSSM	0.267	*0.10*	0.210	*0.06*	*(0.000)*	*(0.000)*
GROSSM+DEPR	0.304	*0.11*	0.249	*0.07*	*(0.000)*	*(0.000)*

Data set AUTO_COMP; Years 1988-1997; p-values in parentheses. For a definition of the variables, see Appendix 8.4

Table 14: Parameter equality test between product and product firms

5.3 DISCUSSION OF RESULTS

This section discusses the econometric regression analysis and testing of the three hypotheses H1 to H3. Detailed information on the data sets, variable definitions, descriptive statistics and correlation coefficients are found in the appendix.

5.3.1 PERFORMANCE DIFFERENCE BETWEEN PRODUCT AND PROCESS FIRMS

The first hypothesis tests whether product or process firms achieve consistently higher economic performance, when controlling for firm size and other factors. The following equation expresses the linear relationship tested in the regression analysis. The dummy variable PROCESS reflects the performance differential between product and process firms.

$$PERFORMANCE_{ijt} = \alpha + \beta_1\, PROCESS_{ij} + \beta_2\, LOG(SALES)_{ijt} + \beta_3\, CAPEX5_{ijt} + \beta_4\, CUSTCONC_{jt} + \beta_5\, DIV\_SEG_{it} + \beta_6\, DIV\_GEO_{it} + \varepsilon_{ijt} \qquad (7)$$

where *PERFORMANCE* is one of the performance measure used (return-on-sales, return-on-assets, return-on-invested capital, market-to-book ratio), *PROCESS* is the dummy variable specifying process-based firms, *LOG(SALES)* is the natural logarithm of firm sales, *CAPEX5* is a dummy variable indicating firms with above average capital expenditure, *CUSTCONC* is the Herfindahl concentration of firm sales to customers, *DIV_SEG* is the Herfindahl diversification of business segment sales, *DIV_GEO* is the Herfindahl diversification of geographical sales, and ε is a randomly distributed error. Subscript i denotes variables available at the firm-level, and j denotes variables available at the segment level. If process firms have on average lower performance than product firms, the coefficient β_1 for *PROCESS* is negative.

The econometric results are summarized in the following tables and figures. Table 15 shows the coefficients of the regression using segment-level data and return-on-sales as performance variable, Table 16 shows the same using return-on-assets as performance variable, Table 17 uses firm-level data and market-to-book ratio as performance variable, and Table 18 uses firm-level data and return-on-invested-capital. Models (a) include both product and process firms, and models (b) and (c) are split data sets of product and process firms, respectively. The text continues after these tables.

Model specification	(2a)		(2b)		(2c)	
Dependent variable	ROS		ROS		ROS	
Data set	AUTO_COMP Segment		AUTO_COMP Segment Product-based firms		AUTO_COMP Segment Process-based firms	
Sample	1988:1997		1988:1997		1988:1997	
C	0.091	*(0.00)*	0.127	*(0.00)*	0.000	*(1.00)*
PROCESS	-0.008	*(0.00)*				
LOG(SALES)	-0.001	*(0.07)*	-0.007	*(0.00)*	0.016	*(0.00)*
CAPEX5	0.007	*(0.00)*	0.012	*(0.00)*	-0.005	*(0.08)*
CUSTCONC	-0.035	*(0.00)*	-0.037	*(0.00)*	-0.028	*(0.00)*
R^2	0.800		0.852		0.662	
R^2 unweighted	0.015		0.028		0.178	
S.E. of regression	0.054		0.054		0.047	
Durbin-Watson stat	0.698		0.784		0.729	
Mean dependent var	0.138		0.159		0.109	
S.D. dependent var	0.119		0.139		0.079	
Regression F-statistic	624		781		138	
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	10		10		10	
Number of cross-sections	91		62		29	
Total panel observations	628		412		216	
Heterosked. corrections	White		White		White	

(p-values in parentheses)

Table 15: Regression model (2a) to (2c) (Return-on-sales, segment-level data)

Model specification	(3a)		(3b)		(3c)	
Dependent variable	**ROA**		**ROA**		**ROA**	
Data set	**AUTO_COMP Segment**		**AUTO_COMP Segment Product-based firms**		**AUTO_COMP Segment Process-based firms**	
Sample	**1988:1997**		**1988:1997**		**1988:1997**	
C	0.146	*(0.00)*	0.180	*(0.00)*	0.046	*(0.01)*
PROCESS	-0.019	*(0.00)*				
LOG(SALES)	-0.002	*(0.01)*	-0.008	*(0.00)*	0.015	*(0.00)*
CAPEX5	-0.004	*(0.03)*	0.001	*(0.51)*	-0.017	*(0.01)*
CUSTCONC	-0.042	*(0.00)*	-0.003	*(0.76)*	-0.035	*(0.05)*
R^2	0.701		0.698		0.394	
R^2 unweighted	0.004		-0.007		0.106	
S.E. of regression	0.103		0.115		0.070	
Durbin-Watson stat	0.739		0.741		0.718	
Mean dependent var	0.224		0.262		0.136	
S.D. dependent var	0.187		0.208		0.089	
Regression F-statistic	364		314		46	
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	10		10		10	
Number of cross-sections	91		62		29	
Total panel observations	627		411		216	
Heterosked. corrections	White		White		White	

(p-values in parentheses)

Table 16: Regression model (3a) to (3c) (Return-on-assets, segment-level data)

Model specification	(4a)		(4b)		(4c)	
Dependent variable	**MTB**		**MTB**		**MTB**	
Data set	**AUTO_COMP**		**AUTO_COMP Product-based firms**		**AUTO_COMP Process-based firms**	
Sample	**1988:1997**		**1988:1997**		**1988:1997**	
C	1.577	*(0.00)*	2.027	*(0.00)*	0.405	*(0.03)*
PROCESS	-0.124	*(0.00)*				
LOG(SALES)	-0.024	*(0.11)*	-0.118	*(0.00)*	0.196	*(0.00)*
CAPEX5	0.034	*(0.20)*	0.127	*(0.00)*	-0.182	*(0.00)*
DIV_SEG	-1.352	*(0.00)*	-1.018	*(0.00)*	-3.407	*(0.01)*
DIV_GEO	-0.003	*(0.96)*	0.296	*(0.00)*	0.073	*(0.71)*
R^2	0.915		0.731		0.520	
R^2 unweighted	-0.030		0.021		0.085	
S.E. of regression	0.800		0.846		0.566	
Durbin-Watson stat	0.671		0.636		0.659	
Mean dependent var	3.098		3.155		1.895	
S.D. dependent var	2.709		1.603		0.802	
Regression F-statistic	486		72		32	
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	10		10		10	
Number of cross-sections	40		23		17	
Total panel observations	233		111		122	
Heterosked. corrections	White		White		White	

(p-values in parentheses)

Table 17: Regression model (4a) to (4c) (Market-to-book ratio, firm-level data)

Model specification	(5a)		(5b)		(5c)	
Dependent variable	**ROIC**		**ROIC**		**ROIC**	
Data set	**AUTO_COMP**		**AUTO_COMP Product-based firms**		**AUTO_COMP Process-based firms**	
Sample	**1988:1997**		**1988:1997**		**1988:1997**	
C	0.117	*(0.00)*	0.185	*(0.00)*	0.014	*(0.36)*
PROCESS	-0.019	*(0.00)*				
LOG(SALES)	-0.003	*(0.18)*	-0.017	*(0.00)*	0.018	*(0.00)*
CAPEX5	0.010	*(0.00)*	0.009	*(0.03)*	-0.016	*(0.05)*
DIV_SEG	-0.093	*(0.00)*	-0.074	*(0.00)*	-0.659	*(0.49)*
DIV_GEO	-0.055	*(0.00)*	-0.005	*(0.58)*	-0.127	*(0.00)*
R^2	0.458		0.385		0.449	
R^2 unweighted	0.050		0.064		0.104	
S.E. of regression	0.123		0.120		0.126	
Durbin-Watson stat	0.863		0.930		0.788	
Mean dependent var	0.174		0.174		0.176	
S.D. dependent var	0.165		0.151		0.167	
Regression F-statistic	42		20		24	
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	10		10		10	
Number of cross-sections	40		22		18	
Total panel observations	256		134		122	
Heterosked. corrections	White		White		White	

(p-values in parentheses)

Table 18: Regression model (5a) to (5c) (Return-on-invested-capital, firm-level data)

The coefficient for *PROCESS* is always negative and statistically significant (model 2a, 3a, 4a, 5a), confirming hypothesis H1, but the difference is considerably small. Process firms have on average about 1-2 percentage points lower returns (ROS, ROA, ROIC), or 12% lower firm value (market-to-book ratio) compared to product firms. The statistical confidence of the regression is very high due to the use of cross-sectional weights and a large number of panel observations. The coefficients of most control variables are confirmed as expected. Above-average capital expenditure is positively correlated with performance, and customer concentration and segment diversification are negatively correlated with performance. Geographic diversification is not consistently correlated with performance.

Surprisingly, returns to scale are almost nonexistent, as indicated by the coefficient of LOG(SALES). The role of firm size was further investigated in regression models (b) and (c), using the same specification as before, but with split data sets for product and process firms.

Model specification	(2a)		(2b)		(2c)	
Dependent variable	ROS		ROS		ROS	
Data set	INDUSTRIAL_COMP Segment		INDUSTRIAL_COMP Segment Product-based firms		INDUSTRIAL_COMP Segment Process-based firms	
Sample	1988:1997		1988:1997		1988:1997	
C	0.083	*(0.00)*	0.130	*(0.00)*	-0.022	*(0.01)*
PROCESS	-0.009	*(0.00)*				
LOG(SALES)	0.000	*(0.75)*	-0.006	*(0.00)*	0.019	*(0.00)*
CAPEX5	0.135	*(0.00)*	0.070	*(0.39)*	0.102	*(0.03)*
Total panel observations	447		252		195	

(p-values in parentheses)

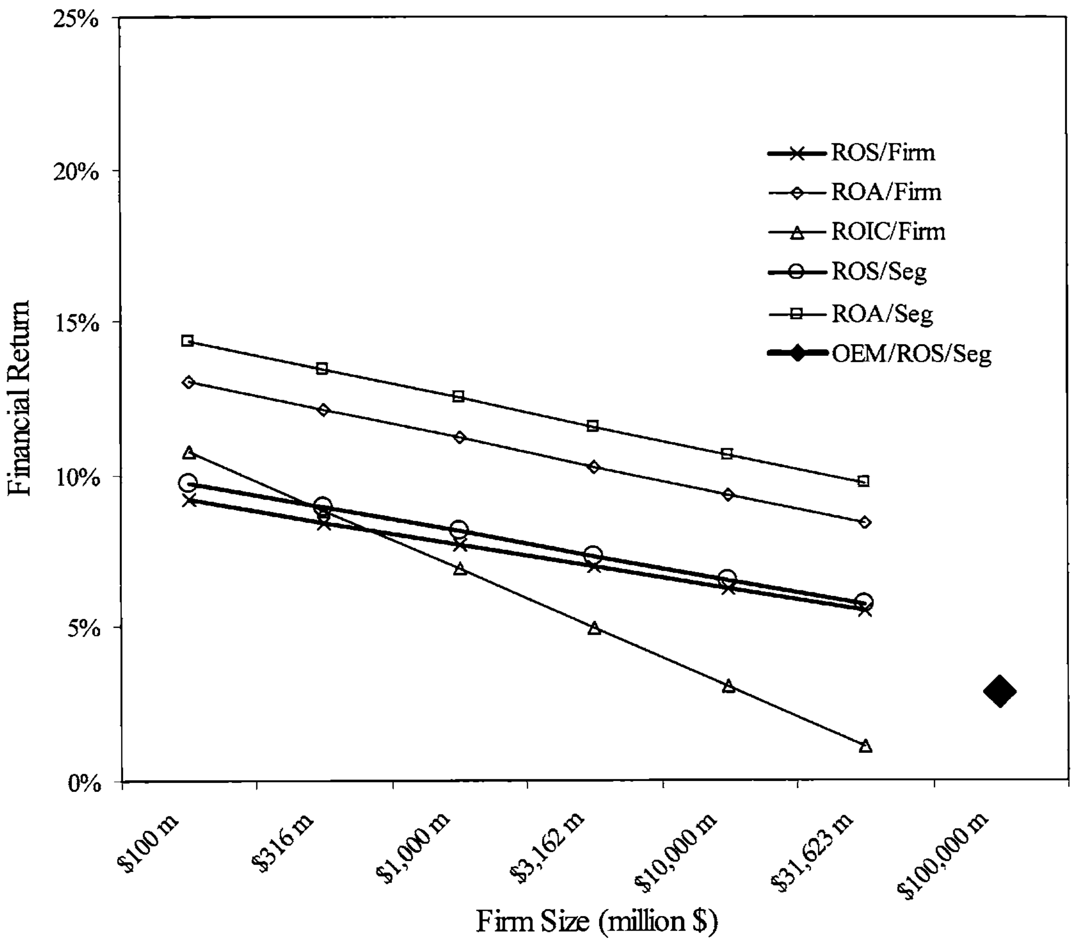
Table 19: Regressions models (2a) to (2c) (repeat with broader data set)

5.3.2 RETURNS TO SCALE

Hypothesis H2 tests the effect of firm size on performance for product and process firms. Process firms are expected to achieve greater returns to scale. The econometric test is similar to the first hypothesis testing, but is based on separate data sets for product and process firms. Returns to scale are expressed by the coefficient β_2.

$$PERFORMANCE_{ijt} = \alpha + \beta_2\, LOG(SALES)_{ijt} + \beta_3\, CAPEX5_{ijt} + \beta_4\, CUSTCONC_{jt} + \beta_5\, DIV\_SEG_{it} + \beta_6\, DIV\_GEO_{it} + \varepsilon_{ijt} \tag{8}$$

Figure 23 summarizes the results for product firms, and Figure 24 for process firms. Process firms exhibit significant positive returns to scale, whereas product firms exhibit negative returns to scale. Every doubling in size means roughly 1% gain in financial return for process firms, and about 0.5% loss in return for product firms. Alternatively, numbers express a 10% gain in firm value for process firms (market-to-book ratio) versus a 5% loss in value for product firms.

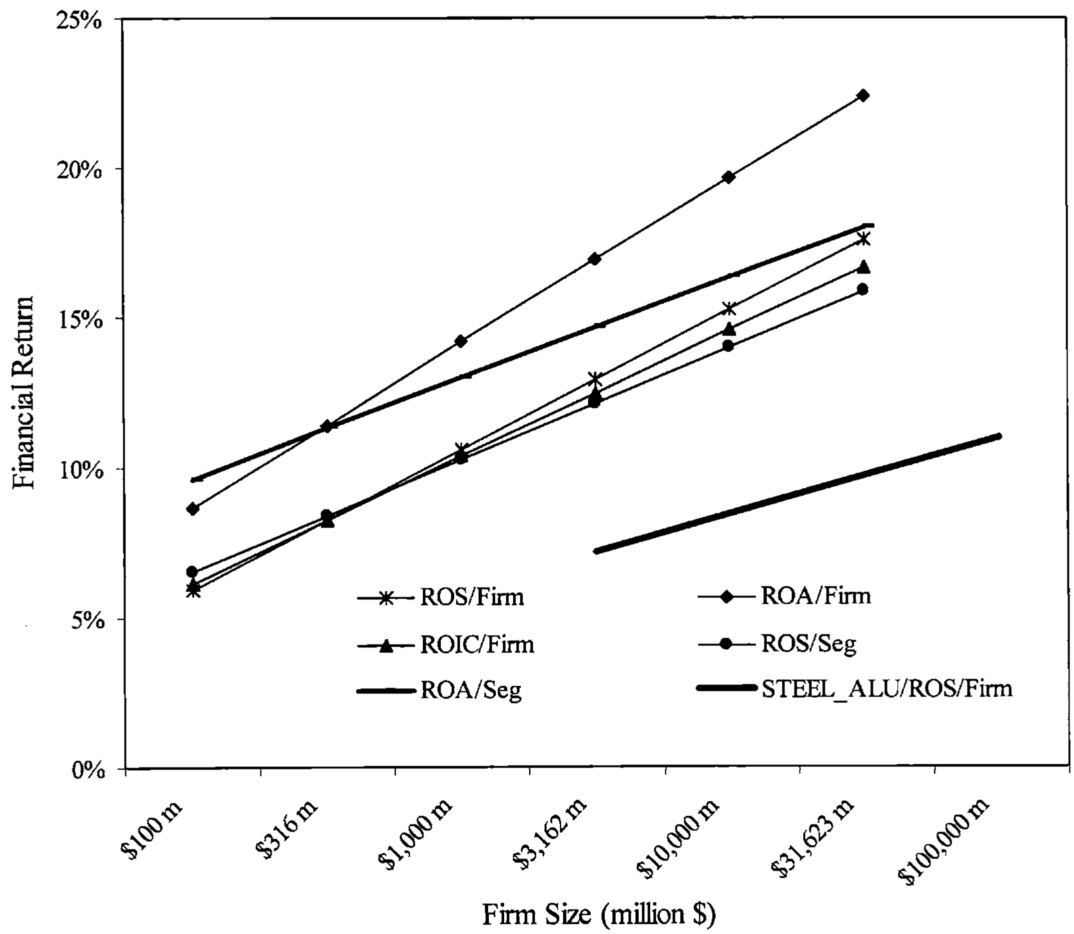


ROS=Return-on-sales; ROA=Return-on-Asset; ROIC=Return-on-invested-capital; Firm=Firm-level data; Segment=Segment-level data; OEM=Automobile manufacturer

Figure 23: Correlation between size and performance for product firms

An interesting conversion is observed in Figure 23, which shows that the performance of large automotive suppliers approaches the performance of automobile manufacturers (OEM). This supports the validity of the results and indicates that the observed negative returns to scale may represent an industry-specific case. Figure 24 contains producers of steel and aluminum as a reference point. Positive returns to scale are also positive for these steel and aluminum producers, supporting the findings for process firms.

These results are very consistent across all performance measures, and for both firm-level and segment-level data. The coefficients of control variables reflect the expected correlation in most model specifications. The statistical significance is lower at the firm-level, because this data set is more broadly defined. The findings are also confirmed when using the data set of more general industrial component manufacturers (INDUSTRIAL_COMP), as shown in Table 19.



ROS=Return-on-sales; ROA=Return-on-Asset; ROIC=Return-on-invested-capital; Firm=Firm-level data; Segment=Segment-level data; STEEL_ALU=Producers of steel and aluminum

Figure 24: Correlation between size and performance for process firms

5.3.3 COHERENCE AND PERFORMANCE

The third hypothesis, H3, tests the formal link of corporate coherence with performance, using the classification scheme of products and processes presented in section 2.2.1 and a measure of concentration expressing coherence of firm capabilities. Because the developed classification may be biased or subjective, U.S. patent classification is used as an alternative scheme to validate the results (only for product firms). In addition, coherence is expressed using two different measures, the Herfindahl concentration ratio and the entropy measure (see equation 4 and 5), and an alternative measure of patent coherence. The following equations are tested to confirm hypothesis H3.

$$PERFORMANCE_{ijt} = \alpha + \beta_7\, PROD\_COH_{ijt} + \beta_2\, LOG(SALES)_{ijt} + \beta_3\, CAPEX5_{ijt} + \beta_4\, CUSTCONC_{jt} + \varepsilon_{ijt} \quad (9)$$

$$PERFORMANCE_{ijt} = \alpha + \beta_8\, PROD\_DISP_{ijt} + \beta_2\, LOG(SALES)_{ijt} + \beta_3\, CAPEX5_{ijt} + \beta_4\, CUSTCONC_{jt} + \varepsilon_{ijt} \quad (10)$$

$$PERFORMANCE_{ijt} = \alpha + \beta_9\, PATENT\_COH_{ijt} + \beta_2\, LOG(SALES)_{ijt} + \beta_3\, CAPEX5_{ijt} + \beta_5\, DIV\_SEG_{it} + \beta_6\, DIV\_GEO_{it} + \varepsilon_{ijt} \quad (11)$$

Coefficients β_7 and β_9 are expected to have a positive correlation with performance. Coefficient β_8 is expected to have a negative correlation with performance, because the entropy index measures the opposite of coherence. The results of the regressions are shown in model (6a) to (6c) in Table 20 (product firms) and Table 21 (process firms).

Table 20 and Table 21 confirm the central hypothesis of this dissertation. Firms with stronger coherence among either product or process capabilities achieve superior economic performance. The coefficient for product-based coherence (PROD_COH) indicates a positive correlation, the coefficient for product-based dispersion of capabilities (PROD_DISP) indicates a negative sign (as expected), and the coefficient of patent-based coherence (PATENT_COH) indicates a positive sign.

Model specification	(6a)		(6b)		(6c)	
Dependent variable	**ROS**		**ROS**		**ROS**	
Data set	**AUTO_COMP Segment Product-based firms**		**AUTO_COMP Segment Product-based firms**		**AUTO_COMP Product-based firms**	
Sample	**1988:1997**		**1988:1997**		**1988:1997**	
C	0.144	*(0.00)*	0.170	*(0.00)*	0.088	*(0.00)*
PROD_COH	0.035	*(0.00)*				
PROD_DISP			-0.004	*(0.00)*		
PATENT_COH					0.022	*(0.00)*
LOG(SALES)	-0.010	*(0.00)*	-0.011	*(0.00)*	0.000	*(0.61)*
CAPEX5	0.007	*(0.00)*	0.007	*(0.00)*	0.023	*(0.00)*
CUSTCONC	-0.015	*(0.07)*	-0.008	*(0.38)*		
DIV_SEG					-0.049	*(0.27)*
DIV_GEO					-0.047	*(0.00)*
R^2	0.948		0.917		0.945	
R^2 unweighted	0.126		0.109		0.147	
S.E. of regression	0.053		0.052		0.053	
Durbin-Watson stat	0.836		0.793		0.743	
Mean dependent var	0.229		0.214		0.193	
S.D. dependent var	0.228		0.180		0.220	
Regression F-statistic	733		448		419	
Method	GLS (cross-section weights)		GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	5		5		10	
Number of cross-sections	57		57		22	
Total panel observations	166		167		127	
Heterosked. corrections	White		White		White	

(p-values in parentheses)

Table 20: Regression model of coherence and performance for product firms

Model specification	(6a)		(6b)	
Dependent variable	**ROS**		**ROS**	
Data set	**AUTO_COMP Segment Process-based firms**		**AUTO_COMP Segment Process-based firms**	
Sample	**1988:1997**		**1988:1997**	
C	-0.078	*(0.00)*	-0.016	*(0.07)*
PROC_COH	0.036	*(0.00)*		
PROC_DISP			-0.028	*(0.00)*
LOG(SALES)	0.024	*(0.00)*	0.021	*(0.00)*
CAPEX5	-0.008	*(0.12)*	-0.007	*(0.14)*
CUSTCONC	0.010	*(0.17)*	0.002	*(0.75)*
R^2	0.943		0.959	
R^2 unweighted	0.343		0.335	
S.E. of regression	0.039		0.039	
Durbin-Watson stat	0.611		0.589	
Mean dependent var	0.130		0.145	
S.D. dependent var	0.159		0.189	
Regression F-statistic	331		470	
Method	GLS (cross-section weights)		GLS (cross-section weights)	
Included obs	5		5	
Number of cross-sections	29		29	
Total panel observations	85		85	
Heterosked. corrections	White		White	

(p-values in parentheses)

Table 21: Regression model of coherence and performance for process firms

5.4 SUMMARY

The analysis presented in this chapter evaluates the performance difference between product and process firms in the automotive supplier industry, and confirms the positive correlation of corporate coherence among product and process dimensions with firm performance.

Hypothesis testing confirms that product and process firms have different performance. Product firms consistently outperform process firms, but only by a small margin. Moreover, the results point out striking differences between product and process firms regarding scale. Firm size is positively correlated with economic performance for process firms, but negatively correlated for product firms. This implies a pattern by which small, product-based firms are more profitable than large product-based firms, but small process-based firms are less profitable than large process-based firms. The results are robust when using different performance measures, and different data sets.

What is behind this difference in returns to scale and performance for product and process firms? The characteristic features of product and process firms suggest that the reasons for the observed performance difference could be found in the different corporate logic as a result of the focus on products or processes. Small product-based firms often manufacture highly differentiated products using proprietary technology, such as for example airbag inflators (OEA, Special Devices), electrochromic rearview mirrors (Gentex), and window washer nozzles (Bowles Fluidics). This focus on specific product capabilities allows these companies to achieve a high return (typically 10% up to 25% return-on-assets). Medium-sized firms that are product-based may still be able to sell such high margin products, but they also manufacture a range of other products that on average result in lower performance as companies grow and provide broader product offerings. Large, diversified component suppliers only achieve returns of 5% to 8%, while the largest companies in the industry, Delphi Automotive, Lear and Johnson Controls have average returns of around 6%. For product firms, the negative returns to scale could therefore be a result of the product diversification of these firms, and the over-proportional loss of coherence with increasing size. In other words, as coherent and profitable product firms expand, they tend to diversify into less coherent, lower return product lines. Firm size apparently has opposite implications for process firm. Small manufacturing-based firms are often below the critical size for achieving the operating efficiency of large processing facilities. The large proportion of fixed costs of equipment, the vulnerability to fluctuations in raw material costs, and the under-utilization of manufacturing capacity due to fluctuations in demand make it difficult for small process firms to achieve high returns. Small manufacturing firms engaged in injection molding of plastic parts (Bailey), rubber parts (Plymouth Rubber) or metal parts machining (Secom, Simpson Industries) are therefore found to have returns of around 5%, whereas large process firms such as PPG Industries are able to achieve returns of 15%-20%, at sales of $1 billion and more.

Testing of the hypothesis on corporate coherence confirms that coherence correlates positively with economic performance. The analysis is based on a measure of technological coherence developed for this dissertation, which expresses the relatedness of capabilities of a firm. The measure is based on a concentration index and a hierarchical classification of products and processes in the automotive supplier industry. Using this measure of coherence, hypothesis testing confirms that firms with stronger coherence are able to better exploit corporate synergies and therefore achieve superior economic performance. That is, firms focusing on a specialized and related set of capabilities are able to outperform less coherent firms. The findings have implications for strategic choices of firms, such as choosing between focus and diversification.

It should be noted that the simple correlation of firm-specific factors with performance measures does not explain causality in the regressions. To add such causality to the analysis, the next chapter focuses on the analysis of acquisition events, providing a more precise observation of cause and effect of factors influencing firm performance.

Chapter 6

VALUE CREATION THROUGH ACQUISITIONS

This chapter presents an empirical analysis of corporate acquisitions that further explains the link between corporate coherence and firm performance. Such a study of acquisition events can provide additional insights and add causality to the link between corporate coherence and firm performance. The analysis examines the market value of firms before and after an acquisition announcement. The stock price valuation of a firm involved in an acquisition typically changes its value after the announcement of the acquisition, reflecting the opinion of shareholders about the future cash flows of the merged company. The analysis of firm value during acquisition announcements therefore provides a valuation measure that reflects the expected synergies of the acquiring and targeted company. In combination with the framework of product and process firms, such as study of acquisitions further explains the link between corporate coherence and firm performance.

A limitation of the analysis in this chapter is that it only reflects the short-term opinion of shareholders. Stock price changes usually take place within hours after the announcement of an acquisition, and involve significant changes in the dollar amount of the firm value. According to the efficient market hypothesis, such changes in firm value upon an announcement of a merger or acquisition reflect the changes in future expected cash flows to shareholders of the company that is due to expected synergies between the acquiror and the target. In other words, stock price changes reflect the change in firm value as the market adjusts for future expected earnings of the combined businesses.

Section 6.1 presents an analysis of the 30 largest acquisitions in the automotive component industry, and section 6.2 presents results. The findings indicate that acquisitions involving closely related product lines are more value-enhancing than acquisitions of unrelated product lines. The findings confirm the hypothesis that coherence among related product capabilities results in superior firm performance due to greater corporate synergies. The results are not indicative for process firms.

6.1 VALUE CREATION THROUGH ACQUISITIONS

Numerous publications have examined the value change of firms involving acquisitions for analyzing the effect of business diversification. Singh and Montgomery (1987) investigate stock price changes in corporate acquisitions and conclude that acquisitions into related markets or technological fields create higher value than unrelated acquisitions, a result that is consistent with the broad financial literature on diversification. Seth (1990) finds that value creation in related acquisitions is associated with economic efficiencies arising from economies of scale and scope, from operating efficiencies, and from market power. Servaes (1991) and Lang, Stulz, and Walkling (1989) analyze large cross-sectional samples and relate the returns from acquisitions to the Tobin's Q ratios of target and bidder firms. They conclude that returns are larger for better performing firms with high Q ratios that acquire poorly performing companies. Characteristics of the acquisition offer (form of payment, number of bidders) and the type of the take-over contest (hostile/friendly) also influence returns. Other papers focus on divestitures (Berger and Ofek, 1996; Kaplan and Weisbach, 1992).

Acquisition event studies can provide useful indications of value differences between product and process firms. Chapter 5 presented an analysis that confirmed the positive correlation of corporate coherence with firm performance. Furthermore, the dependence of performance on firm size is positive for process firms, but negative for product firms. It was hypothesized that the reason behind the negative returns to scale for product firms may have to do with the effect of incoherent product diversification. Small product-based firms typically manufacture highly specialized products for which they have developed proprietary technology, such as airbag inflators, fuel injection components, and electronic controls. Larger product firms diversify into a broader range of unrelated product lines that are associated with less product-related synergies and therefore lower corporate returns. If this correlation holds true, product firms would experience higher performance if they remained focused on product lines in which they have a core competence instead of diversifying into new product areas.

Similar arguments are made for process firms, for which acquisitions are less frequent and typically smaller in size. Process firms achieve higher performance through returns to scale in manufacturing operations, if firms expand within related processes. Greater scale in operations allows process firms to better achieve higher capacity utilization, and balance fluctuations in demand and raw material costs. If this hypothesis holds, process firms that acquire firms using similar processes would perform better than process firms acquiring unrelated processes. The causality of value creation in acquisitions is examined in hypothesis H4, based on the model in Figure 25:

H4: *Acquisition-related creation of firm value is higher for product and process firms that expand coherently, compared to incoherent expansion.*

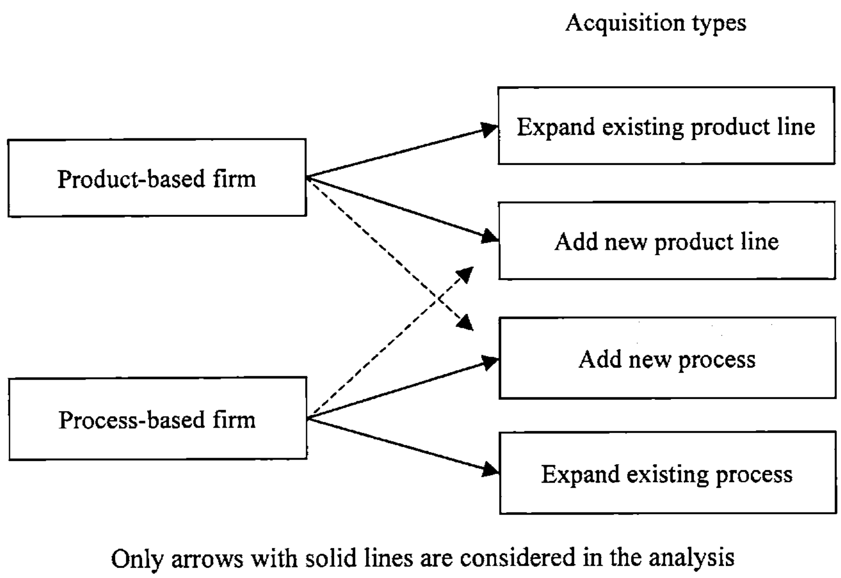


Figure 25: Acquisition types of product and process firms

6.1.1 METHODOLOGY AND DATA SOURCES

The study covers merger and acquisition announcements that occurred between January 1988 and December 1998, and includes both hostile and friendly takeovers. The list was compiled by searching for acquiror or target firms with SIC code 3714 (Motor Vehicle Parts & Accessories) in the SDC Mergers & Acquisitions database. Only public companies registered in the United States were included, and these companies had to be related to the automobile industry.

Not included in the analysis were transactions smaller than $100 million, divestitures, buy-outs, spin-offs, and acquisitions that were the result of a convertible execution. Acquisitions that were too small to cause a stock price change for either target or acquiror firm were excluded.

For each acquisition, the announcement date was verified through news sources, and it was verified that the S&P stock index did not make any major movements (>5%) around the announcement date. Corrections were made for stock splits occurring during the 30-day window of the acquisition announcement (-20/+10 days).

Data on stock prices and number of shares outstanding was taken from the CRSP database. Information on mergers and acquisitions was taken from the SDC Mergers & Acquisitions database. Lexis-Nexis news service and schedules filed with the Securities Exchange Commission (SEC) were used to verify the announcement dates and to evaluate information about products and processes. Table 22 shows the definition of variables used. A detailed list of the acquisitions and stock price graphs are included in appendix 8.7.

Variable	**Definition**	**Data source**
Stock price	P	CRSP
Trading days	T	CRSP
Number of shares outstanding	NOSH	CRSP
Transaction value (acquisition price)	V	SDC
Acquiror firm	A	
Target firm	T	
Target value change / Transaction value	$(p_{T(t+1)}*NOSH_T - p_{T(t-2)}*NOSH_T) / V$	
Acquiror value change / Transaction value	$(p_{A(t+1)}*NOSH_A - p_{A(t-2)}*NOSH_A) / V$	
Total value change / Transaction value	$(p_{A(t+1)}*NOSH_A - p_{A(t-2)}*NOSH_A + p_{T(t+1)}*NOSH_T - p_{T(t-2)}*NOSH_T) / V$	
Date announced	Day of first public announcement	SDC

Table 22: Variable definition of acquisition event studies

6.2 SUMMARY OF RESULTS

Results are summarized in Table 23. Most acquisitions created between 0% and 60% value for the targeted firm (i.e. shareholders of the target receiving a premium over the share price of the target), and between –10% and +30% for the acquiring firm. The size of the transaction values ranges from $100 to $4 billion. The total value creation in most acquisitions ranges from 10% to 50% (as a percentage of the transaction value). Table 23 shows that firms expanding within existing product lines create substantially more value than firms diversifying into new product lines, thus confirming hypothesis H4. Total value creation for expansion of existing product lines is about 70% of the transaction value versus 13% for adding new product lines.

Acquisition type	Acquiror value change / Transaction value	Total value change / Transaction value	Number of acquisitions
Expanding existing product line	33%	69%	7
Expanding existing process	4%	21%	3
Adding new product line	0%	13%	8
Adding new process	4%	17%	4

Table 23: Average value change for acquisitions of product and process firms

Acquisitions of product firms that add new product lines are on average value-neutral to the acquiror, and only slightly value-creating for the combined businesses (13% total value added. In some cases, the acquisition is even overall value-destroying such as the acquisition of Purolator by Mark IV, and the acquisition of Echlin by Dana[36]. The following examples underline the lack of synergies for unrelated business combinations in the case of the Brenco acquisition and General Signal acquisition.

> Acquisition of Brenco by Varlen:
>
> "Brenco is a leading manufacturer and reconditioner of tapered roller bearings for freight cars. Other Brenco subsidiaries make railcar shock control devices, outlet gates, locomotive products and track fastening devices.
>
> Varlen is a leading manufacturer of precision engineered transportation products and analytical instruments for the railroad, heavy-duty truck and trailer, automotive and petroleum industries. Varlen's customers include Freightliner, PACCAR, General Motors and Chrysler." PR Newswire, 14 June 96.
>
> Acquisition of General Signal by SPX
>
> "General Signal Corporation is a leading manufacturer of quality products for the process control, electrical control and industrial technology industries worldwide.

[36] The acquisition of Echlin by Dana may represent a special case because Dana acted as a last minute White Knight in a takeover contest involving Echlin. Therefore, share prices of Echlin may have already reflected the takeover premium, and the transaction value was higher than usual due to the contest.

SPX Corporation is a global provider of vehicle components to the worldwide motor vehicle industry, and a provider of vehicle service solutions to franchised dealers and independent service locations, and to vehicle manufacturers." PR Newswire, 20 July 98.

For process-based firms, hypothesis H4 cannot be confirmed. The value change for acquisitions involving process firms is equally low for firms expanding existing processes and firms adding new processes through acquisitions. The low number of large acquisitions available for the analysis limits the explanatory power of these findings.

Overall, the analysis of firm value in acquisitions indicate that corporate expansion involving closely related product lines are more value-enhancing than acquisitions of unrelated product lines. The findings support causality in the hypothesis that coherence among related product capabilities results in superior firm performance due to greater corporate synergies.

Chapter 7

CONCLUSIONS, AND REFLECTIONS ON THEORY AND EVIDENCE

This dissertation advances the understanding of economic performance and competitive advantage of firms in the automotive supplier industry. Superior performance is explained as a result of corporate coherence in two dimensions, products and processes. The findings have implications for strategic choices of firms, such as choosing between product and process focus, and choosing between focus and diversification.

The dissertation contributes to strategic management theory with a framework of product and process firms that reflects the importance of technological capabilities in manufacturing industries, and with a measure of technological coherence that facilitates empirical research of corporate coherence. The measure of technological coherence expresses the relatedness of capabilities of a firm, and is based on a concentration index and a hierarchical classification of products and processes in the automotive supplier industry. Using this measure of coherence, it is shown that firms with stronger coherence are able to better exploit corporate synergies and therefore achieve superior economic performance. In other words, firms focusing on a specialized and related set of capabilities are able to outperform less coherent firms. The analysis further reveals a significant difference in performance between product and process firms. Product firms in the automotive supplier industry exhibit negative returns to scale, whereas process firms exhibit positive returns to scale. These differences are attributed to the underlying corporate logic of product and process firms, and are supported with studies of value creation in corporate acquisitions.

A summary and discussion of findings is listed at the end of each chapter throughout this dissertation. This final chapter presents additional reflections on the framework of product and process firms, and contains feedback obtained from interviews with senior executives in the automotive industry. The goal of these interviews was to validate the major ideas developed in this dissertation, and to obtain comments that either confirm or disagree with the results. Section 7.1 presents the feedback of these interviews, and section 7.2 concludes with reflections on the contribution of this dissertation and alternative theoretical perspectives.

7.1 MANAGERIAL PERSPECTIVES

To obtain feedback on the major ideas developed in this dissertation, interviews were held with fifteen senior executives, among them CEOs, chairmen, and vice-presidents of major automotive suppliers, and senior consultants, at the beginning of year 2000. The interviewees were given a brief summary of Chapter 2, Chapter 5, and Chapter 6 of this dissertation, and were asked to comment on the ideas and findings presented. The following personal statements made by the interviewees provide additional support or disagreement of the research findings, and add causality as well as anecdotal evidence to the results.

The characterization of firms as product and process firms presented in Chapter 2 provides insights into the sources of competitive advantage of firms in the automotive supplier industry. Many characteristic features of product and process firms follow from the underlying assumption that the two types of firms represent fundamentally different technological capabilities in product and process dimensions. In an econometric analysis presented in Chapter 5, it was found that economic performance differs for product and process firms, and that firms with strong coherence outperform less coherent firms. In addition, product firms in the automotive supplier industry are found to have negative returns to scale, whereas process firms exhibit strong positive returns to scale. These result are attributed to the negative influence of product diversification for large, product-based firms, and the strong operational synergies and ability to sell products in diversified product markets for process firms. These findings were supported by most interviewees. Additional aspects regarding the performance of product firms is reflected in the following statements.

> "It is certainly true that large Tier 1 suppliers (product-based firms) do not achieve the profitability of certain smaller firms. As a small firm, you may have a unique product protected by intellectual property rights, which will earn very high returns."

> "The reasons why large product-based companies in this industry are less profitable than small companies is that they are more exposed to the OEMs. Vehicle manufacturers pay most attention to their largest suppliers, and exercise a lot of pressure to squeeze their margins. As a product-

based firm, you cannot simply walk away from an OEM, if you have already cooperated over a long period of time on the development of a certain component for a new vehicle model."

The first statement supports the importance of unique technological capabilities and the protection through intellectual property rights for small firms to establish a favorable market position. But the statement does not explain why large Tier 1 suppliers should not be able to achieve similarly unique products and higher performance compared to small product firms. The second statement argues that large product firms are less profitable due to the increased pricing pressures from their OEM customers. This would not be a valid argument according to standard economic theory, if only the size of large suppliers increases their exposure to the OEM. The main argument is that the integration of large suppliers with OEMs, such as through cooperation in product development, results in a lock-in situation. This exposes suppliers to increased price pressures imposed by OEMs, according to the statement. The discussion of firm boundaries in Chapter 3 supports the argument that product firms tend to be more vertically integrated and dependent on their customers than process firms, because of their focus on specific markets and product-related capabilities.

But the price pressure of OEMs could also indicate special circumstances of manufacturer-supplier relations (Cusumano and Takeishi, 1995). The interviewee made particular reference to the arms-length model of supplier relationships that were typical for General Motors at the time when Jose Ignacio Lopez fostered vigorous competition among suppliers to generate cost savings for the OEM (Dyer, Cho, and Chu, 1998). In contrast, Japanese supplier relationships and Chrysler in the United States, have developed long term partnerships with suppliers that are based on trust rather than competition (Helper and Sako, 1995). The consensus in the literature is that a trust-based relationship results in higher overall performance for supplier and manufacturer than an arms-length relationship (Dyer, Cho, and Chu, 1998). Another statement made by a different interviewee confirms this point:

> "Profitability of an automotive supplier should differ depending on who the OEM customer is. The biggest difference probably exists between the supply chain of Chrysler and other OEMs. Suppliers of Chrysler tend to have better contract conditions, and therefore presumably higher profits."

The view that a supplier of a specific product line of automotive components is less flexible in absorbing fluctuations in demand from its customers is expressed in the following statement.

> "We have become one of the leading manufacturers of automobile exhaust systems, and owned one of the most productive factory for exhaust products. But then came the negative developments and losses for one of our major OEM customers, and our forecasted sales were completely overstated. This has reduced our profits for the year in an area where we thought to be leading in technology. As a product-based firm, you are dependent on specific customers."

As discussed in the context of market diversification of product and process firms in section 2.4, specialized product suppliers are indeed more dependent on specific customers than process firms, which sell more generic products. This argument is also expressed in the following statements on the performance of process firms:

> "Process-based companies are typically selling their products to multiple industries, because the products are of generic nature. This allows process firms to reject contracts that are not lucrative. In other words, you can say no to orders from the automotive industry, if you can sell the same product to a different industry at a higher margin."
>
> "Process-based companies are focused on optimizing operations. The focus on generic processes instead of sophisticated products requires less complex infrastructure, and allows processing of larger volume badges, continuous improvement of operational efficiency, and greater ability to increase capacity utilization."

These statements confirm that the most important source of competitive advantage for process firms is the ability to diversify market presence by applying process capabilities to a range of product applications. The statement indicates why process firms have positive returns to scale, pointing to the importance of operational efficiency, and the ability to increase capacity utilization by applying excess capacity to explore new product applications.

The views expressed in the above statements made by senior executives in the automotive supplier industry support the main ideas developed in this dissertation, and add a sense of causality and anecdotal evidence to the hypotheses tested in Chapter 5.

7.2 ALTERNATIVE VIEWS IN THEORY

The following section concludes with reflections on the theoretical contribution of this dissertation, and its relation to alternative views on the sources of competitive advantage in the literature on corporate strategy.

One of the initial assumptions made in this dissertation is that the role and understanding of technological capabilities in manufacturing organizations is underrepresented in the existing literature on strategic management. Traditional economic literature ignores any impact technologies may have on shaping a firm. According to Coase (1937), firms are part of an "economic system that is being coordinated by the price mechanism," and the argument is rejected that technology defines firms in the form of economies of scale and technological non-separabilities (Coase, 1937, p. 2; Williamson, 1975). While the general approach in neoclassical economic theory assumes competition in equilibrium, and therefore often disqualifies considerations of innovation, change, and heterogeneity, strategy theory attempts to explain exactly that (see Rumelt, Schendel, and Teece, 1991). The existence of opportunities and heterogeneity among firms is the basis for strategic recommendations, which firms can follow to exploit these opportunities. Among the strategic choices that firms can make are "the selection of goals, the choice of products and services to offer, the design and configuration of policies determining how the firm positions itself to compete in product-markets, the choice of an appropriate level of scope and diversity, and the design of an organization structure, administrative systems and policies" (Rumelt, Schendel, and Teece, 1991). However, the importance of technology is not a central part of the established theories of strategic management, and often seems underrepresented or lacking empirical validation[37]. But the viewpoints of those who write on the importance of technological capabilities in the context of manufacturing, is often not integrated with traditional strategy theory (Skinner, 1969; Hayes and Pisano, 1996). Therefore, the dissertation seeks to make a contribution in combining a technological perspective of firms with strategy theory.

Chapter 2 presented the conceptual details of the framework of product and process firms and discussed the concept of coherence in product and process dimensions. The framework explains technological capabilities and characteristic features of firms in the automotive industry, which provide the basis for explaining corporate coherence. Chapter 2 concluded with remarks that the framework of product and process firms reflects two established theories of strategy, Porter's framework of market positioning and the resource-based view of the firm. It is worth further exploring this thought. The typical product-based firm indeed shares many concepts with Porter's view of a competitive firm. Product firms position themselves in well-defined product lines, automotive airbags for example, and establish entry barriers for competitors in the form of intellectual property rights, preferred relationships with automobile manufacturers, and product differentiation.

[37] With remarkable exceptions, among them Helfat, 1997; and Silverman, 1996.

While product coherence in Porter's framework is not a central issue, it is implicitly included in Porter's assumption that firms are competing in markets of "products that are close substitutes for each other" (Porter, 1980, p. 5). This point is further elaborated in Porter's work on the value chain of a firm (1985). Porter (1985) mentions the principles by which value activities are defined as "(1) having different economics, (2) have a high potential impact or differentiation, or (3) representing a significant or growing proportion of cost." This is where the framework of product and process firms contributes to the understanding of firm activities, and helps identify the value activities of firms. For product-based firms, capabilities in a coherent product line such as integrated airbag and steering wheels provide a value activity, and the basis for competitive advantage. For process-based firms, the operational synergies of a coherent process capability such as fiberglass processing reflect a value activity, and source of competitive advantage.

The alternative theoretical view of the firm, the resource-based view, argues that firm-specific resources allow firms to achieve superior performance as a result of synergies among these resources, or capabilities (Wernerfelt, 1984). The process firm is a typical example of a resource-based firm with a focus on internal procedures, skills and assets. Many exponents of the resource-based view provide additional support for the correspondence between process capabilities and the competitive advantage of firms. The evolution lean manufacturing as a result of superior process capabilities by Japanese automobile producers is one of the prominent examples of a successful resource-based strategy in the automotive industry. Teece et al. (1994) find evidence that manufacturing firms maintain a constant level of coherence between activities as they grow more diverse. Although the authors explain this as a result of enterprise learning, path dependency and the natural selection of the environment, they repeatedly refer to coherent manufacturing processes, such as in the observation that "new product lines very often utilize capabilities common with existing product lines." Prahalad and Hamel (1990) added the idea of "core competencies" as the sources of resource-based competitive advantage. Such core competencies originate in production skills and allow firms to compete in a variety of markets. And Montgomery and Wernerfelt (1988), and Chatterjee and Wernerfelt (1991) find more specific evidence that certain firms diversify in response to excess capacity of productive factors, which this dissertation found as typical for process firms. The authors attest that "knowledge of these resources allows us to make predictions about the direction of a firm's expansion," (Chatterjee and Wernerfelt, 1991), but remain unspecific about the definition of resources.

From these brief excerpts of the resource-based literature, it appears that the framework of process firms corresponds with many aspects mentioned in this literature, and that it can offer a more specific definition of the type of resources and capabilities that provide a source for competitive advantage of process firms.

Are product and process firms then "two sides of the same coin,[38]" the Porter framework and the resource-based theory of corporate strategy? The evidence presented in this dissertation suggests that the two dimensions of product and process share remarkable similarities with the two established frameworks in strategic management theory.

[38] "For the firm, resources and products are two sides of the same coin." Wernerfelt, 1984.

Chapter 8

APPENDIX

8.1 COMPANY PROFILES

The following companies are presented in Chapter 2 as typical examples of product and process-based companies in the automotive component industry.

8.1.1 DANA CORPORATION

Product-based firm:	**Dana Corporation**
Industry Classification (SIC)	Motor Vehicle Parts & Accessories
Sales	$12,636.5 million (1998)
Operating margin	7.9% (average 1994-1998)
R&D expense	2.2% of sales (1998)
Description of the company: Dana is a global leader in engineering, manufacturing and marketing of products for worldwide vehicular, industrial and off-highway original equipment manufacturers and related aftermarkets (axles, driveshafts, engine and chassis parts, fluid power systems, power transmission products). Dana Commercial Credit subsidiary provides leasing and financing services. Dana's major customers include automakers Ford and DaimlerChrysler and truck maker Mack.	
Product lines: AUTOMOTIVE SYSTEMS GROUP This segment serves the global light truck and passenger car markets with light duty axles and driveshafts, structural products, transfer cases, original equipment brakes and integrated modules and systems. AUTOMOTIVE AFTERMARKET GROUP Created in 1998 from the merger with Echlin, this segment sells hydraulic brake components and disc brakes for light vehicle applications, external engine components for the vehicle maintenance and repair markets and a complete line of filtration products for a variety of vehicle and industrial applications. ENGINE SYSTEMS GROUP This segment serves the automotive, heavy truck, agricultural, construction, and industrial markets with sealing products, engine parts, piston rings, cylinder liners and camshafts and fluid system products. HEAVY TRUCK GROUP This segment produces heavy axles and brakes, trailer products, medium and heavy duty driveshafts and power take-off units and commercial vehicle systems for heavy trucks. OFF-HIGHWAY SYSTEMS GROUP This segment produces axles and brakes, transaxles, power-shift transmissions, torque converters and electronic controls and hydraulic pumps, motors, valves, filters and electronic components for the construction, agriculture, mining, and leisure utility equipment markets. INDUSTRIAL GROUP This segment sells products and systems that drive and control motion, including clutches, brakes, linear actuators, motors and controls, hose products, couplings and electric and electronic sensors. LEASING SERVICES (DANA COMMERCIAL CREDIT) This segment provides services to selected markets including leasing and finance products, and asset and real property management.	
Engineering and R&D: The company is engaged in ongoing engineering, research and development activities to improve the reliability, performance and cost-effectiveness of existing products and to design and develop new products. Dana now has some 70 technical centers worldwide, of which 40 with full research and development capabilities.	
Manufacturing processes: Dana's products are manufactured in over 300 manufacturing facilities worldwide using a very diverse range of manufacturing processes.	
Source of information: Company Annual Reports	

8.1.2 GENTEX CORP

Product-based firm:	**Gentex Corp**
Industry Classification (SIC)	Motor Vehicle Parts & Accessories
Sales	$202 million (1998)
Operating margin	26.2% (average 1994-1998)
R&D expense	5.0% of sales (1998)
Description of the company: Gentex develops and manufactures automatic-dimming rearview mirrors using electro-optic technology. The company was organized in 1974 to manufacture residential smoke detectors, and in 1982 introduced an automatic interior rearview mirror that was the first commercially successful glare-control product offered as an alternative to the conventional, manual day/night mirror.	
Product lines: AUTOMATIC REARVIEW MIRRORS The company achieved a significant technological breakthrough by applying electrochromic technology to the glare-sensing capabilities of rear-view mirrors. Through the use of electrochromic technology, this mirror is continually variable and automatically darkens to the degree required to eliminate rearview headlight glare. The company markets its automatic rearview mirrors to domestic and foreign automotive manufacturers, and the mirrors are standard equipment on many automobile vehicle models. Gentex currently is the dominant supplier to the automotive industry with an approximate 87% market share worldwide. FIRE PROTECTION PRODUCTS The company also manufactures smoke detectors. These products provide the flexibility to be wired as part of multiple-function systems and consequently are generally used in fire detection systems common to large office buildings, hotels, and other commercial establishments.	
Engineering and R&D: The company continually invests in improving its products and has been devoting substantial research and development efforts. The Company owns 35 U.S. patents, 33 of which relate to electrochromic technology and automotive rearview mirrors.	
Manufacturing processes: The company uses various manufacturing processes to make its products, including assembly.	
Source of information: Company Annual Reports	

8.1.3 TOWER AUTOMOTIVE INC.

Process-based firm:	**Tower Automotive Inc.**
Industry Classification (SIC)	Metal Forging & Stampings
Sales	$1,836 million (1998)
Operating margin	9.4% (average 1994-1998)
R&D expense	None reported
Description of the company: Tower Automotive is a leading producer of structural components for Ford, Chrysler, General Motors, Honda, Toyota, Nissan, Auto Alliance, Fiat, BMW, Volkswagen and Mercedes.	
Product lines: The company produces a broad range of stamped and welded assemblies for vehicle body structures and suspension systems, many of which are critical to the structural integrity of a vehicle. These products include body structural assemblies such as pillars and package trays, control arms, suspension links, engine cradles and full frame assemblies. These stampings and assemblies are attached directly to the frame of an automobile at the OEM assembly plant and comprise the major structure of a vehicle. The company does not produce exposed sheet metal components, such as exterior body panels.	
Engineering and R&D: The company maintains technical centers to service its OEM customers. The company does not report any R&D expense and does not own patents.	
Manufacturing processes: The company's manufacturing operations consist primarily of stamping operations, roll-forming and hydroforming operations and associated coating operations. Stamping involves passing metal through dies in a stamping press to form the metal into three-dimensional parts. The company produces stamped parts using over 640 progressive and transfer presses, ranging in size from 150 to 4,000 tons. The company's assembly operations are performed on either dedicated, high-volume welding/fastening machines or on flexible-cell oriented robotic lines for units with lower volume production runs. The products manufactured by the company use various grades and thickness of steel and aluminum, including hot and cold rolled, galvanized, coated, stainless and aluminized steel. The primary raw material used to produce the majority of the products is steel. Raw material costs represented approximately 49% of revenues in 1998. The company is involved in ongoing evaluations of the potential for the use of aluminum and of specialty steel in its products.	
Source of information: Company Annual Reports	

8.1.4 PPG INDUSTRIES INC.

Process-based firm:	**PPG Industries Inc.**
Industry Classification (SIC)	Paints, Varnishes, Lacquers, Enamels & Allied Products
Sales	$5,986 million (1998)
Operating margin	16.7% (average 1994-1998)
R&D expense	4.8 % of Sales (1998)

Description of the company:

PPG Industries is comprised of three basic business segments: coatings, glass and chemicals. Products include automotive original, refinish, industrial, packaging and architectural coatings; flat glass, automotive glass, aircraft transparencies, continuous-strand fiber glass; and chlor-alkali and specialty chemicals.

Product lines:

COATINGS

The coatings business involves the supply of protective finishes for automobiles and industrial equipment, and aluminum extrusions for architectural uses. PPG also supplies adhesives and sealants for the automotive industry.

GLASS

PPG is one of the major producers of flat glass, fabricated glass and continuous-strand fiber glass in the world. PPG's major markets are automotive, construction, aircraft transparencies, marine and electronics industries, and other markets.

CHEMICALS

PPG is a major producer of chlor-alkali chemicals and specialty chemicals. Most of these products are sold directly to manufacturing companies in the chemical processing, rubber and plastics, paper, minerals and metals, and water treatment industries.

Engineering and R&D:

PPG operates facilities to conduct research and development involving new and improved products and processes. Additional development work is also undertaken at many of the company's manufacturing plants.

Manufacturing processes:

The coatings business operates 37 principal production facilities to produce automotive and industrial coatings. The glass business manufactures flat glass by the float process and fiber glass by the continuous-filament process in 21 plants. Chemicals are manufactured in seven plants, the largest of which primarily produce chlor-alkali products. The company's most significant raw materials are titanium dioxide and epoxy and other resins in the coatings segment; sand, soda ash and energy in the glass segment, and ethylene in the chemicals segment. Most of the raw materials used in production are purchased with long term supply arrangements to meet the planned operating requirements for the future.

Source of information: Company Annual Reports

8.2 PRODUCT AND PROCESS CLASSIFICATION

This hierarchical classification of products and processes in the automotive supplier industry is based on the interrelationship of products and processes. Two products are related if they share are in the same three-digit product or process classification.

The classification is used to identify product and process capabilities of firms in the data sets listed in this appendix. The classification is also used to construct a measure of corporate coherence based on the concentration of capabilities of a firm within the hierarchical classification. This measure of coherence is used in Chapter 5 to test for the effect of corporate coherence on firm performance.

Interrelationship of products was based on the following criteria:

Similarities in functionality and price
- Functional requirements (performance, features, reliability, durability)
- Price requirements
- Complexity and system integration requirements

Similarities in science and technology
- Scientific and technical knowledge requirement
- Intellectual property basis

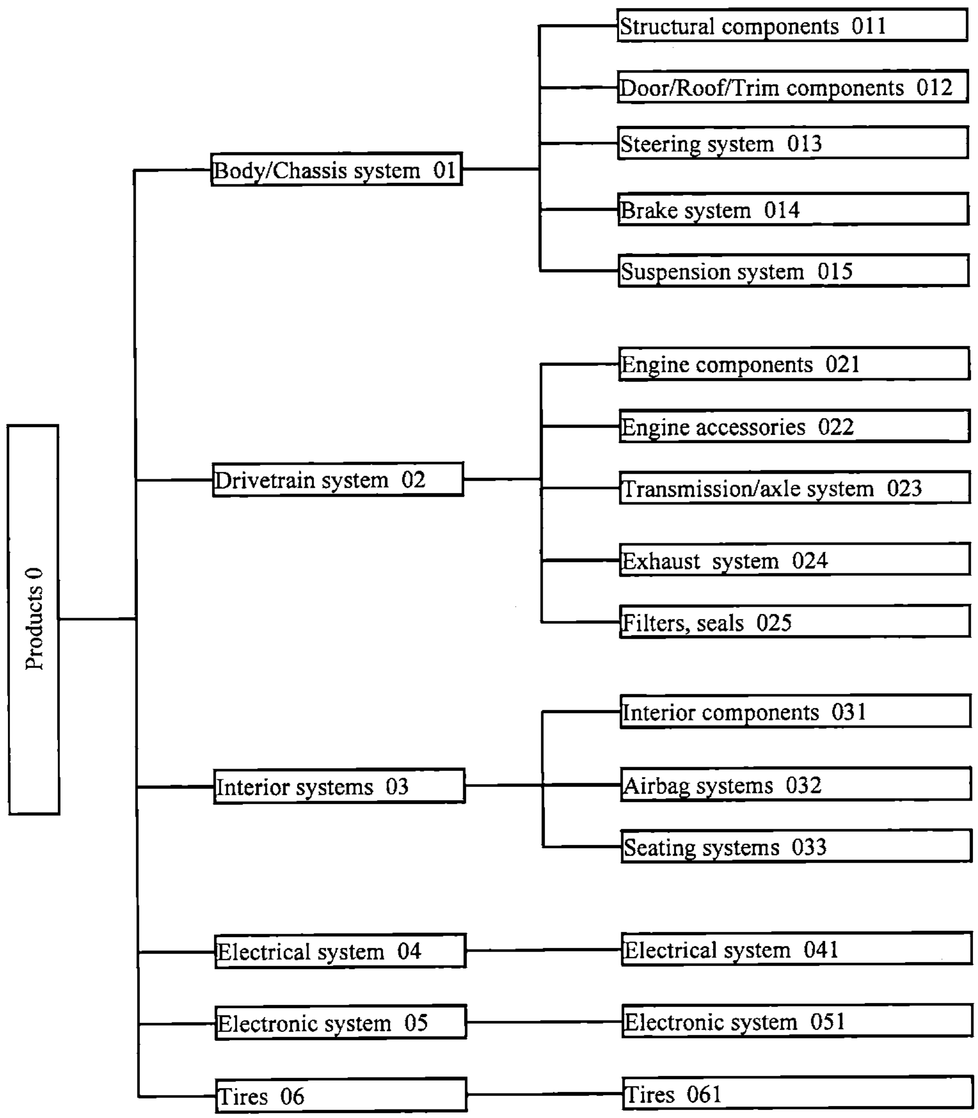
Similarities in engineering, design, and marketing
- Development requirements
    - Lead time
    - Coordination
    - Prototyping and testing
- Marketing requirements
- Product economics
    - Development and engineering costs
    - Manufacturing and assembly requirements (costs and production volume)
    - Logistics requirements

Interrelationship of processes was based on the following criteria:

Similarities in properties of processed materials
- Manufacturing properties, mechanical behavior (tension, compression, torsion, bending, hardness, fatigue, creep, impact)
- Physical properties (density, melting point, thermal conductivity, corrosion)

Similarities in manufacturing process
- Process methods
    - Equipment requirements
    - Coordination requirements
- Process conditions (work, heat, temperature, moisture)
- Process economics
    - Material costs
    - Equipment costs
    - Operating costs (operation, tooling, service and maintenance)
    - Production volume and rate
- Quality, testing, and inspection requirements

8.2.1 PRODUCT CLASSIFICATION



- Body/Chassis system 01
  - Structural components 011
    - Chassis components
    - Structural components
    - Metal stampings
      - Stamping (fenders, hub caps, tops, trim)
      - Stamping body parts
    - Panels (metal)
    - Panels (plastic)
    - Fasteners, brackets
  - Door/Roof/Trim components 012
    - Exterior trim
      - Trim, plastic
    - Seals, rubber
    - Bumper systems
      - Bumper components
    - Roof systems
      - Roof components
      - Sunroof
    - Door systems
      - Door components
      - Door handles
      - Locks
    - Windows, glass systems
      - Window components
      - Glass
      - Power window
    - Mirrors
    - Wipers
    - Luggage racks, liners
    - Paint and coatings
  - Steering system 013
    - Power steering
    - Rack and pinion
    - Steering column
    - Steering wheel
    - Other steering components
  - Brake system 014
    - Brake components
      - Brake lining
      - Brake disks, drums
      - Brake pads and shoes
      - ABS brakes
      - Brake cylinders
      - Parking brake
    - Hydraulic systems, parts, solenoid valves
    - Wheels
      - Wheel components
  - Suspension system 015
    - Shock absorbers
    - Struts
    - Other suspension components
    - Springs
    - NVH components

- Drivetrain system 03
  - Engine components 031
    - Engine components
      - Cylinder head
      - Valves
      - Piston, piston rings
      - Rockers
      - Camshaft
      - Connecting rods
      - Other engine components
    - Castings, engine
    - Engine controls (electronic), engine management
    - Fuel delivery
    - Carburetor
    - Fuel injection
      - Diesel
      - Gasoline
    - PCV valves
    - Timing gears, chains, valvetrain
    - Throttle
    - Crankshaft
    - Thermal engine management (cooling)
    - Engine, rebuilt
    - Compressors, turbocharger
    - Fuel tank
  - Engine accessories 032
    - Heating/Ventilation
    - Air conditioning
    - Radiators
    - Pump (fuel, oil, water, except power steering)
    - Flywheels
    - Tubular parts
    - Thermoplastics, rubber parts
    - Heatproofing
    - NVH components
    - Hoses, belts
    - Bearings
  - Transmission/axle system 033
    - Transmission
      - Automatic transmission
      - Clutch
      - CV joint
      - Gearbox
      - Transmission components
    - Transmissions, rebuilt
    - Transfer case
    - Torque converter
    - Axle system
      - Axle components
      - Axle bearings
    - Differential
    - Driveshaft
      - Driveshaft components
      - Universal joints
  - Exhaust system 034
    - Manifold
    - Exhaust systems
      - Exhaust components
      - Tail pipes
      - Mufflers
    - Emission control system
    - Emission control components
      - On-board diagnostics
      - Oxygen sensor
      - Catalyst
  - Filters, seals 035
    - Filter
      - Filter oil
      - Filter fuel
      - Filter air
    - Seals
    - Gaskets

- Electrical system 04
  - Electrical system 041
    - Wiring harnesses
    - Wires
    - Cables
    - Connectors
    - Multiplex wiring systems
    - Actuators
    - Charging system
      - Alternators, generators
    - Starting system
      - Starters
    - Distributors
    - Ignition system
      - Ignition, coils
      - Spark plugs
    - Sensors
    - Switches
    - Electric motors
    - Lightings (exterior)
    - Lightings (interior)
    - Horns
    - Fan motors
    - Wiper motors
    - Signaling circuits
    - Heating/air conditioning sensors, controls
    - Seat heaters
    - Electric power steering
    - Electric seats
    - Electric mirrors
    - Electric locks
    - Electric sunroof
    - Electric window
    - Batteries
      - Lead-acid battery
      - Advanced batteries
- Interior systems 03
  - Interior components 031
    - Interior components
      - Carpets
      - Consoles
      - Dashboard
      - Door panels
      - Plastics
      - Other trim
      - Other interior components
    - Mirrors
  - Airbag systems 032
    - Airbag
      - Crash sensors
      - Inflators
      - Fabric bag
      - Other airbag components
    - Seat restraints
  - Seating systems 033
    - Seat covers
    - Foam
    - Seat frames
    - Other seat components
- Electronic System 05
  - Electronic System 051
    - Central control unit
    - Trip computer
    - Engine management systems
      - Ignition and fuel management control
      - Exhaust emission control
    - Electronic fuel control
    - ABS electronics
    - Active suspension
    - Traction control
    - Automatic transmission control
    - Instrumentation
      - Gauges and sensors
      - Driver information systems
      - Visual displays
    - Cruise control
    - Entertainment systems
      - Audio
      - Video
    - Communication systems
    - Navigation systems
    - Collision warning system
    - IVHS systems
    - Security systems
    - Adaptive noise control
    - Drive-by-wire
    - Fiber optic control

8.2.2 PROCESS CLASSIFICATION

- Processes 1
  - Assembly 11
    - Assembly 111
  - Metal processing 12
    - Casting 121
    - Machining 122
    - Forming 123
    - Welding 124
    - Stamping 125
    - Forging 126
    - Powder sintering 127
    - Extrusion 128
  - Plastics processing 13
    - Stamping 131
    - Molding 132
    - Foaming 133
    - Laminates 134
    - Composites 135
    - Rubber 136
    - Extrusion 137
  - Surface treatment 14
    - Painting 141
    - Coating 142
  - Glass processing 15
    - Glass processing 151
  - Ceramics 16
    - Ceramics 161
  - Textile processing 17
    - Textile processing 171
  - Chemical processing 18
    - Chemical processing 181
  - Electronic component mfg 19
    - Electronic component mfg 191

- Assembly 11
  - Assembly 111
    - Assembly
      - Manual assembly
      - Automated assembly
    - Assembly line
    - Remanufacturing
- Metal processing 12
  - Casting 121
    - Casting
      - Sand casting
      - Die casting
      - Investment casting
      - Permanent mold casting
    - Bodyside moldings
  - Machining 122
    - Machining
      - High-speed machining
      - Precision machining
    - Hydroforming
  - Forming 123
    - Hot-forming
    - Cold-forming
    - Wire drawing
    - Roll forming
    - Bending
    - Tubular parts manufacturing
  - Welding 124
    - Welding
      - Spot welding
      - Laser welding
  - Stamping 125
    - Stamping metal
  - Forging 126
    - Forging
  - Powder sint. 127
    - Powder sintering
  - Extrusion 128
    - Extrusion metal

- Plastics processing 13
  - Stamping 131
    - Stamping plastic
  - Molding 132
    - Molded plastic
      - Compression molding (SMC)
      - Injection molding
      - Reaction injection molding (RIM)
      - Vacuum forming
    - Blow molding
  - Foaming 133
    - Foaming
  - Laminates 134
    - Laminates
  - Composites 135
    - Composites
  - Rubber 136
    - Tire molds
    - Elastomers (rubber)
  - Extrusion 137
    - Extrusion plastics
    - Coextrusion

- Surface treatment 14
  - Painting 141
    - Painting
  - Coating 142
    - Coating
      - Hard coating
      - Chrome plating
      - Steel coating

8.3 DATA SETS

The following data sets of companies in the automotive industry are used throughout the dissertation for various empirical analysis.

Financial data was taken from several COMPUSTAT™ files (Current and Research). Data on products and processes was evaluated using company annual reports (10-K) filed with the Securities Exchange Commission (SEC). Because such reports are only available electronically after 1993, detailed data on products and processes in this study covers the period from 1993 to 1998. For all other cases, the time period studied covers ten years, from 1988 to 1997. Corrections to align the end of fiscal years have not been made.

The following table displays a summary all data sets used.

Firm-segment level data sets (1988-1997)	**Operating Margin (Return-on-Sales)**		**Firms**	**Segments**	**Segment-Years**
	Mean	**Median**			
AUTO_COMP Segment	8.4%	7.8%	92	131	633
INDUSTRIAL_COMP Segment	8.6%	8.2%	135	193	1068

Firm level data sets (1988-1997)	**Operating Margin (Return-on-Sales)**		**Firms**	**Firm-Years**
	Mean	**Median**		
OEM	4.6%	4.5%	9	89
AUTO_COMP	8.2%	7.7%	46	276
INDUSTRIAL_COMP	8.6%	7.9%	99	791
STEEL_ALU	7.1%	6.4%	26	223

8.3.1 AUTO_COMP Segment

The following list contains product and process information of company segments that are included in the *AUTO_COMP Segment* data set. This list represents segments of U.S. registered, public companies, for which sales to the automotive industry represent at least 50-80% (or more)of total segment sales (131 firm segments in total).

Firm Name	**Firm Segment**	**Product-based firm: Main Products**	**Process-based firms: Main Processes**
AEROQUIP-VICKERS INC	AUTOMOTIVE	Air conditioning, power steering, oil and transmission cooler, and fuel line components and assemblies; bodyside moldings; decorative bumper strips; roof moldings; spoilers; rocker panel claddings; engine components; louvers and trim plates; interior trim; garnish moldings; structural products such as bumper beams; interior engine covers; instrument clusters; radio bezels; and display products	
AEROQUIP-VICKERS INC	FLUID CONNECTORS	Hose and hose assemblies; fittings, adapters, couplings and swivels; automotive air conditioning, power steering, and oil and transmission cooler components and assemblies; tube fittings and assemblies; refrigeration/air conditioning connectors; clamps and V-band couplings; fuel-handling products; noise-reduction products; chemical containment products; and electronic fluid system products	
AETNA INDUSTRIES INC	STAMPING MODULES		Stampings and metal-forming
AETNA INDUSTRIES INC	COMPONENTS - EUROPE		Stampings and metal-forming
AETNA INDUSTRIES INC	COMPONENTS - NORTH AMERICA		Stampings and metal-forming
ALLIEDSIGNAL INC	AUTOMOTIVE	Filters and electronic, brake and steering components, car care products, friction materials, filters and spark plugs, truck air brake systems, turbocharging systems	
ALLIEDSIGNAL INC	TRANSPORTATION PRODUCTS	Filters and electronic, brake and steering components, car care products, friction materials, truck air brake systems	
AMCAST INDL CORP	ENGINEERED COMPONENTS		Fabricated metal products, cast and tubular metal products
ARVIN INDUSTRIES INC	AUTOMOTIVE ORIGINAL EQUIP	Exhaust systems (mufflers, exhaust and tail pipes, catalytic converters, flex tubes and tubular manifolds), ride control products (shock absorbers, struts, ministruts and corner modules), gas lift supports, vacuum actuators, engine and steering dampers, and power steering pumps	
ARVIN INDUSTRIES INC	AUTOMOTIVE	Exhaust systems (mufflers, exhaust and tail pipes, catalytic converters, flex tubes and tubular manifolds), ride control products (shock absorbers, struts, ministruts and corner modules), gas lift supports, vacuum actuators, engine and steering dampers, and power steering pumps	
AUTOCAM CORP	METAL ALLOY COMPONENTS		Specialty metal-alloy components
AUTOLIV INC	AIRBAGS & SEAT BELTS	Driver-side airbags, side-impact airbag protection systems, seat belts, steering wheels, safety seats and other safety systems and products	
BAILEY CORP	AUTO PARTS & COMPONENTS		Injection and compression molded plastics
BORG WARNER AUTO	AUTOMOBILE COMPONENTS	Four-wheel drive and all-wheel drive transfer cases; Friction plates, one-way clutches, transmission bands, and races for automatic transmissions; Timing chain and timing chain systems, crankshaft and camshaft sprockets, chain tensioners and snubbers; Mechanical, electro-mechanical and electronic components and systems	
BORG WARNER AUTO	POWERTRAIN SYSTEMS	Four-wheel drive and all-wheel drive transfer cases	

BORG WARNER AUTO	AUTOMATIC TRANSMISSION SYS	Friction plates, one-way clutches, transmission bands, and races for automatic transmissions	
BORG WARNER AUTO	CHAIN SYSTEMS	Timing chain and timing chain systems, crankshaft and camshaft sprockets, chain tensioners and snubbers	
BORG WARNER AUTO	AIR-FLUID SYSTEMS	Mechanical, electro-mechanical and electronic components and systems used for engine air intake and exhaust management, fuel and vapor management, electronically controlled automatic transmissions and steering and suspension systems	
BOWLES FLUIDICS CORP	COMPONENT PRODUCTS	Windshield and rear window washer nozzles, and defroster nozzles	
BREED TECHNOLOGIES INC	AIRBAG SYSTEMS	Airbag modules and inflators, sensors, electronics and related software, seatbelt systems and steering wheels	
BRIGGS & STRATTON	LOCKS	Mechanical locks, electro-mechanical locks and related products	
CAPCO AUTOMOTIVE PRODS	MANUAL TRANSMISSIONS	Transmission components	
CHERRY CORP	AUTOMOTIVE MARKET	Switches, switch assemblies, sensors and electronic modules	
CHERRY CORP	AUTOMOTIVE SWITCHES & MODULE	Switches, switch assemblies, sensors and electronic modules	
CITATION CORP/AL	IRON & STEEL CASTINGS		Aluminum, iron and steel castings, steel forgings and machining
CLARCOR INC	ENGINE-MOBILE FILTRATION	Filters for oil, air, fuel, coolants and hydraulic fluids	
COLLINS & AIKMAN CORP	AUTOMOTIVE PRODUCTS	Molded floor carpet, acoustical products, luggage compartment trim, accessory floormats, and plastic-based interior trim systems	
COLLINS & AIKMAN CORP	N AMERICA AUTO INTERIOR SYS	Molded floor carpet, acoustical products, luggage compartment trim, accessory floormats, and plastic-based interior trim systems	
COLLINS & AIKMAN CORP	EUROPE AUTO INTERIOR SYS	Molded floor carpet, acoustical products, luggage compartment trim, accessory floormats, and plastic-based interior trim systems	
COLLINS & AIKMAN CORP	SPECIALTY AUTO PRODUCTS	Automotive fabrics and convertible top systems	
COLTEC INDUSTRIES	AUTOMOTIVE	Fuel injection assemblies and components, transmission controls, engine induction systems and components, steering controls, suspension controls, emission control air pumps, oil pumps and seals	
COOPER INDUSTRIES INC	AUTOMOTIVE PRODUCTS	Automotive and heavy-duty brakes, automotive lights, wire and cable, spark plugs, glow plugs, windshield wipers, steering, suspension, driveline and temperature control products and other products for the automotive aftermarket; brake products, lights, spark plugs, glow plugs, ignition coils and windshield wipers	
COOPER TIRE & RUBBER	MISC AUTO PRODUCTS		Rubber processing
DANA CORP	ENGINE SYSTEMS GROUP	Sealing products, engine parts, piston rings, cylinder liners and camshafts and fluid system products	
DANA CORP	VEHICULAR	Drivetrain systems, such as axles, driveshafts, clutches and transmissions; engine parts, such as gaskets and sealing systems, piston rings, and filtration products; structural components, such as vehicular frames, engine cradles and heavy duty side rails; chassis products, such as steering and suspension components; fluid power systems, such as pumps, cylinders, control valves, brass and steel fittings and hoses	
DANA CORP	AUTOMOTIVE SYSTEMS GROUP	Light duty axles and driveshafts, structural products (such as engine cradles and frames), transfer cases, original equipment brakes	
DEFIANCE INC	ENGINE PTS-AUTO RELATED PDS		Precision-machined parts, injection molding

DELPHI AUTOMOTIVE SYS CORP	ELECTRONICS & MOBILE COMM	Audio Systems, communication and information systems, microprocessor-based engine management controllers and anti-lock brake controllers, powertrain and engine control modules, collision warning systems, security systems such as sounders, inclination sensors, glass breakage sensors, remote key actuation products, and safety systems including frontal inside airbag controllers, occupant positioning, adaptive restraints and roll-over sensing	
DELPHI AUTOMOTIVE SYS CORP	SAFETY-THERMAL & ELEC ARCHIT	Driver and passenger airbag modules, side airbag modules and integral steering wheels; integrated door hardware systems including safety and security, HVAC, electronic control and interior trim systems; power products including power sliding doors, power liftgates and power decklids; Fully integrated interior cockpits, including electrical/electronic systems, structure and trim systems, steering systems, thermal systems and entertainment and safety systems	
DELPHI AUTOMOTIVE SYS CORP	DYNAMICS & PROPULSION	Thermal management systems; climate control systems which include HVAC modules, compressors and condensors; HVAC systems and modules including evaporators, lightweight aluminum heater cores, blower motor fans and compressors; powertrain cooling systems, including radiators, fans and hoses; complete front end modules	
DEXTER CORP	AUTOMOTIVE		Plastic coating and specialty materials
DONNELLY CORP	AUTOMOTIVE PRODUCTS	Interior and exterior rear view mirror products, modular window assemblies, interior trim products including dome lights, interior door lights, map lights, courtesy lamps, lighted and non-lighted grab handles, visors and trim components such as overhead consoles interior and exterior handle products	
DOUGLAS & LOMASON CO	AUTOMOTIVE PRODUCTS	Fully trimmed seating, seat frame assemblies and mechanisms soft tops and accessories decorative moldings	
DURA AUTOMOTIVE SYS -CL B	AUTOMOTIVE BRAKES AND PARTS	Automotive cables such as parking brake, shifter, throttle, oil level, hood release, and fuel door; parking brake mechanisms; transmission shifter mechanisms; latches; lighting products; and other engineered mechanical components	
EAGLE-PICHER INDS	AUTOMOTIVE	Transmission pump assemblies, vibration dampening devices sealing and compressor gaskets tubing and hose assemblies turbocharger components	
EATON CORP	VEHICLE COMPONENTS	Sensors, valves, actuators, switches, engine valves, cylinder heads, lifters and rocker assemblies, knock sensors, fuel management systems, brake switches, remote keyless entry, vehicle on-board radar, steering systems, superchargers, traction systems, transmission systems, hoses, fittings, adapters and couplings, tire valves, gauges, cores and caps, spoilers and body side moldings	
EATON CORP	AUTOMOTIVE PARTS	Sensors, valves, actuators, switches, engine valves, cylinder heads, lifters and rocker assemblies, knock sensors, fuel management systems, brake switches, remote keyless entry, vehicle on-board radar, steering systems, superchargers, traction systems, transmission systems, hoses, fittings, adapters and couplings, tire valves, gauges, cores and caps, spoilers and body side moldings	
ECHLIN INC	MOTOR VEHICLE PARTS-SUPPLIES	Brake system parts including master cylinders, brake shoes, drums, disc pads, calipers, hoses and antilock brake systems; Engine system parts including condensers, distributors, ignition coils, rotors, control modules, sensors, actuators, wire and cable products, carburetor and emission control parts, fuel pumps, water pumps, oil pumps, filters, gaskets, heating and air-conditioning coupled hose assemblies, oil coolers, electronic fuel injection systems, PCV valves; and other vehicle parts.	
EDELBROCK CORP	AUTOMOTIVE PARTS MFG	Intake manifolds, carburetors, camshafts, cylinder heads, exhaust systems, shock absorbers	
ELCO INDUSTRIES INC	INDUSTRIAL PRODUCTS		Cold-forming, precision metal stamping and plastic molding
EXCEL INDUSTRIES INC	WINDOW SYSTEMS	Automotive windshields including rear, vent, quarter, push out and sliding windows; and window regulator systems, latches, door frames and related components	

EXCEL INDUSTRIES INC	LIGHT VEHICLE PRODUCTS	Automotive windshields including rear, vent, quarter, push out and sliding windows; and window regulator systems, latches, door frames and related components	
FEDERAL SCREW WORKS	INDUSTRIAL COMPONENT PARTS		Machining, cold forming, hardened and ground metal parts
FEDERAL-MOGUL CORP	VEHICLE-MACHINERY COMPONENTS	Engine bearings, bushings, washers, large bearings, pistons, piston pins, rings, liners and ignition products, dynamic seals, gaskets and wiper blades, camshafts, brake and friction products, sintered products, systems protection products, fuel systems components, lighting products, chassis products, and heat transfer products	
FEDERAL-MOGUL CORP	POWERTRAIN SYSTEMS	Engine bearings, bushings, washers, large bearings, pistons, piston pins, rings, liners and ignition products	
FEDERAL-MOGUL CORP	SEALING SYSTEMS	Dynamic seals, gaskets and wiper blades	
FEDERAL-MOGUL CORP	GENERAL PRODUCTS	Camshafts, brake and friction products, sintered products, systems protection products, fuel systems components, lighting products, chassis products, and heat transfer products	
FOAMEX INTERNATIONAL INC	AUTOMOTIVE TEXTILES		Foam processing
FOAMEX INTERNATIONAL INC	AUTOMOTIVE PRODUCTS		Foam processing
GENCORP INC	AUTOMOTIVE		Extruded and molded rubber products and plastic extrusions
GENERAL MOTORS CL H	AUTO SYSTEMS & COMPONENTS	Powertrain and engine control modules, collision warning systems, security systems, safety systems, advanced controllers, audio systems, communication systems	
GENERAL MOTORS CL H	AUTOMOTIVE PRODUCTS	Powertrain and engine control modules, collision warning systems, security systems, safety systems, advanced controllers, audio systems, communication systems	
GENTEX CORP	AUTOMATIC REARVIEW MIRRORS	Automatic-dimming rearview mirrors	
GENTEX CORP	AUTOMOTIVE PRODUCTS	Automatic-dimming rearview mirrors	
GLAS-AIRE INDS GROUP LTD	AUTO DEFLECTORS-HOOD PROTECT		Acrylic thermoforming
HANDY & HARMAN	AUTOMOTIVE-OEM	Brake and fuel products, including electroplating of electronic connectors, bearings, brushes, cable lashing, hose reinforcements	
HARVARD INDS INC	AUTOMOTIVE ACCESSORIES	Rubber glass-run channels; rubber seals for doors and trunk lids; outside rearview mirrors; complex, high volume aluminum castings and other cast, fabricated, machined and decorated metal products; and metal stamped and roll form products	
HAYES LEMMERZ INTL INC	AUTOMOBILE & TRUCK WHEELS		Aluminum casting
HAYES LEMMERZ INTL INC	AUTOMOTIVE WHEELS		Aluminum casting
HAYES LEMMERZ INTL INC	CASTING PRODUCTS		Aluminum casting
HILITE INDUSTRIES INC	TRANSMISSION COMP&BRK VALVES	Brake valves, power transmission components and specialty components	
HOWELL INDUSTRIES INC	STRUCTURAL AUTOMOTIVE COMP		Metal stamping
IMPCO TECHNOLOGIES INC	ELECTRONIC FUEL INJECTION PD	Electronic fuel injection	
INSILCO HOLDING CO	METAL PARTS	automotive heat exchangers and related tubing, and automatic transmission and suspension components	
INSILCO HOLDING CO	AUTOMOTIVE COMPONENTS	automotive heat exchangers and related tubing, and automatic transmission and suspension components	
INTERMET CORP	DUCTILE & GRAY IRON CASTINGS		Precision ductile iron, gray iron and aluminum cast
INTERMET CORP	FOUNDRY OPERATIONS		Precision ductile iron, gray iron and aluminum cast

ITT INDUSTRIES INC	AUTOMOTIVE	ABS and traction control systems, chassis systems, foundation brake components, fluid handling products and shock absorbers door and window assemblies, wiper module assemblies, seat systems, air management systems, switches and fractional horsepower DC motors	
JASON INC	AUTOMOTIVE TRIM PRODUCTS	Exterior trim products	
JOHNSON CONTROLS INC	AUTOMOTIVE	Seating systems products includuing seats, seating foam pads, mechanisms, metal frames and trim covers; interior systems products including overhead systems, door systems, floor consoles and instrument panels	
JOHNSON CONTROLS INC	AUTOMOTIVE	Seating systems products includuing seats, seating foam pads, mechanisms, metal frames and trim covers; interior systems products including overhead systems, door systems, floor consoles and instrument panels	
JPE INC	MOTOR VEHICLE PARTS		Forming and co-extrusion of steel and PVC and extruded and injection molded plastics
JPE INC	TRIM PRODUCTS		Forming and co-extrusion of steel and PVC and extruded and injection molded plastics
LARIZZA INDUSTRIES INC	AUTOMOTIVE		Injection molding, compression molding, rotocast molding, vacuum forming and polyurethane foaming
LEAR CORP	AUTOMOBILE SEATING SYSTEMS	Complete seating systems, floor and acoustic systems; door panels; headliners; and instrument panels	
LEAR CORP	AUTOMOTIVE INTERIORS	Complete seating systems, floor and acoustic systems; door panels; headliners; and instrument panels	
LYDALL INC	HEAT MANAGEMENT PRODUCTS		Organic or inorganic fiber processing and fiber-and-metal combinations
MARK IV INDUSTRIES INC	MASS TRANSIT & TRAFFIC CNTRL	power transmission, and air-intake and cooling systems, fluid handling products including hose and hose assemblies for power steering, air conditioning, oil cooling; fuel systems including tubes, hose, couplings, fuel fillers, fuel pumps, fittings, valves, canisters, filters	
MARK IV INDUSTRIES INC	AUTOMOTIVE	power transmission, and air-intake and cooling systems, fluid handling products including hose and hose assemblies for power steering, air conditioning, oil cooling; fuel systems including tubes, hose, couplings, fuel fillers, fuel pumps, fittings, valves, canisters, filters	
MASCOTECH INC	TRANSPORTATION		Cold, warm and hot metal forming, powder metalworking, tubular steel fabricating and hydroforming
MASCOTECH INC	SPECIALTY METAL FORMED PRODS		Cold, warm and hot metal forming, powder metalworking, tubular steel fabricating and hydroforming
MASLAND CORP	CARPET & VINYL - AUTOMOTIVE	Seat systems, interior trim products, such as door panels, armrests and headliners, interior component products such as seat frames and seat covers	
MERITOR AUTOMOTIVE INC	AUTOMOTIVE COMPONENTS	Axles, brakes, transmissions, clutches, drivelines, roof systems, door systems, access control systems, seat adjusting systems, suspension products, wheel products	
METHODE ELECTRONICS -CL A	ELECTRONIC COMPONENTS	electrical, electronic and optical sensors, interconnections and controls	
MICHIGAN RIVET CORP	STEEL FASTENERS		Wire drawing, cold extrusion, cold heading
MODINE MFG CO	HEAT TRANSFER PRODUCTS	Radiators and radiator cores, air conditioning systems	

MODINE MFG CO	ORIGINAL EQUIPMENT	Radiators and radiator cores, air conditioning systems	
MODINE MFG CO	EUROPEAN OPERATIONS	Radiators and radiator cores, air conditioning systems	
MORTON INTERNATIONAL INC	INFLATABLE RESTRAINT SYSTEMS	Airbag inflators and modules for use in driver-side and passenger-side airbag passive restraint systems including modules for side impact airbag systems	
NATIONAL-STANDARD CO	WIRE AND RELATED PRODUCTS		Wire production, welding wire, stainless steel spring, and nonwoven metal fiber materials production
NEWCOR INC	PRECISION MACHINED PARTS		Machining large gray iron, nodular iron and steel foundry castings
NEWCOR INC	RUBBER & PLASTIC AUTO PARTS		Dip, cast and injection molding plastics and rubber processing
NOBLE INTERNATIONAL LTD	AUTOMOBILE COMPONENT SUPPLY		Laser welding of tailored blanks, progressive die stamping and injection molding of plastics
NOBLE INTERNATIONAL LTD	METAL PROCESSING		Laser welding of tailored blanks, progressive die stamping
NOBLE INTERNATIONAL LTD	PLASTICS & COATING		Injection molding of plastics
OEA INC	AUTOMOTIVE	Aingle-stage hybrid and electric inflators for passenger, driver, and side-impact airbags	
OPTEK TECHNOLOGY INC	OPTOELECTRONIC COMPONENTS	Optoelectronic and magnetic sensors	
PLYMOUTH RUBBER -CL A	RUBBER AND VINYL PRODUCTS		Rubber and vinyl processing
PPG INDUSTRIES INC	COATINGS & RESINS		Coatings and resins
PPG INDUSTRIES INC	GLASS		Float glass processing and fiber glass continuous-filament processing
REYNOLDS METALS CO	TRANSPORTATION PRODUCTS		Aluminum processing
ROCKWELL INTL CORP	AUTOMOTIVE	Sunroof, door, access control and seat adjusting systems, suspensions, electronic controls, axles, clutches, transmissions, drivelines, brakes, automatic slack adjusters, ABS systems	
SAFETY COMPONENTS INTL INC	AUTOMOTIVE AIRBAGS	Passenger and driver side airbags	
SECOM GENERAL CORP	METAL PARTS FORMING		Cold forming and machining
SIMPSON INDUSTRIES	MACHINED PRODUCTS		Castings and forgings
SMITH (A O) CORP	ORIGINAL EQUIPMENT MFG	Structural and chassis components including truck frames and axles	
SPECIAL DEVICES INC	AUTOMOTIVE PRODUCTS	Airbag inflators	
SPX CORP-OLD	ORIGINAL EQUIPMENT COMPONENT	Steering systems, automatic transmission filters and other filter products, automotive piston rings and cylinder liners	
STANDARD PRODUCTS CO	TRANSPORTATION EQUIPMENT		Rubber processing, injection molding
STANT CORP	AUTOMOTIVE PARTS-TOOLS-ACCES	Windshield wiping systems, closure caps and fuel valves, engine thermostats, hose clamps, and automotive heaters	
STONERIDGE INC	ELECTRONIC COMPONENTS	Wiring systems, power distribution panels, electronic and electrical switches, electronic instrumentation and information display products, actuators and sensors	
STRATTEC SECURITY CORP	AUTOMOTIVE LOCKS & KEYS	Locks and security systems	
SUPERIOR INDUSTRIES INTL	AUTOMOTIVE PARTS-ACCESSORIES		Aluminum casting

TENNECO INC	AUTOMOTIVE PARTS	Automotive exhaust products including mufflers, catalytic converters, tubular exhaust manifolds, pipes, exhaust accessories and electronic noise cancellation products; ride control products including shock absorbers and struts, electronically adjustable suspension systems, vibration control components, bushings, springs	
TEXTRON INC	AUTOMOTIVE	Instrument panels, door and sidewall trim, airbag doors, consoles, trim components, armrests and headliner systems; bumpers and fascia, body side moldings, fender liners, decorative wheel trim, signal lighting, engine camshafts and vibration dampers, seating comfort systems, windshield and headlamp washers	
TOWER AUTOMOTIVE INC	METAL STAMPINGS & ASSEMBLIES		Stamping, roll-forming, and hydroforming
TRW INC	AUTOMOTIVE	Occupant safety systems such as seat belt systems and inflatable restraint systems, steering wheels, manual and power steering gears, engine valves and valve train components, suspension components, electronic monitoring and control systems, electromechanical assemblies, fasteners, stud welding systems and other components	
U S INDUSTRIES INC	AUTOMOTIVE COMPONENTS	Automotive leather, tubular assemblies, dowels, fittings, shafts and air conditioning and fuel manifolds, armrests, assist handles, cupholders, glove box doors and large interior trim panels	
UNITED TECHNOLOGIES CORP	INDL PDS-AUTO & OTHER IND	Wire harnesses, headliners, door trim assemblies, vehicle remote entry systems, fractional horsepower DC electric motors, interior trim (instrument panels, sun visors, armrests, package trays and consoles), mirrors, thermal and acoustical barriers, airbag covers, steering wheels, electronic controls and modules, relays, interior lighting systems, switches, and windshield wiper systems	
VARITY CORP	TRANSPORTATION PRODUCTS	ABS, disc and drum brakes, disc brake rotors, hubs, drums and sensors; fully assembled diesel engines	
WALBRO CORP	AUTOMOTIVE	Fuel pumps, fuel modules, fuel level sensors, plastic fuel tanks, bracket assemblies and plastic fuel rails	

Source: SEC filings and company annual reports.

*) Firm segment exists in 1998 only

The following list repeats company segments in the *AUTO_COMP Segment* data set, listing average net sales and operating margin in the time period 1988-1997. The list represents segments of U.S. registered, public companies, for which sales to the automotive industry represent at least 50-80% (or more) of total segment sales (131 firm segments in total).

Firm Name	Firm Segment	Average Net Sales ($ million) (1988-97)	Average Operating Margin (1988-97)
AEROQUIP-VICKERS INC	AUTOMOTIVE	454	6.6%
AEROQUIP-VICKERS INC	FLUID CONNECTORS	* 1,071	* 11.6%
AETNA INDUSTRIES INC	STAMPING MODULES	210	5.9%
AETNA INDUSTRIES INC	COMPONENTS - EUROPE	* 542	* 3.6%
AETNA INDUSTRIES INC	COMPONENTS - NORTH AMERICA	* 169	* -4.5%
ALLIEDSIGNAL INC	AUTOMOTIVE	4,374	7.5%
ALLIEDSIGNAL INC	TRANSPORTATION PRODUCTS	* 2,441	* 4.3%
AMCAST INDL CORP	ENGINEERED COMPONENTS	152	7.2%
ARVIN INDUSTRIES INC	AUTOMOTIVE ORIGINAL EQUIP	1,012	4.5%
ARVIN INDUSTRIES INC	AUTOMOTIVE	466	3.6%
AUTOCAM CORP	METAL ALLOY COMPONENTS	44	15.0%
AUTOLIV INC	AIRBAGS & SEAT BELTS	1,994	9.3%
BAILEY CORP	AUTO PARTS & COMPONENTS	69	2.7%
BORG WARNER AUTO	AUTOMOBILE COMPONENTS	1,295	8.0%
BORG WARNER AUTO	POWERTRAIN SYSTEMS	* 516	* 5.5%
BORG WARNER AUTO	AUTOMATIC TRANSMISSION SYS	* 392	* 10.2%
BORG WARNER AUTO	CHAIN SYSTEMS	* 511	* 15.4%
BORG WARNER AUTO	AIR-FLUID SYSTEMS	* 344	* 7.3%
BOWLES FLUIDICS CORP	COMPONENT PRODUCTS	12	8.5%
BREED TECHNOLOGIES INC	AIRBAG SYSTEMS	360	18.0%
BRIGGS & STRATTON	LOCKS	71	4.8%
CAPCO AUTOMOTIVE PRODS	MANUAL TRANSMISSIONS	183	5.7%
CHERRY CORP	AUTOMOTIVE MARKET	196	5.7%
CHERRY CORP	AUTOMOTIVE SWITCHES & MODULE	* 159	* 4.2%
CITATION CORP/AL	IRON & STEEL CASTINGS	357	8.5%
CLARCOR INC	ENGINE-MOBILE FILTRATION	208	16.6%
COLLINS & AIKMAN CORP	AUTOMOTIVE PRODUCTS	1,035	10.1%
COLLINS & AIKMAN CORP	N AMERICA AUTO INTERIOR SYS	* 1,065	* 7.0%
COLLINS & AIKMAN CORP	EUROPE AUTO INTERIOR SYS	* 338	* 2.7%
COLLINS & AIKMAN CORP	SPECIALTY AUTO PRODUCTS	* 422	* 3.4%
COLTEC INDUSTRIES	AUTOMOTIVE	453	20.2%
COOPER INDUSTRIES INC	AUTOMOTIVE PRODUCTS	1,376	10.6%
COOPER TIRE & RUBBER	MISC AUTO PRODUCTS	* 432	* 12.0%
DANA CORP	ENGINE SYSTEMS GROUP	* 2,013	* 4.5%
DANA CORP	VEHICULAR	4,717	8.3%
DANA CORP	AUTOMOTIVE SYSTEMS GROUP	* 4,268	* 7.7%
DEFIANCE INC	ENGINE PTS-AUTO RELATED PDS	76	7.4%
DELPHI AUTOMOTIVE SYS CORP	ELECTRONICS & MOBILE COMM	* 4,566	* 4.2%
DELPHI AUTOMOTIVE SYS CORP	SAFETY-THERMAL & ELEC ARCHIT	* 11,059	-* 0.4%
DELPHI AUTOMOTIVE SYS CORP	DYNAMICS & PROPULSION	* 12,854	-* 1.3%
DEXTER CORP	AUTOMOTIVE	50	-3.5%
DONNELLY CORP	AUTOMOTIVE PRODUCTS	306	4.3%
DOUGLAS & LOMASON CO	AUTOMOTIVE PRODUCTS	405	3.1%
DURA AUTOMOTIVE SYS -CL B	AUTOMOTIVE BRAKES AND PARTS	316	7.7%
EAGLE-PICHER INDS	AUTOMOTIVE	351	8.3%
EATON CORP	VEHICLE COMPONENTS	2,475	10.9%
EATON CORP	AUTOMOTIVE PARTS	* 1,943	* 10.3%
ECHLIN INC	MOTOR VEHICLE PARTS-SUPPLIES	2,141	6.8%
EDELBROCK CORP	AUTOMOTIVE PARTS MFG	73	12.0%
ELCO INDUSTRIES INC	INDUSTRIAL PRODUCTS	135	7.6%

EXCEL INDUSTRIES INC	WINDOW SYSTEMS	415	4.4%
EXCEL INDUSTRIES INC	LIGHT VEHICLE PRODUCTS	735	4.2%
FEDERAL SCREW WORKS	INDUSTRIAL COMPONENT PARTS	77	6.0%
FEDERAL-MOGUL CORP	VEHICLE-MACHINERY COMPONENTS	1,451	5.4%
FEDERAL-MOGUL CORP	POWERTRAIN SYSTEMS	* 1,883	* 11.8%
FEDERAL-MOGUL CORP	SEALING SYSTEMS	* 925	* 14.4%
FEDERAL-MOGUL CORP	GENERAL PRODUCTS	* 1,636	* 9.4%
FOAMEX INTERNATIONAL INC	AUTOMOTIVE TEXTILES	237	11.1%
FOAMEX INTERNATIONAL INC	AUTOMOTIVE PRODUCTS	* 285	* 5.9%
GENCORP INC	AUTOMOTIVE	457	4.2%
GENERAL MOTORS CL H	AUTO SYSTEMS & COMPONENTS	5,021	-1.2%
GENERAL MOTORS CL H	AUTOMOTIVE PRODUCTS	4,328	14.0%
GENTEX CORP	AUTOMATIC REARVIEW MIRRORS	41	12.8%
GENTEX CORP	AUTOMOTIVE PRODUCTS	130	24.6%
GLAS-AIRE INDS GROUP LTD	AUTO DEFLECTORS-HOOD PROTECT	5	6.6%
HANDY & HARMAN	AUTOMOTIVE-OEM	138	5.3%
HARVARD INDS INC	AUTOMOTIVE ACCESSORIES	616	3.0%
HAYES LEMMERZ INTL INC	AUTOMOBILE & TRUCK WHEELS	633	10.1%
HAYES LEMMERZ INTL INC	AUTOMOTIVE WHEELS	* 1,269	* 2.9%
HAYES LEMMERZ INTL INC	CASTING PRODUCTS	* 89	* 5.5%
HILITE INDUSTRIES INC	TRANSMISSION COMP&BRK VALVES	51	10.5%
HOWELL INDUSTRIES INC	STRUCTURAL AUTOMOTIVE COMP	54	4.9%
IMPCO TECHNOLOGIES INC	ELECTRONIC FUEL INJECTION PD	39	1.7%
INSILCO HOLDING CO	METAL PARTS	205	9.7%
INSILCO HOLDING CO	AUTOMOTIVE COMPONENTS	* 213	* 10.8%
INTERMET CORP	DUCTILE & GRAY IRON CASTINGS	470	5.6%
INTERMET CORP	FOUNDRY OPERATIONS	* 731	* 5.5%
ITT INDUSTRIES INC	AUTOMOTIVE	3,959	5.7%
JASON INC	AUTOMOTIVE TRIM PRODUCTS	94	10.7%
JOHNSON CONTROLS INC	AUTOMOTIVE	2,331	4.9%
JOHNSON CONTROLS INC	AUTOMOTIVE	8,022	6.0%
JPE INC	MOTOR VEHICLE PARTS	130	6.6%
JPE INC	TRIM PRODUCTS	* 86	-* 9.6%
LARIZZA INDUSTRIES INC	AUTOMOTIVE	129	7.0%
LEAR CORP	AUTOMOBILE SEATING SYSTEMS	3,071	5.4%
LEAR CORP	AUTOMOTIVE INTERIORS	* 9,050	* 5.9%
LYDALL INC	HEAT MANAGEMENT PRODUCTS	* 85	* 9.5%
MARK IV INDUSTRIES INC	MASS TRANSIT & TRAFFIC CNTRL	179	14.0%
MARK IV INDUSTRIES INC	AUTOMOTIVE	1,011	11.0%
MASCOTECH INC	TRANSPORTATION	1,040	10.7%
MASCOTECH INC	SPECIALTY METAL FORMED PRODS	* 760	* 13.9%
MASLAND CORP	CARPET & VINYL - AUTOMOTIVE	427	9.0%
MERITOR AUTOMOTIVE INC	AUTOMOTIVE COMPONENTS	3,193	5.9%
METHODE ELECTRONICS -CL A	ELECTRONIC COMPONENTS	226	11.6%
MICHIGAN RIVET CORP	STEEL FASTENERS	35	1.6%
MODINE MFG CO	HEAT TRANSFER PRODUCTS	705	10.0%
MODINE MFG CO	ORIGINAL EQUIPMENT	* 492	* 14.0%
MODINE MFG CO	EUROPEAN OPERATIONS	* 334	* 10.2%
MORTON INTERNATIONAL INC	INFLATABLE RESTRAINT SYSTEMS	541	9.7%
NATIONAL-STANDARD CO	WIRE AND RELATED PRODUCTS	231	3.1%
NEWCOR INC	PRECISION MACHINED PARTS	39	9.6%
NEWCOR INC	RUBBER & PLASTIC AUTO PARTS	40	5.0%
NOBLE INTERNATIONAL LTD	AUTOMOBILE COMPONENT SUPPLY	11	6.0%
NOBLE INTERNATIONAL LTD	METAL PROCESSING	* 55	* 10.5%
NOBLE INTERNATIONAL LTD	PLASTICS & COATING	* 35	* 0.2%
OEA INC	AUTOMOTIVE	87	27.7%
OPTEK TECHNOLOGY INC	OPTOELECTRONIC COMPONENTS	57	9.2%
PLYMOUTH RUBBER -CL A	RUBBER AND VINYL PRODUCTS	53	6.8%
PPG INDUSTRIES INC	COATINGS & RESINS	2,454	16.1%
PPG INDUSTRIES INC	GLASS	2,401	12.6%
REYNOLDS METALS CO	TRANSPORTATION PRODUCTS	340	4.0%
ROCKWELL INTL CORP	AUTOMOTIVE	2,615	5.7%
SAFETY COMPONENTS INTL INC	AUTOMOTIVE AIRBAGS	64	5.4%
SECOM GENERAL CORP	METAL PARTS FORMING	14	1.2%
SIMPSON INDUSTRIES	MACHINED PRODUCTS	286	7.3%
SMITH (A O) CORP	ORIGINAL EQUIPMENT MFG	829	5.8%

SPECIAL DEVICES INC	AUTOMOTIVE PRODUCTS	45	-13.1%
SPX CORP-OLD	ORIGINAL EQUIPMENT COMPONENT	273	-28.0%
STANDARD PRODUCTS CO	TRANSPORTATION EQUIPMENT	669	6.8%
STANT CORP	AUTOMOTIVE PARTS-TOOLS-ACCES	409	10.2%
STONERIDGE INC	ELECTRONIC COMPONENTS	364	10.0%
STRATTEC SECURITY CORP	AUTOMOTIVE LOCKS & KEYS	136	9.9%
SUPERIOR INDUSTRIES INTL	AUTOMOTIVE PARTS-ACCESSORIES	374	15.0%
TENNECO INC	AUTOMOTIVE PARTS	2,120	11.8%
TEXTRON INC	AUTOMOTIVE	1,357	8.1%
TOWER AUTOMOTIVE INC	METAL STAMPINGS & ASSEMBLIES	422	9.6%
TRW INC	AUTOMOTIVE	4,943	7.0%
U S INDUSTRIES INC	AUTOMOTIVE COMPONENTS	384	9.2%
UNITED TECHNOLOGIES CORP	INDL PDS-AUTO & OTHER IND	2,533	6.3%
VARITY CORP	TRANSPORTATION PRODUCTS	1,120	7.4%
WALBRO CORP	AUTOMOTIVE	323	7.4%

*) Firm segment exists in 1998 only

8.3.2 INDUSTRIAL_COMP Segment

The following list represents company segments that are included in the *INDUSTRIAL_COMP Segment* data set. This list represents segments of U.S. registered, public companies, for which sales to the automotive industry represent at least 20-50% (or more)of total segment sales (62 firm segments plus 131 firm segments of AUTO_COMP).

Firm Name	Firm Segment	Average Net Sales ($ million) (1988-97)	Average Operating Margin (1988-97)
AMP INC	ELECTRICAL-ELECTR CONNECTORS	3,886	15.5%
AMP INC	TERM-CONNECTORS	* 4,200	* 14.6%
APPLIED POWER -CL A	ENGINEERED SOLUTIONS GROUP	177	7.7%
APPLIED POWER -CL A	ENGINEERED SOLUTIONS	192	9.3%
AUGAT INC	ELECTROMECHANICAL COMPONENTS	382	5.4%
CARLISLE COS INC	TRANSPORTATION PRODUCTS	270	6.9%
CARLISLE COS INC	AUTOMOTIVE COMPONENTS	* 272	* 6.5%
CHICAGO RIVET & MACHINE CO	FASTENER	22	10.3%
CHICAGO RIVET & MACHINE CO	FASTENER	* 34	* 20.8%
CLARCOR INC	FILTRATION	150	16.7%
CONTROL DEVICES INC	CIRCUIT BREAKERS	57	15.2%
CONTROL DEVICES INC	ELECTRONIC COMPONENTS	* 31	* 7.4%
CONTROL DEVICES INC	CIRCUIT BREAKERS	* 49	* 16.8%
CTS CORP	ELECTRONIC COMPONENTS	276	6.7%
CTS CORP	ELECTRONIC COMPONENTS	* 248	* 16.9%
DANA CORP	OFF-HIGHWAY SYSTEMS GROUP	* 898	* 5.3%
DANA CORP	INDUSTRIAL GROUP	* 712	* 5.6%
DANA CORP	INDUSTRIAL	1,241	5.3%
DONALDSON CO INC	AIR-SOUND-LIQUID FILTERS	555	9.4%
EATON CORP	HYDRAULICS & OTHER	* 599	* 15.5%
EATON CORP	ELEC & ELECTRONIC CONTROLS	2,445	7.9%
ENGELHARD CORP	ENGINEERED MATR-METALS MGMT	1,672	2.4%
ENGELHARD CORP	ENVIRONMENTAL TECHNOLOGIES	* 559	* 15.0%
ESSEX GROUP INC	WIRE-CABLE & INSULATION PDS	1,087	7.4%
FOAMEX INTERNATIONAL INC	FOAM PRODUCTS	846	7.1%
FURON CO	ENGINEERED COMPONENTS	331	5.2%
GENERAL BEARING CORP	BALL AND ROLLER BEARINGS	41	7.9%
GENERAL BEARING CORP	ORIGINAL EQ MFG MARKET	* 31	* 6.9%
HARMAN INTERNATIONAL INDS	HIGH FIDELITY AUDIO PRODUCTS	867	6.3%
ILLINOIS TOOL WORKS	DOMESTIC ENGINEERED PRODS	* 1,790	* 20.3%

ILLINOIS TOOL WORKS	INTL ENGINEERED PRODUCTS	* 937	* 15.0%
ILLINOIS TOOL WORKS	ENGINEERED COMPONENTS	1,610	13.8%
INTERNATIONAL JENSEN INC	LOUDSPEAKERS & COMPONENTS	201	4.5%
JPE INC	FASTENERS	* 38	* 3.8%
KYSOR INDUSTRIAL CORP	TRANSPORTATION PRODUCTS	132	11.8%
LITTELFUSE INC	CIRCUIT PROTECTION DEVICES	207	14.0%
LOCTITE CORP	ADHESIVES & SEALANTS	582	16.9%
LYDALL INC	FIBER MATERIALS & COMPONENTS	177	12.5%
MEDALIST INDS	FASTENERS	85	7.8%
O'SULLIVAN CORP	MOLDED PLASTICS & RUBBER PDS	194	11.7%
OWENS CORNING	INDUSTRIAL MATERIALS	1,060	17.9%
PARK OHIO HOLDINGS CORP	MANUFACTURED PRODUCTS	* 187	* 6.4%
PARK OHIO HOLDINGS CORP	INDUSTRIAL PRODUCTS	97	2.4%
PARK OHIO HOLDINGS CORP	MANUFACTURED PRODUCTS	209	8.1%
PUROFLOW INC	FLUID FILTERS-WATER PURE PDS	10	1.9%
QUANEX CORP	COLD FINISHED STEEL BARS	138	4.7%
QUANEX CORP	STEEL TUBES	138	9.2%
QUANEX CORP	HOT ROLLED STEEL BARS	213	13.7%
REGAL BELOIT	POWER TRANSMISSION	166	16.2%
SHELDAHL INC	MATERIALS FABRICATION	92	2.6%
SHILOH INDUSTRIES INC	STEEL PROCESSING	199	10.7%
SINTER METALS INC -CL A	PRESSED METAL COMPONENTS	89	13.2%
SPARTON CORP	AUTOMOTIVE & INDUSTRIAL PDS	82	1.3%
SUDBURY INC	INDUSTRIAL PRODUCTS	270	6.4%
TELEFLEX INC	COMMERCIAL PRODUCTS	283	13.7%
THOMAS & BETTS CORP	ELECTRONIC-OEM COMPONENTS	591	11.2%
THOMAS & BETTS CORP	ELECTRONIC-OEM COMPONENTS	* 640	* 10.3%
TIMKEN CO	BEARINGS	1,282	7.5%
TRIPLE S PLASTICS INC	PLASTICS MOLDING	54	7.3%
TUSCARORA INC	CUSTOM MOLDED FOAM PRODUCTS	119	10.1%
UNIROYAL TECHNOLOGY CORP	COATED FABRICS	50	-15.4%
WYNN'S INTERNATIONAL INC	AUTOMOTIVE - INDL COMPONENTS	154	16.1%

*) Firm segment exists in 1998 only

8.3.3 AUTO_COMP

The following list represents companies that are included in the *AUTO_COMP* data set. This list represents U.S. registered, public companies, for which sales to the automotive industry represent at least 50-80% (or more)of total sales (46 firms)

Firm Name	Average Net Sales ($ million) (1988-97)	Average Operating Margin (1988-97)
AETNA INDUSTRIES INC	210	5.9%
ARVIN INDUSTRIES INC	1,861	5.4%
AUTOCAM CORP	44	14.9%
AUTOLIV INC	1,994	9.3%
BAILEY CORP	69	2.7%
BORG WARNER AUTO	1,295	8.0%
BOWLES FLUIDICS CORP	12	8.5%
BREED TECHNOLOGIES INC	360	18.0%
CAPCO AUTOMOTIVE PRODS	183	5.7%
CITATION CORP/AL	357	8.5%
COOPER TIRE & RUBBER	1,221	12.2%
DEFIANCE INC	76	7.4%
DELPHI AUTOMOTIVE SYS CORP	* 28,479	* 1.8%
DONNELLY CORP	321	4.2%
DOUGLAS & LOMASON CO	436	2.4%
DURA AUTOMOTIVE SYS -CL B	316	7.7%

ECHLIN INC	2,141	6.8%
EDELBROCK CORP	73	12.0%
EXCEL INDUSTRIES INC	517	4.5%
FEDERAL SCREW WORKS	77	6.0%
FEDERAL-MOGUL CORP	1,506	4.8%
GENTEX CORP	73	16.2%
GLAS-AIRE INDS GROUP LTD	5	6.6%
HAYES LEMMERZ INTL INC	633	10.1%
HILITE INDUSTRIES INC	51	10.5%
HOWELL INDUSTRIES INC	54	4.9%
IMPCO TECHNOLOGIES INC	39	1.7%
INTERMET CORP	470	5.6%
JPE INC	130	6.6%
LARIZZA INDUSTRIES INC	135	6.2%
LEAR CORP	3,071	5.4%
LYDALL INC	177	12.5%
MASLAND CORP	427	9.0%
MERITOR AUTOMOTIVE INC	3,193	5.9%
METHODE ELECTRONICS -CL A	226	11.6%
MICHIGAN RIVET CORP	35	1.6%
MODINE MFG CO	705	10.0%
NATIONAL-STANDARD CO	249	1.4%
OPTEK TECHNOLOGY INC	57	9.2%
PLYMOUTH RUBBER -CL A	50	4.7%
SIMPSON INDUSTRIES	286	7.3%
STANT CORP	409	10.2%
STONERIDGE INC	364	10.0%
STRATTEC SECURITY CORP	136	9.9%
SUPERIOR INDUSTRIES INTL	374	15.0%
TOWER AUTOMOTIVE INC	422	9.6%

*) Firm segment exists in 1998 only

8.3.4 INDUSTRIAL_COMP

The following list represents companies that are included in the *INDUSTRIAL_COMP* data set. This list represents U.S. registered, public companies, for which sales to the automotive industry represent at least 20-50% of total sales (99 firms plus 46 firms of AUTO_COMP).

Firm Name	**Average Net Sales ($ million) (1988-97)**	**Average Operating Margin (1988-97)**
AMP INC	3,886	15.5%
AUGAT INC	382	5.4%
CARLISLE COS INC	718	7.8%
CHICAGO RIVET & MACHINE CO	22	10.3%
CLARCOR INC	250	13.9%
COLLINS & AIKMAN CORP	1,364	9.1%
COLTEC INDUSTRIES	1,394	16.7%
CONTROL DEVICES INC	57	15.3%
CTS CORP	279	6.4%
DANA CORP	6,200	7.9%
DONALDSON CO INC	555	9.4%
EAGLE-PICHER INDS	710	6.7%
EATON CORP	4,983	8.5%
ELCO INDUSTRIES INC	183	7.1%
ESSEX GROUP INC	1,087	7.4%
FOAMEX INTERNATIONAL INC	982	8.5%
FURON CO	333	6.1%

GENCORP INC	1,803	6.0%
GENERAL BEARING CORP	41	7.9%
HANDY & HARMAN	580	7.8%
HARMAN INTERNATIONAL INDS	827	6.4%
HARVARD INDS INC	700	2.3%
ILLINOIS TOOL WORKS	3,309	13.8%
INTERNATIONAL JENSEN INC	201	4.5%
ITT INDUSTRIES INC	15,898	7.2%
JOHNSON CONTROLS INC	6,354	5.3%
KYSOR INDUSTRIAL CORP	279	6.3%
LITTELFUSE INC	207	14.0%
LOCTITE CORP	582	16.9%
MARK IV INDUSTRIES INC	1,410	10.7%
MASCOTECH INC	1,519	7.5%
MEDALIST INDS	109	5.1%
NEWCOR INC	103	5.2%
NOBLE INTERNATIONAL LTD	15	7.4%
OEA INC	106	23.1%
O'SULLIVAN CORP	211	9.2%
OWENS CORNING	3,272	10.7%
PPG INDUSTRIES INC	6,260	15.0%
PUROFLOW INC	9	2.4%
REGAL BELOIT	236	13.0%
SAFETY COMPONENTS INTL INC	85	7.9%
SECOM GENERAL CORP	25	4.0%
SHELDAHL INC	92	2.6%
SHILOH INDUSTRIES INC	210	10.6%
SINTER METALS INC -CL A	89	13.2%
SPECIAL DEVICES INC	64	8.1%
STANDARD PRODUCTS CO	779	6.1%
SUDBURY INC	314	2.4%
TRIPLE S PLASTICS INC	54	7.3%
TRW INC	8,661	6.9%
TUSCARORA INC	119	10.1%
VARITY CORP	2,768	6.1%
WALBRO CORP	314	6.8%
WYNN'S INTERNATIONAL INC	292	7.3%

8.3.5 OEM

The following list represents automobile manufacturers that are included in the *OEM* data set. This list represents international, public automobile manufacturers registered in the U.S. (9 firms).

Firm Name	**Average Net Sales ($ million) (1988-97)**	**Average Operating Margin (1988-97)**
CHRYSLER CORP	42,600	6.7%
DAIMLERCHRYSLER AG	60,509	-1.4%
FIAT SPA -ADR	43,828	4.2%
FORD MOTOR CO	114,930	11.2%
GENERAL MOTORS CL H	140,486	6.8%
HONDA MOTOR LTD -AM SHARES	35,981	4.3%
NISSAN MOTOR CO LTD -SP ADR	51,319	1.4%
TOYOTA MOTOR CORP -ADR	79,777	4.7%
VOLVO AB SWE -ADR	17,505	2.8%

8.3.6 STEEL_ALU

The following list represents producers of steel and aluminum that are included in the *STEEL_ALU* data set. This list represents North American, public companies registered in the U.S. (26 firms).

Firm Name	Average Net Sales ($ million) (1988-97)	Average Operating Margin (1988-97)
AK STEEL HOLDING CORP	2,123	9.5%
ALCAN ALUMINIUM LTD	8,160	7.9%
ALCOA INC	10,863	10.8%
ALCOA INTERNATIONAL HOLDINGS	2,721	22.8%
ALGOMA STEEL INC	890	4.5%
ALLEGHENY LUDLUM CORP	1,148	10.3%
ALUMAX INC	2,758	5.0%
ARMCO INC	1,927	4.3%
BETHLEHEM STEEL CORP	4,729	2.8%
BLISS & LAUGHLIN IND INC	131	2.0%
CARPENTER TECHNOLOGY	667	12.2%
COLD METAL PRODUCTS INC	240	3.8%
ISPAT INLAND INC	2,288	1.6%
KAISER ALUMINUM & CHEMICAL	2,038	6.1%
KAISER ALUMINUM CORP	2,072	8.7%
KEYSTONE CONS INDUSTRIES INC	322	3.7%
LTV CORP	5,119	1.8%
LUKENS INC	827	6.1%
NATIONAL STEEL CORP -CL B	2,655	2.0%
PHELPS DODGE CORP	3,044	20.5%
REYNOLDS METALS CO	6,127	6.9%
ROUGE INDUSTRIES INC	1,234	4.7%
TIMKEN CO	1,896	7.2%
USX-U S STEEL GROUP	6,088	5.6%
WCI STEEL INC	640	9.4%
WORTHINGTON INDUSTRIES	1,267	9.3%

8.3.7 LIST OF ADDITIONAL COMPANIES

The following large, automotive component manufacturers have not been included in the analysis, because they are either private or registered outside the United States.

Company	Country of Origin
A.G. Simpson	USA
Aetna Industries Inc.	USA
Aisin Seiki	J
American Axle & Mfg	USA
ASC Inc.	USA
BASF	G
Benteler Automotive Corp.	USA
Bertrand Faure	F
Bridgestone	J
BTR Automotive	UK
Budd Co.	G
Calsonic	J
Cambridge Industries Inc.	USA
Continental	G
Denso	J
DuPont Automotive	US
Ecia	F
Freudenberg and NOK Group	USA
GE Automotive	US
GKN	GB
Grede Foundries Inc.	USA
Guardian Industries Corp.	USA
Krupp Hoesch Automotive	G
Magneti Marelli	I
Mannesmann	G
Mayflower	UK

Company	Country of Origin
Michelin	F
Nemak	F
NHK Spring	J
Nippon Steel	J
NSK	J
Ogihara	J
Oxford Automotive	USA
Peregrine Inc.	USA
Pilkington-Libbey-Owens-Ford	UK
Pirelli	F
Plastic Omnium	G
Rieter	CH
Robert Bosch Corp	G
Rockwell Automotive	US
Sachs	G
SAI Automotive	G
Solvay	B
Sumitomo Electric Industries	J
Toyoda Gosei	J
Unisia Jecs	J
Unisor Sacilor	F
Usinor	F
Valeo	F
VDO	G
Yazaki	J
ZF Group	G

8.4 VARIABLE DEFINITIONS

The following variables are used as dependent, independent and control variables in the regression analysis of Chapter 5.

8.4.1 DEPENDENT VARIABLES

Dependent variable	**Abbreviation**	**Definition**	**COMPUSTAT firm-level data type**	**COMPUSTAT segment-level data type**
Return-on-Sales (= operating profit margin)	ROS	Operating Income After Deprec. (MM$) / Sales (Net) (MM$)	d178 / d12	SDATA2 / SDATA5
Return-on-Assets	ROA	Operating Income After Deprec. (MM$) / Total Assets (MM$)	d178 / d6	SDATA2 / SDATA1
Return-on-Invested Capital	ROIC	Income Before Extraordinary Items (MM$) / (Total Common Equity (MM$) + Debt due in One Year (MM$) + Total Long-Term Debt (MM$))	d18 / (d60 + d44 + d9)	n/a
Market-to-Book ratio	MTB	(Market capitalization + Book Value) / Book Value = (Common Shares Outstanding (MM) * Closing Share Price Fiscal Year ($) + Total Assets (MM$) - Total Common Equity (MM$) - Deferred Taxes (Balance Sheet) (MM$)) / Total Assets (MM$)	(d25 * d199 + d6 – d60 – d74) / d6	n/a

8.4.2 INDEPENDENT VARIABLES

Independent variable	**Abbreviation**	**Definition**	**Available at firm-level**	**Available at segment-level**
Product/Process dummy	PROCESS	Dummy for process-based firm (versus product-based firm)	Yes	Yes
Product coherence	PROD_COH	Herfindahl concentration ratio of products, based on product classification scheme at 2nd hierarchy level		Yes
Process coherence	PROC_COH	Herfindahl concentration ratio of processes, based on process classification scheme at 2nd hierarchy level		Yes
Product dispersion	PROD_DISP	Entropy measure of product dispersion based on product classification scheme at 2nd hierarchy level		Yes
Process dispersion	PROC_DISP	Entropy measure of process dispersion based on process classification scheme at 2nd hierarchy level		Yes
Product patent coherence	PATENT_COH	Herfindahl concentration ratio of 10 year patent stock, based on 3-digit US patent classification (for product firms only)	Yes	No

8.4.3 CONTROL VARIABLES

Control variable	Abbreviation	Definition	COMPUSTAT firm-level data type	COMPUSTAT segment-level data type
Sales	SALES	Sales (Net) (MM$)	d12	SDATA1
R&D expense % of Sales	R_D	Research and Development Expense (MM$) / Sales (Net) (MM$)	d46 / d12	SDATA11 / SDATA1
Above average R&D expense	R_D1	Dummy if Research and Development Expense is at least 1% of Sales		
Capital expenditure % of Sales	CAPEX	Capital Expenditures (SCF) (MM$) / Sales (Net) (MM$)	d128 / d12	SDATA4 / SDATA1
Above average capital expenditure	CAPEX5	Dummy if Capital Expenditure is at least 5% of Sales		
Customer concentration ratio	CUSTCONC	Herfindahl concentration ratio of Sales to General Motors, Ford and Chrysler	n/a	Using CSALE3…6 and CNAME3...6
Segment diversification	DIV_SEG	Herfindahl diversification ratio of Sales in industry segments with different 1-digit SIC codes (different 2-digit codes for manufacturing SIC codes 3300-3999)	Using SDATA1 for all segments	n/a
Geographic diversification	DIV_GEO	Herfindahl diversification ratio of Sales in the three Large Existing Markets (North America, Japan/Asia, Europe)	Using GDATA1A...E for all geogr. Segments	n/a
Log	LOG	Natural logarithm		
Autoregressive error specification	AR(1)	Autoregressive error specification, first order component		

8.4.4 OTHER VARIABLES

Variable	Abbreviation	Definition	COMPUSTAT firm-level data type	COMPUSTAT segment-level data type
Asset turnover	ATO	Sales (Net) (MM$) / Assets - Total (MM$)	d12 / d6	SDATA1 / SDATA5
Fixed asset turnover	FIX_ATO	Sales (Net) (MM$) / PPE – Machinery & Equip (Net) (MM$)	d12 / d156	n/a
PP&E(Machinery)/Assets	PPE	PPE – Machinery & Equip (Net) (MM$) / Assets - Total (MM$)	d156 / d6	n/a
PP&E(Net)/Assets	NET_PPE	Property, Plant & Equip - .(Net)(MM$) / Assets - Total (MM$)	d8 / d6	n/a
Acquisition – Sales contribution	ACQ_S	Acquisition - Sales Contribution (MM$) / Sales (Net) (MM$)	d249 / d12	n/a
Acquisition – Income contrib.	ACQ_I	Acquisition - Income Contribution (MM$) / Sales (Net) (MM$)	d248 / d12	n/a
SG&A/Sales	SG_A	Selling, General & Admin. Expenses (MM$) / Sales (Net) (MM$)	d189 / d12	n/a
Gross operating margin	GROSSM	(Sales (Net) (MM$) - Cost of Goods Sold (MM$)) / Sales (Net) (MM$)	(d12 - d41) / d12	n/a
Depreciation and amortization margin	DEPR	Depreciation and Amortization (MM$) / Sales (Net) (MM$)	d14 / d12	SDATA3 / SDATA1
Gross op. Margin + Depreciation and amortization	GROSSM_DEPR	(Sales (Net) (MM$) - Cost of Goods Sold (MM$)) + Depreciation and Amortization (MM$) / Sales (Net) (MM$)	(d12 - d41) / d12 + d14 / d12	n/a

8.5 DESCRIPTIVE STATISTICS

Descriptive statistics of variables in equation (2a):

	ROS	PROCESS	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.083	0.336	6.026	0.533	0.144
Median	0.078	0.000	6.062	1.000	0.072
Maximum	0.315	1.000	9.461	1.000	0.980
Minimum	-0.115	0.000	3.048	0.000	0.000
Std. Dev.	0.056	0.472	1.503	0.499	0.192
Skewness	0.609	0.695	-0.008	-0.133	1.865
Kurtosis	5.340	1.483	2.028	1.018	7.017
Jarque-Bera	207	254	28	123	924
Probability	0.000	0.000	0.000	0.000	0.000
Observations	712	1441	712	737	738
Cross sections	128	131	128	123	128
Data set	AUTO_COMP Segment	AUTO_COMP Segment	AUTO_COMP Segment	AUTO_COMP Segment	AUTO_COMP Segment
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (2b):

	ROS	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.087	6.402	0.495	0.109
Median	0.080	6.413	0.000	0.025
Maximum	0.315	9.461	1.000	0.962
Minimum	-0.099	3.048	0.000	0.000
Std. Dev.	0.056	1.468	0.500	0.170
Skewness	1.019	-0.255	0.021	2.417
Kurtosis	5.727	2.196	1.000	10.281
Jarque-Bera	224	18	80	1515
Probability	0.000	0.000	0.000	0.000
Observations	464	464	479	476
Cross sections	87	87	83	85
Data set	AUTO_COMP Product-based segments	AUTO_COMP Product-based segments	AUTO_COMP Product-based segments	AUTO_COMP Product-based segments
Sample	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (2c):

	ROS	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.076	5.323	0.605	0.208
Median	0.076	5.256	1.000	0.149
Maximum	0.204	8.149	1.000	0.980
Minimum	-0.115	3.147	0.000	0.000
Std. Dev.	0.054	1.304	0.490	0.212
Skewness	-0.301	0.321	-0.428	1.294
Kurtosis	3.768	2.147	1.183	4.762
Jarque-Bera	10	12	43	107
Probability	0.007	0.003	0.000	0.000
Observations	248	248	258	262
Cross sections	41	41	40	43
Data set	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments
Sample	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (3a):

	ROA	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.129	6.026	0.533	0.144
Median	0.112	6.062	1.000	0.072
Maximum	0.882	9.461	1.000	0.980
Minimum	-0.561	3.048	0.000	0.000
Std. Dev.	0.112	1.503	0.499	0.192
Skewness	2.035	-0.008	-0.133	1.865
Kurtosis	15.220	2.028	1.018	7.017
Jarque-Bera	4873	28	123	924
Probability	0.000	0.000	0.000	0.000
Observations	705	712	737	738
Cross sections	123	128	123	128
Data set	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments
Sample	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (3b):

	ROA	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.141	6.402	0.495	0.109
Median	0.115	6.413	0.000	0.025
Maximum	0.882	9.461	1.000	0.962
Minimum	-0.121	3.048	0.000	0.000
Std. Dev.	0.121	1.468	0.500	0.170
Skewness	2.601	-0.255	0.021	2.417
Kurtosis	13.085	2.196	1.000	10.281
Jarque-Bera	2468	18	80	1515
Probability	0.000	0.000	0.000	0.000
Observations	460	464	479	476
Cross sections	85	87	83	85
Data set	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments
Sample	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (3c):

	ROA	LOG(SALES)	CAPEX5	CUSTCONC
Mean	0.107	5.323	0.605	0.208
Median	0.104	5.256	1.000	0.149
Maximum	0.330	8.149	1.000	0.980
Minimum	-0.561	3.147	0.000	0.000
Std. Dev.	0.086	1.304	0.490	0.212
Skewness	-1.648	0.321	-0.428	1.294
Kurtosis	16.550	2.147	1.183	4.762
Jarque-Bera	1985	12	43	107
Probability	0.000	0.003	0.000	0.000
Observations	245	248	258	262
Cross sections	38	41	40	43
Data set	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments	AUTO_COMP Process-based segments
Sample	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (4a):

	MTB	PROCESS	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	1.556	0.435	5.852	0.495	0.024	0.236
Median	1.306	0.000	5.768	0.000	0.000	0.000
Maximum	10.455	1.000	10.257	1.000	0.406	1.000
Minimum	0.680	0.000	3.933	0.000	0.000	0.000
Std. Dev.	0.950	0.496	1.226	0.501	0.076	0.292
Skewness	4.584	0.263	0.368	0.022	3.265	0.765
Kurtosis	34.852	1.069	2.591	1.000	12.734	2.102
Jarque-Bera	11993	84	9	61	2112	48
Probability	0.000	0.000	0.010	0.000	0.000	0.000
Observations	262	506	311	368	369	369
Cross sections	40	46	43	46	46	46
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (4b):

	MTB	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	1.650	6.242	0.430	0.035	0.313
Median	1.330	6.143	0.000	0.000	0.301
Maximum	10.455	10.257	1.000	0.406	1.000
Minimum	0.791	3.943	0.000	0.000	0.000
Std. Dev.	1.195	1.291	0.496	0.090	0.311
Skewness	4.323	0.077	0.283	2.567	0.378
Kurtosis	27.150	2.464	1.080	8.334	1.699
Jarque-Bera	3454	2	32	441	18
Probability	0.000	0.337	0.000	0.000	0.000
Observations	126	168	193	193	193
Cross sections	23	25	26	26	26
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (4c):

	MTB	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	1.469	5.394	0.566	0.013	0.152
Median	1.297	5.362	1.000	0.000	0.000
Maximum	4.534	7.537	1.000	0.372	0.803
Minimum	0.680	3.933	0.000	0.000	0.000
Std. Dev.	0.638	0.964	0.497	0.056	0.243
Skewness	1.997	0.331	-0.265	4.793	1.258
Kurtosis	8.411	2.263	1.070	26.340	3.008
Jarque-Bera	256	6	29	4669	46
Probability	0.000	0.054	0.000	0.000	0.000
Observations	136	143	175	176	176
Cross sections	17	18	20	20	20
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (5a):

	ROIC	PROCESS	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	0.079	5.422	0.495	0.024	0.764	0.236
Median	0.080	5.450	0.000	0.000	1.000	0.000
Maximum	0.737	10.257	1.000	0.406	1.000	1.000
Minimum	-0.832	1.433	0.000	0.000	0.000	0.000
Std. Dev.	0.137	1.515	0.501	0.076	0.292	0.292
Skewness	-1.307	-0.025	0.022	3.265	-0.765	0.765
Kurtosis	15.538	2.689	1.000	12.734	2.102	2.102
Jarque-Bera	1961	2	61	2112	48	48
Probability	0.000	0.465	0.000	0.000	0.000	0.000
Observations	287	371	368	369	369	369
Cross sections	41	46	46	46	46	46
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (5b):

	ROIC	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	1.650	6.242	0.430	0.035	0.313
Median	1.330	6.143	0.000	0.000	0.301
Maximum	10.455	10.257	1.000	0.406	1.000
Minimum	0.791	3.943	0.000	0.000	0.000
Std. Dev.	1.195	1.291	0.496	0.090	0.311
Skewness	4.323	0.077	0.283	2.567	0.378
Kurtosis	27.150	2.464	1.080	8.334	1.699
Jarque-Bera	3454	2	32	441	18
Probability	0.000	0.337	0.000	0.000	0.000
Observations	126	168	193	193	193
Cross sections	23	25	26	26	26
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

Descriptive statistics of variables in equation (5c):

	ROIC	LOG(SALES)	CAPEX5	DIV_SEG	DIV_GEO
Mean	1.469	5.394	0.566	0.013	0.152
Median	1.297	5.362	1.000	0.000	0.000
Maximum	4.534	7.537	1.000	0.372	0.803
Minimum	0.680	3.933	0.000	0.000	0.000
Std. Dev.	0.638	0.964	0.497	0.056	0.243
Skewness	1.997	0.331	-0.265	4.793	1.258
Kurtosis	8.411	2.263	1.070	26.340	3.008
Jarque-Bera	256	6	29	4669	46
Probability	0.000	0.054	0.000	0.000	0.000
Observations	136	143	175	176	176
Cross sections	17	18	20	20	20
Data set	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP	AUTO_COMP
Sample	1988:1997	1988:1997	1988:1997	1988:1997	1988:1997

8.6 CORRELATION COEFFICIENTS

Correlation coefficients of variables in equation (2a):

	ROS	PROCESS	LOG(SALES	CAPEX5	CUSTCONC
ROS	1.000				
PROCESS	-0.086	1.000			
LOG(SALES)	0.028	-0.339	1.000		
CAPEX5	0.143	0.104	-0.171	1.000	
CUSTCONC	-0.101	0.270	-0.172	0.008	1.000

Observations	712
Data set	AUTO_COMP Segment (pooled)
Sample	1988:1998

Correlation coefficients of variables in equation (3a):

	ROS	PROCESS	LOG(SALES	CAPEX5	CUSTCONC
ROS	1.000				
PROCESS	-0.146	1.000			
LOG(SALES)	0.037	-0.339	1.000		
CAPEX5	-0.038	0.117	-0.030	1.000	
CUSTCONC	-0.081	0.270	-0.171	0.051	1.000

Observations	712
Data set	AUTO_COMP Segment (pooled)
Sample	1988:1998

Correlation coefficients of variables in equation (4a):

	MTB	PROCESS	LOG(SALES	CAPEX5	DIV_SEG	DIV_GEO
MTB	1.000					
PROCESS	-0.169	1.000				
LOG(SALES)	-0.127	-0.368	1.000			
CAPEX5	0.104	0.140	-0.080	1.000		
DIV_SEG	-0.120	-0.280	0.516	-0.155	1.000	
DIV_GEO	-0.123	-0.335	0.614	0.012	0.283	1.000

Observations 990
Data set AUTO_COMP (pooled)
Sample 1988:1998

Correlation coefficients of variables in equation (5a):

	ROIC	PROCESS	LOG(SALES	CAPEX5	DIV_SEG	DIV_GEO
ROIC	1.000					
PROCESS	-0.061	1.000				
LOG(SALES)	0.047	-0.349	1.000			
CAPEX5	0.063	0.145	-0.094	1.000		
DIV_SEG	0.028	-0.279	0.532	-0.164	1.000	
DIV_GEO	0.023	-0.313	0.584	0.031	0.294	1.000

Observations 990
Data set AUTO_COMP (pooled)
Sample 1988:1998

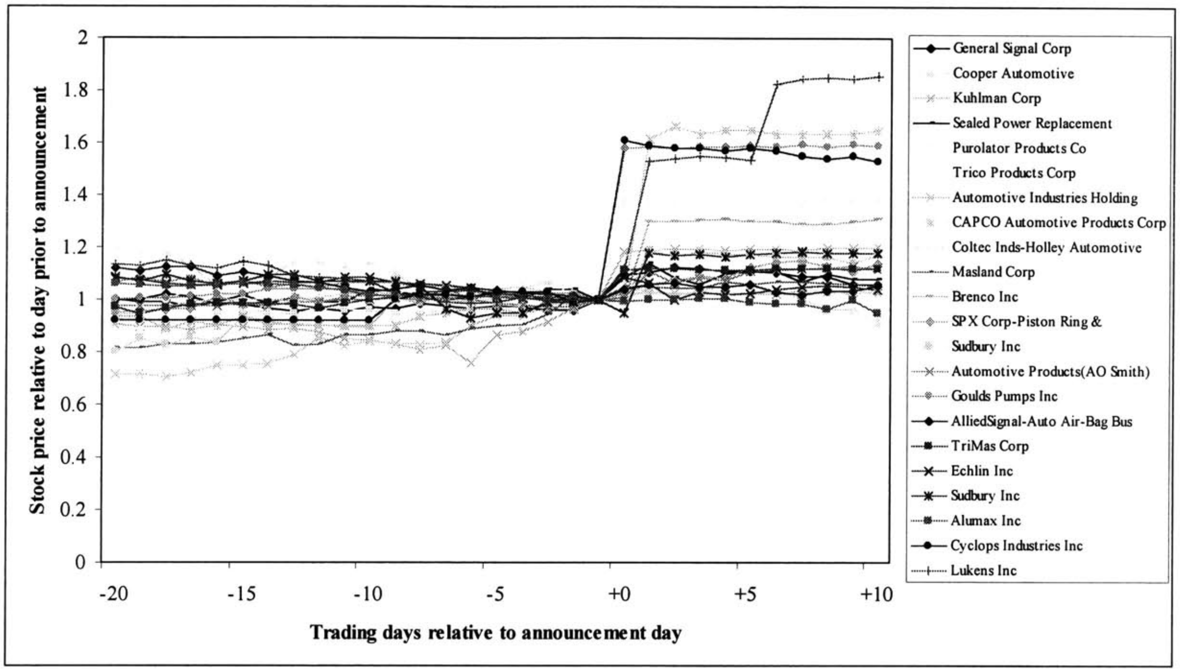
8.7 ACQUISITION EVENT STUDY

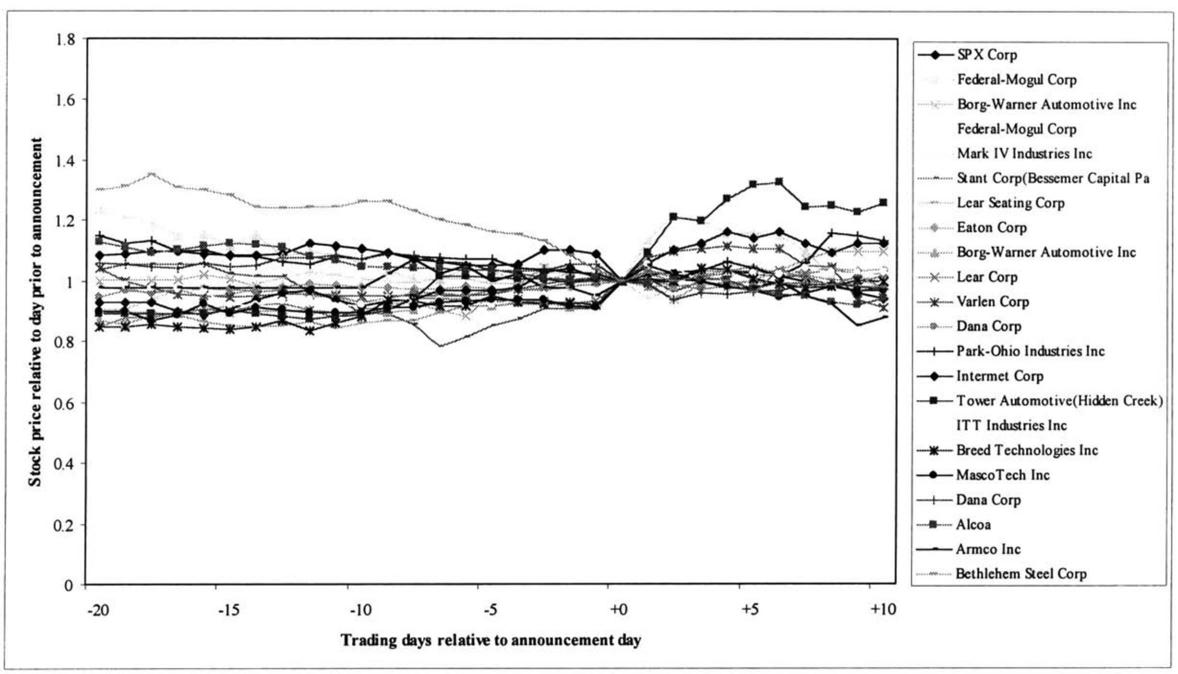
8.7.1 TRANSACTION SUMMARY

No.	Acquisition of Product or Process (New or Existing)	Date Announced	Target Name	Acquiror Name	Value of Transaction ($m)
A	EX PROC	16-Jan-91	Cyclops Industries Inc	Armco Inc	$ 156
B	EX PROC	12-Dec-97	Lukens Inc	Bethlehem Steel Corp	$ 700
C	EX PROC	03-Jun-98	Alumax Inc	Alcoa	$ 3,944
D	EX PROD	16-Sep-93	Sealed Power Replacement	Federal-Mogul Corp	$ 150
E	EX PROD	17-Jul-95	Automotive Industries Holding	Lear Seating Corp	$ 613
F	EX PROD	13-Mar-96	CAPCO Automotive Products Corp	Eaton Corp	$ 129
G	EX PROD	26-Apr-96	Coltec Inds-Holley Automotive	Borg-Warner Automotive Inc	$ 283
H	EX PROD	24-May-96	Masland Corp	Lear Corp	$ 414
I	EX PROD	21-Apr-97	Goulds Pumps Inc	ITT Industries Inc	$ 922
J	EX PROD	02-Sep-97	AlliedSignal-Auto Air-Bag Bus	Breed Technologies Inc	$ 710
K	NEW PROC	03-Sep-96	Sudbury Inc	Park-Ohio Industries Inc	$ 127
L	NEW PROC	18-Nov-96	Sudbury Inc	Intermet Corp	$ 155
M	NEW PROC	24-Jan-97	Automotive Products(AO Smith)	Tower Automotive	$ 725
N	NEW PROC	11-Dec-97	TriMas Corp	MascoTech Inc	$ 912
O	NEW PROD	03-Oct-94	Purolator Products Co	Mark IV Industries Inc	$ 264
P	NEW PROD	08-Nov-94	Trico Products Corp	Stant Corp	$ 160
Q	NEW PROD	14-Jun-96	Brenco Inc	Varlen Corp	$ 161
R	NEW PROD	29-Aug-96	SPX Corp-Piston Ring	Dana Corp	$ 232
S	NEW PROD	04-May-98	Echlin Inc	Dana Corp	$ 4,125
T	NEW PROD	20-Jul-98	General Signal Corp	SPX Corp	$ 2,319
U	NEW PROD	17-Aug-98	Cooper Automotive	Federal-Mogul Corp	$ 1,900
V	NEW PROD	18-Dec-98	Kuhlman Corp	Borg-Warner Automotive Inc	$ 790

No.	Acquisition of Product or Process (New or Existing)	Target value change / Transaction value	Acquiror value change / Transaction value	Total value change / Transaction value
A	EX PROC	34%	21%	55%
B	EX PROC	18%	-8%	10%
C	EX PROC	0%	-3%	-2%
D	EX PROD	15%	24%	39%
E	EX PROD	4%	21%	25%
F	EX PROD	42%	68%	110%
G	EX PROD	6%	23%	29%
H	EX PROD	2%	55%	57%
I	EX PROD	30%	34%	64%
J	EX PROD	154%	7%	161%
K	NEW PROC	18%	-3%	15%
L	NEW PROC	14%	4%	18%
M	NEW PROC	3%	7%	10%
N	NEW PROC	16%	8%	23%
O	NEW PROD	29%	-30%	-1%
P	NEW PROD	19%	14%	33%
Q	NEW PROD	21%	6%	27%
R	NEW PROD	11%	11%	22%
S	NEW PROD	5%	-9%	-4%
T	NEW PROD	10%	-3%	8%
U	NEW PROD	0%	16%	16%
V	NEW PROD	15%	-8%	7%

8.7.2 STOCK PRICE MOVEMENTS





REFERENCES

Abernathy, William J, and James M Utterback. 1978. Patterns of Industrial Innovation. *Technology Review* 80 (7):40-47.

Altmann, O. 1991. *Plastics in automotive engineering*. Düsseldorf: Association of German Engineers (VDI).

Altshuler, Alan A. et al. 1984. *The Future of the automobile*. Cambridge, Mass.: MIT Press.

Andrews, Kenneth Richmond. 1971. *The concept of corporate strategy*. Homewood, Ill.,: Dow Jones-Irwin.

Athey, Susan, and Scott Stern. 1998. *An empirical framework for testing theories about complementarity in organizational design*. Cambridge, Mass.: National Bureau of Economic Research.

Autocam. *Autocam: Capabilities* http://www.autocam.com/capabilities/index.html, 2000 [cited 24 April, 2000 .

Autoliv. *Autoliv - Products* http://www.autoliv.com/appl_alv/Autoliv.nsf/pages/products, 2000a [cited 24 April, 2000 .

Autoliv. *Components to a driver airbag* http://www.autoliv.com/appl_alv/library.nsf/Files/ratt06/$file/ratt06.jpg, 2000b [cited 24 April, 2000 .

Automotive News. 1999. Automotive news, Market data book. Detroit, Mich.: Crain Automotive Group Inc.

Baldwin, Carliss Y, and Kim B Clark. 1997. Managing in an age of modularity. *Harvard Business Review* 75 (5):84-93.

Barney, Jay. 1991. Firm Resources and Sustained Competitive Advantage. *Journal of Management* 17 (1):99-120.

Barton, David C. 1996. *Advances in automotive braking technology: design analysis and materials development*. London: Mechanical Engineering Pub. Ltd.

Berger, Philip G, and Eli Ofek. 1995. Diversification's effect on firm value. *Journal of Financial Economics* 37 (1):39-65.

Berger, Philip G, and Eli Ofek. 1996. Bustup takeover of value-destroying diversified firms. *Journal of Finance* 51 (4):1175-1200.

Berle, Adolf Augustus, and Gardiner Coit Means. 1932. *The modern corporation and private property*. New York: Harcourt Brace & World.

Berry, Charles Harris. 1975. *Corporate growth and diversification*. Princeton, N.J.: Princeton University Press.

Bodie, Zvi, Alex Kane, and Alan J. Marcus. 1996. *Investments*. Chicago: Irwin.

Bolton, Patrick, David S. Scharfstein, and Patrick Scharfstein David S. Bolton. 1998. Corporate Finance, the Theory of the Firm, and Organizations. *Journal of Economic Perspectives* 12 (4):p 95-114.

Chandler, Alfred Dupont. 1962. *Strategy and structure: chapters in the history of the industrial enterpise*. Cambridge, Mass.: MIT Press.

Chatterjee, Sayan, and Birger Wernerfelt. 1991. The Link Between Resources and Type of Diversification: Theory and Evidence. *Strategic Management Journal* 12 (1):33-48.

Clark, Kim B., and Takahiro Fujimoto. 1991. *Product development performance: strategy, organization, and management in the world auto industry*. Boston, Mass.: Harvard Business School Press.

Coase, R. H. 1937. The Nature of the Firm. *Economica* 4:386-406.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2000. Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firm patent (or not). *NBER Working Paper* 7552.

Collis, David J. 1996. Related corporate portfolios. In *Managing the multibusiness company: strategic issues for diversified groups*, edited by M. Goold and K. S. Luchs. London: Routledge.

Collis, David J., and Cynthia A. Montgomery. 1997. *Corporate strategy: resources and the scope of the firm*. Chicago: Irwin.

Comment, Robert, and Gregg A. Jarrell. 1995. Corporate Focus and Stock Returns. *Journal of Financial Economics* 37 (1):p 67-87.

Copeland, Thomas E., Tim Koller, and Jack Murrin. 1994. *Valuation: measuring and managing the value of companies*. New York: Wiley.

Cusumano, Michael A. 1985. *The Japanese automobile industry: technology and management at Nissan and Toyota*. Cambridge, Mass.: Harvard University Press.

Cusumano, Michael A., and Kentaro Nobeoka. 1998. *Thinking beyond lean: how multi-project management is transforming product development at Toyota and other companies*. New York: Free Press.

Cusumano, Michael A., and Akira Takeishi. 1995. *What we have learned and have yet to learn from manufacturer-supplier relations in the auto industry*. Cambridge, MA: International Motor Vehicle Program, MIT.

Delios, Andrew, and Paul W Beamish. 1999. Geographic scope, product diversification, and the corporate performance of Japanese firms. *Strategic Management Journal* 20 (8):711-727.

Delphi Automotive Systems Corporation. 1999. SEC Filing: Amendment No. 4 to form S-1, filed with the SEC on January 27, 1999.

Dierickx, Ingemar, Karel Cool, and Jay B Barney. 1989. Asset Stock Accumulation and Sustainability of Competitive Advantage. *Management Science* 35 (12):1504-1514.

Dyer, Jeffrey H. 1994. Dedicated assets: Japan's manufacturing edge. *Harvard Business Review* 72 (6):174-178.

Dyer, Jeffrey H., Dong Sung Cho, and Wujin Chu. 1998. Strategic supplier segmentation: The next "best practice" in supply chain management. *California Management Review* 40 (2):57-77.

Dyer, Jeffrey H., and William G. Ouchi. 1993. Japanese-style partnerships: Giving companies a competitive edge. *Sloan Management Review* 35 (1):51-63.

Ealey, Lance, Dave Robertson, and Jeff Sinclair. 1996. Beyond suppliers tiers: Facing the platforming challenge. *International Motor Business*.

Fama, Eugene F. 1970. Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance* 25 (2):p 383-417.

Fama, Eugene F. 1991. Efficient Capital Markets: II. *Journal of Finance* 46 (5):p 1575-617.

Fenton, John. 1998. *Handbook of automotive body construction and design analysis*. London: Professional Engineering.

Fine, Charles H., and Daniel E. Whitney. 1996. *Is the make-buy decision process a core competence?* Cambridge, Mass.: International Center for Research on the Management of Technology, MIT.

Fisher, Franklin M, and John J McGowan. 1983. On the Misuse of Accounting Rates of Return to Infer Monopoly Profits. *American Economic Review* 73 (1):82-97.

Fujimoto, Takahiro. 1999. *The evolution of a manufacturing system at Toyota*. New York: Oxford University Press.

Gibbons, Robert. 1998. Firms (and Other Relationships). In *Firm Futures*, edited by P. DiMaggio. Princeton: Princeton University Press.

Gollop, Frank M, and James L Monahan. 1991. A Generalized Index of Diversification: Trends in U.S. Manufacturing. *Review of Economics & Statistics* 73 (2):318-330.

Grossman, Sanford J, and Oliver D Hart. 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy* 94 (4):691-719.

Haldenwanger, H. G., and L. Vollrath. 1994. *Plastics in automotive engineering: materials, components, systems*. Munich: Hanser Publishers.

Hammer, Michael, and James Champy. 1994. *Reengineering the corporation*. New York: HarperBusiness.

Hammer, Michael, and Steven Stanton. 1999. How process enterprises really work. *Harvard Business Review* 77 (6):108-118.

Hart, Oliver, and John Moore. 1990. Property Rights and the Nature of the Firm. *Journal of Political Economy* 98 (6):p 1119-58.

Hayes, Robert H, and Gary P Pisano. 1996. Manufacturing Strategy: At the Intersection of Two Paradigm Shifts. *Production and Operations Management* 5 (1):25-41.

Hayes, Robert H, Gary P Pisano, and David M Upton. 1996. *Strategic operations: competing through capabilities*. New York: Free Press.

Hayes, Robert H, and Steven C Wheelwright. 1979a. Link Manufacturing Process and Product Life Cycles. *Harvard Business Review* 57 (1):133-140.

Hayes, Robert H, Steven C Wheelwright, and Kim B Clark. 1988. *Dynamic manufacturing: creating the learning organization*. New York: Free Press.

Hayes, Robert H, and Steven G Wheelwright. 1979b. The Dynamics of Process-Product Life Cycles. *Harvard Business Review* 57 (2):127-136.

Helfat, Constance E. 1997. Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strategic Management Journal* 18 (5):339-360.

Helper, Susan. 1997. *Supplier relations and adoption of new technology: results of survey research in the U.S. auto industry*. Cambridge, Mass.: International Motor Vehicle Program, MIT.

Helper, Susan, and Mari Sako. 1995. *Supplier relations in Japan and the United States: are they converging?* Cambridge, Mass.: International Motor Vehicle Program, MIT.

Heywood, John B. 1988. *Internal combustion engine fundamentals*. New York: McGraw-Hill.

Holmstrom, Bengt, and John Roberts. 1998. The Boundaries of the Firm Revisited. *Journal of Economic Perspectives* 12 (4):p 73-94.

Ichniowski, Casey, Kathryn Shaw, Giovanna Prennushi, and Casey Shaw Kathryn Prennushi Giovanna Ichniowski. 1995. The Effects of Human Resource Management Practices on Productivity. *NBER Working Paper* 5333.

Irani, Shahrukh A. 1999. *Handbook of cellular manufacturing systems*. New York: Wiley.

Jensen, Michael C. 1986. Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers. *American Economic Review* 76 (2):p 323-29.

Jensen, Michael C., and William H. Meckling. 1976. Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics* 3 (4):p 305-60.

Kalpakjian, Serope. 1995. *Manufacturing engineering and technology*. Reading, Mass.: Addison-Wesley.

Kalpakjian, Serope. 1997. *Manufacturing processes for engineering materials*. Menlo Park, Calif.: Addison-Wesley.

Kaplan, Robert S., and Robin Cooper. 1998. *Cost & effect: using integrated cost systems to drive profitability and performance.* Boston: Harvard Business School Press.

Kaplan, Steven N, and Richard S Ruback. 1995. The valuation of cash flow forecasts: An empirical analysis. *Journal of Finance* 50 (4):1059-1093.

Kaplan, Steven N, and Michael S Weisbach. 1992. The Success of Acquisitions: Evidence from Divestitures. *Journal of Finance* 47 (1):107-138.

Kilpatrick, Auston Marmaduke. 1997. Lean manufacturing principles: a comprehensive framework for improving production efficiency.

Klein, Benjamin. 1988. Vertical Integration as Organizational Ownership: The Fisher Body-General Motors Relationship Revisited. *Journal of Law Economics & Organization* 4 (1):p 199-213.

Klein, Benjamin, Robert Crawford, and Alchian Armen. 1978. Vertical Integration, Appropriable Rents, and the Competitive Contracting Process. *Journal of Law & Economics* 21:297-326.

Krafcik, J.F., and J.P. Macduffie. 1989. *Explaining High Performance Manufacturing: The International Assembly Plant Study.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

Lamming, Richard. 1989. *The causes and effects of structural changes in the European automotive components industry.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

Lang, Larry H P, and Rene M Stulz. 1994. Tobin's q, corporate diversification, and firm performance. *Journal of Political Economy* 102 (6):1248-1280.

Lang, Larry H P, Rene M Stulz, and Ralph A Walkling. 1989. Managerial Performance, Tobin's Q, and the Gains from Successful Tender Offers. *Journal of Financial Economics* 24 (1):137-154.

Lechner, G., Harald Naunheimer, and Joachim Ryborz. 1999. *Automotive transmissions: fundamentals, selection, design and application.* Berlin ; New York: Springer.

Leonard-Barton, Dorothy. 1992. Core Capabilities and Core Rigidities: A paradox in managing new product development. *Strategic Management Journal* 13:111-125.

Levin, Doron P. 1995. *Behind the wheel at Chrysler: the Iacocca legacy.* New York: Harcourt Brace.

Lewellen, Wilbur G. 1971. A Pure Financial Rationale for the Conglomerate Merger. *Journal of Finance* 26 (2):p 521-37.

Liker, Jeffrey K, Rajan R Kamath, S Nazli Wasti, and Mitsuo Nagamachi. 1996. Supplier involvement in automotive component design: Are there really large US Japan differences? *Research Policy* 25 (1):59-89.

Lindenberg, Eric B, and Stephen A Ross. 1981. Tobin's q Ratio and Industrial Organization. *Journal of Business* 54 (1):1-32.

Lynch, Teresa M. 1998. *Leaving home: three decades of internationalization by American automobile firms.* Cambridge, Mass.: Industrial Performance Center, MIT.

Lynch, Teresa M. 1999. *Globalization in the motor vehicle industry: final conference summary.* Cambridge, Mass.: Industrial Performance Center, MIT.

MacDuffie, John Paul. 1991. Beyond mass production--flexible production systems and manufacturing performance in the world auto industry. Doctoral dissertation, Sloan School of Management, MIT, Cambridge, Mass.

MacDuffie, John Paul, and Susan Helper. 1997. *Creating lean suppliers: diffusing lean production through the supply chain.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

MacDuffie, John Paul, and Frits K. Pil. 1999. *Performance findings of the International Assembly Plant Study.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

MacDuffie, John Paul, Kannan Sethuraman, and Marshall L Fisher. 1996. Product variety and manufacturing performance: Evidence from the International Automotive Assembly Plant Study. *Management Science* 42 (3):350-369.

Markides, Constantinos C, and Peter J Williamson. 1994. Related diversification, core competences and corporate performance. *Strategic Management Journal* 15 (Special Issue):149-165.

Maxwell, James. 1994. *Plastics in the automotive industry*. Warrendale, PA: Society of Automotive Engineers.

McGahan, Anita M, and Michael E Porter. 1997. How much does industry matter, really? *Strategic Management Journal* 18:15-30.

Meckling, William H, and Michael C Jensen. 1986. Divisional Performance Measurement. *Working Paper*.

Milgrom, Paul, and John Roberts. 1990. The Economics of Modern Manufacturing: Technology, Strategy, and Organization. *American Economic Review* 80 (3):p 511-28.

Milgrom, Paul, and John Roberts. 1995. Complementarities and Fit: Strategy, Structure, and Organizational Change in Manufacturing. *Journal of Accounting & Economics* 19 (2-3):p 179-208.

Monteverde, Kirk, and David J Teece. 1982. Supplier Switching Costs and Vertical Integration in the Automobile Industry. *The Bell Journal of Economics* 13 (1):206-213.

Montgomery, Cynthia A. 1985. Product-Market Diversification and Market Power. *Academy of Management Journal* 28 (4):789-798.

Montgomery, Cynthia A, and Birger Wernerfelt. 1988. Diversification, Ricardian Rents, and Tobin's q. *Rand Journal of Economics* 19 (4):623-632.

Mowery, David C, Joanne E Oxley, and Brian S Silverman. 1998. Technological overlap and interfirm cooperation: implications for the resource-based view of the firm. *Research Policy* 27 (5):507-523.

Nelson, Richard R., and Sidney G. Winter. 1982. *An evolutionary theory of economic change*. Cambridge, Mass.: Harvard University Press.

Nishiguchi, Toshihiro, and Masayoshi Ikeda. 1996. Suppliers' Process Innovation: Understated Aspects of Japanese Industrial Sourcing. In *Managing Product Development*, edited by T. Nishiguchi. New York: Oxford University Press.

Odaka, Konosuke. 1983. *The Motor vehicle industry in Asia: a study of ancillary firm development*. Singapore: Singapore University Press.

Ostermann, Friedrich, and Roy Woodward. 1993. *Aluminium materials technology for automobile construction*. London: Mechanical Engineering Publications.

Palepu, Krishna. 1985. Diversification Strategy, Profit Performance and the Entropy Measure. *Strategic Management Journal* 6 (3):239-255.

Palepu, Krishna G., Paul M. Healy, and Victor L. Bernard. 2000. *Business analysis & valuation: using financial statements*. Australia: South-Western College Pub.

Palich, Leslie E., Laura B. Cardinal, and C. Chet Miller. 2000. Curvilinearity in the diversification-performance linkage: An examination of over three decades of research. *Strategic Management Journal* 32:155-174.

Penrose, Edith Tilton. 1959. *The theory of the growth in the firm*. Oxford: Basil Blackwell.

Pisano, Gary P. 1997. *The development factory: unlocking the potential of process innovation*. Boston: Harvard Business School Press.

Porter, Michael E. 1980. *Competitive strategy: techniques for analyzing industries and competitors*. New York: Free Press.

Porter, Michael E. 1985. *Competitive advantage: creating and sustaining superior performance*. New York: Free Press.

Porter, Michael E. 1996. What is strategy? *Harvard Business Review* 74 (6):61-78.

Prahalad, C K, and Gary Hamel. 1990. The Core Competence of the Corporation. *Harvard Business Review* 68 (3):79-91.

Prahalad, C. K., and Gary Hamel. 1994. *Competing for the future*. Boston, Mass.: Harvard Business School Press.

Ravnitzky, Michael. 1996. *Automotive interior trim*. Warrendale, PA: Society of Automotive Engineers.

Robins, James, and Margarethe F Wiersema. 1995. A resource-based approach to the multibusiness firm. *Strategic Management Journal* 16 (4):277-299.

Rotemberg, Julio J. 1999. Process- versus Function-Based Hierarchies. *Journal of Economics & Management Strategy* 8 (4):p 453-87.

Rumelt, Richard P. 1974. *Strategy, structure, and economic performance*. Boston, Mass.: Harvard University Press.

Rumelt, Richard P. 1984. Towards a strategic theory of the firm. In *Competitive strategic management*, edited by R. Lamb. Englewood Cliffs, NJ: Prentice-Hall.

Rumelt, Richard P. 1991. How Much Does Industry Matter? *Strategic Management Journal* 12 (3):167-185.

Rumelt, Richard P, Dan Schendel, and David J Teece. 1991. Strategic Management and Economics. *Strategic Management Journal* 12:5-29.

Rumelt, Richard P., Dan Schendel, and David J. Teece. 1995. *Fundamental issues in strategy: a research agenda*. Boston, Mass.: Harvard Business School Press.

Sako, Mari, and Susan Helper. 1995. *Supplier relations and performance in the auto industry: European-Japanese-US comparisons of the voice/exit choice*. Cambridge, Mass.: International Motor Vehicle Program, MIT.

Sako, Mari, and Max Warburton. 1999. *Modularization and Outsourcing Project. Preliminary Report*. Cambridge, Mass.: International Motor Vehicle Program, MIT.

Scherer, F M. 1982. Inter-Industry Technology Flows in the United States. *Research Policy* 11 (4):227-245.

Schmalensee, Richard, and Robert D. Willig. 1989. *Handbook of industrial organization*. New York: Elsevier Science Pub. Co.

Schumpeter, Joseph Alois. 1942. *Capitalism, socialism, and democracy*. New York,: Harper.

Scott, Gregory Keith. 1994. *IMVP new product development series: the Chrysler Corporation*. Cambridge, Mass.: International Motor Vehicle Program, MIT.

Seiffert, Ulrich, and Peter Walzer. 1984. *The future for automotive technology, Future for science and technology series*. London: F. Pinter.

Servaes, Henri. 1991. Tobin's Q and the Gains from Takeovers. *Journal of Finance* 46 (1):409-419.

Seth, Anju. 1990. Sources of Value Creation in Acquisitions: An Empirical Investigation. *Strategic Management Journal* 11 (6):431-446.

Shimokawa, Koichi. 1995. *Restructuring and global strategy of the Japanese automobile industry and its perspective*. Cambridge, Mass.: International Motor Vehicle Program, MIT.

Shimokawa, Koichi, Ulrich Jürgens, and Takahiro Fujimoto. 1997. *Transforming automobile assembly: experience in automation and work organization*. Berlin: Springer.

Silverman, Brian S. 1996. Technical assets and the logic of corporate diversification. Ph.D. thesis, University of California, Berkeley.

Silverman, Brian S. 1998. Technological resources and the direction of corporate diversification: Toward an integration of the resource-based view and transaction cost economics. *Management Science* 45 (8):1109-1124.

Singh, Harbir, and Cynthia A Montgomery. 1987. Corporate Acquisition Strategies and Economic Performance. *Strategic Management Journal* 8 (4):377-386.

Skinner, Wickham. 1969. Manufacturing - Missing Link in Corporate Strategy. *Harvard Business Review.* (May-June):136-145.

Skinner, Wickham. 1974. The Focused Factory. *Harvard Business Review.*

Smirlock, Michael, Thomas Gilligan, William Marshall, and Michael Gilligan Thomas Marshall William Smirlock. 1984. Tobin's q and the Structure-Performance Relationship. *American Economic Review* 74 (5):p 1051-60.

Society of Automotive Engineers. 1997a. *Concepts in new engine and component design.* Warrendale, PA: Society of Automotive Engineers.

Society of Automotive Engineers. 1997b. *Steel in automotive applications.* Warrendale, PA: Society of Automotive Engineers.

Society of Automotive Engineers. 1998. *New engine design and automotive filtration.* Warrendale, PA: Society of Automotive Engineers.

St. John, Caron H, and Jeffrey S Harrison. 1999. Manufacturing-based relatedness, synergy, and coordination. *Strategic Management Journal* 20 (2):129-145.

Sturgeon, Timothy J., and Richard L. Florida. 1997. *Research note: the globalization of automobile production.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

Takeishi, Akira. 1998. Strategic management of supplier involvement in automobile product development, MIT, Cambridge, Mass.

Takeishi, Akira, and Michael A. Cusumano. 1995. *What we have learned and have yet to learn from manufacturer-supplier relations in the auto industry.* Cambridge, Mass.: International Motor Vehicle Program, MIT.

Teece, David J. 1982. Towards an Economic Theory of the Multiproduct Firm. *Journal of Economic Behavior & Organization* 3 (1):p 39-63.

Teece, David J. 1986. Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy* 15 (6):285-305.

Teece, David J, Gary Pisano, and Amy Shuen. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal* 18 (7):509-533.

Teece, David J, Richard Rumelt, Giovanni Dosi, and Sidney Winter. 1994. Understanding corporate coherence: Theory and evidence. *Journal of Economic Behavior & Organization* 23 (1):1-30.

Topkis, Donald M. 1998. *Supermodularity and complementarity, Frontiers of economic research.* Princeton, N.J.: Princeton University Press.

Ulrich, Karl T., and Steven D. Eppinger. 1995. *Product design and development.* New York: McGraw-Hill.

Wernerfelt, Birger. 1984. A Resource-Based View of the Firm. *Strategic Management Journal* 5 (2):171-180.

Wernerfelt, Birger, and Cynthia A Montgomery. 1988. Tobin's q and the Importance of Focus in Firm Performance. *American Economic Review* 78 (1):246-250.

Williamson, Oliver E. 1975. *Markets and hierarchies.* New York: Free Press.

Womack, James P., Daniel T. Jones, and Daniel Roos. 1991. *The machine that changed the world.* New York, NY: HarperPerennial.