EXAMINING THE RELATIONSHIP BETWEEN RESEARCH AND DEVELOPMENT RESOURCE FLOWS AND KNOWLEDGE-BASED CAPABILITIES: INTEGRATING RESOURCE-BASED AND ORGANIZATIONAL LEARNING THEORY

By

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ABSTRACT

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This dissertation addresses the development of knowledge-based research and development capabilities. The resource-based view of the firm suggests that knowledge-based capabilities can be an important source of sustainable competitive advantage. Thus, the question of how such capabilities are developed is of great interest to both managers and researchers. A process model is presented linking the concepts of research and development resource flows, research and development capabilities, and firm performance. The model is predicated on theories of learning and knowledge development that consider the structure of knowledge as consisting of data and nonlinear relationships among those data. The model is tested using fifteen years of data from the pharmaceutical industry. Although the data did not support any of the hypotheses, the theoretical development of nonlinear flow and stock relationships provides a new lens to develop future research.

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This dissertation was challenging on many fronts. I greatly appreciate the support and perseverance of my committee over this long process. Each one contributed in unique ways above and beyond what can normally be expected from a dissertation committee.

I also thank my family for their unconditional support and love – those two intangible but tremendously valuable resources were dearly appreciated throughout this process. The value placed on education by my parents and grandparents has been markedly impressed upon me, and has most certainly deeply influenced how I've spent the last decade.

Over the years, I have been extraordinarily fortunate to develop many close friends, each of whom has helped me in a variety of important ways. Most of these folks I still talk with regularly - they know how grateful I am! Some of them I've lost touch with, but all have been important and are appreciated.

I also want to thank someone whom I never met, and who I am quite certain knows nothing about me. When I was a struggling adolescent, fighting just to make it through junior high school, I read an article on the back page of the Detroit Free Press about an old woodcutter from Idlewild, Michigan named Andy Horujko. At age 66, he was retiring from woodcutting and returning to college after a 45-year absence. The article included a quote that really stuck with me and served as the core of the personal philosophy that I still hold strictly to: "When a man stops learning he starts dying. I've got to learn something every day or at least get a good laugh." I'm sure if this old woodcutter is still around, and knew how much that article 20 years ago meant to me, he'd get a good laugh.

Most importantly, I thank my wife Sandy for her love, support, partnership, and help. Without her, this undoubtedly would never have happened.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Why have some firms consistently outperformed rivals? In search of answers to this question, the strategic management literature has extended beyond its roots in industrial organization economics and its emphasis on industry structure as the prime driver of firm performance. Indeed, the strategy field has blossomed as researchers have begun to examine firm-level sources of variance, originally thought to include diversification (Rumelt, 1974) and generic business-level strategies (Porter, 1980). Students of organizations have followed the development of the strategy field through theoretical growth in areas such as strategic groups (Cool & Schendel, 1988) and upper echelons theories (Hambrick & Mason, 1984), into the present. Currently, the resource-based view of the firm is one theory rapidly becoming popular in the literature. It is apparent that the shift to resource-based theory has made a significant impact on the way managers manage, students learn, and academicians think about competitive advantage (Barney, 1996; Montgomery, 1995; Wernerfelt, 1995).

As knowledge becomes an increasingly important aspect of the economy (Grant, 1996; Spender, 1996), researchers must find a way to adequately develop and test theory that reflects this phenomenon (Conner & Prahalad, 1996). Resource-based theory shows great promise to improve understanding of competition in knowledge-intensive industries, that is, those firms that rely on knowledge as an important input, including the semiconductor, pharmaceutical, and telecommunication industries. As the world shifts from a labor-based to an information-based economy, the development and management of knowledge becomes increasingly important. In knowledge-intensive industries, differences in both the amount of knowledge and in the rate of learning (or the speed at which the existing knowledge base changes) become key issues in understanding interfirm performance differences, or <u>why some firms consistently outperform rivals</u>.

Yet, there is considerable debate about the usefulness of resource-based theory. The underlying logic of the resource-based view is intuitively appealing, yet the combination of undefined internal processes and difficult to measure key variables creates skepticism (Montgomery, 1995). This dissertation attempts to clarify these processes and measure some of the key variables by adopting concepts from a range of disciplines and applying them to the notion of resource flows and stocks, ideas previously mentioned by Dierickx and Cool (1989), but given short shrift by many resource-based theorists (notable exceptions being Conner, 1991 and Black and Boal, 1994). In an effort to develop and extend resource-based theory, the impact of knowledge on the transformation of research and development resource flows into capability stocks becomes a prime theoretical driver of interfirm differences in knowledge-intensive industries. Concepts from cognitive psychology, sociology, and organizational theory are reviewed and integrated in an effort to complement recent ideas addressed in the strategic management literature about the development of sustained competitive advantage in knowledge-intensive industries.

The body of this dissertation is presented as follows: The second chapter reviews resource-based theory and the literature on learning and innovation. The third chapter integrates the issues raised in the literature review, and a process model with related hypotheses is developed. The fourth chapter addresses data collection and analytical methodology. The fifth chapter details the results of the data analysis. Finally, the sixth chapter discusses the findings, limitations, implications, and directions for future research.

LITERATURE REVIEW

In an effort to better understand the relationship between firm resources and firm performance in knowledge-intensive industries, this review explores and integrates two research streams: the development of resource-based theory and learning and innovation from an organizational perspective. This review is particularly focused on the relationship between research and development resource flows and knowledge-based capabilities, and the impact of both on firm performance.

The Evolution of the Resource-Based View of the Firm - Three Eras

Over the past twenty-five years, the central premise of the strategic management field has expanded from its roots in industrial organizational economics to acknowledge that indeed, some firms can, and do, enjoy persistent performance advantages over rivals (Aharoni, 1993; Barney, 1991; Istvan, 1992; Peteraf, 1993; Wernerfelt, 1995). Therefore, the essential question for strategy researchers has shifted from whether certain firms enjoy sustained extranormal performance, to why certain firms enjoy sustained extranormal performance.

In an attempt to answer this question, strategic management researchers have focused on studying the determinants of firm performance. In the first half of the 1980s, the scope of strategic management research focused on product and market characteristics, including studies based on industry environment (Harrigan, 1980; Porter, 1980), form and level of diversification (Bettis, 1981;

Montgomery, 1982; Rumelt, 1974), and generic strategic archetypes based on what and where the firm sold its output (Dess & Davis, 1984; Hambrick, 1983; Miles & Snow, 1978). However, in response to the equivocal results from research using these traditional product and market dependent variables, Wernerfelt (1984) made a significant shift away from the popular research streams of that time. Wernerfelt drew on the work of Edith Penrose who proposed that the firm may be viewed as "a collection of productive resources" (1959:24). Wernerfelt integrated this concept of viewing a firm in terms of its inputs with the notion that certain resources can act as barriers to competition (Porter, 1980), which gave rise to what is known today as the resource-based view of the firm. This period of 1984-1991 marked the introduction of the resource-based view of the firm into the strategic management literature.

The citations generally considered to be the foundation of the resource-based view, published in this period, are summarized in Table 1. Barney (1986) extended the resource-based view by discussing the linkage between strategies and the resources necessary for implementing those strategies. Barney (1986) used the concept of the strategic factor market to explain the importance of managerial expectations about the future value of resources. The important point here was that managers could gain superior expectations of the future value of resources not by the traditional method of analyzing the environment (because all managers would come to similar conclusions thus nullifying any advantage), but in identifying the skills and resources residing within the organization. This way, managers can acquire complementary resources that have more value to their firms than to rivals, and thus gain an advantage in assessing the future value of a given resource. Barney (1986) brought focus and relevance to the Wernerfelt (1984) paper by showing that viewing the firm as a collection of resources can fit in with traditional strategic management techniques and offered initial insights on the link between resources and competitive advantage.

Dierickx and Cool (1989) offered an alternative to Barney's notion of resource acquisition. Dierickx & Cool (1989) suggested that firms accumulate resources over time and that the key to competitive advantage was in the development of difficult-to-imitate bundles of interconnected resources that are built over time. The process by which resources are accumulated was discussed in terms of resource flows and resource stocks. This notion will be discussed in more detail later in this chapter.

Prahalad and Hamel (1990) brought the resource-based view to practitioners through the lens of core competencies in a widely cited Harvard Business Review article. Prahalad and Hamel prescribed that managers should identify the key bundles of resources that underlie their sources of competitive advantage and both protect and leverage those bundles. In another important article, Barney (1991) refined the underpinnings of the resource-based view, arguing that firms can obtain extranormal performance by acquiring resources that are rare, valuable, lack substitutes, and are difficult for rivals to imitate. Barney cemented the linkage between resources and competitive advantage, integrating the prescriptive logic of Prahalad and Hamel (1990) with the conceptual clarity of Wernerfelt (1984) and Barney (1986). Barney (1991) provided needed detailed definitions of resources and discussed how resource based analysis fit into formal planning processes. Importantly, Barney (1991) provided a framework (rare, valuable, lack substitutes, difficult to imitate) useful to both researchers and practitioners.

By 1991, it was apparent to some that the resource-based view had great potential for impacting how managers and researchers think about strategic management of the firm (Conner, 1991). The seminal work by Wernerfelt (1984) and Barney (1986, 1991) laid the theoretical groundwork, while Prahalad and Hamel (1990) piqued the interest of managers and provided a real life context for further study.

Resource-Based Theory, 1991-1995 - Economic Justification & Tacit Resources

The foundation laid by Wernerfelt and Barney in the 1980's developed into a fertile research stream in the 1990s. Most recent studies follow Wernerfelt (1984) and Barney (1986) by applying the resource-based lens to examine competitive advantage. During the first half of the 1990's, resource-based theory development followed two relatively distinct paths. One stream developed the economic justification of the resource-based view (Conner, 1991; Peteraf, 1993). The second attempted to further define firm resources and tilted toward the consideration of tacit resources (Castanias & Helfat, 1991; Hall, 1992, 1993).

The Economic Justification of Resource-Based Theory. Conner (1991) and Peteraf (1993) underscored important linkages between industrial-organization economics and the resource-based view. Their efforts provided important economic justification for the proposition that firm resources are an important source of interfirm performance differences and have helped the resource-based view gain acceptance among management researchers.

Conner (1991) accelerated the justification of resource-based theory in economic terms, providing a detailed comparison among traditional industrial organization economic theories and resource-based theory. Her central conclusions were that the resource-based view exists as both a complement and an alternative to traditional industrial organization (IO) economic theory. Conner asserted that resource-based theory shares key characteristics with the neoclassical and Chicago economic views about the role of the firm, but is at odds with several central assumptions, including perfect information and resource mobility. Resource-based theory is considered similar to the Schumpeterian process of creative destruction and Bain-type IO theories in the important assumption that persistent extranormal profits are possible in the long run.

In Conner's (1991) final analysis, two points stand out. First, an important economic justification of resource-based theory is predicated on the idea that interfirm performance differences can be attributed to the possession of unique resources. Second, the recognition of resource stocks and flows, representing the level at which resources are defined, is important in "preventing resource-based theory from becoming tautological" (1991: p. 145). Both points are important in later research using resource-based theory.

Peteraf (1993) presented the first resource-based model of firm performance. The model was based in part on the generation of economic rents through resource mobility barriers and other limits to competition. Thus, Peteraf built on the justifications made by Conner (1991), and integrated work by Wernerfelt (1984) and Barney (1986) into a concise statement of the "cornerstones of competitive advantage." Peteraf (1993) provided descriptive examples of how her model could be applied across both business and corporate levels of study within strategic management research.

Despite the increase in theoretical specification that resulted from the work of Conner (1991) and Peteraf (1993), relatively few pure empirical tests of resource-based theory had been conducted. Much of this can be traced to difficulty in identifying and measuring resources (Conner, 1991). In an effort to address the paucity of quantitative research, researchers started to tackle specification and measurement issues, focusing at first on tacit resources.

<u>Specifying Tacit Resources</u>. Conner (1991) explicitly specified that 1) unique resources are the key to competitive advantage and 2) that the identification and measurement of these unique resources is a major obstacle to empirical research using resource-based theory. However, many researchers attempted to develop explicit resource definitions, primarily of tacit resources, in an effort to bridge the gap that was preventing broad empirical testing of resource-based theory.

Table 1

Foundation Resource-Based Citations (1984-1991)

Citation	Contribution
Penrose (1959)	Introduced the notion of the firm as a collection of resources.
Wernerfelt (1984)	Reintroduced the notion of the firm as a collection of resources. Defined a resource as "anything which can be thought of as a strength or weakness of a given firm" (p. 172). Concluded that some resources could be considered as 'position' barriers that can inhibit competition.
Barney (1986)	Resources are traded on factor markets, and play an important role in firm performance
Dierickx & Cool (1989)	Differentiated the ideas of asset stocks vs. asset flows; specified the notion that time compression diseconomies, interconnectedness, asset mass efficiencies, asset erosion, and causal ambiguity are drivers of the asset accumulation process, by which inimitable resource stocks that support competitive advantage are accumulated over time
Prahalad & Hamel (1990)	Defined the term 'core competence' and discussed the applicability of the resource-based view to practitioners
Barney (1991)	Defined the nature of resources that support competitive advantage: Rare, valuable, difficult to imitate, lack substitutes

Castanias and Helfat (1991) extended the ideas of Barney (1991), specifying managerial expertise as an essential firm resource that generated rent. Hall (1992, 1993) followed this stream by creating a framework of the intangible resources and capabilities that support competitive advantage. These resources include patents, trademarks, reputation, expertise, data bases, culture, and organizational networks. Each of these resources was broken down along three dimensions; the people dependence or independence of the resource, skill versus asset, and the nature of the capability: functional, cultural, positional, or regulatory.

Using case study data across industries and survey data, Hall (1993) concluded that expertise and reputation were the two most durable types of intangible resources and thus the most likely to support sustained competitive advantage. Hall's empirical work provided initial support for the arguments of both Barney (1991) and Castanias and Helfat (1991) about the relationship between resources and firm performance. Knez and Camerer (1994) defined tacit resources such as reputation as nontradeable, and underscored the importance of building these resources over time. Based on a lab study, Knez and Camerer concluded that these tacit resources do indeed exist and are highly complex, providing some additional empirical support for the fundamental assumptions of Castanias and Helfat (1991) and Hall (1992, 1993).

Amit and Schoemaker (1993) made an effort to better specify the links among resources, strategy, and performance. They defined important resources and capabilities at both the industry and firm levels, and then identified decision making patterns by which managers attempt to align firm-level resources and industry-level resources in such a way as to produce sustainable rents. This paper was an exemplar of work in 1992-93 that specified tacit resources in more defined terms and set out logical boundaries of what should and should not be considered a resource.

An important step in defining tacit resources came when researchers started to explore and explain the complexity of these resources. In this vein, Black and Boal (1994) theorized that resources must be utilized in configurations, or network relationships over time to allow resource flows to become non-tradeable asset stocks, the most likely resource configuration to support sustained competitive advantage. Specifically, Black and Boal defined resources in terms of their inherent nature (tradeable/non-tradeable and flow/stock) and in the nature of the relationships among resources. Black and Boal concluded that the longitudinal processes by which bundles of resources are developed over time are important for both managers and practitioners in determining the sources of sustained competitive advantage.

Barney and Hansen (1994) started to push the outer boundaries of the types of tacit resources that can be considered sources of competitive advantage, looking specifically at the nature of trust in economic exchanges. Barney and Hansen (1994) identified several distinct forms of trust, relating each level to the likelihood of that trust supporting competitive advantage. Other studies in 1994 and 1995 continued to push on these boundaries as well. In an interesting twist on the traditional approach in the diversification literature, Robins and Wiersema (1995) adopted the commonly used construct of relatedness as a proxy for important strategic assets. Their resource-based index of relatedness appeared to provide an alternative to traditional entropy-based measures and may, along with Stimpert and Duhaime (1997) who also provided a new interpretation of relatedness, serve as a useful tool for a new wave of more useful diversification studies.

Collis (1994) addressed the issue of capability development, delineating three types of capabilities: the ability to perform basic functional activities of the firm, the ability to make dynamic improvements in the firm, and the ability to develop the "metaphysical strategic insights" (1994: p. 145) that allow managers to develop and implement strategies that both use existing firm resources develop important new resources. Collis acknowledged the resource-based assumption that capabilities are asset stocks accumulated over time and thus can form the basis of inimitability so important for sustained competitive advantage. However, the key contribution of Collis was his identification of the problems inherent in the use capabilities as a tool for prediction and explanation of phenomena.

Collis (1994) concluded that capabilities are just another level in the search for the sources of sustained competitive advantage, not the primary source, and researchers would be well advised to remember this in future research. Specifically, Collis advised that any given capabilities can always be subsumed by higher-order capabilities, thus rendering any competitive advantage gained by the original capability useless. Thus, in a few short years, work on tacit resources appeared to come full circle from a theoretical standpoint (see Table 2 for a summary of these studies), and as the preceding review clearly shows, very few empirical resource-based studies were undertaken to provide any support for the existence of these tacit resources.

Despite the prolonged delays in publishing solid empirical work, increased theoretical specification of the economic bases and the nature of tacit resources helped enhance the resource-based theory in its emergent stages during the early 1990s. In the middle of the decade, both Barney (1996) and Wernerfelt (1995) noted that resource-based theory was on the brink of becoming a critical part of the mainstream strategic management literature. As explained below, research published in late 1996 and early 1997 suggests that these predictions may be coming to fruition.

1996-97: Integrating Resource-Based Theory

Recently, the resource-based view has been woven into existing research streams, such as the strategic group, diversification, and strategic alliance literatures, with interesting and meaningful results. Table 3 summarizes current work using resource-based theory. For example, Mehra (1996) extended strategic group research by introducing a resource-based explanation of commonalities among strategic group members. Hypotheses about the sources of performance variation, drawn from the resource-based approach, were empirically supported.

Markides and Williamson (1996) extended the diversification literature by presenting a new conceptualization and measurement of the relatedness between businesses. They demonstrated empirically that their resource-based measurement system improved on two traditional measures of relatedness, the entropy measure and the Rumelt (1974) classification. Along similar lines, Eisenhardt and Schoonhoven (1996) integrated the resource-based view with the literature on strategic alliances, concluding that firms form strategic alliances for more reasons than usually discussed; that is, justification built on transaction-cost economics. These alternative reasons can be considered resource-based, in that firms are attempting to propel themselves from threatening competitive situations by rapidly building access to key strategic resources.

Although Eisenhardt and Schoonhoven did not specifically address knowledge or expertise as a specific type of key strategic resource, it certainly should be considered as a potential independent variable in future research. Nevertheless, their data supported their hypotheses that firms undertake strategic alliances in order to build essential resources, and marked another successful effort at blending resource-based theory with traditional strategic management viewpoints.

Other authors branched out farther, looking at areas often considered outside traditional strategic management research streams, and used resource-based theory to relate important issues back into a strategic management framework. For example, Powell and Dent-Micallef (1997) applied the resource-based view in a study that explored the linkages between information technology

Table 2

Selected Studies 1991-1995: Examining Tacit Resources

Citation	Contributions
Amit & Schoemaker (1993)	Defined resources as "stocks of available factors that are owned or controlled by the firm" Resources "consist, inter alia, of know-how that can be traded (e.g. patents and licenses), financial or physical assets (e.g. property, plant, and equipment), human capital, etc." (p. 35)
Barney & Hansen (1994)	Defined trust as a valuable resource, difficult to imitate, and accumulated over time, and thus can help support sustained competitive advantage.
Black & Boal (1994)	Categorized resources in terms of traits, configurations and paths using network theory and the notion of flows and stocks.
Castanias & Helfat (1991)	Defined the role of managerial expertise as a resource essential for the development of sustained competitive advantage. Argued that resource-based logic better explains manager-shareholder coalignment that agency theory.
Collis (1994)	Defined three categories of capabilities: ability to perform basic functional activities, dynamic improvement, metaphysical strategic insights
Hall (1992, 1993)	Categorized intangible resources by their relationships to people, a firm's asset base, and where it lies in the organization. Concluded that expertise and reputation were the two most durable and important intangibles
Knez & Camerer (1994)	Defined expectational assets, or reputation, as non-tradeable, developed over time, and generating firm-specific rent. Concluded that expectational assets (individual beliefs) exist and are socially complex and difficult to develop accurately
Robins & Wiersema (1995)	Defined resources as knowledge or capability that creates competitive advantage. Concluded that the performance of large manufacturing firms is impacted by relatedness, an indirect measure of knowledge resources

and performance. Their data suggested that information technology alone is not a source of sustained competitive advantage, but can support competitive advantage when used in combination with complementary human and business resources. Russo and Fouts (1997) looked at corporate environmental performance as a firm resource and found an empirical link with firm performance. Maijoor and van Witteloostuijn (1996) explored the relationships among regulation, firm resources, and performance. This was done through a reexamination of the levels at which resources exist. Maijoor and van Witteloostuijn concluded that resources exist at the firm, group, and industry level. Empirical analysis of the Dutch audit industry suggested that regulation can be considered a resource at the industry level.

The Future of Resource-Based Theory - Focus on Knowledge-Based Resources

The preceding review supports one of the fundamental premises of resource-based theory, that industry structure does not fully explain performance patterns and that barriers to imitation do exist. As a result, firms are often unable to imitate the specific factors that make some rivals more successful than others. It is also apparent that capability development, not imitation, is the key to competitive advantage (Lippman & Rumelt, 1982; Reed & DeFillippi, 1990). This important point becomes even more relevant when considering a recent and useful distinction of knowledge-based resources (Conner & Prahalad, 1996;

Table 3

Important Resource-Based Studies 1996-1997: Integrating and Extending RBV

Citation	Contributions
Eisenhardt & Schoonhoven (1996)	Examined building firm resources through alliances. Strategic alliances are more likely when firms are in a vulnerable strategic position, and led by large experienced top mgmt teams
Maijoor & van Witteloostuijn (1996)	Explored the link among regulation, firm resources, and performance. Concluded that regulation can be considered a resource at the industry level.
Markides & Williamson (1996)	Presented an alternative, resource-based measurement of the relatedness, and demonstrated empirically that it improved on traditional measures of relatedness
Mehra (1996)	Conducted an exploratory study that showed a significant relationship between firm resources and performance. Certain configurations work better than others.
Powell & Dent-Micallef (1997)	Concluded that information technology supports competitive advantage when used in combination with other, tacit, human and business resources
Russo & Fonts (1997)	Examined corporate environmental performance as a firm resource and concluded empirically that a positive relationship with performance exists.

Kogut & Zander, 1996) and other types of resources. Knowledge-based resources are important because they may impact the economic reasons that firms organize.

Organization, as opposed to market contracting, makes available expertise that can be jointly utilized (Conner & Prahalad, 1996). In a market contract, expertise not related to the expressed purpose of the contract is not shared, and cannot then be applied in future work. This is a very important point because, by extension, it may justify the existence of the resource-based view of the firm. That is, organization is important because it supports the accumulation of knowledge and the development of valuable stocks of expertise that would probably not be developed under a market contract relationship (Conner & Prahalad, 1996).

It is important to remember that the resource-based view of the firm was built on the idea that important interfirm performance differences are based on valuable, rare, and difficult to imitate resources rather than products and markets (Barney, 1986). One way to better address this notion of interfirm performance differences in knowledge-intensive industries might be to turn back to the notion of resource flows and stocks, a set of ideas that were presented relatively early in the history of the resource-based view by Dierickx and Cool (1989), and is widely cited by current resource-based researchers.

The flow and stock distinction came about as part of a discussion in the literature between Dierickx and Cool and Barney. An early central theme was the distinction between resource acquisition and resource accumulation. Barney

(1986) addressed resource acquisition, arguing that all resources were essentially tradable on what he termed "strategic factor markets." Barney defined a strategic factor market as a market where resources required for the implementation of a strategy are exchanged.

Dierickx and Cool (1989) countered this argument with a discussion of resource accumulation, asserting that sustainable competitive advantage is built on the deployment of nontradable assets not readily available on open markets. Nontradable resources include reputation for quality, dealer loyalty, firm-specific human capital, and research and development capability. Dierickx and Cool argued that these nontradeable resource stocks are not available on any type of strategic factor market, rather, that these can only be "built or accumulated through a consistent time pattern of expenditures or flows" (1989: p. 1509). This has two implications. First, since resource stocks cannot be purchased in a market setting, these stocks must be developed by a firm over time. Second, since these stocks cannot be sold in a market setting, these stocks must be deployed in a product market in order to realize their value.

One way to address some of the differences between the concepts of resource accumulation and resource acquisition is by examining the conceptualization of how "flows" of resources develop into the configurations or "stocks" of assets that are rare, valuable, and difficult for rival managers to imitate. If, as Dierickx and Cool (1989) asserted, asset configurations or stocks that develop over time are more difficult to imitate than the individual resources purchased or acquired, then understanding interfirm differences in both strategy and performance may rely on examining the underlying resource accumulation patterns.

Back to Basics - Reexamining the Idea of Resource Flows and Stocks

Dierickx and Cool (1989) presented a framework that described the processes by which asset stocks accumulate over time to support the development of sustained competitive advantage. The resource accumulation process is based on assumptions that, over time, an organization develops a stockpile of resources, and that resources "flow" into and out of this "stock" as resources are acquired and used up as the firm operates.

The flow and stock idea is not new, and more importantly, continues to be refined. For example, McCarthy (1979, 1982) used the flow-stock conceptualization as a tool for understanding the relationship between economic events and accounting procedures. The idea was that balance sheet items, capital assets that exist at a given point in time, are stocks. Stocks might include plant, land, and inventory. Income statement items, cash that moves into and out from the firm during a given time period are flows. Flows might include sales revenues, rent, advertising expenses, and payroll.

Very recently, Samuelson (1996) called for enhanced clarification of the conceptual framework of the FASB, and suggested that solidifying the definition of stocks and flows would be beneficial within such a conversation. Samuelson defined flows, in the accounting sense, as the movement of resources to or from an organization during a defined set of time periods; whereas stocks are defined as a factor that maintains the potential of creating future value for the firm at a given time point in time.

In the econometrics literature, the flow and stock distinctions are used in modeling continuous processes over time where variables need to be understood 1) in terms of a certain state at a given point in time, and 2) as that variable changes over time. Thus, the variable can be examined at a single point in time, as a state, defined as a stock. Alternatively, the variable can also be decomposed and studied in terms of the changes to the stock over a defined time period. These changes in the state of the variable are defined as flows (Lancaster & Imbens, 1995; Robinson, 1993).

Since Dierickx and Cool (1989), there have been two instances where the flow and stock concepts have been discussed in detail within the strategic management literature. Black and Boal (1994) built on the flow-stock conceptualization as a key to understanding the nature of resources and capabilities in their model of firm performance. Almeida (1996) used the flow and stock idea to highlight the nature of innovation, arguing that information flows and knowledge stocks lead to innovation.

In the few applications that applied flows and stocks in the strategy literature, resource flows have been consistently defined as investments intended to be transformed (or used to support the transformation) into the end product or service; that is, flows are the building blocks of "capabilities" which are then applied in product markets. Resource flows can be acquired repetitively, as in regular purchases of raw materials or regular upgrades of computer software. However, resource flows can also include one-time purchases, such as raw materials, machinery, or computers. In a discussion of flows and stocks in the accounting literature, McCarthy (1979, 1982) defined flows as transactions whereby goods, services, or claims are brought into the firm over a defined period of time.

For example, a firm can purchase 100 sets of pre-developed training materials from a consulting company. This is a resource flow that is purchased by the firm. Alternatively, the firm can hire and pay a training professional, (where hiring costs would be a one-time resource flow and each pay period would be considered a recurring resource flow), buy paper, materials, doughnuts and coffee, and other essentials.

Resource stocks are defined as bundles of resources that are used to create or add value to end products. Resource stocks can include expertise, reputation, relationships with suppliers, and relationships with customers. These bundles of associated resources are often associated with the term capability in the literature (Black & Boal, 1994). In the accounting literature, McCarthy (1979, 1982) defines stocks as balance sheet assets consisting of goods, services, or claims that grow or shrink in monetary value as resources flows move into and out of that asset.

Examples include research and development capabilities (collections of resources that provide a firm with the ability to invent and bring new compounds to market), marketing capabilities (collections of resources that result in developing valuable advertising, market research, and after-sale service), reputation (for quality, for financial strength, for quality of work life, etc.), manufacturing capabilities (resulting in flexibility, meeting tolerances, and speed), and human resource capabilities (collections of resources that facilitate recruiting, selection, compensation, training, even 'downsizing'). In the earlier training example, the expertise developed by employees that participated in a successful training program would be the resource stock. Dierickx and Cool concluded that "(t)he common element in all of these cases is that the strategic asset is the cumulative result of adhering to a consistent set of policies over a period of time. Put differently, strategic asset stocks are accumulated by choosing appropriate time paths of flows over a period of time" (1989:1506).

Dierickx and Cool (1989) argued that sustained competitive advantage is developed through the accumulation of interdependent stocks of resources. Several processes that underlie this stock and flow conceptualization were identified. These include time compression diseconomies, asset mass efficiencies, interconnectedness of asset stocks, asset erosion, and causal ambiguity.

Time compression diseconomies develop as assets are accumulated over time. According to Dierickx and Cool:

> Conceptually, time compression diseconomies and the notion of "strictly convex adjustment costs" in the theory of capital investment to which they are related express the same fundamental mechanism: the "law of diminishing returns" when one input, viz. time, is held constant. For example, MBA students may not accumulate the same stock of knowledge in a one-year program as in a two-year program, even if all inputs other than time

> are doubled. In the case of R&D, the presence of time compression diseconomies implies that maintaining a given rate of R&D spending over a particular time interval produces a larger increment to the stock of R&D know-how than maintaining twice this rate of R&D spending over half the time interval (1989: p. 1507).

Asset mass efficiencies relate to the idea that the asset accumulation process is facilitated as firms accumulate large asset stocks (Dierickx & Cool, 1989). According to Dierickx and Cool:

> Sustainability will be enhanced to the extent that adding increments to an existing asset stock is facilitated by possessing high levels of that stock. The underlying notion is that 'success breeds success': historical success translates into favorable initial asset stock positions which in turn facilitate further asset accumulation. For example, firms who already have an important stock of R&D know-how are often in a better position to make further breakthroughs and to add to their existing stock of knowledge than firms who have low initial levels of know-how . . . The competitive implication is clear: when asset mass efficiencies are important, building asset stocks starting at low initial levels may be difficult (1989: p. 1507-08).

Interconnectedness of asset stocks refers to the notion that certain resources are complimentary, and as such, can result in superior returns when accumulated and implemented together. As Dierickx and Cool explained, "(a)ccumulating increments in an existing stock may depend not just on the level of that stock, but also on the level of other stocks" (1989: 1508). For example, a firm that possesses outstanding process technology resources, resulting in low production costs, will earn greater returns from these assets when the firm also maintains high levels of marketing expertise, resulting in the ability to generate high levels of brand recognition and the perception of value. According to Dierickx and Cool, "(h)ere, the difficulty of building one stock is related, not to the initial level of that stock, but to the low initial level of another stock which is its complement" (1989: 1508) Thus, the interconnectedness of asset stocks contributes to causal ambiguity and uncertain imitability, as the nature of these complementary relationships may not be precisely visible to rival managers.

Asset erosion occurs when resource stocks, which deteriorate over time, are not replenished (Dierickx & Cool, 1989). Thus, asset stocks must be continuously maintained if competitive advantage is to be sustained. For example, relationships with suppliers or customers must be maintained in order for those assets to remain productive. Dierickx and Cool stated the following:

> R&D know-how depreciates over time because of technological obsolescence, brand awareness erodes because the consumer population is not stationary (existing consumers leave the market, while new consumers enter), consumers forget, etc. The characteristics of this decay process have several managerial implications. There is an important relation between an asset's 'half-life' and strategic entry deterrence. To credibly deter entry, firms must be committed to punitive post entry behavior. Thus, output and advertising policies are not, in general, credible vehicles for entry deterrence, whereas capacity and brand loyalty are. The reason is that the former, pertaining to flow variables, could be adjusted at will should entry occur, whereas the latter, being stock variables, cannot. (1989: p. 1508).

Dierickx and Cool argued that "managers often fail to recognize that a bundle of assets, rather than the particular product market combination chosen for its deployment, lies at the heart of their firm's competitive position" (1989: p. 1504), and concluded that "a firm's current strategy involves choosing optimal time paths of flows, whereas its competitive position and hence its potential profitability is determined by the level of its stocks " (1989: p. 1510). This argument is consistent with the overall role of resource accumulation in the strategy process.

Dierickx and Cool argued that resource accumulation is both the direct result of past patterns of strategic decisions and the driver of future strategic decisions. This is consistent with Mintzberg's (1973) definition of strategy as a pattern in a stream of decisions. Thus, resource accumulation is embedded in, and is a product of, the long term strategy of the firm. This argument makes the ability to identify and study resource accumulation patterns even more essential to a unified understanding of the sources of firm performance. These strategic implications are just one result of using the Dierickx and Cool framework to study the determinants of firm performance.

Other constructs in the strategic management literature are illuminated when examined through an asset accumulation lens. For example, Thompson (1967) used the term "technical core" to describe the internal processes that firms use to transform inputs into outputs. Thompson held that the technical core was, for many firms, a strategic asset that must be buffered from external forces. While Thompson drew attention to the significance of the internal processes of the firm, he did little to specify the nature of the technical core.

Since Thompson's book, many researchers have amplified this pattern; that is, highlighted the importance of internal processes while ignoring the specification of those processes. The simple input-'black box'-output approach has consistently failed to consider these internal processes, and it should be little surprise that these researchers failed to discover consistent relationships between input and output variables. Specifically, researchers including Cohen and Levinthal (1989) and Narin, Noma, and Perry (1987) have looked before at the relationship between R&D expenditures and patents. The problem, or what has escaped notice or rigorous study, has been how R&D expenditures feed or develop the innovation process, or how marketing expenditures build brand awareness and loyalty.

There is a link between tangible resources, such as R&D expenditures, and outputs, such as patents, that most researchers skirt over. The value of the Dierickx and Cool framework is that it directs attention to not only resource flows, but on the resource stocks that make up Thompson's "technical core," providing clearer understanding of how R&D dollars are transformed into R&D performance. Put another way, the key resource is not in the easily imitated R&D expenditures, but the strategic component of how the R&D dollars are used to build the capability to innovative.

Dierickx and Cool argued that their framework details the process by which flows of inputs are developed into intangible resource configurations that are then deployed in product markets and can be used to drive competitive advantage. Consistent with the Dierickx and Cool framework, Prahalad and Hamel asserted that "(c)ulitvating core competence does not mean outspending rivals on research and development" (1990:83).

The key contribution of Dierickx and Cool is that the stock of resources must not be ignored. Understanding the processes that drive the creation of these capabilities is an essential component of identifying the internal processes that occur within the "technical core" of the firm. In summary, the concepts of resource flows and stocks are important conceptualizations of how rare, valuable, and difficult to imitate capabilities develop. Thus, Dierickx and Cool (1989) added an additional and complementary dimension to the seminal Wernerfelt (1984) and Barney (1986) cites. Specifically, the identification of resource accumulation patterns should provide a clearer understanding of how firm resource stocks develop over time. Better understanding of the resource stock development should allow greater understanding of interfirm performance differences. The next step in building a theoretical basis for understanding the flow and stock relationship and the resulting impact on performance lies in the literature on individual and organizational learning.

The Nature of Learning

The study of individual learning has been evolving for well over one hundred years. Theorizing about learning and knowledge development spans several disciplines, including sociology, psychology, philosophy, economics, and more recently, organizational theory and strategic management. In the past thirty years, a substantial literature on organizational learning has emerged as a sub-discipline to specifically address how knowledge develops within firms (Levitt & March, 1988; March, 1991). Within the last decade, strategic management researchers have started to examine to impact of cognition and associated learning processes on firm performance (Barr, Stimpert, & Huff, 1992; Prahalad & Bettis, 1986; Spender, 1989; Walsh, 1995; Zajac & Bazerman; 1991). In the strategy domain, much has been gained from this work, yet researchers have yet to ask important questions about the nature of knowledge development and how the process by which knowledge accumulates can lead to sustained performance differences between firms (Aharoni, 1992; Walsh, 1995).

Specifically, broad questions remain about why certain firms get more "bang for the buck" from research and development resource investments, why firms making similar levels of research and development investments develop widely dissimilar innovation capabilities, and why firms that cease making investments in certain research and development resources continue to enjoy fruits from knowledge-based capabilities for many years. The strategic management literature suggests one key may lie in improving understanding of the relationship between research and development resource flows and knowledge-related resource stocks (Dierickx & Cool, 1989).

Further, as Levitt and March (1988), Senge (1990) and others have suggested, building and maintaining "learning organizations" may be a key to understanding the development of those key knowledge based resources that lead to competitive advantage. If this logic is to be developed, we must first clearly define knowledge, learning, and other related terms. As Boisot stated, "(t)he terms 'knowledge', 'information', and 'data'. . .tend to be used interchangeably. . . Failure to clarify the terms used sometimes leads to some pretty loose thinking. . ." (1995; p. 450).

<u>Knowledge.</u> Knowledge, within any given domain, consists of both <u>data</u> and the <u>relationships</u> abstracted from data and used for decision making. A piece of data, at the most fundamental level, is defined as "a discernible difference in the energy states of phenomena as they occur and propagate in

space-time, whether as matter or electromagnetically" (Boisot, 1995, p. 22). Data exist, then, when variance in the environment stimulate our sensory apparati. The signals received by the brain from the sensory organs, called perceptions, are attended to, recognized, encoded, and stored in memory.

This conceptualization of knowledge is consistent with Newell and Simon (1972), who found that individuals store bits of information (analogous to data herein) and subroutines (similar to linked pieces of data herein) in memory and then recall and organize these in response to stimuli in the environment for use in decision making. This is also consistent with Fiegenbaum's (1970) theory of perception and memory at the individual level, and also with the action theories of Argyris (1976) and Argyris and Schön (1978) at the organizational level.

According to theory that addresses knowledge development, there are three types of knowledge: declarative, structural, or procedural (Jonassen, et al., 1993). Declarative knowledge is the recollection of stored facts, or data labels (Anderson, 1982). However, declarative knowledge may be tacit (Polanyi, 1966). For example, declarative knowledge would be recalling the atomic weight of the element molybdenum, or recalling the average salary of tenured organizational behavior faculty at Big 10 universities. Procedural knowledge is knowing how to do something (Anderson, 1982; Anderson & Fincham, 1994). For example, procedural knowledge would include analyzing a sample of the element molybdenum in a mass spectrograph for purity, or using the World Wide Web to locate the average salary of tenured Organizational Behavior faculty at Big 10 universities is located using the World Wide Web.

Structural Knowledge. Structural knowledge is the type of knowledge that recollects relationships among data (Jonassen, et al., 1993). Structural knowledge can be either causal or categorical. Causal knowledge is reflected in simply understanding the impact of a on b. Categorical knowledge entails placing a in group of similar facts or concepts, and linking it to being dissimilar to other groups of related facts (Jonassen, et al; 1992). Regardless of the causal/categorical distinction, this type of knowledge consists of related data that are interconnected, or linked, and organized in such a way as to provide explanatory power. For example, structural knowledge is the recollection of the expected reaction when the element molybdenum is combined with hydrogen gas under pressure. This knowledge is driven by recalling specific data about 1) the molecular structure of molybdenum, 2) the molecular structure of hydrogen, 3) how the two elements would combine, and 4) the impact of pressure on this combination. The data must be organized so that causal relationships are clear and can be applied to decision making and action. In this case, the expert chemist would know that the resulting combination would result in explosion and would not carry out the experiment.

In the other example, structural knowledge about average tenured faculty salaries would include the relationship, or comparison among, several pieces of data: 1) the average Big 10 salary, 2) the Michigan State University (MSU) average salary, and 3) knowledge about faculty research productivity at other Big 10 schools. The comparison among 1) and 2) would lead to the addition of data 3) and the "why" component of the knowledge. In this simple example, these pieces of data would be organized and linked to determine that MSU's average salary is higher than most Big 10 schools because our faculty is more productive. It should be evident that all three types of knowledge: declarative, procedural, and structural are important; however, structural knowledge binds declarative and procedural knowledge together and is important for the development of knowledge related capabilities in organizations.

Cognitive Structures and Mental Models. The information processing approach used by cognitive psychologists has been extended and developed into a theory of cognitive structures. This theory that has rapidly entered into the organization sciences literature (Klimoski & Mohammed, 1994; Walsh, 1995). The term cognitive structure is defined as "the organization of the relationships of concepts in long-term memory (Shavelson, 1972, pp. 226-227). It is similar to the terms "knowledge structure" (Neisser, 1976) and "mental model" (Johnson-Laird, 1983; Klimoski and Mohammed, 1994; Rouse & Morris, 1986) that have appeared in the managerial literature (Walsh, 1995). The cognitive structures represent data and the relationships among those data; thus providing an important explanation for how and why information or data becomes knowledge or expertise (Klimoski & Mohammed, 1994). Cognitive structures provide a measurable construct that identifies expertise and learning, and is capable of addressing the rate and level of change in knowledge over time.

It is relatively straightforward to apply the concept of cognitive structures to the concepts of learning and knowledge development. Importantly, the notion of cognitive structure provides an ex1planation for organizational learning that is relevant at both the individual and organizational levels (Klimoski & Mohammed, 1994; Walsh, 1995) and provides justification for the development of expertise that is, on one hand, difficult to imitate, yet on the other hand, transferable across time and space.

Defining Learning Using Cognitive Structures. One way to conceptualize learning is through this idea of the cognitive structure. Learning is defined as change in the cognitive structure, or in other words, changes in both the amount of data, and/or the relationships among those data (Jonassen, et al., 1993). Learning a new piece of data adds to the network and also enhances the knowledge structure in a much more powerful way. That is, each new piece of data builds increased relationships among several other discrete pieces of data by providing the individual or organization with increased understanding about those facts in relation to the newly learned bit of data.

At the most fundamental level, simple declarative knowledge is applied recalling the stored labels that represent data. But in organizations, more complex associative and causal forms of knowledge are invoked to make inferences and decisions. From this, reasoning and problem solving processes can occur. The data (or more precisely, the stored labels that represent data) are not necessarily important in and of themselves to an organization, but they are critical in that these data are building blocks for more complex and commercially important relationships and associations. The amount of data stored or known is important because it determines the amount of commercially relevant and complex knowledge that can be used in the competitive arena.

The Geometric Nature of the Learning Process

When looked at as a whole, the literature on cognitive structures suggests that the relationship between the number of discrete pieces of data stored and the number of relationships among those data (structural knowledge) is curvilinear. The more an organization knows, the more an organization benefits from each additional piece of data learned. For each piece of data added to the knowledge structure, multiple relationships among data become known or further elaborated and enriching existing relationships.

Knowledge grows through learning in a curvilinear manner -- the more data known, the greater the knowledge gained from new data. Put another way, learning is characterized by knowledge that is increased at the most basic level in a linear manner by simply adding one piece of data to an existing cognitive structure. However, a more realistic understanding consistent with recent advances in cognitive psychology, recognizes that knowledge grows in a nonlinear fashion. When a new piece of data is retained, the learner stores it in the brain, and during this process, relates this new piece of data to other previously known data. As a result, the learner now knows about the individual piece of data, but also knows more about other related pieces of data and the relationships among them. Thus one new piece of data adds to the knowledge based, but also increases the knowledge about existing data, as those relationships become known more fully.

The table and graphs below look at three situations. The far right column in Table 4, represented on Figure 1 by the top (dark solid) line, represents the relationship between the addition of individual data points and the resulting number of direct relationships by which the knowledge structure is increased. This assumes that one additional piece of data is linked to all other pieces of data in that particular knowledge domain.

However, this assumption may not always hold. For a variety of reasons, there may not be relationships among all data in a given domain. The middle and left columns, and the middle (diamond-marked) and lowest (dotted) lines in Figure 1 show the relationship between an additional piece of data and the size of the knowledge structure under two additional conditions. Each line shows knowledge structure growth under conditions where 75% and 50% of data are 'linked' or associated in some way with the existing fact base in the domain area. It is important to note that these relationships only consider direct links among data, and do not include indirect links. Thus, the number of relationships generated from additional data is probably quite conservative.

Learning and Innovation: An Organizational Perspective

The nature of, and relationship between, the constructs of learning and innovation have been widely addressed (Cohen & Levinthal, 1990; Cyert & March, 1963; David, 1985; Nelson & Winter, 1982; Simon, 1976) in the management and economics literatures. Learning has been described as cumulative (Hedberg, 1981), and includes processes such as perception, attention, selection, memory storage, retrieval, reasoning, and problem solving (Ashcraft, 1989). The relationship between individual and organizational learning is posited to be dynamic. "Organizations do not have brains, but they have cognitive systems and memories" (Hedberg, 1981; p. 6), including customs, values, standard operating procedures, policies, and myths. Organizations can leverage individual learning by facilitating the development of accurate mental models or cognitive structures, by decreasing the cognitive effort involved in ramping up to master new tasks, and by providing "shortcuts" that foster continued success. This can be facilitated through training or mentoring. Hedberg (1981) emphasized that organizational learning is not merely the accumulation of individual learning. Thus, despite the fact that organizations generally "know" less than the sum of the individuals that make up the organization (Hedberg, 1981), two important points can be deduced. First, individual learning can act as a "multiplier", as one person's individual learning or expertise is rapidly transferred through organizational routines and other structures to a large number of other employees. Second, new structures that enhance organizational learning (such as new forms of "organizational memory" or new pathways to disseminate stored organizational knowledge) can rapidly enhance or "multiply" knowledge at both the individual and organizational levels. These two points underscore the importance of learning in the organization, and

Table 4

Linkages Between Data and Relationships

Number of discrete data bits	Number of relationships (50% relatedness)	Number of relationships (75% relatedness)	Number of relationships (100% relatedness)
1	0	0	0
2	1	1	1
3	1	2	3
4	3	4	6
5	5	7	10
6	7	10	15
7	10	14	21
8	14	21	28
9	18	24	36
10	22	33	45

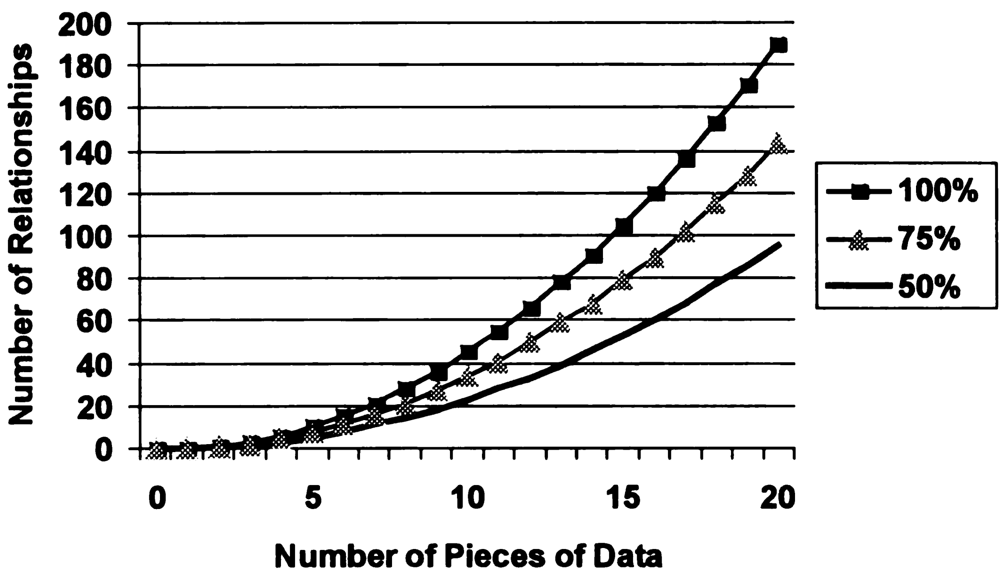

Figure 1. Influence of Additional Data Pieces on Knowledge Structure

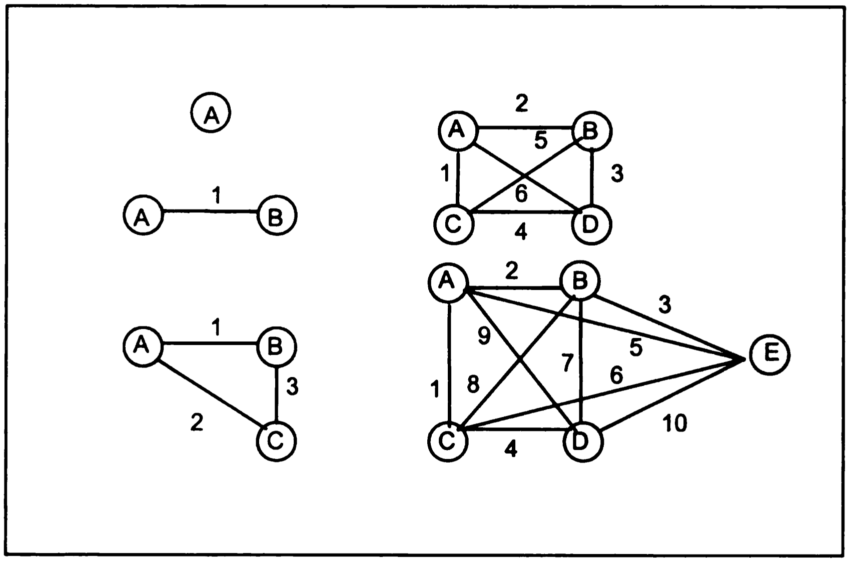

Figure 2. Linkages Among Data -- Building Knowledge

highlight the potentially powerful relationship that may exist underneath the visible resources that the organization controls.

However, questions remain: How does learning relate to resource flows and stocks? How does learning relate to firm performance? One way to address this issue was broadly discussed by March (1991), who examined the link between organizational learning and competitive advantage. March framed the issue as a dilemma between "exploiting the known" and "exploring the new". Firms generally have some ability to "explore the new", but they have continually improve the ability to innovate in order to build competitive advantage. This process was further delineated by the idea of absorptive capacity introduced by Cohen and Levinthal (1990).

Absorptive Capacity. Absorptive capacity is the ability of organization to recognize, assimilate, and apply outside knowledge to internal innovative processes (Cohen & Levinthal, 1990). Important factors in the development of absorptive capacity include internalization, routinization, and cumulativeness. Thus, "(t)o the extent that an organization develops a broad and active network of internal and external relationships, individuals' awareness of others' capabilities and knowledge will be strengthened. As a result, individual absorptive capacities are leveraged all the more, and the organization's absorptive capacity is strengthened" (Cohen & Levinthal, 1990; 134).

Absorptive capacity is, in essence, the organizational capacity to learn. Given that data exist in the environment, then organizations must develop the capacity to notice, attend, encode, and store these data. Usually these data are ‘sensed’ (noticed, attended, and encoded) by its members, although increasingly, computer power is driving automation of these tasks. Organizational structures serve as memory, including databases, policies, and myth (Hedberg, 1981). The organization of data within these structures, and the ability to infer categories and causation from these data by the individuals in the organization complete the development of knowledge structures within an organization. Thus, the greater an organization’s absorptive capacity, the greater the likelihood it can build structures that result in the development of knowledge.

Absorptive capacity creates learning, or knowledge growth, by building mechanisms for individuals to sense, notice, and encode data or changes in the environment. Traditionally, knowledge is thought to be built in firms by storing data within the organizational structure in computer databases, manuals, or within individuals (March & Simon, 1993). Relationships among those data are made as access to data within the organization is shared and organized such that categorical and causal links are elucidated. Over time, these structures (the data and the relationship among the data) change, and this is the point when learning occurs. Structural change implies that knowledge is created and is ready to apply in the competitive environment. The context-specific knowledge developed can, as Prahalad and Hamel (1990) argued, create competitive advantage.

The development of absorptive capacity is the result of resources invested in the organization, by the organization. The firm invests in R&D

related infrastructure to facilitate the collection and storage of data. Employees create relationships with others both within and outside the organization and share information, both adding data and building relationships among data. Examples include purchasing computer hardware and database software, creating and supporting cross functional teams, building a culture where employees are encouraged to interact with peers through publication and joint research, or by developing joint ventures and technology sharing alliances. All of these increase the amount of data available for learning and improve the likelihood that relationships among those data can be understood.

As Cohen and Levinthal (1990) stated, absorptive capacity is largely a function of an organization's prior level of knowledge. This is because awareness of new knowledge is dependent to a great extent on having some level of existing knowledge, so that important information can be recognized as important. Additionally, new knowledge is often built onto existing knowledge. In this manner, a new piece of information can be compared and contrasted to a wider base of initial knowledge, providing a greater probability that the new information can be used in a productive manner. As such, a reinforcing relationship exists between existing capacity in a knowledge-based activity and the future potential for knowledge-based activity, the impact of which was described by Cohen and Levinthal as, "dynamically self-reinforcing behavior" (1990: p. 138). As the capacity to absorb data (learning) increases, the amount of data absorbed increases, and vice-versa. As these data are stored, organized and used, the organization increases its ability to further absorb or learn from the environment, up to limits based on size and structure of the organization.

An example of the learning process is evident in the time required to fully utilize resources such as computers or buildings. Employees must learn how to use and integrate the new resource into work routines. This is consistent with arguments advanced by Arrow (1962), who found empirical support for his hypothesis that technical change is derived from learning over time.

Current research is starting to reflect greater understanding of the impact of learning on innovation. The essential nature of the accumulation of knowledge was discussed by Helfat (1994). She posited, from an evolutionary perspective, that tacit knowledge and the accumulation of learning would combine to cause persistent interfirm differences in patterns, or trajectories, of research and development expenditures. Helfat used evolutionary theory to support her argument that research and development expenditures were path dependent, and that persistent differences exist among firms that compete in a single industry. Helfat's data supported these two broad hypotheses, implying that there are persistent differences in research and development expenditures.

While Helfat (1994) made an interesting and important set of arguments, a gap in the literature exists. Helfat implied, but did not address the issues of organizational learning and its impact on relationships between R&D flows or expenditures, which she studied. In fact, in her conclusions, Helfat stated:

> It would be helpful to analyze the joint evolution of bundles of activities within the firm. For example, this study tested for the importance to R&D activity of ties to related firm-level assets and

investment. While the investment and asset variables were jointly significant, in most of the regressions the variables had relatively low coefficient estimates (even when standardized). Path dependence in R&D does not preclude ties of R&D to related firm resources, or the joint evolution of R&D and other firm resources. As a first step, the analysis performed here could incorporate longer term lags of both R&D expenditures and of related investment and assets to examine the persistence for all three variables over time. It also might help to separate the analysis of investment and assets from that of lagged R&D.

In summary, the persistent differences in petroleum firms' R&D activities documented here suggest that the associated knowledge bases change only slowly (Helfat, 1994, p. 1745).

Thus, from a research and development standpoint, absorptive capacity appears to be an important property, driven by organizational learning, that firms use to facilitate innovation. Firms use absorptive capacity to maintain existing knowledge resources and to build new knowledge (learning). Through these two processes, firms in knowledge-intensive industries can develop the building blocks of competitive advantage. Helfat's (1994) findings reinforced the assertion that the process by which capabilities create innovations is an important aspect in examining how firm capabilities or resource stocks develop. However, another important issue, similar to the issue raised by Collis (1994), is the issue of potential limitations on the development of knowledge-based capabilities.

Potential Limits on the Development of Knowledge-Based Capabilities

Research in the strategic management literature suggests that there are potential limits on the development of knowledge-based capabilities associated with increasing organizational size. Graves and Langowitz (1993) examined a sample of sixteen U.S. pharmaceutical firms during the period 1969 through 1987 and concluded that there are decreasing returns to scale from large amounts of investment in research and development. They argued that "bigness" creates inefficiencies that create limits to innovation.

These limits are likely driven by organizational constraints on individual learning. If an individual cannot attend to or process new information, that information has no way of integrating with existing knowledge structures and thus learning, or knowledge growth, is stunted. Put simply, the benefits of learning occur to an organization because individuals are able to access and use information developed by others as well as their own individual contributions. Organizations become shared repositories of mutual experiences. Structures such as policies, training, and myths provide the capacity for individual learning to become stored and allow others access to it across time and space. As these structures become filled with information, individuals become less able to access and use it. The amount of information stored by the organization continues to grow, but often the individuals that work within the organization become unable to use all of it, either because of a breadth or depth of data that is overwhelming to individuals. This limiting function is evident in that, as explained earlier, knowledge grows exponentially, while the number of new employees usually grows at a much slower rate. Thus, as the knowledge base becomes increasingly broad and deep, people are unable to take advantage of organizational learning because of interdependencies and complexities in both the information itself and the structures within the organization that contain the information.

Another approach to understanding the limits to growth can be found in the work of Paul Romer. Romer's idea that rival and excludable goods create limits on the sharing and use of knowledge and ideas. A rival good can only be used by one person at a time. Excludability means that the owner can prevent others from using her or his good. The catch here is that ideas that are non-rival (i.e. a piece of software or a procedure to duplicate biological material) and many that are non-excludable (no enforceable patent rights or no physical ownership) can lead to exponential growth. However, as goods or ideas become rival or excludable, limits to growth can occur (Nelson & Romer, 1996; Romer, 1990). The likely existence of limitations to innovative capabilities suggests that the relationship between research and development resource flows and knowledge-based capabilities maps out as a cubic, or S-shaped function.

Summary

Three relevant and important theoretical issues have emerged from integrating the resource-based view of the firm and the organizational learning literature. First, resource-based theory has evolved to recognize that stocks of knowledge-based resources are becoming increasingly important drivers of firm performance in many industries. Second, the organizational learning literature suggests that these resource stocks may take the form of capabilities that allow organizations the capacity to store, develop, and utilize knowledge, despite the lack of existence of a "brain" or living cognitive organism. Third, and most importantly, the building blocks for these organizational-level capabilities include both individual and organizational knowledge structures, which are dynamic and interdependent. Furthermore, these structures are related geometrically, and this idea plays an important role in the dynamic nature of organizational capabilities.

Thus, the literature review suggests that organizational learning may play an important, and as of yet unexplored, role as a keystone in improving specification and measurement of resource based theory. In essence, organizational learning may be the linking pin in the relationship between resource flows and resource stocks and thus is very important in determining the development of capabilities that firms use to develop sustained competitive advantage. Many questions exist, including what are the timing issues around these processes? What are the accelerating or decelerating factors in these processes? How do these resource flows turn into stocks or capabilities and what is the precise impact of this process on performance? In an effort to address these questions, the next section builds a theoretical model and develops the hypotheses.

PROCESS MODEL AND HYPOTHESES

The preceding literature review suggests three important points. First, sustainable interfirm performance differences stem from organizational capabilities, or stocks, which are organized collections of associated resources owned or controlled by the firm (Aharoni, 1993; Dierickx & Cool, 1989; Prahalad & Hamel, 1990). Next, a developing theoretical stream suggests that interfirm differences in the development of organizational capabilities are often knowledge-related (Conner & Prahalad, 1996; Grant, 1996; Spender, 1996), especially in the growing number of industries involved with technology and/or information processing. Finally, differences in knowledge-related capabilities can and should be examined by studying the relationship between the flows of research and development resources into an organization and the resulting knowledge-based capability stocks (Dierickx & Cool, 1989). Specifically, capabilities based on the geometric nature of the development of mental models or cognitive structures may be a fruitful way to examine capability development in knowledge-intensive industries such as the pharmaceutical industry.

These three points suggest the following research question: given that it is increasingly important that firms in many industries develop capabilities to develop knowledge and apply that knowledge in the generation of new products and services, how do knowledge-based capabilities develop? In an effort to answer this question, a process model and related hypotheses are developed in the next sections.

The following discussion outlines a process model that, based on an integration of the cognitive psychology, sociology, organizational theory, and strategic management literatures, suggests an innovative explanation for the knowledge accumulation process in organizations. For the sake of clarity, the model is examined in steps, one relationship at a time. Step one addresses the core of the model, the relationship between research and development resource flows and knowledge-related resource stocks. In step two, a moderator variable, the consistency of resource flows, is introduced. In the third and final step, critical firm performance outcomes are integrated into the model.

Step One – Flows and Stocks

The core relationship in this process model is that between research and development resource flows and knowledge-related resource stocks. Resource flows, including money, equipment, and information, are accumulated by the firm with the expectation that these resources will be transformed into capabilities, which are in turn used to convert raw materials into outputs. In the case of the pharmaceutical industry, one form of resource flows is expenditures into ongoing research; that is, money needed to run laboratories and pay researchers. The managers and owners of pharmaceutical firms want these investment flows to develop into the capability to continuously bring patented compounds into the marketplace, providing large, long-lasting profit streams. Non-financial resource flows, especially flows of information, are also posited to directly affect resource stocks or capabilities. This core aspect of the model is displayed in Figure 3, and drives the first hypothesis.

The first hypothesis examines the relationship between the size of the research and development resource flows, and the stock of research and development capabilities. This relationship is hypothesized to be curvilinear, as depicted in Figure 3. That is, increases in research and development resource expenditures impact the development of knowledge-related capabilities in at least two distinct phases. First, increasing returns to resource investments are expected to provide modest increases in research and development capabilities. This modest effect is a result of firms slowly building knowledge about a given domain area. In this learning stage, people in the organization build expertise about the product or service itself, as well as find colleagues, exchange information, take advantage of organizational repositories of knowledge, and build or specialize the infrastructure required to support innovation. This is the point at which knowledge flows, or data, are absorbed into the system relatively slowly, and organizational knowledge structures become enriched with data.

The second phase of the relationship is marked by large increases in the knowledge base derived from any additional research and development flows. Individual and organizational learning increase rapidly at this stage, as the increased abilities of firms to absorb and develop innovation from within and outside of the firm's boundaries greatly improves the transformation of research and development expenditures into research and development capabilities. This phase reflects organizational learning and is driven by processes similar to those discussed in the literature on learning curves. Learning curves are based on the notion that organizational learning drives a curvilinear decrease in unit costs relative to the number of units produced (Gruber, 1994; Spence, 1981; Zimmerman, 1982). Levitt & March describe this same effect and call it a "competency multiplier" (1988, p. 332).

High rates of resource flow to stock transformation may be further increased by the development of a direction or as Sahal (1985) labeled it, the "avenue" of innovation, where greater focus, along with organizational and individual commitment to the innovation, greatly speed the transformation of resource flows to resource stocks. Consequently, the relationships among data are used by members of the organization, resulting in knowledge generation, or innovation. This is where the non-linearity discussed earlier comes into play. Specifically, each piece of information has the potential to impact multiple other pieces of information. In effect, a web of relationships can be created from one additional piece of information, driving the aforementioned nonlinear relationship between flows (of information for example) and knowledge-related capabilities.

Finally, a third phase of the relationship between flows and stocks may include a decrease in the rate of flow to stock transformation. This decrease may result from the inability of organizations to adequately manage large flows of resource inputs, which would cause a ceiling effect on the transformative

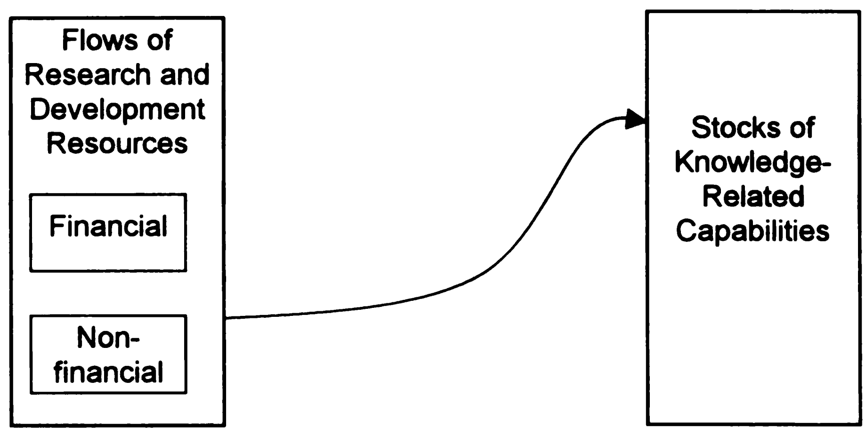

Figure 3. A Process Model of Knowledge Development in Organizations - Step One

process (Garud & Nayyar, 1995). This could be caused by problems organizations develop in learning during conditions of rapid change or uncertainty.

For example, a new compound is developed in the R&D labs of a major pharmaceutical firm. At first, the compound shows promise but little is known about the compound's long term effects and its potential interactions with other compounds. Little knowledge is generated relative to the inputs of money and efforts. Over time, more is learned about the new compound, including alternative uses, potentially beneficial and harmful side effects, and long term impacts that were previously unknown. This information is shared with other development groups within the firm, who contribute to the speed of development and find new areas to apply new knowledge generated by the initial innovation. Here, the knowledge base is increasing rapidly through this flurry of knowledge development. At some point, the speed of the transformation process may be limited by constraints such as information overload or information technology shortcomings. In this example, the curvilinear relationship between flows and stocks would best describe the long-term pattern of capability development.

Other support for a curvilinear relationship comes from revisiting and integrating pharmaceutical industry research and economics research. Schwartzman (1975) reported that, in pharmaceutical research, the expected rate of return from investment in 1960 ranged from 11.4 to 18.4 percent. While this is interesting, it falls short of explaining why some firms outperform others.

Most firms see positive, double digit rates of return on R&D investment, but there is significant firm-level variation that is left unexplained by the simple linear models created by Clarkson (1977) and Schwartzman (1975).

Capon, Farley, and Hoenig (1990) reported results of their meta-analysis of the literature linking a variety of organizational and industry factors. Across studies, research and development explained 10.7% of the variance in financial performance, which was statistically significant at $p<.01$. Pakes and Griliches (1984) reported that the form of the relationship between research and development expenditures and patents was "the logarithm of patents as a function of time, current and five consecutive lagged values of the logarithm of R & D expenditures, and (correlated) firm-specific constant terms" (1984: p, 70). This may be because of a nonlinear relationship, and suggests that by positing curvilinearity, the estimates presented in the Capon, et al., (1990) meta-analysis may be significantly attenuated.

The first hypothesis examines the form of the relationship between research and development resource flows and research and development capabilities. The relationship is posited to be curvilinear, specifically either of a quadratic (or J-curve) or cubic (or S-curve) form.

> Hypothesis 1: The relationship between the size of the research and development resource flows and research and development capabilities will be curvilinear in knowledge-intensive firms, of either the form $Y = a+x + x^2$ or $Y=a + x + x^2 + x^3$

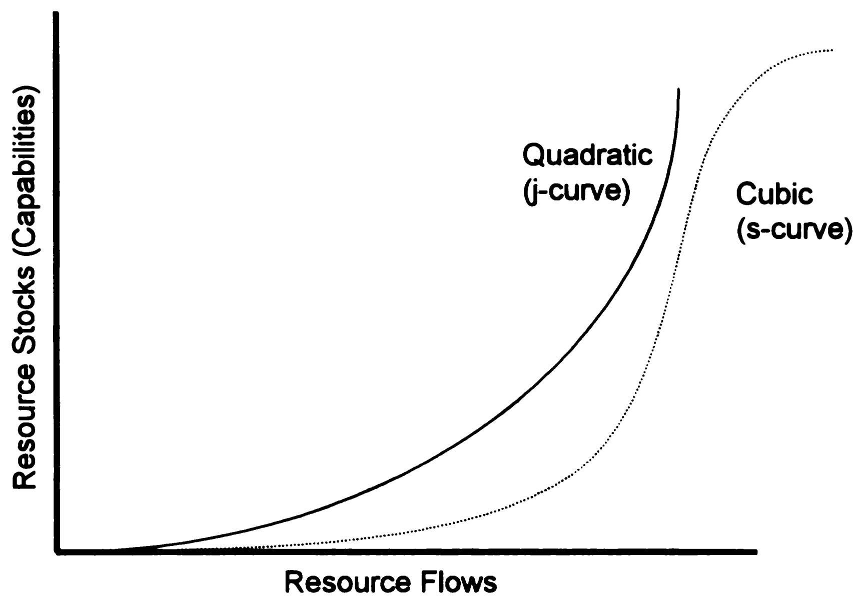

Figure 4. Hypothesized Relationships Between Resource Flows and Capability Stocks

Next, an important moderator variable, consistency, is introduced in an effort to refine the theoretical development of the model, and to improve its explanatory and predictive capability. Consistency is suggested to be a moderator that can enhance or constrain knowledge development. Consistency of resource flows is related to the important role of timing and feedback in learning.

Step Two -- Consistency

The relationship between research and development resource flows and research and development capabilities is hypothesized to be moderated by the consistency with which the organization has directed research and development resource flows into the firm. Consistency means low deviation over time, or a lack of "time gaps" or temporal holes in investments. In general, consistency should moderate the relationship between inputs and outputs, as higher consistency results in a more effective conversion of inputs to outputs, or flows to stocks. Specifically, the logic underlying consistency is similar to that developed by Argyris and Schön (1978), Cyert and March (1963), Hedberg (1981), Senge (1992), and others who described simple and higher-order learning.

This idea is displayed in figure 5, which illustrates a primary relationship of actions leading to outcomes, a process that repeats regularly. The results of the outcome are used to guide future decisions, as learning takes place (Cyert & March, 1963). Some firms build structures, and over time, gather and use the feedback to impact action in the next cycle (Hedberg, 1981). These firms minimize errors based on past performance while firms that do not utilize feedback make avoidable mistakes or worse, change future actions without understanding cause-effect relationships from previous iterations, confounding the ability of employees to make sense of data from previous actions (Hedberg, 1981). Pressures for speed can thus cause arbitrary or ill-informed decisions (Cyert & March, 1963).

Consistency in the process of building knowledge is important because of the role of feedback and adjustment. That is, after every action in an organization, there is an outcome, often after a delay. This outcome generates feedback that must be returned to the originator of the action, processed and then integrated into knowledge, where it can be reapplied. This is a basic learning process and helps explain how firms build expertise (Hedberg, 1981; Simon, 1991).

Consistency over time is also important in building research and development capabilities because of the role of practice. Both individuals and organizations need time to practice in order to refine procedures and capabilities for implementing knowledge -- or in other words, learning by doing (Levitt & March, 1988). This can also be viewed as learning from failure. Individuals and their organizations learn through trial-and-error. Innovative effort then results from practice, or "doing", but under the condition that feedback can be obtained (Levitt & March, 1988). Practice allows the construction of a feedback loop, or cybernetic system, to improve knowledge about phenomena. As discussed above, if the feedback is not incorporated into future iterations, learning becomes more difficult. As Levitt & March concluded, "learning procedures will become common when they lead to favorable outcomes and that organizations will become effective at learning when they use learning routines frequently" (1988, p. 332).

Organizations streamline knowledge structures by creating "avenues" or "pathways" for knowledge collection from internal and external sources, structures or storehouses for this knowledge, and pathways for knowledge to be accessed by organizational members (Sahal, 1985). These pathways can include information technology, interpersonal networks, or policies (Hedberg,1981). All three of the structural elements (collection, storage, and access) can be lost if not maintained or used. Moreover, these processes require consistent activity to collect, organize, prioritize, and absorb data effectively. "Forgetting" or decay can occur readily at the organizational level if key resources leave, databases become outdated, or communication networks are severed (Hedberg, 1981).

The second hypothesis suggests that research and development capabilities cannot be built in a short amount of time by making huge, one-time investments, or by intermittent investment in the development of knowledge. This assertion was supported by an empirical study by Harrison, Hall, and Nargundkar (1993), who found a weak but significant positive relationship between consistency in research and development investments and return on assets using a sample of 96 firms across a variety of industries. Their results suggest that consistency may indeed be an important factor in determining firm performance. However, from the logic developed above, consistency is hypothesized to impact performance not as a main effect, but as a moderating variable in the relationship between flows and stocks.

Hypothesis 2 posits the moderating influence of the consistency of resource flow investments on knowledge-related capabilities (see Figures 6 and 7). A lower intra-organizational standard deviation of research and development flows over time can be interpreted as meaning that firms do not greatly alter the level of R&D flow investments. As noted in the previous section, consistency is important for learning or knowledge-development because under situations of consistent investment, researchers have the opportunity to use feedback to improve the accuracy of the relationships among data. Swings in investment inhibit the construction of relationships among data as projects become abandoned in periods of low funding and flurries of new projects start in periods of high funding levels. The moderating impact of consistency is relevant to the relationship among research and development resource flows and research and development capabilities in that consistency increases the impact of flows on the development of capabilities and inconsistency decreases the impact of flows on the development of capabilities.

> Hypothesis 2: The interaction between the consistency of R&D resource flows and the size of R&D resource flows on R&D capabilities in knowledge-intensive firms will be significant.

Step 3 -- Linkages Between Stocks and Performance

The third and final component of the process model links capabilities, or stocks, and performance. The strategic management literature suggests that knowledge-related capabilities drive performance (Conner & Prahalad, 1996). The notion of core competencies (Prahalad & Hamel, 1990) suggests that areas of expertise within the firm can provide sustained performance advantages when applied in various product markets, and further, that these capabilities are difficult for rivals to imitate. Figure 6 depicts the complete process model.

The outcomes of knowledge-related capabilities generate economic rent (Peteraf, 1994) that can be used by the firm to reinvest in research and development resource flows, or can be banked in times of prosperity to ensure the firm's ability to make consistent investments in resource flows in leaner times. The implication here is that once an organization moves down the learning curve, knowledge builds rapidly and creates an asset that is difficult to imitate, thus creating economic rent and building a cornerstone of competitive advantage (Barney, 1986; Peteraf, 1994).

In general, many researchers have noted empirical results that suggest that research and development capabilities impact firm performance (see for example, Grabowski & Vernon, 1990; Helfat, 1997; Henderson & Cockburn, 1994). However, these data are generally input related, focusing only on research and development expenditures, and the researchers merely imply that research and development capabilities are the unmeasured intervening

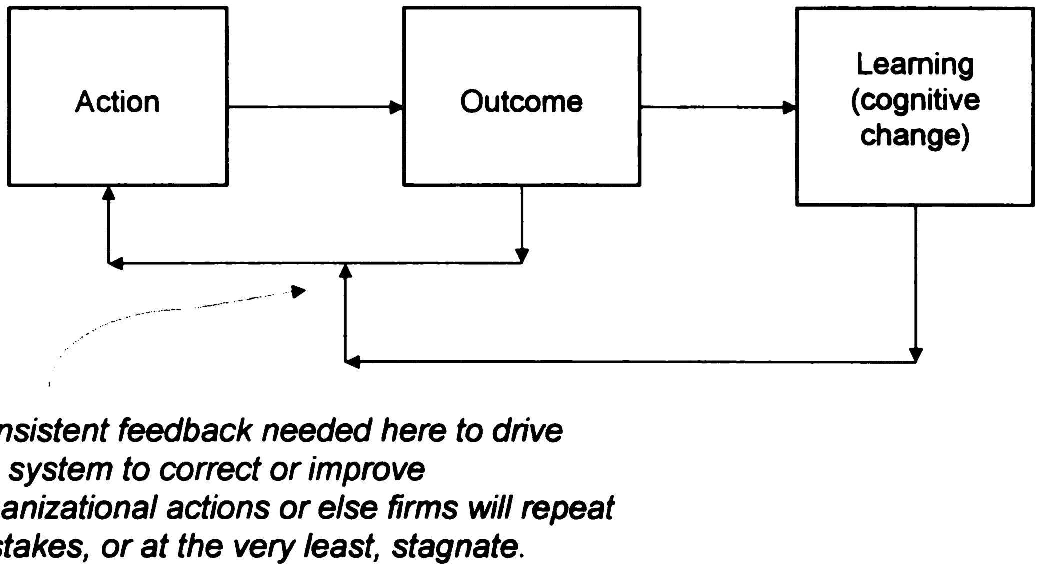

Figure 5. The Importance of Consistency in Learning

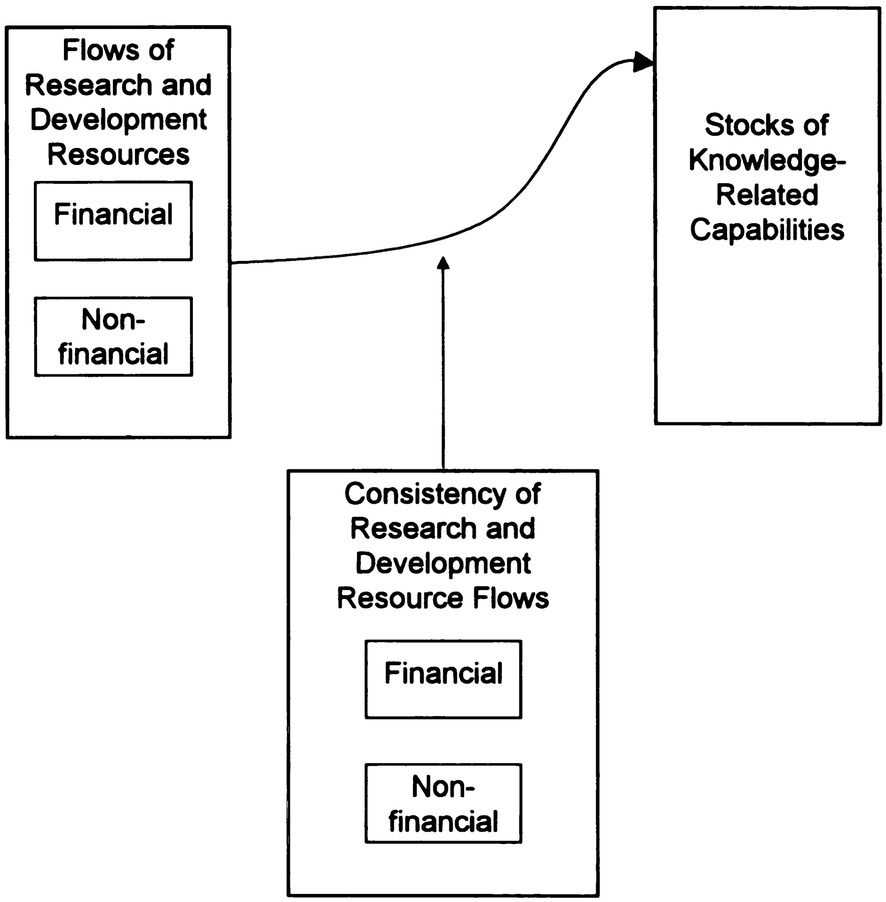

Figure 6. The Moderating Impact of the Consistency of Flows

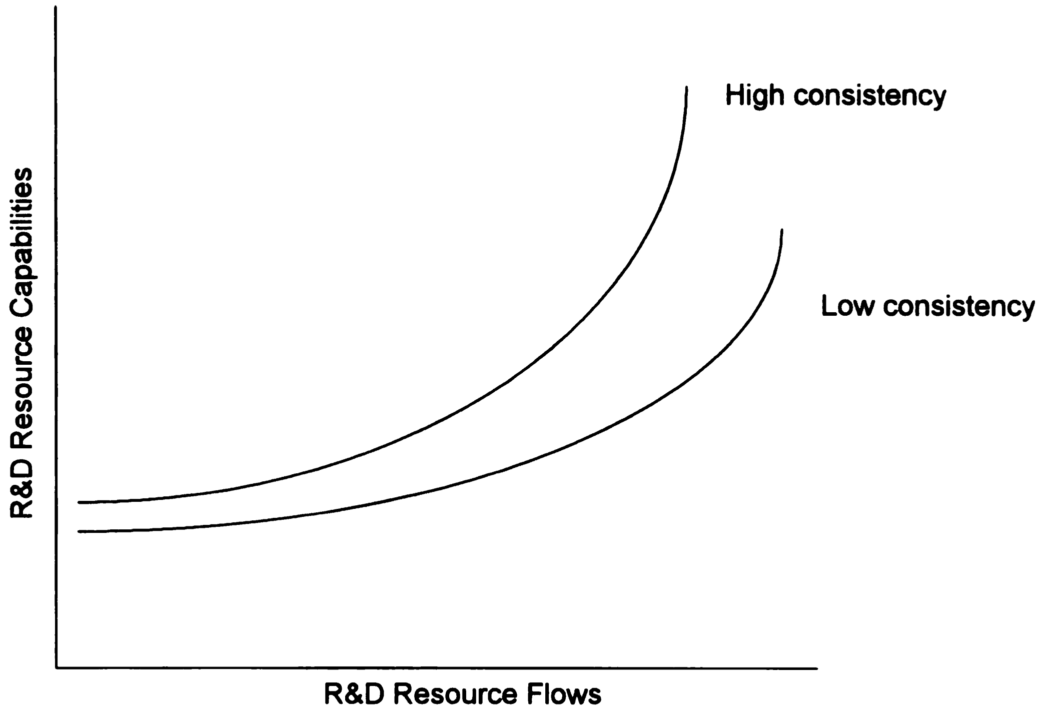

Figure 7. Hypothesized Moderated Relationship

variable. Hypothesis 3 broadly tests specific and often unmeasured linkage between research and development capabilities and performance in knowledge-intensive firms.

Hypothesis 3: Firm performance is positively related to research and development capabilities in knowledge-intensive firms.

<u>Step Four – The Full Model</u>

Hypothesis 4 addresses the full model, including research and development resource flows, the moderating impact of consistency, research and development capabilities, and firm financial performance. This model is depicted in Figure 8. The implication of Hypothesis 4 is that the curvilinear model relating flows and stocks is a better predictor of firm performance than a linear model. The logic driving this hypothesis is predicated by the fact that strategic management researchers have previously emphasized the relationship between research and development and performance in the pharmaceutical industry (Bogner, Thomas, & McGee, 1996; Cool & Schendel, 1988; Grabowski & Vernon, 1990; Henderson & Cockburn, 1994). Further, these studies have primarily examined linear relationships between inputs (research and development dollars) and outputs (measured by firm performance).

However, if the premise of the resource-based view is correct, the standard input-output model is not sufficient to fully capture either the interesting distinctions between firms on the input side of the equation or the sustained performance differences on the output side of the equation. This would be consistent with an important issue raised by Henderson and Cockburn (1994), who concluded that despite controlling for quantitative measures of firm size, scope, research program size, and intra- and inter-firm spillovers in their econometric model, they "still found surprisingly large and persistent heterogeneities among firms in their research performance" (p. 69). Henderson and Cockburn's response to this issue was to "expand the set of explanatory variables" (p. 69).

Henderson and Cockburn concluded that "(o)ur results provide considerable support for the importance of 'competence' as a source of competitive advantage in research productivity. Idiosyncratic firm effects account for a very substantial fraction of the variance in research productivity across the firms in our sample" (1994, p. 77). However, Henderson and Cockburn used linear econometric models. This research extends the literature by using learning theory as a reason to hypothesize non-linear relationships between resource flows and resource stocks.

> Hypothesis 4: The variance explained in performance by the indirect effect of R&D flows on R&D capabilities (and through R&D capabilities, on performance) will be significantly greater when the curvilinear effect of lows on capabilities is included in the model.

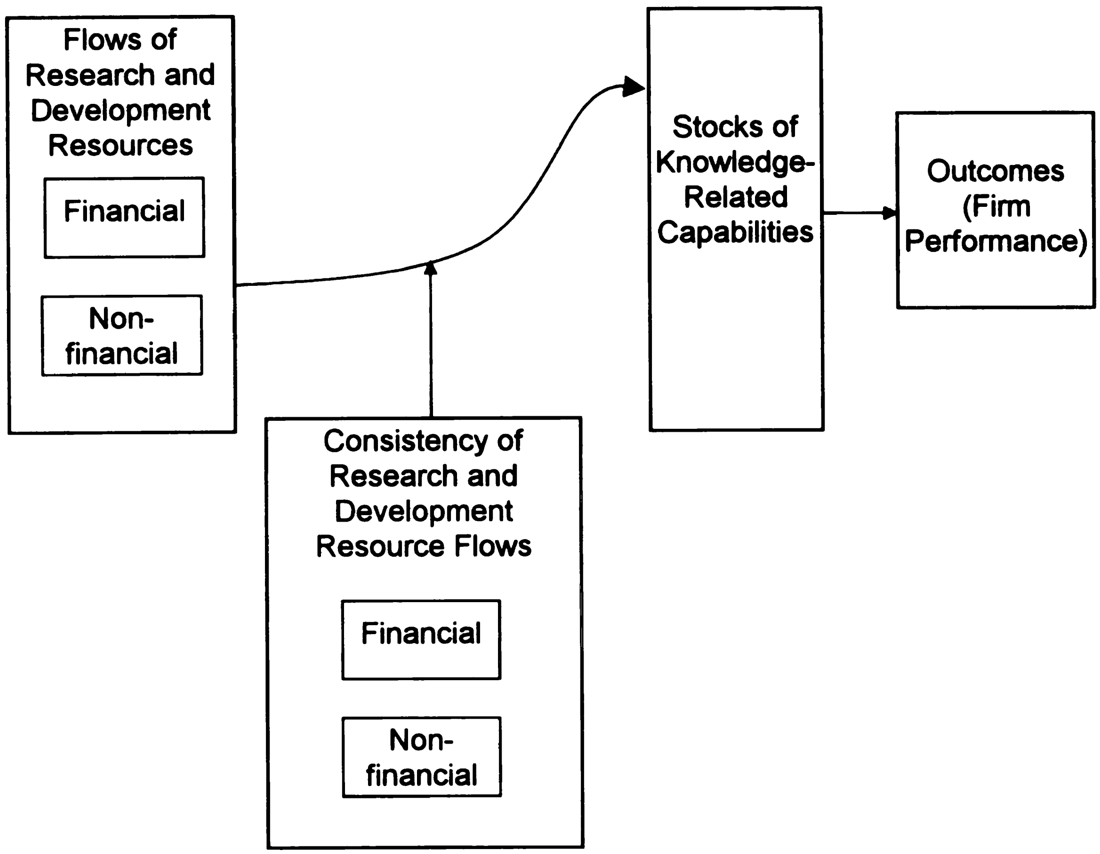

Figure 8. The Complete Process Model

Hypotheses 1-3 test each part of the model individually, in an effort to answer the question how do knowledge-based capabilities develop? The final hypothesis posits that, as a whole, the curvilinear model linking research and development expenditures and firm performance offers a) a clearer picture of the drivers of firm performance in knowledge-intensive industries, and b) addresses the relevance of a resource-based approach focusing on knowledge-based capabilities vis-à-vis the traditional linear model. The next section addresses research methodology.

RESEARCH METHODOLOGY

Population, Sample, and Time Frame

This study examined all 22 publicly traded firms that competed in the pharmaceutical industry during the period between 1978 and 1996 (see Table 5 below) and were either U.S.-based or reported in U.S. dollars using U.S. accounting procedures as a result of their financial structure. The 1978 start date was selected to balance data availability limitations with sample size concerns. This particular date, 1978, is a natural breakpoint in the industry, where changes in pricing, advertising, and substitution regulations created, to some degree, a level playing field (Bogner, Thomas, & McGee, 1996). The last year of the time frame, 1996, is the most recent year for which complete data are available. The fifteen year time period also helps address fluctuations in financial measures, which are frequently affected by accounting changes, one-time charges against earnings, and other financial activity which may not be representative of the underlying construct of performance.

The pharmaceutical industry was selected for several reasons. First, this population has been extensively studied in the strategic management literature (Bogner, Thomas, & McGee 1996; Cool & Schendel, 1988; Graves & Langowicz, 1993). There appears to be a consensus as to the nature of competition in the pharmaceutical industry, providing some signposts to guide the present research in sample, time frame, and variable selection (Bogner, Thomas, & McGee, 1996;

Table 5

<u>Companies Included in the Study</u>

Abbott Laboratories
American Home Products
Bausch and Lomb
Becton Dickenson
Bristol Myers Co.
Carter Wallace
Glaxo Holdings PLC
ICN Pharmaceuticals
Johnson & Johnson
Lilly (Eli) & Co.
Mallinkrodt
Merck & Co.
Monsanto
Pfizer
Rhone Poulenc Rorer
Schering-Plough
Searle, G. D.
SmithKline Beckman
Squibb Corp.
Syntex Corp.
Upjohn Co.
Warner-Lambert Co.

Cool & Schendel, 1989). Table 6 outlines a range of recent research that has examined the pharmaceutical industry.

Second, there is evidence that the pharmaceutical industry environment has been fairly stable and that particular points in time, including the 1978 datewithin this sample, can be clearly identified as break points in industry continuity (Bogner, Thomas, & McGee, 1996; Cool & Schendel, 1988). Environmental consistency is an important aspect of selecting the population in any resource-based study, especially in light of findings presented by Miller and Shamsie (1996) that suggested environment does play a significant role in the development of resources. Thus, for the purposes of this study, the examination of firms under a single set of industry conditions limits one potentially large source of error variance.

Finally, the characteristics of this industry make several specific resources especially important, especially given the fact that large components of the value of pharmaceutical firms consists of information and expertise. Research and development expenditures are widely recognized as important drivers of innovation and new product development (Bierly & Chakrabarti, 1996; Halliday, Drasdo, Lumley, & Walker, 1997). Innovation and new product development, central to pharmaceutical firm profits, are themselves important capabilities that are derived from information and expertise held by employees and organizations (Bierly & Chakrabarti, 1996). Thus, this population is appropriate for assessing issues surrounding knowledge-based resources, an area identified in the literature review as an important stream driving the development of resource-based theory.

Merged Firms. Four firms in the sample merged during the time frame under study. COMPUSTAT combines data for these firms into one for the years preceding the mergers. Bristol Myers and Squibb, as well as Monsanto and Searle, are restated into a combined firm for the years prior to their merger. This process is carried out consistent with generally accepted accounting practices. By following this practice, only two of the firms were dropped from the sample, for a total sample size of 20, but no data were lost, as the restated data for the single firm contains all the data from both firms.

Power. The present sample is broader and covers more years than almost all other studies that have studied the pharmaceutical industry (e.g. Bogner, et al, 1993; Gambaradella, 1992; Koenig, 1983; Pisano, 1994). However, statistical power is an area of concern. The sample size was limited by the number of firms in the industry and data availability. The second component of power to examine is estimated effect size. However, traditional estimates of effect size are questionable in repeated measure studies. Commonly, this is handled by assuming a small effect size, which creates low power.

However, Dunlap, Cortina, Vaslow, and Burke (1996) argued that in a within-subjects design, there is 'built-in' control for extraneous error variance, so moderate effect sizes can be used for power calculations. Given this, power calculations for a sample size of 20 for a .05 level of significance are in the .30-.34 range and go up to .39-.42 range using an alpha of .10. This research, where sample size is limited by the level of analysis (due to the limited number of firms) seems suited for such an adjustment. While this is still low, it is an improvement on other single industry, firm-level research that has appeared in the strategy literature. This is true both in the sense that the power issue is even addressed (Mone, Mueller, & Mauland, 1996) and that power is being improved over existing studies. Power is being improved by using a slightly larger sample size and by using a higher alpha, recognizing the issue of practical vs. statistical significance where in this case, the sample size is constrained by the number of firms that participate in this segment of knowledge-intensive firms. This limitation is described in light of the fact that in the strategic management literature, a high degree of statistical power is often difficult to achieve, since the focal unit of study is the firm, whereas in the behavioral sciences greater numbers of the unit of study, the individual or team, are available (Mone, Mueller, & Mauland, 1996).

Dependent Measures

The dependent variable in the first two hypotheses is the stock of research and development capabilities (a summary table of the methods and variables for all five hypotheses is presented in Table 7). This variable was operationalized by using the stock of patent-years possessed by each firm; more specifically, the total number of years of patent protection possessed by each firm. Patent data has been used as a proxy variable for research and

Table 6

Selected Studies Examining the Pharmaceutical Industry

Citation	Time-frame	Sample Size	Indep. Vars.	Dep. Vars.	Findings
Bogner, Thomas, & McGee (1996)	1969-1988	25 firms	R&D, market position,	Market entry, exit	Long term competitive posture is impacted by nature of firm resources
Cool and Dierickx (1993)	1963-1982	Not reported	profitability (ROS)	industry structure, rivalry	Declines in ROS are linked to rivalry, not structure
Gambardella (1992)	1973-1986	14 firms	publications R&D expendits.	patents	patents are positively related to scientific publications even after controlling for R&D expend.
Graves & Langowitz (1993)	1969-1987	187 obs. 16 firms	# of new chemical entities	Avg. R&D exp (6 & 3 yr avgs.), firm size, regulation	Returns to scale in R&D increase as R&D expenditures increase
Henderson and Cockburn (1994)	1975-1988	3120 obs., 10 firms	knowledge flow across firm and national boundaries, emphasis on publications	Patents	productivity drove firm effects, research portfolio variations were large, persistent, and impacted productivity
Koenig (1983)	1970-1974	24 firms	publications & citations, R&D expendits., expert judgment	Important thera-peutic gains	publications and citations are positively correlated with successful pharmaceutical research
Narin, Noma, & Perry (1987)	1975-1983	17 firms	publications & citations, expert judgment, financial performance	patents	strong positive relationship between patent data and technological strength, using expert opinions and citation freq.
Pisano (1994)	Cross-ectn'l analy.	11 firms 23 proj-ects	learning strategy, org structure, technical content	lead time	lab learning drives increasing lead times in traditional, chemical based research, but not in biotechnology

development capability in pharmaceutical industry research by many, including Helfat (1994, 1997), Henderson and Cockburn (1994), and Pakes and Griliches (1984).

Some have used simple patent counts as an output, but there are compelling reasons to support the use of the stock of patent years as a proxy for research and development capabilities. A recent stream of research has thoroughly examined the relationship between patent data, patent citations, scientific publication, and performance in the pharmaceutical industry in similar studies using different data and a variety of sources (Archibugi & Pianta, 1992; Gambardella, 1992; Narin, Noma, & Perry, 1987). These researchers consistently found that correlations among patents and a variety of performance measures were relatively stable across firms and over time. Nevertheless, patent citations and R&D expenditures are both imperfect indicators of firm performance (Capon, et al., 1990; Gambardella, 1992). However, patent data have been shown to correlate strongly with innovation capabilities in the pharmaceutical industry (Narin, et al, 1987) when the innovation capabilities are assessed using survey data collected from multiple sources.

The more recent work discussed above can be contrasted with a stream of economic work from the 1970s and 1980s led by Griliches and his colleagues, who studied the relationship between research and development and patents. Pakes and Griliches (1984) concluded that the relationship between research and development expenditures and patents was indeed curvilinear. Pakes and Griliches (1984) could not explain the curvilinearity clearly using existing economic theory. These conclusions suggest that there are significant opportunities to explain the curvilinear relationships using theory drawn from organizational learning and the resource based view. The resource-based view suggests that patents may represent a stock of knowledge resources that are applicable in the marketplace, and as such are most likely an antecedent of firm performance. The organizational learning literature suggests that there likely exists intermediate learning processes that impact the relationship between the flows of research and development resources and patents. Integrating the two theoretical approaches, it is apparent that patents represent an important variable that is both impacted by research and development resource flows, and impacts firm performance.

This view of patents as a linkage between resources flows and performance can be supported by carefully reviewing the large body of research addressing patents. Narin, et al., (1987) suggested that patent data is a reliable and valid source of data on pharmaceutical knowledge and learning. While patents are related to performance and are considered by some to be an output, there is evidence to suggest that patents, specifically the sum total of patent-years accrued to the firm, are more accurately a stock of potential performance. Viewed in this state, this stock of potential performance can be viewed in two ways. First, the stock is representative of the capability of the firm to develop, internalize, and formally obtain intellectual property rights to knowledge (Kerssens-Van Drongelen, de Weerd-Nederhof, & Fisscher, 1996). Second, the patent stock is a stable of accumulated knowledge that potentially can be applied in the marketplace with some associated performance outcome.

The key aspect is that patents have limited value if the knowledge represented by the patent is not applicable in the market. Patent counts do not and cannot accurately assess the market potential of an innovation. Often times "can't miss" blockbuster patents fail to succeed on the market (i.e. interferon) or are determined to be unsafe after reaching the market (i.e. Seldane), while little-heralded advances often are later realized to be breakthroughs (i.e. some of the drugs now being used as part of AIDS fighting "cocktails"). As such, a patent really has no value until it is applied in the marketplace, either by bringing the associated product to market, or by licensing or selling the patent itself to another company. In short, patents merely reflect a non-subjective assessment of new or unique, and thus patentable, information generated by the firm. It is neither relevant nor possible to assess the revenue generating potential of the patent. Patents are useful measures if the variable under study is simply an assessment of a firm's ability to generate new knowledge, which is the case in the present study.

The patent stock data was collected from the U.S. Patent Office CASSIS database at the U.S. Patent Office in Alexandria, VA. Each patent granted to a firm or an individual associated with that firm was coded and a measure of total patent life accrued to each firm was computed for each firm for each year in the sample. This was computed by subtracting the expiration year from the year under study. This process was repeated for each patent held and summed to create a stock of patent-years for each firm for each year of the study.

The dependent variable in hypotheses 3 and 4 is financial performance, measured two ways. The first measure, Return on Assets, was used following Geroski (1990), Mueller (1986), Russo and Fouts (1997), and Helfat (1994, 1997). These data were collected from the COMPUSTAT databases, augmented by audited company financial reports. The second measure, Tobin's q was also collected using data from the COMPUSTAT database and calculated following Chung and Pruitt (1994).

Independent Measures

Research and Development Flows. Two different types of research and development flows were examined; financial and non-financial. Financial resource flows were operationalized using research and development expenditures. This includes money spent on equipment, supplies, facilities, salaries and expenses of R&D staff. Research and development expenditures are reasonable proxy of research and development intensity and have been often used, especially in pharmaceutical industry research (Clarkson, 1977; Schwartzman, 1975). More recently, in the strategic management literature, Helfat (1994, 1997), and Bogner, Thomas, and McGee (1996) used R&D expenditures to measure R&D resources acquired by the firm.

Non-financial resource flows were examined in terms of interorganizational links. Interorganizational links create resource flows driven from structural links developed between specific domains of knowledge outside the firm. Interorganizational links are defined as the structural links that exist between an organization with human and informational resources outside the firm (Goes & Park, 1997). Firms that can successfully integrate multiple types of data from strategic partners can take advantage of the cross-fertilization of ideas as information from different sources is exchanged and processed. Interorganizational links provide both new information and can serve as a catalyst for existing data to be integrated in new ways. This improves understanding of causal and categorical relationships among data by members of the organization (Goes & Park, 1997).

These non-financial interorganizational linkages were operationalized in two forms. The first operationalization was corporate-level strategic partnering with other firms, following Goes and Park (1997), Colombo and Garrone (1996), Hagedoorn and Schakenraad (1994), and Joly and Mangematin (1996). This partnering was accomplished through strategic alliances, joint ventures, mergers, acquisitions, or licensing agreements. Following Goes and Park (1997), the number of external links made by an organization included the number of mergers, acquisitions, joint ventures, and strategic alliances made for each firm, each year in the sample. Goes and Park found that there was variation in patterns of resource and development flows, and that this variation was correlated with performance differences. These findings are consistent with the idea of building complementary knowledge (Teece, 1981) by developing opportunities for sanctioned exchange of information with other organizations.

Table 7

Hypotheses, Methods, and Variables

H	D.V.	D.V. Measures	I.V.	I.V. Measures	Test
1	R&D capability stocks	Patent life in years	Size of R&D resource flows	1. R&D expenditures 2. Number of intra-org. information links (citations). 3. Number of intra-org. structural links	Polynomial regression
2	R&D capability stocks	Patent life in years	Consistency of R&D resource flows	Variance of hyps 1, 2, and 3, above	Polynomial regression
3	Firm performance	Return on assets, Tobin's Q	R&D capability stocks	patent life in years	Multiple regression
4	Firm performance	Return on assets, Tobin's Q	1. Size of R&D resource flows 2. Consistency of R&D resource flows 3. R&D capability stocks	1. R&D expenditures 2. Number of external links 3. Number of cites with external orgs 4. patent life in yrs	Polynomial regression

Table 8

Pharmaceutical Journals Used for Citation Counts

Journal of Pharmaceutical Sciences
General Pharmacology
Pharmacology & Therapeutics
Journal of Clinical Pharmacology
Pharmacology
Progress in Biochemical Pharmacology
Journal of Pharmacology and Experimental Therapeutics
Molecular Pharmacology
Clinical Pharmacology and Therapeutics
Biochemical Pharmacology

A second operationalization of non-financial resource flows was the number of citations of published work done jointly between a member of the focal firm and researchers from another institution (see Table 8 for list of journals used for citation counts), following logic set out by Koenig (1983) and Gambaradella (1992). Both studies examined the relationship between patents and citations in scientific journals. Gambaradella concluded that these external links, developed through publication in scientific journals, were an important part of the innovation process because they help drive the rate of knowledge development within the firm. Especially in the pharmaceutical industry, where knowledge is complex and rapidly changing, organizations must be able to absorb and utilize information from the external environment. In fact, Koenig (1983) found that pharmaceutical company research was as highly cited in medical journals as research from top medical schools. This suggests that these citations may be interesting drivers of capability development, as they represent an active sharing of information among the scientific community. Gambaradella (1992) found that patents are positively correlated with scientific publications by firms even after partialling out the size of the firm's research and development expenditures. Gambaradella argued that firms that were best at developing in-house innovations were more effective at exploiting outside research.

These operationalizations are representative of the nature of research work in the pharmaceutical industry. Drug discovery teams consist of researchers focusing on similar task areas, but often with different sets of expertise. Thus, a common body of knowledge or team mental model (Klimoski

& Mohammed, 1994) becomes the basis for speeding discovery. This contrasts to a cross-functional team, where a common set of understandings often does not exist, creating tension and slowing the decision making process. It is the common understandings of the specialty research teams that facilitate new knowledge development as new relationships are understood when new data are added to the milieu.

This interorganizational linkage variable is important because the research and development process is complex and involves much more than pure scientific research in the laboratory. Effective research and development requires building knowledge from inside and outside the firm, integrating that knowledge, and using that knowledge to spur discovery. Without an adequate breadth of knowledge, research and development capabilities will be stunted by a failure to take advantage of knowledge that lies outside the walls of the research and development department. Breadth of knowledge is important because almost always, discovery is built on the knowledge of others, either within the same domain of knowledge, or by taking information outside the domain of knowledge and applying it in a different context. The more interorganizational links at all levels (between individuals, departments, organizations, and industries), the higher the likelihood this cross-fertilization process can occur and result in innovation.

For both interorganizational linkage variables, three data collection guidelines were developed to clarify exactly what constitutes a link. For the interorganizational linkage variable, a linkage was only recorded if it is clear that

1) a merger or acquisition includes considerable integration of at least one functional unit, 2) a strategic alliance includes a target purpose that involves coordination of business units from both partners. 3) Strictly marketing linkages were not counted as there is likely little learning transferred across firms. The citations were culled from the pharmaceutical journals listed in Table 8 above. A random subset of the primary data was cross-checked by a specifically trained George Mason University graduate student for accuracy and inter-rater reliability. No differences in these ratings were reported between the raters in the random sample.

Consistency. Consistency was measured using the variance in research and development intensity for the three years prior to the given year sampled. This straightforward measure follows Harrison, et al., (1993). Harrison et al. used the variance in research and development intensity to study consistency of resource allocation decisions. In a footnote, the authors noted that "(t)here was no theoretical reason to believe that variance was superior to other potential methods of dispersion. Consequently, in pretests we substituted standard deviation and a measure that compared the highest to the lowest intensity and found comparable results" (1993: p. 1035).

Consistency was operationalized using a three-year time period in an effort to balance the development of a stable measure of variance with the benefits of having as many discrete time periods as possible so as to maximize the ability to detect fine-grained changes in resource development. Interaction terms were created by multiplying each resource flow term by its associated consistency.

Firm Performance. Firm performance was measured using both financial and market based data. There is much discussion about the use of financial based performance measures (Lubatkin & Shrieves, 1986). Of the various accounting based measures it is apparent that Return on Assets (ROA) is the measure of choice in the strategic management literature. Many researchers concluded that ROA is better because it is broadly used by managers as a measure of performance (Keats & Hitt, 1988; Bettis & Mahajan, 1985). Others (Ball & Brown, 1968; Gonedes, 1973) argued that ROA is a better measure of performance than other market related variables because assets are much more under the control of managers, and ROA has been shown to be closely related to market value. ROA is considered better than other accounting measures because it is not as vulnerable to variability as a result of changes in leverage (Meeks & Meeks, 1981; Ramaswamy, 1997). The widespread use of ROA creates another incentive to use this measure. Robins and Wiersema strongly supported the use of ROA in their 1995 SMJ article that applied resource-based theory to diversified firms. They argued that "(t)he use of ROA as a performance measure allows the results of the analysis to be directly compared with a substantial body of work on related topics in strategy, and it helps to make the research replicable and cumulative" (1995: p . 287).

However, given the general advisability of using multiple performance measures (Venkatramen & Ramanujam, 1986), firm performance was also operationalized using Tobin's q, a market-based measure of firm performance, following Wernerfelt and Montgomery (1988) and Chung and Pruitt (1994). Tobin's q is widely used in the research literature (Chung & Pruitt, 1994) and is held by Industrial Organization Economists to be a strong alternative to financial based measures.

Data Sources

Archival data from the years 1978-1996 were extracted from a variety of sources. Research and development expenditures and firm performance data were gathered primarily from the COMPUSTAT database, and checked against audited company financial reports and Moody's Industrial Manual. Interorganizational linkage data were collected from the Wall Street Journal, and Moody's Industrial Manual. Citation data were collected from a selection of major pharmaceutical journals. Patent data were collected from the the U.S. Patent Office CASSIS database at the U.S. Patent Office in Alexandria, Virginia.

RESULTS

Data Analysis Strategy

The overall intent of this research has been to examine the nature of relationships among resource flows, capability stocks, and firm performance. To what extent are capability stocks related to performance? Is the relationship between flows and stocks curvilinear? Does consistency of resource flow investments impact the development of knowledge-based resource stocks? Does a curvilinear model of stocks and flows explain firm performance better than a linear model? The data analysis strategy outlined in the previous chapter on research methodology provides a blueprint to address these research questions.

However, the threats of autocorrelation and time dependencies inherent in analyzing time-series data must be considered. In an effort to address these threats, two diagnostic analyses were initially conducted on the data. First, the Durbin-Watson test for autocorrelation was conducted. Then, a repeated measures MANOVA with a time-varying covariate was conducted to assess time dependencies within the data. Once these tests detailed the data structure, pooled analyses were run on the data using repeated measures regression with an autoregressive error structure to test the four hypotheses.

Data Structure and Results of the Diagnostic Analyses

Autocorrelation occurs when error terms in regression equations are positively correlated over time because key variables are unspecified. This is a common problem with time series data in strategic management research, and it is an important problem because when error terms are autocorrelated the variance of the error term regression estimates may be seriously underestimated. This may reduce the efficiency of the regression estimators, and invalidate standard statistical tests (Neter, Kutner, Nachtsheim, & Wasserman, 1996).

The Durbin-Watson test is commonly used to identify first-order autocorrelation. The D statistic yielded by the Durbin-Watson was compared to the lower and upper bounds of 0.77 and 1.25 (calculated using alpha=.01 and n=17 and p = 2 (number of X variables) using tables from Durbin & Watson, 1951). If the D statistic falls above the upper bound, the test indicates no first-order autocorrelation. If the D statistic falls below the lower bound, the test indicates first-order autocorrelation. If the test statistic falls between the bounds, the test is inconclusive (Neter, et al., 1996). Durbin-Watson tests for autocorrelation were conducted on the data, the results of which are displayed in Table 9 below. The results of the Durbin-Watson tests suggest that the research and development and patent years variables appear to be impacted by autocorrelation. The presence of autocorrelation in this test suggests that additional diagnostic analyses should be run to assess the degree and form of the autocorrelation so that the error matrices used in the hypothesis testing phase of the analysis can be structured so as to properly reflect the correlated terms.

The impact of time on the variance explained in each relationship, between flows and stocks and stocks and performance, is another issue with important implications for the data analysis. To assess time dependencies in the dataset, a repeated measures Multiple Analysis of Variance (MANOVA) with a time varying covariate was performed to assess the possibility that the relationships in the data were

spurious, that is due solely to growth trends in either the dependent or independent variables, rather than because of the hypothesized causal factors. Each independent variable was analyzed using patent years as the dependent variable, and then patent years was used as the independent variable with ROA and Tobin's q used as the dependent variables in separate analyses. These tests were limited to variable pairs due to constraints on degrees of freedom that were inherent in the study design. Thus, no interaction effects or nonlinear models could be tested with repeated measures MANOVA.

The results of the MANOVA, summarized in Table 10 below, suggest that when time is used as a covariate, the relationship between the various independent variables and patent year dependent variable is significant at the .05 level for 6 of the 11 relationships and in 8 of 11 relationships at the .10 level. Additionally, the F-ratios were not significant for the relationships between patent years and both Return on Assets and Tobin's *q*. These findings suggest that the correlations may indeed be spurious, that is driven by trends in the

Table 9

Durbin-Watson d Statistics for Repeated Measures MANOVA

Durbin-Watson *D* Statistic				
Firm	R&D Exp	Org. Links	Citation Links	Patent Years
Abbott	0.193	2.349	1.477	0.316
AHP	0.293	2.076	2.177	0.167
B-L	0.375	1.626	not computable*	0.346
Becton	0.425	2.135	not computable*	0.211
BMS	0.424	2.592	2.406	0.777
Car-Wal	0.797	2.300	not computable*	0.310
Glaxo	0.145	1.736	0.970	0.207
ICN Phar	0.923	0.525	1.600	0.993
J&J	0.272	1.873	2.035	0.612
Lilly	0.537	2.370	2.451	0.185
Mallin	0.596	1.972	not computable*	0.369
Merck	0.181	1.660	1.676	0.366
Mons	0.301	2.022	2.381	0.210
Pfizer	0.190	1.338	2.038	0.489
Rhone PR	0.278	2.452	2.208	0.329
SKB	0.922	1.699	1.388	0.615
Scher PI	0.206	2.383	2.398	0.430
Syntex	0.639	2.831	2.063	0.361
Upjohn	0.863	2.115	2.514	0.273
Warn-Lm	0.466	2.072	0.887	0.200

* all values of this were 0, thus D-W statistic was not computable (/0 error)

Below lower bound (autocorreclation present)	20	1	1	19	using p=2, n=20, sig.=.01, upper bound=1.15, lower=0.95
Between upper & lower bounds (inconclusive)	0	0	1	1	
Above upper bound (autocorrelation not present)	0	19	14	0	
using p=2, n=20, sig.=.01, upper bound=1.15, lower bound=0.95					

independent and dependent variables, rather than by causal relationships between the variables. Thus, an autoregressive error structure is necessary to analyze the pooled data.

The information about the data structure yielded by these initial diagnostic analyses drove the final step in addressing the autocorrelation and time dependence issues, which was to perform a repeated measures regression with an auto-regressive error structure on the pooled dataset. By using an auto-regressive error structure, the autocorrelation suggested by the initial Durbin-Watson tests was more clearly assessed in both degree and form and this information was used to test the hypotheses controlling for the tendency of the errors in the data to be correlated over time.

The autoregressive structure is the standard tool used in time-ordered data and reflects the decreasing correlation in errors over time. The repeated measures regression with an auto-regressive error structure was conducted in SAS using the AR(1) first-order structure using the PROC MIXED procedure on data that were pooled over time. The descriptive analysis and correlation matrix are presented in Table 11.

Results of the Pooled Analyses

All four hypotheses were tested by analyzing the data using repeated measures regression with an autoregressive error structure. The data were pooled across all companies for all years. Hypotheses 1, 2 and 4 addressed the linear versus curvilinear question. Each of these hypotheses was tested using a linear model and two different polynomial models, quadratic (j-curve) and cubic (s-curve). Hypothesis 3 addressed the relationship between capability stocks and firm performance. This relationship was hypothesized to be linear; thus only a linear model was used in this analysis.

Hypothesis 1: Flows and stocks. Hypothesis 1 suggested that the relationship between the size of the research and development flows and research and development capability stocks is positive and curvilinear. Separate linear, quadratic, and cubic regression analyses were conducted using each of the three independent variables, research and development expenditures, interorganizational linkages and interorganizational citations, presented in Table 12.

The analysis of the first hypothesis confirmed that the patent years variable is severely autocorrelated, as suggested by the large z-test for parameter estimates in Table 12. The results suggest that none of the independent variables explained a significant amount of variance in patent years using the linear, the quadratic, or the cubic model. Therefore, there is no evidence for a curvilinear relationship between flows and stocks; Hypothesis 1 is not supported.

Hypothesis 2: Consistency of flows. The second hypothesis examined the impact of the consistency of resource flows on stock or capability development as measured by total patent years held by the firm. Specifically, the relationship between flows and stocks was hypothesized to be moderated by consistency, as measured by the average variance in the flow variable across

Table 10

Results of Repeated Measures MANOVA with Time Varying Covariate

Independent Variable	Dependent Variable	F ratio	Significance (df=1)
R&D Expenditures	Patent Years	18.66	.000
Organizational Links	Patent Years	23.63	.000
Citation Links	Patent Years	11.86	.003
Variance in R&D Exp.	Patent Years	3.62	.086
Variance in Org. Links	Patent Years	4.78	.042
Variance in Cit. Links	Patent Years	8.52	.009
Variance by R&D Interaction	Patent Years	4.44	.061
Variance by Org. Links Interaction	Patent Years	4.67	.044
Variance by R&D Cit. Links Interaction	Patent Years	2.79	.112
Patent years	Return on Assets	0.60	.451
Patent years	Tobin's *q*	0.33	.572

Table 11

Repeated Measures Regression with an Auto-Regressive Error Structure: Descriptives and Correlation Matrix

Variable	Abbr	Mean	Std. Dev	N
R&D Expenditures	RDEXP	31923.762	30806.44	336
Variance in R&D Expenditures	VRDEXP	43056238	1.17E+08	320
Organizational Linkages	ORGLNX	3.0882	2.4273	340
Variance in Organizational Linkages	VORGLNX	3.8206	4.7045	340
Intraorganizational Citation Linkages	CITLNX	0.7265	1.2894	340
Variation in Citation Linkages	VCITLNX	0.7784	2.1965	340
Patent Years (Capability Stock)	PATYRS	10536.58	8182.08	340
Return on Assets	ROA	0.107049	0.06709	337
Tobin's q	TOBQ	2.9245	0.9808	311

	RDEXP	VRDEXP	ORGLNX	VORGLX	CITLNX	VCITLNX	PATYRS	ROA
RDEXP								
VRDEXP	.510**							
ORGLNX	.342**	.002						
VORGLX	.228**	.000	.480**					
CITLNX	.466**	.161**	.290**	.080				
VCITLNX	.339**	.084	.214**	.048	.605**			
PATYRS	.293**	-.052	.366**	.231**	.259**	.117*		
ROA	215**	-.005	.125*	.056	.071	-.018	.125*	
TOBQ	.494**	.187**	.182**	.105	.250**	.060	.059	.569**

Note: *p<.05 **p<.01

three prior years. This was tested by regressing stock of patent years on research development expenditures, the consistency of those expenditures over time, the product of the two preceding terms, organizational linkages, the variance in those linkages, and the product of the two preceding terms, and citation linkages, the variance in those linkages, and the product of the two preceding terms as the independent variables.

The results of the analysis for Hypothesis 2 suggested that the only significant interaction term was between R&D expenditures and variance of R&D expenditures using the quadratic model (see Table 13). However, plotting the interaction indicated that the direction of the interaction was the opposite of the hypothesized direction. Specifically, the data suggested that high variance in R&D expenditures, coupled with high levels of R&D expenditures, was associated with higher ROA. Given the overall lack of evidence of significant interactions in the hypothesized direction, these results indicate that Hypothesis 2 was not supported.

Hypothesis 3: Stocks and performance. The third hypothesis examined the relationship between capability stocks, measured by accrued patent years, and firm performance, as measured by 1) a financial measure of performance, return on assets and 2) a market-based measure of performance, Tobin's *q*. This hypothesis was tested by regressing firm performance on patent years. As shown in Table 14, capability stocks generally did not explain a significant amount of variance in firm performance as measured by either return on assets or Tobin's *q*. Thus, Hypothesis 3 was not supported.

Table 12

Pooled Analysis, z-test Parameters - Hypothesis 1

	Patent Years		
	Linear	Quadratic	Cubic
Covariance Parameter Z	923.10**	930.91**	904.74**
Independent Variables			
YEARID	-3.23**	-2.66**	-2.92**
RDEXP	1.03	-0.70	0.86
ORGLNX	1.28	0.45	-0.27
CITLNX	-0.17	-0.15	-0.09
RDSQ		1.23	-1.13
ORGSQ		0.03	0.58
CITSQ		0.06	0.04
RDCUB			1.41
ORGCUB			-0.59
CITCUB			-0.03

Note: *p<.05 **p<.01

Hypothesis 4: The full process model. The fourth hypothesis examined the entire process model as shown in Figure 8. Given that the first three hypotheses were not supported, there is no possible way hypothesis four can be supported, so there was no reason to test the fourth hypothesis.

Table 13

Pooled Analysis, z-test Parameters - Hypothesis 2

Without Interaction Term

	Dependent Variable = PATYR			Dependent Variable = ROA		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Covariance Parameter Z	839.44**	856.28**	833.35**	11.96**	11.21**	11.51**
Independent Variables						
YEARID	-2.87**	-2.10*	-2.29*	-2.89**	-2.83**	-2.55*
RDEXP	1.18	-0.48	0.96	2.94**	1.29	2.71**
RDSQ		1.11	-1.26		0.03	-2.38*
RDCUB			1.52			2.42
VRDEXP (Var. in R&D)	-0.49	-0.08	0.20	0.24	0.22	1.00
ORGLNX	0.71	0.47	-0.10	1.04	0.14	0.65
ORGSQ		-0.24	0.34		0.30	-0.63
ORGCUB			-0.41			0.76
VORGLNX (Var. in Org Lnx)	0.53	0.57	0.58	-1.04	1.07	-1.11
CITLNX	1.13	-0.05	0.01	0.40	0.35	0.89
CITSQ		1.20	0.21		-0.11	-0.89
CITCUB			0.03			0.87
VCITLX (Var. in Cit Lnx)	-1.91	-2.30*	-2.20	-1.27	1.10	-0.79

Note: *p<.05 **p<.01

With Interaction Term

	Dependent Variable = PATYR			Dependent Variable = ROA		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
Covariance Parameter Z	829.58**	855.54**	835.29**	12.51**	13.02**	12.99**
Independent Variables						
YEARID	-2.82**	-2.06*	2.23*	-2.23*	-2.67**	2.47*
RDEXP	1.22	-1.03	0.51	1.87	2.98**	3.03**
VRDEXP (Var. in R&D)	0.05	1.12	1.34	-3.35**	-4.09**	-3.42**
RDSQ		1.65	-1.02		-2.38*	-2.21*
RDCUB			1.54			1.73
RDXVRD (Interaction)	-0.35	-1.26	-1.37	3.91**	4.52	4.10**
ORGLNX	0.72	0.45	0.31	0.41	-0.04	0.64
ORGSQ		-0.12	0.55		0.16	-0.70
ORGCUB			-0.62			0.81
VORGLNX (Var. in Org Lnx)	0.56	0.44	0.00	-0.88	-0.90	-0.30
OLXVOL (Interaction)	-0.30	-0.09	0.39	0.37	0.26	-0.38
CITLNX	0.71	-0.40	0.00	0.47	0.05	0.71
CITSQ		1.29	0.27		0.37	-0.67
CITCUB			0.30			0.76
VCITLX (Var. in Cit Lnx)	1.77	-1.68	-1.52	-0.88	-0.81	-0.67
CLXVCL (Interaction)	0.51	-0.86	-0.88	-0.05	-0.27	-0.18

Note: *p<.05 **p<.01

Table 14

Pooled Analysis - Hypothesis 3

	Dependent Variable	
	ROA	Tobin's q
Covariance Parameter Z	14.25**	19.49**
Independent Variable		
YEARID	-0.60	2.97**
PATYR	1.57	0.86
Independent Variable		
YEARID	-0.67	3.08**
NUMBER OF PATENTS	1.39	1.52

Note: *p<.05 **p<.01

DISCUSSION

The purpose of this study was to examine the relationships among resource flows, stocks, and performance in an effort to better determine why some firms outperform rivals consistently over time. This research project was designed to address three specific gaps in the existing strategy literature. First, the study was designed to explore an important hole in the resource-based literature by empirically testing the underlying notion of resource flow and stock concepts (Dierickx & Cool, 1989), and extend this framework by positing and testing for a curvilinear relationship between resource flows and capability stocks. Second, this study was designed to look at a potentially major source of unmeasured variance in firm performance: the impact of consistency in the development of research and development capabilities. Third, and most broadly, this study was designed to investigate the important issue of knowledge development within and between organizations using an integrated model drawn from both resource-based theory and the organizational learning literatures. Sixteen years of archival data from twenty firms in the pharmaceutical industry were analyzed using repeated measures regression with an autoregressive error structure.

Summary of Findings

Flows, stocks, and curvilinearity. The first hypothesis addressed the concept of resource flows and capability stocks. In their seminal paper on asset stock accumulation, Dierickx and Cool (1989) described, but did not test, the importance of asset mass efficiencies in the development of valuable resource stocks. This study examined the relationship between flows and stocks, but results did not suggest evidence of a significant curvilinear relationship. This was a disappointing finding, but some interesting issues were nevertheless raised by the data analysis. The analysis found a significant correlation between each of the three flow variables (research and development expenditures, organizational linkages, and citation linkages) and the stock variable, patent years (see Table 11). This suggests that relationships do exist among these variables, but these relationships disappear when an autoregressive error structure is used. There are at least three possible reasons for this result.

First, there simply may be no empirical relationship between flows and stocks, after controlling for size and time. If these findings could be replicated across time, across samples, and with a variety of operationalizations, the logic presented by Dierickx and Cool (1989) and almost every resource-based study that uses the flow-stock relationship and would be weakened. Second, and more likely, is that the operationalizations of flows and stocks are poor. This seems especially probable for the stock variable, which had severe autocorrelation problems, as mentioned in the previous section. Third, there may be major sources of unmeasured variance that impact the ability of the statistical tests used in this study to detect a relationship, including financial structure, managerial cognition, diversification strategies, etc. Each of these three possibilities might yield interesting findings for future work.

Consistency. The data do not seem to support the impact of consistency on capability development. In fact, a strong and significant correlation in the opposite direction of that hypothesized was found. However, the pooled nature of the analysis makes the interpretation that increased variance in expenditures positively impacts firm asset stock development questionable. Since the analysis is pooled, the results are capturing the huge growth in all pharmaceutical firms during the time period under study. The successful firms grew the most, driving the variability, and thus driving the unexpected result.

In fact, there were many instances of significant negative parameter estimates when performance was regressed on variance, suggesting that as expected, lower variance (more consistency in investments) may be related to performance, but the interaction terms in many of these cases were not significant or significant in the opposite direction. This may be a function of autocorrelation or the above-mentioned issue of increasing size of research and development investments driving firm performance and masking the true impact of variance.

Another possible interpretation is that perhaps consistency does not matter. Perhaps the drivers and limits of organizational learning are driven more by the total accrued amount of research and development flow investment and less by the consistency of resource flows. Given the general acceptance for spaced over massed learning in the individual learning literature, this may either be a major contribution to the literature, or at the very least, fodder for a more detailed study comparing individual to organizational learning processes. The focus of such a study might be to determine if scale economies have more influence on organizational learning than the timing or pace of new knowledge acquisition.

Linkages between resource stocks and firm performance. The data did not support the existence of a causal relationship between resource stocks, as measured by accrued patent years and performance, as measured by either return on assets or Tobin's *q*. Thus, the mediated relationship between resource flows and performance through resource stocks as measured by patent years possessed by the firm was also not supported. The lack of support for a relationship between the capability measures in this study and performance prevents successful support for the Dierickx and Cool (1989) framework.

The absence of a relationship between stocks and performance has three possible explanations. First, the operationalization of capability stocks, the accrued patent years measure, is likely a deficient proxy for capability stocks given the aforementioned problems with autocorrelation. Second, as in Hypotheses 1 and 2, there may be other important but unmeasured sources of variance that would mask any existing relationship. Third, and less likely, the link between capabilities and performance may be weaker than traditionally viewed in the literature.

A final possible interpretation is that, by taking into consideration alternate performance measures, the data may yet yield valuable conclusions. The ability of resource stocks to predict sales revenue and net income may support the notion that pharmaceutical companies need many years of patent protection to develop high sales, but this particular capability may not result in the efficient use of assets. Those capabilities may be more operational in terms of manufacturing and distribution. Further study of firm capabilities should involve multiple capability measures, including the previously mentioned operational types of variables.

Full model. The data failed to provide support for the full model as described in Hypothesis 4, in that the regression of all the independent variables against the dependent performance variables yielded no significant parameters. This is not surprising, given the failure of each of the first three hypotheses.

The failure to find strong results in this study is especially disappointing in light of recent trends in the pharmaceutical industry. The pharmaceutical industry has undergone rapid change since the end of the dataset timeframe and is continuing to experience upheaval to date. The emergence of small biotechnology firms with genetic-based therapies has rocked the stability of the large pharmaceutical firms. As a result, large pharmaceutical firms have followed a two-pronged strategy. The first response has been for large pharmaceutical firms to link up with small biotech firms. The small firms provide a hedge against genetic-based therapies by providing access to a potentially lucrative source of revenues, while the large firms provide distribution and marketing expertise, along with access to low-cost financial capital.

A second response of large pharmaceutical companies has been an acceleration of large transnational mergers. Given this pattern, any findings in this study would have made important contributions. Any findings would have built the groundwork for such important questions as how do knowledge stocks develop between firms using different technologies, or between firms with different national cultures? At the least, increased transnational merger activity drives the need to better understand the lack of findings in this dissertation and lends urgency to the need to develop better understanding of the processes at work in the pharmaceutical and other knowledge-intensive industries.

Limitations

There are several key limitations that afflicted this research project; some were anticipated at the outset and some were unanticipated (and very interesting). The three central anticipated limitations were autocorrelated predictors, sample size limitations, and weaknesses in both the flow and stock variables. The three unanticipated limitations were the use of variance as a measure of consistency, the impact of growth and ambiguity within the industry, and the use of time as a control variable.

Anticipated limitations. It was expected that, as in most time series analyses using financial data, autocorrelated predictors would be limit the interpretability of the data analysis results. An attempt to address this limitation was made by analyzing the data using repeated measures MANOVA with a time varying covariate and repeated measures regression with an autoregressive error structure. This strategy was an attempt to assess the existence and impact of autocorrelation on the results and control accordingly. Moderate to severe autocorrelation was indeed detected, reducing confidence in the results, despite using an autoregressive error structure in the data analysis.

Limitations on sample size, and thus degrees of freedom, influenced the ability to perform the repeated measures MANOVA in that only first order individual variable pairs could be tested. However, almost the entire population of U.S. pharmaceutical firms was used. To increase sample size, one would have to examine firms in multiple industries, potentially blurring results, an obvious trade-off.

The study was most clearly limited because of weaknesses in the variable operationalizations, especially in the stock or capability variable, as measured by patent years. This was especially evident given the general lack of correlation between patent years and either financial or non-financial measures of firm performance. This suggests that the patent year measurement was simply not an effective proxy for capabilities. More specific capability operationalizations need to be developed and assessed, probably down to the level of studying specific product development teams for shared, accumulated, knowledge-driven skills and knowledge.

Finally, the citation linkage variable did not have adequate variance to be a useful predictor, given that many of the firms in the sample had no citation linkages with other organizations in many of the time periods studied. There were most likely many sources of unmeasured variance that further limited the ability to make causal inferences.

Unanticipated limitations. A major unanticipated limitation revolved around the use of variance as a measure of consistency in a fast growing industry such as pharmaceuticals. Also unanticipated were questions about the appropriateness of firm performance measures. One financial (return on assets) and one non-financial (Tobin's *q*), both commonly used, were used, however, both adjust for size. Bigger definitely seems to mean better in the pharmaceutical industry and perhaps by controlling for size, we lose some important information about performance. When either of two variables collected but not introduced in the hypotheses, sales revenue and net income, were used in the model in lieu of ROA or Tobin's *q*, strong evidence of curvilinear and flow-to-stock relationships was found. Reasons for this may include the existence of relationships between organizational learning and firm size that are masked when the performance measures control for size. More analysis using alternative performance measures is warranted to determine the nature of these relationships.

Also, there were unexpected limitations on the study stemming from the nature of the pharmaceutical industry itself. In addition to the limitations that we anticipated, mentioned above, the industry's fast growth and ambiguity about the location and nature of asset stock development may have limited the effectiveness of the data to answer the research questions. Again, additional studies with different samples are warranted.

A final and intriguing limitation is that time was controlled for in the data analysis, consistent with much of the research using time series financial-based data. However, after evaluating the results, it is apparent that controlling for time may not have been appropriate. As mentioned earlier, in the pharmaceutical industry, flows, stocks, and performance all tend to grow positively over time. By controlling for time, covariance among the three types of variables is eliminated, which eliminates any possibility of detecting relationships, linear or curvilinear.

Future Research Directions

The results of this study suggest several follow-up studies, each of which in some way addresses the key limitations of the present approach. First, cross-sectional and case study designs using methods such as growth curve analysis might be used to identify individual patterns of resource accumulation and capability development within organizations. These may yield insight into specific resource and capability drivers, and help focus attention on factors that both support and hinder organizational learning.

A second study might be to use a sample in a different industry, both as a tool for validation and to help sample size constraints. The information technology and biotechnology industries would be ideal candidates. Also, this research is likely related to the emerging construct of knowledge management. Such a study might be an effective lens through which to base better measures of knowledge-based capabilities. Future research linking the development of knowledge management systems to firm performance would be a valuable addition to the research literature.

Refinements of the resource flow and stock variables are needed. As mentioned earlier, reanalysis should likely use additional performance variables, not adjusted for size, such as sales revenue and net income. Also, the need for finer-grained research approaches is clearly evident. Examples include tracking resource flows on specific products, and as discussed earlier, measuring specific capabilities at the individual and team level.

Other future research questions driven by this research include, is there a limit to the synergies possible from combination in the pharmaceutical industry? Is a partnering strategy effective given the growth in the biotechnology sector? Can structural linkages between firms improve performance in some situations?

Conclusions

Results failed to support the existence of a curvilinear relationship between research and development flows and firm performance. Many possible explanations for the failure to find results were discussed, relating both to possibilities that either the relationships posited do not exist or, given the patterns of results in the data analysis, it is more likely that variables were misspecified and models were underspecified. These results do however, provide specific directions for future research and perhaps provide a new lens to reassess past research. These future directions will be especially relevant given the emergence of the biotechnology sector and the strategic shifts developed by large traditional pharmaceutical firms in attempts to maintain historically torrid levels of revenue and profit growth while addressing the rapid changes in the health sciences.

REFERENCES

Aharoni, Y. (1993). In search for the unique: Can firm-specific advantages be evaluated? Journal of Management Studies, 30, 31-49.

Almeida, P. (1996) Knowledge sourcing by foreign multinationals: patent citation analysis in the U.S semiconductor industry. Strategic Management Journal, 17 (Winter 1996 Special Issue), 155-166.

Amit, R., & Schoemaker, P. J. H. (1993). Strategic assets and organizational rent. Strategic Management Journal, 14, 33-46.

Anderson, J. R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

Anderson, J. R., & Fincham, J. M. (1994). Acquisition of procedural skill from examples. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 1322-1340.

Archibugi, D., & Pianta, M. (1992). Specialization and size of technological activities in industrial countries: The analysis of patent data. Research Policy, 21, 79-93.

Argyris, C. (1976). Leadership, learning, and changing the status quo. Organizational Dynamics, 4, 29-43.

Argyris, C., & Schön, D. (1978). Organizational Learning. Reading, MA: Addison-Wesley.

Arrow, K. (1962). The economic implications of learning by doing. Review of Economic Studies, 29, 155-173.

Ashcraft, M. H. (1989). Human Memory and Cognition. HarperCollins.

Ball, R. & Brown, P. (1968). An empirical evaluation of accounting income numbers. Journal of Accounting Research, 6, 159-178.

Barney, J. B. (1986). Strategic factor markets: Expectation, luck, and business strategy. Management Science, 32, 1231-1241.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17, 99-120.

Barney, J. B. (1996). The resource-based theory of the firm. Organization Science, 7, 469.

Barney, J. B., & Hansen, M.H. (1994).Trustworthiness as a source of competitive advantage. Strategic Management Journal, Winter Special Issue, 15, 175-190.

Barr, P. S., Stimpert, J. L., & Huff, A. S. (1992). Cognitive change, strategic action, and organizational renewal. Strategic Management Journal, 12, 15-36.

Bettis, R. A. (1981). Performance differences in related and unrelated diversified firms. Strategic Management Journal, 2, 379-393.

Bettis, R. A., & Mahajan, (1985) Risk-return performance of diversified firms. Management Science, 31, 785-800.

Bielry, P. & Chakrabarti, A. (1996). Determinants of technology cycle time in the U.S. pharmaceutical industry. R&D Management, 26, 115-126.

Black, J. A., & Boal, K B. (1994). Strategic resources: Traits, configurations and paths to sustainable competitive advantage. Strategic Management Journal, Summer Special Issue, 15, 131-148.

Bogner, W. C., Thomas, H., & McGee, J. (1996). A longitudinal study of the competitive positions and entry paths of European firms in the U.S. pharmaceutical market. Strategic Management Journal, 17, 85-107.

Boisot, M. H. (1995). Information Space: A framework for learning in organizations, institutions, and culture. New York: Routledge.

Capon, N., Farley, J. U., & Hoenig, S. (1990). Determinants of financial performance: A meta-analysis. Management Science, 36, 1143-1159.

Castanias, R. P., & Helfat, C. E. (1991). Managerial resources and rents. Journal of Management, 17, 155-171.

Chung, K. H., & Pruitt, S. W. (1994). A simple approximation of Tobin's q. Financial Management, 23, 70-74.

Clarkson, K. W. (1977). Intangible Capital and Rates of Return. Washington, D.C.: American Enterprise Institute for Public Policy Research.

Cohen, J. & Cohen, P. (1983). Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences, (Second Edition). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, W. M. & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. The Economic Journal, 99, 569-596.

Cohen, W. M. & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35, 128-152.

Collis, D. J. (1994). How valuable are organizational capabilities? Strategic Management Journal, 15 (Winter Special Issue), 143-152.

Colombo, M.G., & Garrone, P. (1996). Technological cooperative agreements and firm's R&D intensity. A note on causality relations. Research Policy, 25, 923-932.

Conner, K. R. (1991). A historical comparison of resource-based theory and five schools of thought within industrial organization economics: Do we have a new theory of the firm? Journal of Management, 17, 121-154.

Conner, K. R. & Prahalad, C. K. (1996). A resource-based theory of the firm: Knowledge versus opportunism. Organization Science, 7, 477-501.

Cool, K. & Dierickx, I. (1993). Rivalry, strategic groups, and firm profitability. Strategic Management Journal, 14, 47-59.

Cool, K. & Schendel, D. (1988). Performance differences among strategic group members. Strategic Management Journal, 9, 207-223.

Cyert, R. M. & March, J. G. (1963). A Behavioral Theory of the Firm. Englewood Cliffs, NJ: Prentice-Hall, Inc.

David, P. A. (1985). Clio and the economics of QWERTY. American Economic Review Proceedings, 75, 332-337

Dess, G. G. & Davis, P. S. (1984). Porter's (1980) generic strategies as determinants of strategic group membership and organizational performance. Academy of Management Journal, 27, 467-488.

Dierickx, I. & Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. Management Science, 35, 1504-1511.

Dunlap, W. P., Cortina, J. M., Vaslow, J. B., & Burke, M. J. (1997). Meta-analysis of experiments with matched groups or repeated measures designs. Psychological Methods, 1, 170-177.

Durbin, J. & Watson, G. S. (1951). Testing for serial correlation in least squares regression. Biometrica, 38, 159-178.

Eisenhardt, K. M. & Schoonhoven, C. B. (1996) Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. Organization Science, 7, 136-150.

Fiegenbaum, E. A. (1970). Information processing and memory. In Donald A. Norman (ed.), Models of Human Memory: 451-468. New York: Academic Press.

Gambaradella, A. (1992). Competitive advantages from in-house scientific research: The US pharmaceutical industry in the 1980s. Research Policy, 21, 391-407.

Garud R. & Nayar, P. R. (1995). Transformative capacity: Continual structuring by intertemporal technology transfer. Strategic Management Journal, 15, 365-385.

Geroski, P. A. (1990). Modeling persistent profitability, in D. C. Mueller (ed.), The Dynamics of Company Profits. Cambridge, UK: Cambridge University Press.

Goes, J. B. & Park, S. H. (1997). Interorganizational links and innovation: The case of hospital services. Academy of Management Journal, 40, 673-696.

Gonedes, N. J. (1974). Capital market equilibrium and annual accounting numbers - empirical evidence. Journal of Accounting Research, 12, 26.

Grabowski, H. & Vernon, J. (1990). A new look at the returns and risks to pharmaceutical R&D. Management Science, 36, 804-821.

Grant, R. M. (1996) Toward a knowledge-based theory of the firm. Strategic Management Journal, 17 (Winter 1996 Special Issue), 109-123.

Graves, S. B. & Langowicz, N. S. (1993). Innovative productivity and returns to scale in the pharmaceutical industry. Strategic Management Journal, 14, 593-605.

Gruber, H. (1994). The yield factor and the learning curve in semiconductor production. Applied Economics, 26, 837-844.

Hagedoorn, J., & Schakenraad, J. (1994). The effect of strategic technology alliances on company performance. Strategic Management Journal, 15, 291-311.

Hall, R. (1992). The strategic analysis of intangible resources. Strategic Management Journal, 13, 135-144.

Hall, R. (1993). A framework linking intangible resources and capabilities to sustainable competitive advantage. Strategic Management Journal, 14, 607-618.

Halliday, R. G., Drasdo, A. L., Lumley, C. E., & Walker, S. R. (1997). The allocation of resources for R&D in the world's leading pharmaceutical companies. R&D Management, 27, 63-77.

Hambrick, D. C. (1983). Some tests of the effectiveness and functional attributes of Miles and Snow's strategic types. Academy of Management Journal, 26, 5-26.

Hambrick, D. C. & Mason, P. A. (1984). Upper echelons: The organization as a reflection of its top managers. Academy of Management Review, 9: 193-206.

Harrigan, K. R. (1980). The effect of exit barriers upon strategic flexibility. Strategic Management Journal, 1, 165-176.

Harrison, J. S., Hall, Jr., E. H., & Nargundkar, R. (1993). Resource allocation as an outcropping of strategic consistency: Performance implications. Academy of Management Journal, 36, 1026-1051.

Hedberg, B. (1981). How organizations learn and unlearn. In P.C. Nystrom & W. H. Starbuck (Eds.) Handbook of Organizational Design (pp. 8-27). London: Oxford University Press.

Helfat, C. E. (1994). Evolutionary trajectory in petroleum firm R&D. Management Science, 40, 1720-1747.

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

Henderson, R. & Cockburn, I. (1994). Measuring competence? Exploring firm effects in pharmaceutical research. Strategic Management Journal, Winter Special Issue, 15, 63-84.

Istvan, R. L. (1992). A new productivity paradigm for competitive advantage. Strategic Management Journal, 13, 525-537.

Johnson-Laird, P. N. (1983). Mental models: Toward a cognitive science of language, inference, and consciousness. Cambridge, MA: Harvard University Press

Joly, P. B., & Mangematin, V. (1996). Profile of public laboratories, industrial partnerships and organisation of R&D: the dynamics of industrial relationships in a large research organization. Research Policy, 25, 901-922.

Jonassen, D. H., Beissner, K. L., & Yacci, M. (1993). Structural Knowledge: Techniques for Representing, Conveying, and Acquiring Structural Knowledge. Hillsdale, NJ: Lawrence Erlbaum.

Keats, B. W., & Hitt, M. A. (1988). A causal model of Llinkages among environmental dimensions. Academy of Management Journal, 31, 570-599.

Kerssens-Van Drongelen, I. C., de Weerd-Nederhof, P. C., & Fisscher, O. A. M. (1996). Describing the issues of knowledge management in R&D: Towards a communication and analysis tool. R&D Management, 26, 213-230.

Klimoski, R. & Mohammed, S. (1994). Team mental model: Construct or metaphor? Journal of Management, 20, 403-437.

Knez, M. & Camerer, C. F. (1994). Creating expectational assets in the laboratory: Coordination in weakest-link games. Strategic Management Journal, 15 (Winter Special Issue), 101-120.

Koenig, M. E. D. (1983). A bibliometric analysis of pharmaceutical research. Research Policy, 12, 15-36.

Kogut, B. & Zander, U. (1996). What firms do? Coordination, identity, and learning. Organization Science, 7, 502-518.

Lancaster, T. & Imbens, G. (1995). Optimal stock/flow panel. Journal of Econometrics, 66, 325-348.

Levitt, B., & March, J. G. (1988). Organizational learning. Annual Review of Sociology, 14, 319-340.

Lippman, S. A. & Rumelt, R. P. (1982). Uncertain imitability: An analysis of interfirm differences in efficiency under competition. Bell Journal of Economics, 13, 418-438.

Lubatkin , M., & Shrieves, R. E. (1986). Towards reconciliation of market performance measures to strategic management research. Academy of Management Review, 11, 497-513.

Maijoor, S. & van Witteloostuijn, A. (1996). An empirical test of the resource-based theory: Strategic regulation in the Dutch audit industry. Strategic Management Journal, 17, 549-569.

March, J. G. (1991). Exploration and exploitation in organizational learning. Organization Science, 2, 71-87.

March, J. G., & Simon, H. A. (1993). Organizations (Second Edition). Cambridge, MA: Blackwell.

Markides, C. C. & Williamson, P.J. (1996). Corporate diversification and organizational structure: A resource-based view. Academy of Management Journal, 39, 340-367.

McCarthy, M. E. (1979). An entity-relationship view of accounting models. The Accounting Review, 54, 667-686.

McCarthy, M. E. (1982). The REA accounting model: A generalized framework for accounting systems in a shared data environment. The Accounting Review, 57, 554-578.

Meeks, G., & Meeks, J. G. (1981). Profitability measures as indicators of post-merger efficiency. Journal of Industrial Economics, 29, 335-344.

Mehra, A. (1996). Resource and market based determinants of performance in the U.S. banking industry. Strategic Management Journal, 17, 307-322.

Miles, G., & Snow, C. C. (1978). Organizational strategy, structure, and process. New York: McGraw-Hill.

Miller, D. & Shamsie, J. (1996). The resource-based view of the firm in two environments: The Hollywood film studios from 1936 to 1965. Academy of Management Journal, 39, 519-543.

Mintzberg, H. (1973). Strategy making in three modes, California Management Review, 16, 44-53.

Mone, M. A., Mueller, G. C. & Mauland, W. (1996) The perceptions and usage of statistical power in applied psychology and management research. Personnel Psychology, 49, 103-120.

Montgomery, C. A. (1982). The measurement of firm diversification: Some new empirical evidence. Academy of Management Journal, 25, 299-307.

Montgomery, C. A. (1995). Of diamonds and rust: A new look at resources, in C. A. Montgomery (Ed.), Resource-Based and Evolutionary Theories of the Firm, Boston: Kluwer Academic Publishers, 251-268.

Mueller, D. C. (1986). Profits in the Long Run. Cambridge, England: Cambridge University Press.

Narin, F., Noma, E., & Perry, R. (1987). Patents as indicators of corporate technological strength. Research Policy, 16, 143-155.

Neisser, U. (1976). Cognition and reality: Principles and implications of cognitive psychology. San Francisco: W.H. Freeman.

Nelson, R. R., & Romer, P. M. (1996). Science, economic growth, and public policy. Challenge, 39 (2), 9-22.

Nelson, R. R. & Winter, S. G. (1982). An Evolutionary Theory of Economic Change. Cambridge, MA: Harvard University Press.

Neter, J., Kutner, M. H., Nachtsheim, C. J., & Wasserman, W. (1996). Applied Linear Regression Models (Third Edition). Chicago: Irwin.

Newell, A., & Simon, H. A. (1972). Human Problem Solving. Englewood Cliffs, NJ: Prentice-Hall.

Pakes, & Griliches, Z. (1984) in Z. Griliches (Ed.) R&D, Patents, and Productivity. Chicago: University of Chicago Press, .

Penrose, E. T. (1959). The theory of the growth of the firm. New York: Wiley.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource-based view. Strategic Management Journal, 14, 179-191.

Pisano, G. P. (1994). Knowledge, integration, and the locus of learning: An empirical analysis of process development. Strategic Management Journal, 15 (Winter Special Issue), 85-100.

Polyani, M. (1966). The Tacit Dimension. New York: Doubleday.

Porter, M. E. (1980). Competitive Strategy. Free Press: New York.

Powell, T. C. & Dent-Micallef, A. (1997). Information technology as competitive advantage: The role of human, business, and technology resources. Strategic Management Journal, 18, 375-405.

Prahalad, C. K. & Bettis R. A. (1986). The dominant logic: A new linkage between diversity and performance. Strategic Management Journal, 7, 485-502.

Prahalad, C. K. & Hamel, G. (1990). The core competence of the corporation. Harvard Business Review, 68, May-June, 79-91.

Ramaswamy, K. (1997). The performance impact of strategic similarity in horizontal mergers: evidence from the U.S. banking industry. Academy of Management Journal, 40, 697-716.

Reed, R. & DeFillippi, R. J. (1990). Causal ambiguity, barriers to imitation, and sustainable competitive advantage. Academy of Management Review, 15, 88-102.

Robins, J. & Wiersema, M. F. (1995). A resource-based approach to the multi-business firm: Empirical analysis of portfolio interrelationships and corporate financial performance. Strategic Management Journal, 16, 277-299.

Robinson, P. M. (1993). Continuous-time models in econometrics: Closed and open systems, stocks and flows. In P.C.B. Phillips (Ed.) Models, Methods, and Applications of Econometrics, 71-90, Basil Blackwell: Cambridge, MA.

Romer, P. M. (1990). Are nonconvexities important for understanding growth? AEA Papers and Proceedings, 80, 97-103.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. Psychological Bulletin, 100, 349-363.

Rumelt, R. P. (1974). Strategy, Structure, and Economic Performance. Cambridge, MA: Harvard University Press.

Russo, M. V., & Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. Academy of Management Journal, 40, 534-559.

Sahal, D. (1985). Technology guide-posts and innovation avenues. Research Policy, 14, 61-82.

Samuelson, R. A. (1996). The concept of assets in accounting theory. Accounting Horizons, 10, 147-157.

Schwartzman, D. (1975). Pharmaceutical R&D expenditures and rates of return. In H. B. Helms (Ed.) Drug Development and Marketing. Washington, D.C.: American Enterprise Institute for Public Policy Research.

Senge, P. M. (1990). The Fifth Discipline: The Art and Practice of the Learning Organization. New York: Doubleday.

Shavelson, R. J. (1972). Some aspects of the correspondence between content structure and cognitive structure in physics instruction. Journal of Educational Psychology, 63, 225-234.

Simon, H. A. (1976). Administrative Behavior (3rd Edition). New York: Macmillan.

Simon, H. A. (1991). Bounded rationality and organizational learning. Organizational Science, 2, 125-134.

Spence, M. (1981). The learning curve and competition. Bell Journal of Economics, 12, 49-70.

Spender, J. -C. (1989). Industry Recipes: The nature and sources of managerial judgment. Oxford: Basil Blackwell.

Spender, J. -C. (1996). Making knowledge the basis of a dynamic theory of the firm. Strategic Management Journal, 17 (Winter Special Issue, 45-62.

Stimpert, J. L., & Duhaime, I. M. (1997). In the eyes of the beholder: Conceptualizations of relatedness held by the managers of large diversified firms. Strategic Management Journal, 18, 111-125.

Teece, D. J. (1981). Toward an economic theory of the multiproduct firm. Journal of Economic Behavior and Organization, 3, 39-63.

Thompson, J. D. (1967). Organizations in Action. New York: McGraw-Hill.

Ventrakamen, N., & Ramanujam, V. (1986). Measurement of business performance in strategy research: A comparison of approaches. Acadmey of Management Review, 11, 801-814.

Walsh, J. P. (1995). Managerial and organizational cognition: Notes from a trip down memory lane. Organizational Science, 6, 280-321.

Wernerfelt, B. (1984). A resource-based view of the firm. Strategic Management Journal, 5, 171-180.

Wernerfelt, B. (1995). The resource-based view of the firm: Ten years after. Strategic Management Journal, 16, 171-174.

Wernerfelt, B., & Montgomery, C. A. (1988). Tobin's q and the importance of focus in firm performance. The American Economic Review, 78, 246-250.

Zajac, E. J. & Bazerman, M. H. (1991). Blind spots in industry and competitor analysis: Implications of inter-firm (mis)perceptions for strategic decisions. Academy of Management Review, 16, 37-56.

Zimmerman, M. B. (1982). Learning effects and the commercialization of new energy technologies: the case of nuclear power. Bell Journal of Economics, 13, 297-310.