Walden University

COLLEGE OF MANAGEMENT AND TECHNOLOGY

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Jonathan William Selby

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ABSTRACT

A Quantitative Study Describing the Impact of Innovation-Related Investment and Management Performance on Corporate Financial Returns

by

Jonathan William Selby

M.S., Johns Hopkins University, 2005
B.S., University of Southern California, 1992

Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy
Applied Management and Decision Sciences

Walden University
May 2010

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ABSTRACT

Some business managers do not utilize quantitative means to identify the relationships among innovation investments, management performance measures, and desired financial outcome. This situation may lead to ineffective corporate resource expenditures and noncompetitive products and services. Academic literature addresses the need for innovation; however, innovation alone does not ensure business success. This descriptive-quantitative study seeks to assist managers in deciding the worth of innovation-related investments, conducted using a nonprobabalistic purposive sample of convenience drawn from U. S. headquartered, publicly traded corporations. The study, based on Christensen's theory of disruptive innovation and the economic theory of Schumpeter, presents a synthesis of related literature and statistical analysis of a model with independent variables (a) year of data collection, (b) innovation intensity, (c) invested capital, and (d) an interaction between innovation intensity and invested capital; and the dependent variable, earnings per share (EPS). Multiple regression analysis of the sample corporations' financial filings validated the regression; however, additional data analysis was performed to find the best fit for the data and considered the influence of time on the results. Analysis results also surprisingly showed that innovation investment had no impact on EPS, whereas invested capital proved to be significantly correlated to EPS. While this study furthers the understanding of innovation activities, additional focused study is necessary to separate the potential effects of other factors further. Results of this study will help managers better understand the impact of innovation expenditures leading to a more efficient allocation of shareholder resources.

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DEDICATION

This work is dedicated to my wife, Dr. Carolyn Selby, and our three daughters, Sarah, Rachel, and Elizabeth. Their patience and support has been the cornerstone of any success I have attained.

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The list of potential acknowledgements is astoundingly long, so I will limit myself to those that had the greatest impact on my efforts related to this study. I would have never gotten through this academic endeavor without the support, patience and wisdom of my mentor and chair, Dr. Irmak Renda-Tanali. I do not have the words to thank her for the time we spent in her office, in the café, and in the cyber world of e-mail. I must also acknowledge the significant and timely contributions of my other committee members, Dr. Reza Hamzaee and Dr. Jeff Prinster. Each not only supported my efforts, but also challenged my thinking, and I am much better for their efforts. A last acknowledgment, richly deserved, belongs to Dr. Raghu Korrapati who served as my interim-Chair and helped successfully conclude this journey.

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CHAPTER 1: INTRODUCTION TO THE STUDY

Professionals in the management community are interested in the use of innovative processes and methodologies to elicit business competitive advantage. Management researchers have acknowledged that successful innovation efforts can affect both long-term corporate sales and stock market performance (Srinivasan, Pauwels, Silva-Risso, & Hanssens, 2009). The act of innovating alone does not add wealth to a corporation, instead wealth is built after products are successfully introduced to the market (O'Brien, 2003). One point important to the present discussion of innovation is that innovation is actually a process; accordingly, it has inputs and outputs. Unfortunately for today's manager, the business literature is vague in its guidance for innovation implementation, a result of the disharmonious state of innovation literature itself (Adams, Bessant, & Phelps, 2006).

Despite the apparent dearth of implementation guidance, businesses understandably seek to bring products to market not only faster and cheaper, but also with sufficient differentiation within the markets to capture the interest and attention of the consumer (Christensen, 1997; Cooper, 1998, 2001; Leifer et al., 2000). A segment of the existing business management literature focuses on the need for introducing these new products and services to the market using deliberate management processes that will ensure innovative output and allow the company to introduce differentiated products or services. Innovation by itself does not ensure this business success, however (Chesbrough, 2006).

To reap the full advantage of innovation-related activity, the management team must go further than simply adopting strategic plans and organizational mission

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statements that espouse a management philosophy calling for such noble goals as "producing truly unique products or services." While much of the current literature describes various processes by which an organization can improve its performance (e.g., Christensen, 1997, 2005; Collins, 2001; Cooper, 2001; Leifer et al., 2000; O'Connor, Leifer, Paulson, & Peters, 2008), there appears to be less information detailing the relationship between corporate innovation investment and the attendant output, namely the financial benefits.

Statement of the Problem

While current managers invest in innovative activities, some likely do not utilize a quantitative means to identify the relationships among innovation expenditures, management performance measures, and the associated benefits. This may result in potentially ineffective expenditure of corporate resources and consumer dissatisfaction with delivered products and services. The body of management research suggests that there is no generally accepted measure of research and development (R&D) effectiveness (Parthasarthy & Hammond, 2002), and so managers struggling to uncover quantitative measures find the literature on the subject inadequate (Adams et al., 2006; Cordero, 1990; Szakonyi, 1994). The task of keeping pace with technological advances and converting them into some form of competitive advantage is a considerable challenge, even for incumbent companies with a strong background in technology (Vanhaverbeke & Peeters, 2005). Stockholders, directly or indirectly, task corporate managers to utilize novel approaches while increasing organizational effectiveness and maximizing shareholder value, regardless of the industry or the organization (Kanter, 2006). To fulfill this

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stockholder requirement, corporations today invest significant stockholder resources in an attempt to deliver innovative new products (Wallace, 2004). Management researchers also implore the manager to perform as a new start-up, characterized by realization of success through resourcefulness, innovativeness, and institutional knowledge (Hayton, 2005). Additionally, the contemporary management literature is replete with declarations that the use of innovative activities is critical to new product development (e.g., Canner & Mass, 2005; Chesbrough, 2006; Christensen, 2005; Christensen & Raynor, 2003; Kanter, 1989; Lilien, Morrison, Searls, Sonnack, & Von Hippel, 2002; Utterback & Acee, 2005).

Despite these assertions, the business literature remains vague in guidance for innovation implementation, a result of the inconsistent innovation literature (Adams et al., 2006). Despite the fragmented state of the art, the current literature provides the corporate executive with various courses of action to implement innovative strategies and practices (Christensen, Suarez, & Utterback, 1998; Cooper, 1998; Pande, Neuman, & Cavanagh, 2000a; Utterback & Acee, 2005). This same body of literature does little to provide the manager with quantified benefits of these undertakings, and does not provide the business leader with a foundation for implementation (Zahra, 1991).

In general, the focus of these calls to action center on the need to assure the corporation of its capacity to deliver competitive goods and services through innovation. The existing literature serves the manger well by accurately identifying the need for innovation in a generic sense, but fails the business manager when attempting to quantify the impact of such innovation-enhancing programs upon an organization. In the end, the

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use of innovation as a nebulous strategic objective has been supplanted by the need to undertake innovation activity as an inherent part of the corporate business processes (Vanhaverbeke & Peeters, 2005).

Background of the Problem

One of the challenges to the manager and accountant alike is accurately reporting the firm's financial status because the financial accounting system is not designed to measure business effectiveness or efficiency (Rappaport, 2005). Complicating the task of accurately accounting for a firm's innovation investment activities are two accounting system issues. The first is the requirement to report innovation investment as an expense or period cost (Anthony, Hawkins, & Merchant, 2007; Bushee, 1998; Chan, Lakonishok, & Sougiannis, 2001); the second is that work-in-progress inventory is also a cost (Anthony et al., 2007). Each of these situations leads to a decrease in the reported corporate return on assets, resulting in a potentially flawed overall view of a firm's investments, resulting in misperceptions of actual corporate (and so management) performance.

Purpose of the Study

A review of the current management literature, presented in chapter 2 of this study, demonstrated the efficacy of using discrete indicators of both the level of innovation investment and management performance as measures related to corporate innovation inputs. Corporations generally use financial returns such as return on assets and return on invested capital to measure the output of its managerial activity. Accepting the premise that innovation investment and management performance each contribute to

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corporate financial output, this study was undertaken as an effort to uncover the relationships, if any exist, between the input and output of innovation activity.

To do this, I first developed a theoretical framework grounded in the economics work of Cobb and Douglas (1928). In the case of the current study, the inputs were not labor and capital, but rather (a) innovation investment, as measured by II; (b) internal corporate investment, as measured by IC; (c) association with innovative products, vice services or processes. The study output was the financial performance of the corporation, as measured by its EPS. In this way, the relationship and correlation between investment activity and financial return were analyzed. The assumption was that a positive relationship existed between the inputs and the corporate output.

Summarizing, the purpose of this study was to help business managers understand the potential impact of innovative investment on business profitability. The results of this study should help executive management teams to determine the efficacy of investing in an innovation process.

Study Significance

In general, one might say that companies serve to improve society. Such a greater good is served by providing to consumers the goods and services they demand. Thusly, consumers enjoy the benefits of corporate investments in innovation in the form of pleasing products, services, and associated delivery mechanizations. As will be presented within the present study, these corporate innovative undertakings can effect positive social change. Such effects are evident if one thinks about the introduction of the World Wide Web and the power it has brought through electronic connectivity, or the

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proliferation of cellular phone technology, which has allowed social interactions previously unachievable. In the end, corporate innovation-related investments allow society to progress and prosper. This study provides corporate management teams a better understanding of innovation investment.

The results of this study will help answer the management executive's question, "Is it worth our effort to undertake innovation-enhancing efforts?" To achieve the desired result, existing literature on the subject of innovation investment activity was synthesized in an effort to develop a quantified model of the correlation between innovation expenditures and financial outcomes. The goal of the present study was to help managers better understand the impact of innovation expenditures, potentially leading to a more efficient allocation of shareholder resources.

Theoretical Framework

A theoretical model was developed not only to frame the study but also to provide a context for answering the research questions. Extending the work conducted at the Rensselaer Polytechnic Institute, Christensen's disruptive innovation, and the economic theory of Schumpeter, the objective of this research was to evaluate the relationship of specific investment performance indicators to organizational financial outcomes. The model was developed by first identifying the appropriate innovation-related investment indicators and identification of innovation indicators uncovered in the body of literature presented in chapter 2. Additionally, the model discussion found in the first section of chapter 3 describes the dependent and independent variables.

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The theoretical model is an application of the general multiplicative model of regression analysis (Aczel & Sounderpandian, 2006). The specific form of the research model is based on its use as a production function equating economic inputs to an associated output. The equation form is found in the Cobb-Douglas production function (Cobb & Douglas, 1928), which in general form is given as

$$\prod_{i=1}^{N} x_i^{\alpha_i}$$

When applied to the economic theory of Cobb and Douglas, the equation is generally rewritten in the form $Y = AL^{\alpha}K^{\beta}$. The research model did not include one capital (K^{β}) and one labor (L^{α}) variable as the general model did. Instead, the general format of the Cobb-Douglas model was used to capture as the dependent variable the expected economic output of its independent variables, which in this study are rooted in both accounting and business performance metrics.

Research Questions

The overarching objective of this study was to find an answer to the question of whether investment in innovation leads to increased financial output. To answer this primary major research question, the following enabling research questions guided this study.

1. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in innovation intensity?
2. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in invested capital?

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3. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in the product of innovation intensity and invested capital?
4. What is the relationship between earnings per share and the year the data was collected?

Assumptions and Limitations

The scope of this study did not allow an open-ended examination of the topic of innovation inputs and outcomes. Accordingly, certain constraints in the form of assumptions and limitations were imposed. These constraints were imposed to facilitate a coherent and manageable study.

Assumptions

Innovativeness. In this study, a key assumption is that the term *innovativeness* is sufficiently generic enough to apply to all the sample companies. Chapter 2 of this study includes a section devoted to the complications of defining the term *innovation*. In the case of the current paper, innovation is deemed appropriate to not only research and development efforts, but also other corporate activities that are not or cannot be fully accounted under current accounting principles. Accordingly, investments in new facilities or equipment may serve as sufficient examples of innovation, just as direct investments in research and development activities.

Innovation investments. The measurement of financial performance benefits associated with innovation investment is not unique to a particular industry. Accepting such a premise, a manager can use generally accepted financial performance metrics to

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capture the benefits of such investments. These metrics may include direct research and development investments, or other non-traditional investments such as process improvements, equipment upgrades, or new facilities. This term is not synonymous with the study variable innovation intensity, which will be define later.

Linearity of the model. A key assumption with the research model was that the study variables had a nonlinear relationship. To overcome the nonlinearity, the research model was formed as an application of the Cobb-Douglas production function (Cobb & Douglas, 1928), which is a general nonlinear economic model. Unfortunately, this proved to be less effective than expected and the model was reassessed as a linear research model.

Price-to-earnings ratio (P/E). In the free market, one assumes that shares of stock will trade at a price that captures the expectation of future benefits; in the case of stocks, this would be cash returns. The P/E ratio is a ratio of current stock price to earnings per share, and is a valuable and generally accepted measure of overall corporate financial performance (Anthony et al., 2007). Acceptance of this measure may be due to the inclusion of the market expectations of a firm's future financial performance. As such, the corporate price to earnings ratio is an effective measure of overall financial performance according to the free market. Since a key component of the ratio is the earnings per share, one may assume that the EPS is also a key measure of corporate performance.

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Limitations

Correlation study. This study will be a correlational analysis of innovative companies. A necessary limitation of such a study is the absence of direct causation (Aczel & Sounderpandian, 2006; Diaz & Osuna, 2008; Glymour, Scheines, Spirtes, & Meek, 1994; Leedy & Ormrod, 2005; Lind, Marchal, & Wathen, 2008; O'Hara, 2008; Singleton & Straits, 2005; Trochim, 2001). The goal of the study is thus to describe the economic environment vice demonstrating that a causal relationship exists between or among the study variables.

Innovation investment. Lloyd and Davis (2007) stated that companies assessing investment opportunities should compare the expected return on invested capital (ROIC) to the weighted average cost of capital (WACC). The ROIC was not used in the current study to avoid unacceptable collinearity between study variables; instead the variable invested capital (IC) was used. The recommendation by Lloyd and Davis was not germane to the present study because the goal of the study did not include an assessment of discrete investment opportunities.

Innovation process. Recognizing that innovation is not merely an outcome, but rather a system with inputs and outputs (Kleinknecht, Van Montfort, & Brouwer, 2002), this paper focused on particular innovation-related inputs and the effects they produce on the financial outcomes of a corporation. Deliberately omitted were a discourse on the particular organizational processes and the accompanying effects on internal product development.

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Randomized sampling. The design of this study precluded the establishment of a true random sample collected from a distinct population. The study sample was developed through convenience, and included only publicly traded companies with corporate headquarters in the United States. The sample selection is addressed further in chapter 3.

Sample size. The sample under study was limited to 51 companies from across the U.S. economic base. The sample was smaller than desired, but the methodology used in participant selection (see chapter 3) deliberately avoided complications that may have risen from criteria related to an arbitrary definition of innovativeness, an issue that will be addressed in chapter 2.

Definition of Terms

The following definitions apply to the terms used in this study:

Commoditization: The point at which customer demands with regard to the performance of each product attribute have been met (Christensen, 1997). It is at this point that the basis of competition shifts from differentiation based on performance to differentiation based on price.

Derived data: Derived data is that set of data developed from primary sources. The variables used in the research model were derived from primary data found in public corporate financial statements.

Earnings per share (EPS): A measure of a corporation's performance relative to its outstanding stock; it is divided into two categories, basic and diluted earnings per share (Anthony et al., 2007). The basic EPS value reported in the corporate financial

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statements was used in this study; the reported values are derived by dividing net income by all outstanding common stock. The diluted figure is the result of adding to the outstanding stock figure those stocks that could have been outstanding during the reporting period (e.g., convertible stock or convertible debt).

Innovation intensity: This term is often used as an equivalent to the term *research and development intensity* (defined in chapter 2), particularly within European literature (e.g., Klomp & VanLeeuwen, 2001). It is also used as a general term to describe the technical innovativeness of an organization. Within the present study, the term was used as a variable to measure a firm's strength of investment in innovation. It is defined as the total research and development expenditures divided by the total expenditures, given as a percentage. In equation form, this is (R&D expenditures) / (total expenditures).

Invested Capital: The return on invested capital is an accepted measure of corporate financial performance geared to the specific analysis of a company's use of its invested capital (Anthony et al., 2007; Lloyd & Davis, 2007). The return is defined by dividing the sum of net income and interest expense by the sum of non-current liabilities and shareholder equity. In common practice, the measure can also be derived by not including the interest expense variable (Anthony et al., 2007). The resulting equation would then become (net income) / [(noncurrent liabilities) + (shareholder equity)]. In this study, the desire was to use EPS as an outcome variable and return on invested capital as a measure of management performance. Considering the use of net income by both metrics, there would be an unacceptable collinearity between EPS and ROIC. Accordingly, the ROIC was reduced to IC by eliminating the numerator and so the metric

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invested capital became (noncurrent liabilities) + (shareholder equity). This metric is used within the study as a measure of management investment strategy.

Philips innovation index (PII): This metric was conceived by the electronics company Philips to capture the return on its investment in new product development (Andrew & Sirkin, 2006, p. 175). The index results from the product of two elements; the first is new product sales divided by total sales, and the second is the sum of income from operations and R&D expenditures divided by R&D expenditures. In equation form, this is (new product sales/total sales) x [(income from operations + R&D expenditures)/R&D expenditures].

Price to earnings ratio (P/E): A commonly used measure of market value is the price-to-earnings ratio. This metric is a simple ratio of current common stock share price to company earnings per share, given as a number. In equation form it is (current common stock price) / (earnings per share).

Research and development intensity: In a macroeconomic sense, this measure was defined by the National Science Foundation (2008) by dividing the amount of capital spent on research and development by the national gross domestic product. In a microeconomic sense, this measure is defined by dividing total R&D expenditures by the corporation's total sales (Baysinger & Hoskisson, 1989; Thomas, 2001; van der Panne, van Beers, & Kleinknecht, 2003). In equation form, RDI is expressed as (R&D expenditures) / (total sales).

Return on assets (ROA): This is a widely used measure detailing a company's return on its total committed financial resources. In this study, the variable is a lagging

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indicator used to report on the efficacy of management performance during an antecedent period. The measure is fully determined by dividing the sum of net income and interest expense by the total assets. For simplicity, the measure will use the methodology encountered in common practice by removing the interest expense variable from the equation (Anthony et al., 2007). In this study, the equation was (net income) / (total assets).

Tobin's q: Tobin's q is a measure of a firm's market performance. This measure is a ratio of a firm's market value (defined as the market value of its debt and equity) divided by the replacement cost of its assets (Cho & Pucik, 2005; Chung & Pruitt, 1994).

Weighted average cost of capital (WACC): The WACC is a measure of the combined cost of debt and cost of equity held by a company, weighted by the percentage of each in the company's accounts. While the cost of debt is reasonably straight forward, due to complications within financial accounting, the cost of equity is necessarily an estimate (Anthony et al., 2007). Despite the apparent shortcoming, this metric is used as a gauge of investment viability when juxtaposed with the return on investment (Lloyd & Davis, 2007).

Summary

Innovation runs along a continuum, not unlike other qualitative concepts. In innovation-related material, the term innovation is commonly used in broad and general terms, even taking on the airs of a cliché. At one extreme, there is incremental innovation, which describes those modifications and improvements to existing product lines normally encountered throughout the life cycle (Christensen et al., 1998; Leifer et

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al., 2000). At the other extreme lies the realm of disruptive innovations, which are dramatic and fundamentally new applications of technology or knowledge that can go so far as to change social practices (Chesbrough, 2006, p. ix). By examining the various definitions of innovation and the economic realities of the business environment, this study was undertaken to help the business manager understand the nature of innovation and its impact on earnings per share.

As a first step toward accomplishing the stated goal of the study, a review of the current literature relating to innovation is presented in the next chapter. The literature review was undertaken to examine the confusion surrounding the concepts of innovation, differentiate research and development from invention, and develop the need for a deliberate business plan for dealing with innovative activities. The study methodology, theoretical model, and research hypotheses are provided in chapter 3. Chapter 4 of this study presents a description of the independent and dependent variables, and the procedures used for data analysis to accomplish the study goals. Finally, the conclusions and recommendations of the study are offered in chapter 5.

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CHAPTER 2: LITERATURE REVIEW

Introduction

This study was designed to address the engineering managers' challenge to quantify the business impact of investment in innovative activities. The goal was not to provide an engineering management checklist for developing innovative products and services, but rather to examine the business effects of the investments made. This paper provides a review of existing literature addressing how investment activities might affect the business outcomes. Accordingly, the initial focus of this chapter is an examination of the various definitions of innovation and related concepts. From there, the focus shifts to providing an outline of the economic considerations and the need for an appropriate business model; it then moves to a discussion of what innovation activities might mean to a company. The chapter concludes with a discourse on business management concerns.

Only publicly accessible sources were used in this review. The search for current literature was accomplished using published books, journal articles, and the World Wide Web. Of particular note was the use of the online Business Source Premier database as a means of collecting current journal articles. When using public electronic databases for collection, the most common research terms used were *innovation*, *management*, *production function*, *performance measures*, *financial metrics,* and *financial performance*. The original sources used provided not only primary references, but also additional references. This compounding of sources not only ensured the use of primary sources within the literature review, but also expanded the body of material available. The technique for expanding the material used in this paper is consistent with the notion of snowball or chain sampling (Creswell, 1998).

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When evaluating the challenges associated with bringing differentiated products or services to the market, an organization must find ways to ensure it establishes and maintains some form of competitive advantage. With regard to the issue of new product development, an effort generally requiring innovative processes and applications, the problem becomes one of finding and resourcing an innovative idea. In this study, the objective was to examine the business payoff of investing in innovative processes through a focus on the investment mechanisms and the associated value of incorporating innovation into the organizational processes and corporate identity.

Problem Description

From a public policy standpoint, there is increased recognition that innovation is a critical catalyst of economic growth (Kleinknecht et al., 2002). Additionally, one of the challenges facing management teams today is to operate within the fast-paced and highly competitive market where companies must compete faster, better, and cheaper to satisfy both the customer base and the corporate shareholders (Thamhain, 2004). Corporate leaders are led to believe they can achieve competitive advantage through innovative activities (Dulaimi, Nepa, & Park, 2005), and that technology innovation is increasingly critical (Eris & Saatcioglu, 2006). Finally, "A major assumption in the innovativeness and firm performance literature is that innovativeness improves firm performance" (Cho & Pucik, 2005, p. 557). Cho and Pucik succinctly articulated one of the key issues facing the engineering manager; the false notion that innovation alone can lead to improved corporate performance.

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If the goal of a business is to provide the customer with a new and exciting product, one that will become the next market-changing product, then it must be willing to look beyond today and find the need for tomorrow. But, “market[s] that do not exist cannot be analyzed: Suppliers and customers must discover them together” (Christensen, 2005, p. 165). This is the crux of the business problem since the development of these innovative products and services necessitates extending the organization’s reach beyond the known, into the unknown. For an organization to stretch beyond the comfortable and known environment involves increased risk, yet traditional business training tells the manager that the strategy that best assures success is the one that decreases programmatic or project risk. This business logic runs counter to the requirements of technical innovativeness, which necessitates increases in technical and program risk.. The risk increases are the necessary outcome of the fact that new markets are largely unknown and there can be no guarantee of technical success.

Beyond the objective of reducing risk, common business training focuses on delivering quality products to the customer in order to enhance both profitability and returns to the corporate shareholders. However, the organization that is beholden to the current needs of the customer essentially holds the organization hostage to the limited foresight of the customer (Christensen, 2005). Supporting the idea that excessive focus on the customer is dangerous is a European study that concluded that overreliance on customer preferences may lead to a bias toward imitative projects versus innovative projects (van der Panne et al., 2003). The organizational challenge then may be to identify an alternative future to the customer.

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As a business realizes success with its low-risk incremental product improvement efforts, the management team will tend to continue in a bureaucratic manner, avoiding the disruption and risk found in the execution of radical innovation efforts (Utterback, 1994). A corporation constrained by a focus on its current market and customer base may find itself focusing on a relatively short time horizon, as one consumed by the next quarter's profitability (Rappaport, 2005). This short sightedness is driven by such philosophies as *management by objective* and *management by exception*, which result in a focus on simply sticking to a business plan vice looking ahead at what is possible (Christensen, 2005). Each of these business conditions leads to an environment of product commoditization and its associated lower margins.

Faced with short time horizons for product development, management teams may reach to incremental development efforts as a means of differentiating their products. These incremental efforts are generally characterized by a short project life cycle, measured in months; meanwhile real innovative efforts are measured in years (Leifer et al., 2000). Cooper (2001) supported the concept of increasing market tempo by asserting the importance of speed to market and declaring that, "Thus *speed is the pivotal competitive weapon*: The ability to accelerate product innovation . . . [is] central to success" (Cooper, p. 3, original emphasis). However, an unbalanced focus on simply speeding new product development is not enough to assure success.

The engineering or business manager should understand that time to market is not the discriminating element of new product development. In fact, the project timeline is a key element separating incremental innovation from breakthrough innovation since

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incremental improvements take far less time than market-changing improvements. The real return on corporate innovation investments may come from shortening the development cycle and time to market for radically innovative products, vice speeding the incremental improvement cycle.

Concepts of Research, Development, and Innovation

The basic idea behind innovation is the introduction of something new, which in this study means a product or process that is new to the market. Innovation is also fundamentally different from the activities associated with research and development. An understanding of the similarities and differences between and among each of these three terms are critical to further discussion.

Research Versus Development

In general, it is common to see the terms *research* and *development* tied together in the abbreviation R&D. This would seem to imply that the two activities are actually a single function. This is not necessarily the case because the two functions, research and its subsequent development, are actually two distinct elements of a product's lifecycle (Chesbrough, 2006; O'Connor, Leifer, Paulson, & Peters, 2008). To illustrate this difference, consider the notion that scientists generally conduct initial research in the quest for new technology and knowledge, while engineers conduct technology development for the purpose of bringing to market new products based on existing knowledge and scientific research (Chesbrough; Leifer et al., 2000; O'Connor et al.).

When reflecting on the term research, thoughts of basic technology or knowledge investigation emerge. Development then is the set of activities seeking to convert

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technology or knowledge into a viable product. The literal segregation of the research and the development competencies is not a necessary condition of an innovation process implementation; however, a conceptual separation may be required to understand and control the function of each activity. Development of new products requires a systemic coherence that starts at basic technological inquiry, passes through development and market introduction, and ends at product salvage. Simply developing an idea in the research office and passing it to the development team does not make for an efficient and effective innovation process (Chesbrough, 2006).

An examination of the extant literature establishes the need for an appropriate business model. Synthesizing the call for a business model and the activities of research and development, it becomes clear that without development and a corresponding business model, basic technology uncovered by a company's research activities has no intrinsic value (Chesbrough, 2006). A research team from RPI went further in this line of reasoning when it articulated the ideas behind the Discovery and Incubation competencies within their DNA (Discovery, iNcubation, and Acceleration) system for innovation management (O'Connor et al., 2008). By separating the development activities from the research activities, management also removes the challenges of finding near-term business opportunities from research staff tasking. Responsibility for developing commercially viable products from research staff discoveries then becomes the domain of the incubation, or development staff. While this example is a deliberate oversimplification, the point remains germane to the understanding of innovation.

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Illustrating the essential separation of research and development activities, and tying them to business management, Chesbrough (2006) described the corporate research activity as a cost center since no marketable products exist within this function. The author then described the development activities as a profit center, since it is from this activity that new products and their associated markets emerge. Each of these activities is thus different from the more general concept of innovation.

Conceptualizing Innovation

Innovation can take the form of a product, a service, or an administrative process, even though there is a bias toward technology when addressing innovation (Adams et al., 2006). Another facet of innovation theory necessitates acceptance of the notion that innovation is a process. As such, process inputs alone do not necessitate successful products or wealth generation (O'Connor et al., 2008; Parthasarthy & Hammond, 2002). There are also two organizational models to describe how companies look for innovation opportunities. These are the problemistic model, in which a company seeks a solution to an identified problem, and the slack model, in which a company uses its excess resources to fund innovative projects (Greve, 2003).

More generally, winning in the marketplace is grounded in the need to innovate (Drucker, 1985; Kanter, 1999). This point does not fundamentally alter the manner in which the manager should conceptualize the notion of innovation. Accepting that no fundamental difference exists among product, service, and process innovations, the manager must understand there is a fundamental difference between invention and innovation. If invention is described as the act of creation, then one can describe

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innovation as the application of invention for the marketplace (Chesbrough, 2006, p. ix). Alternatively, invention can describe the set of activities that results in a new product, process, or technique; an innovation can then describe the introduction of that new thing into the marketplace (O'Connor et al., 2008).

Encapsulating the difference between the ideas of invention and innovation is the notion that innovations require a market. Following from this idea is the notion that a business model is necessary to extract value from the product introduction (Chesbrough, 2006, p. 64). An interesting thought is that neither invention nor innovation has an intrinsic value to be capitalized or fully valued; value comes with a business model to exploit a product based on new technology or knowledge and an accompanying market (Chesbrough).

Economic theory supports this point of view as well. Dr. Schumpeter, a noted economic theorist, asserted that, "as long as they are not carried into practice, inventions are economically irrelevant" (1934/2008, p. 88). Additionally, Schumpeter noted that invention is fundamentally different from bringing that invention to market. Importantly, there is no requirement for invention when examining innovation; they are two fundamentally distinct ideas and repositories of corporate resources. As such, there is no innovation without an appropriate business model (Chesbrough, 2006; O'Connor et al., 2008) .

Operationalizing and Defining Innovation

Drucker gave perhaps the most succinct definition of innovation when he wrote that "an innovation is a change in market or society" (1985, p. 252). This is a simple and

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direct statement of innovation as a concept, but it certainly falls short of providing exploitation guidance to the engineering manager. Bearing this overarching idea in mind, this section addresses the challenges in attempts to define innovation operationally.

When examining innovation-related material, it is common to see the term *innovation* used in broad and general terms, even becoming a cliché. At one extreme is incremental innovation, which describes those modifications and improvements to existing product lines normally encountered throughout a product's life cycle (Christensen et al., 1998; Leifer et al., 2000). At the other end is the realm of disruptive innovations, which are dramatic and fundamentally new applications of invention that can go so far as to change social practices (Chesbrough, 2006, p. ix). Innovation and its associated activities run along a continuum, not unlike other concepts, and so do not possess rigorous characteristics. As such, the definitions of the concept offered by innovation researchers are generally vague (Adams et al., 2006; MacKenzie, 2007).

A research team from the Rensselaer Polytechnic Institute's Lally School of Management and Technology undertook a longitudinal study to investigate radical or breakthrough innovation. To support their Phase 1 efforts, the team defined a radical innovation as

> One with the potential to produce one or more of the following:
> - an entirely new set of performance features;
> - improvements in known performance features of five times or greater; or
> - a significant (30 percent or greater) reduction in cost. (Leifer et al., 2000, p. 5).

While this definition was sufficient for the first phase of the research conducted by Leifer et al. (2000), for the second phase of their research the team determined the need to make

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two significant modifications. The first modification had the research team rename their subject from radical to breakthrough innovation in an effort to describe the nature of their study better. Secondly, the team significantly adjusted its definition of innovation by removing the quantitative elements. The team now described their idea of innovation as,

> the creation of a new platform or business domain that has high impact on current or new markets in terms of offering wholly new benefits *and* high impact on the firm through expansion into new market and technology domains, increased revenue, and ultimately increased profits. (O'Connor et al., 2008, p. 11)

To describe the nature of disruptive innovation, Christensen (1997) used a theory-based definition of the difference between *sustaining* and *disruptive* innovations. He acknowledged that his idea of a sustaining innovation, one that focuses on improving the performance of products within the constraints of the established market, encompasses the breadth of attributes from incremental to discontinuous and radical. Christensen described *disruptive innovation* outputs as those that could, "bring to market a very different value proposition than had been available previously. . . [they] are typically cheaper, simpler, smaller, and frequently, more convenient to use" (Christensen, p. xviii). In fact, such innovative products typically do not bring with their market introduction any improvement in performance, but these products do reset the performance trajectory of the market (Christensen & Raynor, 2003).

Utterback offered a high-level explanation of innovation, one based on the economic theories of Schumpeter, which loosely defined innovation as the, "reduction of an idea to first use or sale" (1994, p. 193). In an earlier work, Utterback wrote that "innovation will be defined to refer to an invention which has reached market

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introduction in the case of a new product, or first use in a production process, in the case of a process innovation" (1971, p. 77). An interesting note in this definition is how Utterback referenced innovation to the idea of invention. In a later work, the author expanded on the theory of disruptive innovation put forth by Christensen (1997), by offering the view that disruptions do not necessarily only occur from below (through low-technology/low-performance products), but also from above and adjacent technologies (Utterback & Acee, 2005). Through this expansion, disruptive innovation takes on a more complete nature that better defines how market disruption occurs.

Research by von Hippel (1988, 2005) focused on lead user theory and so did not overtly define innovation. In the lead user theory, the developing agency relies heavily on its leading customers to identify the system requirements. In this way, the company directly addresses consumer needs. Von Hippel did allude to a definition, which implied a focus on product improvements, and broke innovation into two segments. Major improvements were classified as those offering the user significant improvement in performance relative to the preinnovation state, and minor improvements as those that gave the user increased performance along any dimension of satisfaction such as reduced cost, increased speed, greater quality, or improvements in reliability (von Hippel, 1988, p. 22).

This point of view stands in contrast to Christensen (1997) who described disruptive innovation as that involving market changing characteristics, but generally offering lower performance products based upon existing technology. The description of major innovation offered by von Hippel does fit better with the definition of

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breakthrough innovation (Leifer et al., 2000), which brings new technology and increases in performance to the market. Additionally, Ulwick (2002) asserted that managers focusing on their lead-users, or on customer origination of product ideas as espoused by six sigma advocates, may find they are constrained by the incomplete knowledge of the users.

According to the new product development theorists such as Cooper (1998, 2006), another way to classify innovation is to use terms such as high innovativeness, moderate innovativeness, and low innovativeness. In this light, Cooper provided definitions related to the degree of product or market change. Under this characterization, highly innovative products are new introductions to the marketplace and new product lines for the developing company. Moderately innovative products are those that establish new products within the company, but are not new to the market and are less innovative than the highly innovative products. Lastly, the products rating as low in innovativeness are those that consist of product modifications or redesigns.

An interesting perspective on the idea of identifying a quantification of innovation was provided by Shapiro (2006). Shapiro noted that the concept of innovation-as-novelty might hold the true characteristic of innovation. In fact, Shapiro noted a concern as to whether or not innovation itself might destroy the basis of quantification considering that the greatest innovations change the basis of measuring innovation itself. This idea stems from the assumption that breakthrough innovations fundamentally change the market and so how the market is measured. Many companies measure the profitability of new products and platforms as a means to capture their innovative output (Shapiro, 2006). The

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difficulty lies in determining what is new, and how long a new product remains in such a category. Additionally, a company may have difficulty identifying incremental from breakthrough innovation without clear and detailed accounting.

Recognizing the various definitions of innovation, the concept fits with the definition of a noun. A management team may incorrectly view innovation as a verb that is translated into a process or corporate means, instead of seeing innovation as an objective or corporate end. Accepting the idea that innovation is not a means, leads to the idea that it is more correctly an approach to development consisting of inputs, processes, and outputs. These outputs are the innovative products and services. Consistent with this idea is the result of a study by Cho and Pucik (2005), which found that innovation was not the discriminating factor in an effort to improve profitability, but one of many.

With the discussion of innovation definitions concluded, it may be clear that within these sundry definitions and concepts of innovation, some are competing and some are coherent. The confusion over the precise definition of the term innovation has had a profound effect on the study of innovation and has led to inconsistent theory building (Cho & Pucik, 2005). In the end, the definition seems necessarily qualitative and defies quantification beyond a set of arbitrary or situational attributes. Accepting that defining innovation is a nebulous activity, the management team must still look to introduce new and differentiated products to the market in order to survive and thrive. The engineering manager cannot simply ignore the gradients of innovation since new-to-market type innovation can reap as much as 7 times greater returns than new-to-the-company innovations (Srinivasan et al., 2009). If innovation is difficult to conceptualize,

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and returns can be significant, then a discussion of the business considerations regarding innovation is necessary.

Business Management Considerations

The business and engineering management of innovation requires the deliberate integration of various innovation related concepts or ideas. Among these ideas are economics, business administration, entrepreneurship, and financial accounting. Only by synthesizing what may seem disparate ideas, are the full richness and depth of the business considerations of innovation realized.

Economic Considerations

If the job of business is to sell products and increase shareholder value, then it follows that corporations should look for opportunities to provide a product or service to an underserved market (Drucker, 1985). Accordingly, product differentiation is the root of product success according to many writers (Christensen, 1997; Collins, 2001; Cooper, 1998, 2001; Drucker, 1985; Dulaimi et al., 2005; Hayes & Abernathy, 2007; Kanter, 1989), yet there is a second idea that perhaps the company can afford to sacrifice some differentiation advantage for sales volume increases.

Serving as an example of this idea is IBM's strategy regarding its chip manufacturing business. While IBM has developed an impressive business unit to manufacture chips for its own use, the company also offers those same chips to other companies for inclusion in their product designs (Chesbrough, 2006). If IBM considered its chip manufacturing efforts to be proprietary, they would surely enjoy a level of market

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differentiation. The IBM business model subjugates the product differentiation to increased sales volume, which in turn provides funds for further product development.

This example demonstrates how the business of innovation is essentially an economic endeavor. According to Drucker (1985), innovation might be better aligned as an economic or social activity revolving around the use of resources, as opposed to the more wide spread belief that innovations reside squarely within the world of technology development. Such a concept was furthered by Christensen (1997) when he noted that many disruptive innovations capitalize not on new technology, but new applications of existing technology. Accepting these ideas then, leads to the requirement for a fuller understanding of the economics of innovation. Holding to the basic tenets of the seminal economics educator Dr. Schumpeter, the essence of a discussion of business management and innovation is an economic one. From this perspective then, the economic factors present within the particular business environment set the context within which innovative product development will occur.

Any economic transaction or endeavor has at its core the necessity of fulfilling the needs, wants, or desire of a consumer (Schumpeter, 1934/2008). This is not unlike the idea of a consumer hiring a product to perform a job (Christensen & Raynor, 2003). To this end, Christensen and Raynor looked at economic activity as one in which the consumer ultimately drives the market, since it is the customers' needs that must be met by a company's products. From the view of technology pull, without a need or want, there would be no customer for the product and so there would not be a market, by

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definition. This, of course, is in counterpoint to the technology push idea, where companies push technology to the market to fill a need not yet identified by the customer.

The notion of an appropriate business decision, as determined by the manager, would be one in which the allocation and expenditure of resources for the development of a product is of greater benefit than using those same resources for some other project (Christensen, Kaufman, & Shih, 2008; Drucker, 1985; Schumpeter, 1934/2008). A company with slack or excess resources can afford to undertake innovative activity, and the greater the return on such activity the more slack is generated (Adams et al., 2006). In counterpoint, a design engineer may see the appropriateness of a decision as one that allows the perfection of the application of a technology. According to Schumpeter, these two desires meet at the intersection of economic value and a perfected product; this is the point of a maximized economic state. To arrive at a point of maximized economic value also requires a deliberate analysis of system requirements.

A product that meets, but does not exceed, the specified system requirements is the goal of both the systems engineer and the management team. By deliberately designing a system to exactly meet the system requirements, without exceeding those requirements, prevents the design team from *gold plating* the product (Kossiakoff & Sweet, 2003). Considering this idea from a simpler frame of reference, as requirements are exceeded economic value decreases. This decrease in value results from the use of resources above those necessary to fulfill the needs of the customer.

Such an unnecessary use of resources was identified by Schumpeter (1934/2008) when cautioning against allowing the engineering team to continuously seek the

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perfectly-engineered product at the expense of a perfectly economic product. Again, fulfilling customer needs in an economically efficient manner is the goal of business management. In fact, "If a venture is unable to create new wealth then the funding for the specific venture will dry up" (Deeds, 2001, p. 29). The negotiation of system requirements and the management of performance expectations serve as the intersection of engineering and business management. Importantly, this point does not serve as a prohibition against perfecting or improving an existing product. The continuous improvement of existing products is the essence of incremental innovation and continual product differentiation (Christensen, 1997; Cooper, 2001).

The efforts undertaken by companies to differentiate their existing products, whether through increased performance or improved quality, fall into the arena of incremental innovations (Christensen, 2005). Schumpeter (1934/2008) expressly called for continuous development of ideas, but qualified these efforts by noting that only those improvements that maximize the economic return should continue to market. The other developmental products and ideas should forego development until they meet the requirements for economic maximization.

The idea of development gates and period reviews serves as an application of Schumpeter's idea. Some companies use periodic reviews of a new product's development status as a means to approve or disapprove continuation of the project (Cooper, 2001). In this way, viable products continue along the life cycle and those projects requiring additional maturity remain at the appropriate stage or become candidates for cancellation. In contrast, the use of stages, gates, and rote planning and

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control practices can impede innovation activity by holding new developments captive to the same development system as mature and stable products and services (Kanter, 2006). Christensen (2008) provided support to Kanter's idea when he noted that gate reviews tend to focus on the potential revenues and sales at the expense of the unknown markets characteristic of breakthrough or disruptive innovations. In the latter case, the markets are unknown and the estimated sales are not much more than a guess (Drucker, 1985).

An important idea to remember when examining the economic case is that the developmental product under consideration is not required to serve as a terminal product offered to the consumer. Schumpeter (1934/2008) inserted this caveat into the definition of a *product* by calling upon the idea of value chain addition. In this argument, the author noted that the product output of one company might be an input component of another's system.

Extending this idea further gets to the notion of supplier relations, and internal and external customers. This line of reasoning begins to build the idea of a value chain, a linkage of products in which lower level products combine to form progressively more complex systems of increasing value. From a business standpoint, the value of the final product is the total book value. The economic value is defined not as a profit, but as the excess return when compared to any other product the company could produce with the same resources (Schumpeter, 1934/2008). The effort to evaluate the best options for investment alluded to in this concept fits with that of a portfolio selection model, wherein the choices of investment are driven by their expected returns (Paulson, O'Connor, & Robeson, 2007).

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A complete examination of innovation research should also include some mention of the risks of innovative activities. Two sources of risk are associated with product development efforts, one is that of technologic failure, and the other is commercial failure (Schumpeter, 1934/2008). In the first case, the technology proves to be immature or misapplied to the desired product. In the second case, a market does not exist or the company cannot properly develop a market.

Contrary to lead user theory (von Hippel, 2005), within economic theory the introduction of innovative goods does not necessarily originate with a consumer demand (Christensen, 2005; Schumpeter, 1934/2008). In order for the consumer to drive the market, the consumer would have to convey to the producing company a need, and the company would satisfy that need. Instead, Schumpeter (1934/2008) asserted that the producing organization develops its product platforms and then introduces them into the market. The root of this capacity to develop a unique set of goods or services is the absorptive capacity of the organization (Deeds, 2001).

The absorptive capacity flows from the organization's inherent knowledge and its capability to assess and act upon new externally originated technology and ideas. Once a company or industry has sufficient absorptive capacity to sustain a series of new product introductions, the consumer will become accustomed to the products and create a demand. In this scenario, the production company drives the market, vice the consumer. Following the general acceptance of the functionality and capability of a product, the consumer can then be engaged in efforts to improve the product incrementally. Supporting this concept of the production company driving the market is Schumpeter's

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assertion that the development of fundamentally new products is the province of the new entrant; as Schumpeter noted, “it is not the owner of stage-coaches who builds railways” (Schumpeter, 1934/2008, p. 66).

If one considers the development of new products as a continuum, then five levels of development can be found (Schumpeter, 1934/2008, p. 66). The first three levels are of concern when examining the concept of innovation. The first level is that of the introduction of a completely new product, one with which the market has no experience. The second is that of new production methods and techniques. The third is the entry into a new market. Worth noting is that Schumpeter did not require the emergence of a new market but rather only entry into an unfamiliar market. Bringing a new product to the market is then the goal of entrepreneurship.

Entrepreneurship

As asserted by Drucker (1985) the work of an entrepreneur is to innovate. It follows that the entrepreneur serves the greater market by transforming some set of resources into a marketable product that in turn adds wealth or value to the developing company. This idea is aligned with Schumpeter (1934/2008), who also asserted that an entrepreneur is one who brings together new combinations of materials and processes, independent of risk and financial gain. From this definition, risk is not a necessary element of entrepreneurship; rather entrepreneurship lies completely within the arena of production and capital.

Schumpeter (1934/2008) wrote that a shareholder can also be an entrepreneur, but the usual case is that the shareholder is a capitalist providing only the necessary resources

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to the entrepreneur in exchange for anticipated profits. Going further, entrepreneurship is only applicable until the business is established and stable; there are no new combinations formed once the company's operations become static. According to Schumpeter, even as the business becomes static and the entrepreneur invests the profits as capital, the risk involved is only that of a capitalist or financier, not as an entrepreneur.

In apparent contrast, Drucker (1985) wrote that entrepreneurs are not capitalists, but rather rely on supplied capital to support their objectives. The contrast is degraded if one accepts that Drucker simply drew a distinction between entrepreneurial activity and capitalist activity, whereas Schumpeter allowed a single entity to assume characteristics of both simultaneously.

Since the definition of entrepreneurship includes the original combination of materials and processes into new products, it follows that before an entrepreneurial endeavor can begin, the entrepreneur will require the necessary capital to undertake the venture. Schumpeter (1934/2008) wrote that the collection of resources requires the entrepreneur to first become a debtor as the necessary capital is raised. Hence, Schumpeter (1934/2008) defined *capital* as, "that sum of means of payment which is available at any moment for transference to entrepreneurs" (p. 122). Drucker (1985) wrote that capitalist activity is separate from entrepreneurship, although it would be perhaps incorrect to assert that Drucker necessitated this separation. In fact, Drucker also noted that opportunity for capital support can be found within the corporate sectors realizing unexpected excessive returns.

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Ultimately, the goal of a business is to ensure that the products sold not only enrich the value chain, but also command a total price that exceeds the direct and indirect costs of production (Schumpeter, 1934/2008). Since the production of goods necessarily consumes the resources derived from capital investment, the entrepreneur replenishes these resources through the profits resulting from the sale of the product. These profits are then the net surplus after accounting for all costs, which translates into, "the difference between receipts and outlays in a business" (Schumpeter, 1934/2008, p. 128). Accepting this line of reasoning, then,

> Capital is nothing but the lever by which the entrepreneur subjects to his control the concrete goods which he needs, nothing but a means of diverting the factors of production to new uses, or of dictating a new direction to production. (Schumpeter, p. 116)

Christensen's (2005) assertion that disruptive innovation will demand a premium price despite lower performance, is bolstered by the earlier work by Schumpeter, who noted that, "a new commodity is valued by purchasers… [and that] its price is determined without regard for cost of production… it may sell above costs, including all the expenditures connected with overcoming the innumerable difficulties of the venture" (1934/2008, p. 135). This idea also leads to the necessity of a well-developed business model.

The Need for a Business Model

As Drucker (1985) noted, Leonardo da Vinci produced numerous books detailing his ideas. These ideas spanned from the simple to the (then) technologically impossible; da Vinci certainly could not produce his theoretical helicopter or submarine. What is

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significant about this is that ideas, in and of themselves, do not produce marketable products or services. It is not just the technological challenge that must be overcome; a business model must accompany a product idea in order to earn a satisfactory financial return.

The treatment of innovation-related economics earlier in this section referenced the use of slack or excess resources to fund innovation activities. If such excess resources are to be used, then the management team must form a capital structure that supports the collection of excess capital (O'Brien, 2003). Classical business training includes the call for a corporate goal of maximizing shareholder value (Friedman & Friedman, 1982). To accomplish this maximization, the manager may focus the management team on near-term profitability at the expense of a longer-term strategy (Rappaport, 2005). Perhaps to address the perceived need to maximize short-term profitability, the business environment has become such that earnings are considered to be the primary measure of corporate performance; associated with internal goals such as EPS, or external benchmarking against competitors or the industry at-large (Reda & Schmidt, 2008). Accordingly, there is a focus on the EPS by top managers, making EPS a de facto measure of manager performance (Christensen et al., 2008).

When analyzing new product investments, both from internal and external sources, the business model must capture sufficient returns to make the initial investment worth the commitment of resources (Cooper, 2006; Lloyd & Davis, 2007). When developing the appropriate business model for its new product, the company should see the value position of the opportunity as an independent variable. The company should not

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attempt to shoehorn the innovation into an existing model if that model does not afford the product market maximization. In the end, a need exists to align the corporate strategy and finance activities to reach a common goal (Christensen et al., 2008). This may lead to a spin-off or licensing arrangement that moves the innovation away from the developing organization (Benner, 2007; Chesbrough, 2006; Lavie, 2006; O'Connor et al., 2008). In this way, the company can optimize the return on its investment according to the best implementation strategy.

When an incumbent company is confronted with a radically-new innovation which threatens to wrest its market share, the natural management reaction is to hold the line and focus innovation efforts on the existing product rather than enter into direct competition with the breakthrough innovation (Chesbrough, 2006; Christensen, 1997). Companies seem to have a natural tendency to retreat to mature markets and to focus corporate resources on those mature markets (Andrew & Sirkin, 2006). One possible solution to innovative concepts that do not fit completely within the corporation's existing business model is to allow the technology to migrate to a separate company, or a spin-off (Chesbrough, 2006; Christensen & Raynor, 2003; Leifer et al., 2000; O'Connor et al., 2008).

This is also a factor when looking at the idea of a corporate *hedgehog* (Collins, 2001), which calls for a company to only undertake projects that fit within the company's current business portfolio. Such an approach was also demanded by Drucker (1985) in his list of things an innovative company should not undertake, in this case efforts outside the corporate expertise. In one respect, this hedgehog strategy is useful in that it keeps the

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company focused. Kanter (2006) cautioned against too much reliance on portfolios because a portfolio can dilute the impact of innovation activity. This dilution stems from the spread of resources across too many efforts, increasing the potential of mediocrity in the individual efforts. In contrast, retrenching into only the established business line may also prevent a company from exploiting innovations and their resultant markets.

Developing Markets

Adding to the risk and fears of management regarding breakthrough or disruptive innovation is the risk that fundamental research leading to innovation can be so far ahead of the market that no useful product platform becomes immediately apparent. Worse, there may be a significant infrastructure investment required to introduce the product to the market (Chesbrough, 2006). Utterback (1994) provided an example of the risk inherent with market-leading innovation when he wrote of the introduction of gas lamps into society during the 19th century. In this case, there was a society-wide need to invest in ancillary infrastructure, such as the gas delivery mechanisms (e.g., piping and metering) before a viable market for the new lamps could be established. The challenge of introducing innovative products and platforms then is two-fold. This first issue is to develop the technology such that it is commercially viable; and the second issue, which naturally flows is to develop a market for the product (Chesbrough, 2006).

According to some new product development literature, innovations should not progress through the corporate *new product development* (NPD) process without an identified market (Cooper, 1998, 2001; Pande, Neuman, & Cavanagh, 2000b; Ulwick, 2002). Marketing is a strategic corporate activity that will affect investor reactions to the

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company, which are realized through stock returns (Srinivasan et al., 2009). In fact, management writers have consistently called for market development as an important input to the innovation process. These calls come from the world of six sigma (i.e., Pande et al., 2000b), new product development (i.e., Cooper, 1998, 2001), disruptive innovation (e.g., Christensen et al., 1998), and radical innovation (e.g., Leifer et al., 2000). An important consideration for the introduction of any breakthrough innovation is that the market cannot be known *a priori*, in fact by definition it is unknowable since there is no existing market to which a comparison can be made (Chesbrough, 2006; Drucker, 1985).

Innovation Models

The activities surrounding basic research focus on the exploration of new knowledge and technology (Chesbrough, 2006). Once the basic research phase is over, the new knowledge or technology becomes the fodder for those development activities that will carry a new product to market. From a different perspective, basic research is akin to discovery of new information, which the company then incubates until a new product or service emerges (O'Connor et al., 2008).

A closed system is one designed to discover and develop innovative products completely within a single organization (Chesbrough, 2006). The closed system is the model perhaps most readily called to mind when thinking of a traditional R&D laboratory setting. In such a system, the entire development process is contained within the organization, allowing the company to control all elements of design and to manage all interfaces. Such a development system would be applicable in cases when the company wanted to ensure adequate control over the entire development process (Christensen &

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Raynor, 2003). There are also cases of disruptive innovation efforts wherein the company desires strict adherence to organizational or proprietary development models and processes (Miller, Fern, & Cardinal, 2007). As a final example of when the closed model is appropriate, consider scenarios in which the development team is entering the market prior to the emergence of a dominant design. In these cases, there is a necessity to maintain proprietary control over the product since modularity of the design is necessarily less efficient until the market settles on its preferred design (Christensen et al., 1998; Utterback, 1994).

New-to-the-market products generally require architectures resulting from closed development efforts. This is due to the developing organization's need for full control of all aspects of system design, or in highly proprietary products wherein the company vigorously protects its system design (Christensen & Raynor, 2003). Depending on the architecture implemented, proprietary control can prevent external organizations from interfacing to the new product since there is no mechanism, short of reverse engineering, to uncover the interfaces necessary to integrate the product into a greater enterprise (Chesbrough, 2006). An example of this strategy was the introduction of Xerox's Star workstation, where the product was part of a proprietary enterprise available only through Xerox. Conversely, IBM's introduction of its personal computer, the PC, deliberately introduced the widely-available product as a platform to which other companies could add functionality with relative ease (Chesbrough, 2006). In fact, this openness led to the idea of IBM-compatible products available to the general market. When a company operates within a vertically integrated innovation process structure, it closes the door to

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externally generated ideas and opportunities for exploitation. The use of a closed system may suffer from a formal and centralized hierarchy, a condition that will degrade organizational innovativeness (Adams et al., 2006; Damanpour, 1991).

The closed innovation model grounds itself on the idea that a company should vigorously protect its own product development. If a company instead opens itself to external ideas and opportunities to exploit innovations, regardless of origin, it can effectively multiply its efforts. This line of reasoning makes economic sense since the resultant returns come at a low cost relative to the cost of developing all innovation through internal processes (Chesbrough, 2006). In essence, the concept of open innovation is not much different than the idea of employing innovation hunters, who actively engage in seeking new ideas and innovations (Leifer et al., 2000).

The idea of *open innovation* counters the long-standing assumptions made by those managers who espouse the concept of a closed system. In an open system, the developing organization is freed from the traditional idea of vertical integration and proprietary architectures (Chesbrough, 2006). Under the open innovation model, ideas can originate anywhere. These new ideas can originate within academia, dedicated research laboratories, or internal research activities. Regardless of origin, an important detail of both the open and closed innovation models is that innovative organizations are based on policies that seek and reward the innovation related activities of employees (Drucker, 1985). In addition to other dedicated sources of innovation, the company can bring the customer into the innovation process as what von Hippel calls *lead users* (Franke, von Hippel, & Schreier, 2006; Lilien et al., 2002; von Hippel, 1988).

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Lead users is a term describing the set of customers that help a developing agency to define a new product. What separates the lead user from others is the idea that while the lead user possesses the same operational needs as the greater market, a lead user seeks solutions ahead of the market (von Hippel, 1988). These users, when brought into the development cycle, can be used as catalysts to development activity.

An innovation strategy relying on current user inputs may actually bring a new set of limitations. As Christensen (1997) noted, existing customers will demand increasing performance until the marginal utility of the added performance becomes zero and the customer demand is satisfied. These increases in performance are essentially incremental in nature since they focus on increasing performance within an existing product line. Once the performance trajectory has flattened, and consumer demand for the performance has been met, the product will have reached the point of commoditization; the basis of competition will then change from performance to price. The market becomes ready for disruptive, or radical, or breakthrough, innovations at the this point since the product performance is saturated and the market begins to look for the next leap in capability (Christensen, 1997).

The open innovation model does not stop at the bounds of a particular company. An extra-preneurship approach takes the concept of open innovation even further in the desire for technological openness. Extra-preneurship combines the open innovation model with the practice of out-sourcing by establishing a loose organization built around a *community of practice* (Snyder, 2005). A community of practice is an informal network of people from industry, its suppliers, academia, research laboratories, or external

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organizations brought together to work on areas of common interest. The power of the model is in the collaboration of people who voluntarily come together to solve problems. This model encourages the organization's team members to collaborate openly and actively with external agencies, thus forming a network of practitioners working to solve common problems. The open innovation model also allows other approaches to fund external sources of innovation.

One extension of the open innovation model is to stimulate innovation activity through investment in start-up companies. By using the flexibility and capacity for experimentation normally found in young companies, a stockholder company can reap the benefits of an aggressive innovation process and exploit emerging markets (Chesbrough, 2006). Interestingly, such investment need not stop at the young company. In fact, using innovative processes in the quest for new knowledge, some companies have taken to funding surrogates through external financial venturing (Chesbrough, 2006; Kanter, 2006; Leifer et al., 2000; O'Connor et al., 2008; Vanhaverbeke & Peeters, 2005). These external investments can be successful by expanding a corporation's innovation activities to a virtual network of researchers. The network of researchers comes from not only the particular industry, but also from dedicated research laboratories and academia.

An example of start-up investment is the Intel Corporation's external venturing efforts. Intel is a semiconductor development corporation that relies heavily on external venturing to supplement its core R&D activities in the discovery of new technologies and to expand Intel's interests beyond the semiconductor industry (Chesbrough, 2006). Once an Intel-funded effort bears fruit, in the form of new technology or knowledge, the

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company takes upon itself the responsibility for developing a commercially viable product. This model essentially allows Intel to skip the discovery phase and focus on the development or incubation of technology.

Intel is not alone in this move toward external capital venturing. In an interview conducted on December 8, 2000 Andrew Garman, a veteran of corporate venturing at both Xerox and Lucent, stated that "the trend in corporate America is to decrease R&D investment. Wall street apparently values the Cisco model, where you effectively outsource R&D by making venture investments and doing acquisitions" (as cited in Chesbrough, 2006, p. 152).

Exploiting Innovation

Once the basic research has been conducted and new technology or knowledge uncovered, it is time to exploit the discovery through commercialization (Christensen & Raynor, 2003; Cooper, 2001; O'Connor et al., 2008). One fear directly related to commercialization is cannibalization of existing product lines (Chesbrough, 2006; Kanter, 2006). This fear is rooted in the idea that a new product will cannibalize market share from a mature product line. In a previous section of this study, the idea that management has a natural tendency to support mature products when attacked in the market was presented (Andrew & Sirkin, 2006; Christensen, 1997). In contrast to a defensive management strategy, the management team should consider the possibility that if it forgoes new product development in defense of existing products, another company will attack that same market. The result of such defensive management tactics may be loss of the market share the team was trying to protect.

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Knowingly taking the position of market follower may also lead to lost market share and higher development costs. This can occur whether that strategy focuses on being a fast follower or late follower. On the other hand, taking the deliberate position of fast follower may allow a dominant design to emerge and prevent development of a less-optimal solution for the market (Utterback, 1994). Under either scenario, a management team must recognize the shifting market and aggressively develop solutions or face the possibility of degraded market share as external organizations render existing product lines obsolete. In the best of cases, existing product lines can continue to remain profitable in the near-term by moving up-market through deliberate incremental improvements (Brenner, 1994; Christensen, 1997; Christensen & Raynor, 2003).

Engineering Contributions to Innovation Management

The exploitation activity of a corporation necessitates a systems-level approach and the assurance of system-level expertise. Neglecting, such a focus on the system itself jeopardizes the capability to integrate the new technology or capability into a marketable product (Chesbrough, 2006). The expertise to integrate new developments into existing or new products lies within the competency domain of the systems engineering staff, and this competency becomes increasingly important as the research department develops new technologies (Kanter, 2006; Kossiakoff & Sweet, 2003). From a contrasting point of view, the opportunities to mishandle innovation activity increase when the required expertise necessitates non-organic expertise (Kanter, 2006). The opportunity to mishandle or fail to recognize the opportunity stems from the inability of a core

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management team to assess the innovation properly, due to inadequate knowledge. This is a danger of extending too far beyond the core corporate competencies.

The discipline of systems engineering provides a capability to identify system requirements, analyze and allocate functionalities, and develop system architectures. These architectures then become candidates for further development following introduction to the market. Eventually, market forces determine the dominant product design from competing implementations.

The concept of a dominant design necessarily includes an architecture with refined technical interfaces to support both future growth and to reduce technical complexity (Utterback, 1994). A dominant design, along with its attendant architecture, also allows external agents to produce the sub-systems or modules of the system, allowing the system to become modular. The refinement of technical interfaces found in modular design eases efforts to improve product functionality and performance (Kossiakoff & Sweet, 2003). Modularity is undertaken with the goal of decreasing the complexity of external interfaces and increasing the cohesion within any particular module; the result being to “minimize external coupling and maximize internal cohesion” (Maier & Rechtin, 2002, p. 180). Increases in modularity and refinement of technical interfaces allows external agencies to develop product improvements and customization as seen in the example of the IBM personal computer provided by Chesbrough (2006).

The benefits of modularity do not stop with improvements developed externally, but extend to the entire value chain since the producer can out-source components to other firms. Once a fully developed and exploited product is established in the market,

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the accompanying profits may begin to flow down the value chain. This is due in large measure to the component providers' growth and their movement up-market, or up the value chain. This move up-market by suppliers will continue until the system producer reaps only minimal returns and the component suppliers hold the majority of profits (Christensen & Raynor, 2003). Figure 1 depicts the general process of product commoditization as described by Christensen (2003).

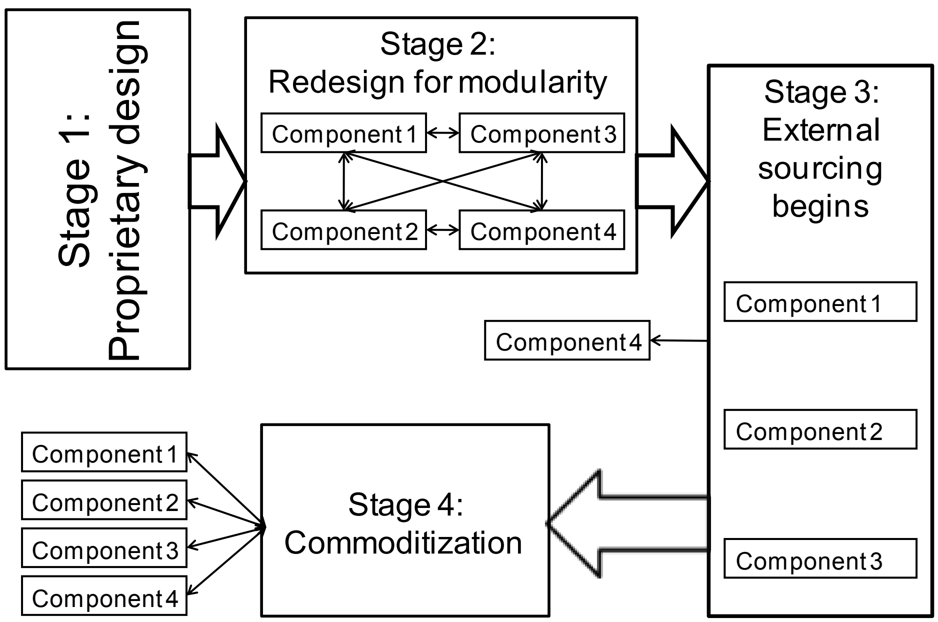

Figure 1. System value shift with increased modularity and external sourcing.

In the theoretical scenario depicted in Figure 1, profits move to external companies as components become increasingly out-sourced. The product development begins at Step 1 as a completely integrated unit, and holds very little in the way of modularity. This stage represents the product before the emergence of a dominant design, when the architecture is completely proprietary and all profits are contained within the

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developing company. In Stage 2, the system design matures and some functions are redesigned to incorporate modularity. At this point in the product life cycle, the developing organization still holds all profits. In the third stage depicted, the designing agency begins to source the lower yielding components from external companies. As out-sourcing continues, the system eventually leads to the final stage where all major components are outsourced and the developing organization retains little in the way of profits. During the non-proprietary stages, the market will establish the dominant design and any number of suppliers be positioned to provide system components. The original system provider will become an assembler of external components. At this point commoditization of the system may occur. Additionally, the profits will move down the value chain to the suppliers, leaving little margin for the product provider.

Once the innovative activities allowing a company to uncover and develop new technology or knowledge are complete, product development and introduction to the market remain open tasks. If the company follows the advice of innovation or new product development experts, marketing and exploitation are critical elements of the strategic development process (Componation, Sadowski, & Youngblood, 2006; Cooper, 1998; Leifer et al., 2000). The process of innovation exploitation is essentially a business management activity. If the exploitation is the outcome of the innovation process, then the corporate innovation investment must be the beginning.

Understanding Business Innovation Investment Trade-Offs

Investing in innovation provides benefits that go beyond increased market share or profitability (Andrew & Sirkin, 2006; Chan et al., 2001; Deeds, 2001; O'Connor et al.,

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2008). The corporate returns range from tangible financial benefits seen in corporate filings to intangible returns such as organizational pride, brand strength, corporate status, and process development. Another of these intangible benefits is corporate learning, which the accountant cannot capitalize. Unfortunately, the benefit will likely go unseen outside the company walls. For example, the innovation investments made by Intel were qualitatively assessed as increasing the total return on investment beyond the most current corporate financial statement; the same can be written with regard to Lucent's innovation investments (Chesbrough, 2006). The management reality is that while a company can quantify its financial return on investment, there are ancillary returns on these investments that defy quantification; these include the organizational learning, reduction in time-to-market, and increased sales (Chesbrough, 2006; Klomp & VanLeeuwen, 2001).

The topic of intangible returns for the corporations were further explored by Cho and Pucik (2005) in their particularly noteworthy study. The authors made the following observation when they examined the concept of innovation from a resource-based view: "a firm should possess certain intangible resources that competitors cannot copy or buy easily. As a result, the firm possessing intangible resources can gain competitive advantage in the market" (Cho & Pucik, 2005, p. 556). One such intangible asset might be the corporate marketing activity. In this light, the marketing department helps the stock market properly discount and appropriately value the corporation's innovation activities (Srinivasan et al., 2009).

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Without a clear link to financial statements, the total returns available to an organization from investment in innovative processes and technologies go unquantified. Following then, is the notion that traditional financial reporting does not support effective valuation of breakthrough innovation (Shapiro, 2006). This difficulty lies in the length of time necessary to see projects to fruition, the uncertainties inherent in this type of project, and the challenges to define what *new* really means.

The financial return on innovation investment generally requires at least 3 years to take effect, the length of time required to develop a product and see it to the market (O'Connor et al., 2008). The lag in tangible profits results in the management predicament wherein the intangible benefits of the breakthrough precede any increase in financial returns (Paulson et al., 2007). This complicates the financial valuation of a company and may reduce the incentive to invest in those activities that are not fully accounted. Managers of breakthrough innovation projects must demonstrate project value to corporate leadership and they may not have a readily accessible tool to normalize the project value.

Recognizing the challenges of valuing research and development (R&D) investments, accounting for R&D costs is not generally of immediate value when looking to assess the stock value of an R&D intensive company. Many commonly used measures of company stock value (e.g., book value of equity and assets, and cost of capital) do not include intangible assets (Chan et al., 2001; Smith, 2007). This leads to the unfortunate situation wherein the accountant expenses the costs associated with innovation investment, yet is unable to capitalize a corresponding asset due to the inherent lag in

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asset realization. It appears that accurately accounting R&D investment is sufficiently difficult that financial experts have turned to other ratios in the effort to demonstrate the actual value. These other measures include R&D expenditures/total sales, R&D exp./earnings, R&D exp./dividends, or R&D exp./book equity (Chan et al., 2001).

A common idea found in business training is that profits or shareholder value must be maximized (Christensen, 1997; Friedman & Friedman, 1982). Extending this idea, there is concern that the theory calling for profit maximization forces a focus on near-term performance (Bushee, 2001; Christensen et al., 2008; Rappaport, 2005; Reda & Schmidt, 2008). Supporting the assumption of short term focus is the increasing management reliance on cash flow analyses as the primary measure of corporate performance (Gundavelli, 2006). Complicating valuation as measured through cash flows, is the idea that cash flows are not necessarily true reflections of how the company is operating (Frigo, 2003). Additionally, Trigeorgis (1993) asserted that simple assessments of net present value and cash flows provide insufficient information to management teams as they work to identify proper strategic financing options. The valuation of the innovative activity or new product development should also be put into the context of what other products or services could be made available with a different allocation scheme (Christensen et al., 2008). This context establishes a *best value* among competing products or services.

According to Kanter (1989) one of the requirements for “swimming in newstreams” of innovativeness is that the capital investment must not be committed with a requirement for near-term return. Drucker (1985) expressed a similar point when he

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noted that growth is the objective of a new venture and that profitability during the infant stage is likely fictitious. In contrast, Christensen and Raynor (2003) asserted that profitability in the near-term was necessary to demonstrate product viability. Despite the top-level divergence in these ideas, Christensen and Raynor coalesce with Kanter on the more general idea that growth need not be fast, but rather deliberate. In this way, the innovative product demonstrates a satisfactory level of viability not through forcing a tactically focused win-or-go-home strategy, but rather by establishing an environment of strategic development and growth.

Corporate Indicators of Innovation

One commonly used measure of corporate investment in innovation activity is *innovation intensity*. Innovation researchers use this measure to capture the qualitative strength of a firm's investment in its R&D efforts (Klomp & VanLeeuwen, 2001). By dividing the direct R&D expenditures by total sales, an analyst can quickly determine how much profit the corporation invests directly into its R&D activities. Innovation intensity can also use market equity, net earnings, or total dividends in the denominator to describe the investment intensity (Chan et al., 2001).

In a review of existing literature, one study found that R&D intensity was controversial as an indicator of an innovative project's technical viability (van der Panne et al., 2003). The controversy reported by van der Panne et al. is rooted in the challenge of identifying the reason for the success enjoyed by companies that invest heavily in research and development. It is not clear that the simple act of investing in R&D necessitates innovative output. Worth noting is that the study authors identified R&D

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intensity as the ratio of R&D expenditure to total sales, which is the definition of innovation intensity in the present study.

The National Science Foundation (NSF) provided management researchers another measure of innovation investment vigor through its version of R&D intensity. This modification allows a researcher to divide the R&D expenditures by total expenses instead of the firm's total sales (National Science Foundation, 2007). In this way, the R&D intensity measures the ratio of R&D expenditures to general capital expenditures, whereas innovation intensity provides a measure of the percentage of sales fed back into the R&D effort.

According to the NSF and the National Research Council (NRC), the overwhelming majority of R&D investments come from the industrial sector (National Research Council, 2005). In fact, the NSF reported that before 1983 approximately 95% of R&D investment came from the manufacturing segment of industry. There appears to be a shifting trend in innovation investment, demonstrated by a decrease in industrial innovation investment between 1983 and 1993 from 95% to 75%. This trend appears to have stabilized as of 2005 when the manufacturing segment accounted for 70% of industrial R&D investment. In 2005, contributions to R&D from the manufacturing segment accounted for $158 billon and $68 billion was contributed by the non-manufacturing segment (Wolfe, 2007). Of particular note, in 1994 industrial R&D investment declined to a level below inflation for the first time. Van der Panne et al. (2003) conducted an extensive review of the innovation literature and found that intensity measures do not account for the wide variety of inputs to innovation processing. Despite

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any disagreements or controversy, the NSF continues to use R&D intensity as a leading indicator of U. S. R&D investment in total (National Research Council, 2005).

The use of corporate patents as an indicator of innovative activity is wide spread within management research; however, the use of patents in such a manner is controversial (Adams et al., 2006; Bessen & Meurer, 2008; Gittelman, 2008; Kleinknecht et al., 2002; Parthasarthy & Hammond, 2002; Szakonyi, 1994; Ziedonis, 2008). The research by Kleinknecht et al. was clear in its rejection of patent information as an adequate indicator of innovation performance. The crux of their argument centered on the nebulous character of patent filings. The team noted that an issued patent does not necessarily elicit a new product, and companies have been known to apply for patent protection to support both defensive and offensive market strategies (Kleinknecht et al., 2002). Going further, Kleinknecht et al. listed as the limitations of patent filing the underestimation of innovation within low technology sectors, overestimation of innovation within companies involved in extensive R&D collaboration, underestimation of small firm innovativeness, and overestimation of innovation for small firms that did obtain patents. Cordero (1990) asserted the concern that patents do not necessitate innovative products or services, but rather may serve as an indication of potential marketability.

Degrading the utility of using patent applications further is the fact that patents do not demand breakthrough performance or even significant product or technology improvement. In fact, issuance of a patent does not necessitate anything beyond unique modifications. Some companies exercise a management strategy that precludes patent

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applications due to the cost, time, and effort involved, while others execute marketing strategies which would be unnecessarily encumbered through patent protections (Chesbrough, 2006). Primary among these strategies is the use of licensing agreements.

Some advocates of documenting all intellectual property would make a claim such as, “Corporate America is wasting a staggering $1 trillion dollars in underutilized patent assets” (Chesbrough, 2006, p. 155). However, if one subscribes to the notion that a patent, idea, discovery, or invention has no tangible fiscal value absent a business model to capture financial returns, this argument fails. A patent, trademark, or copyright has no intrinsic value; the accompanying product holds the value. An exception to this rule exists in the deliberate strategy of employing intellectual property rights as a defensive measure designed to prohibit others from exploiting a discovery. Considering the time investment, reported by the U. S. Patent Office as about 32 months for utility patents (see the U. S. Patent Office website at http://www.uspto.gov), and monetary cost of patenting a discovery, there may not be sufficient motivation to claim the intellectual property (Chesbrough, 2006). Additionally, without acceptable business models the mere existence of intellectual property right protection is not a sufficient indicator of effective innovation activity since there is no mechanism for assuming their benefits.

Financial Accounting Measures Related to Innovation

One challenge to uncovering the proper financial indicator of innovation activity is that the generally accepted accounting principles (GAAP) do not adequately handle R&D expenditures since they force the immediate expensing of the investment (Frigo, 2003; Smith, 2007). The lag between innovation expenditures and their effect on the

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business financial condition is minimally three years (O'Connor et al., 2008). This leads to a situation in which an analyst would have to correlate an initial expenditure to a developed product that would emerge years later. In this scenario, the analysis would be by project, vice total corporate expenditures and income. To demonstrate the apparent inefficiency of the accounting requirements associated with R&D investment is the assertion by the National Science Foundation and the Bureau of Economic Analysis that,

> Gross Domestic Product (GDP) would be nearly 3 percent higher each year between 1959 and 2004--$284 billion higher in 2004 alone--if research and development (R&D) spending were treated as investment in the U.S. national income and product accounts, the Bureau of Economic Analysis (BEA) and the National Science Foundation (NSF) announced on Friday. (National Science Foundation, 2007, p. 1)

The Royal Philips Electronics Company, headquartered in the Netherlands, used a unique company-specific metric they term the *Philips innovation index* to assess new product developments. The measure is more complex than either R&D intensity or innovation intensity. The basic equation holds two elements; the first is new product sales divided by total sales, and the second is the sum of income from operations and R&D expenditures divided by R&D expenditures. The result is an innovation index that must result in a value greater than 1 to establish commercial viability (Andrew & Sirkin, 2006). The uniqueness of this valuation tool comes from its focus on new products and the financial return on the innovation investments. The indicators described above capture the inputs to the innovation process, and there exists a complementary set of measures to describe the financial output of the innovation process.

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In a rational market, the individual shareholder will invest personal capital in a company with the expectation of financial returns greater than the investment (Chan et al., 2001). One popular measure used to capture the expectation of future earnings is the price-to-earnings ratio (P/E). This measure demonstrates the investor population's confidence in the future performance of the firm (Anthony et al., 2007). If a firm's stock price is high relative to the company earnings, then the P/E ratio is high. This indicates investor support for the firm's potential for future earnings. Accordingly, when a company's outlook holds the likelihood of future profit, indicated in this case by a high P/E ratio, a generic investor will be more inclined to buy that stock. It also follows that in a rational securities market the P/E ratio will reach a point where the potential for earnings has saturated and the investor will see the P/E ratio as excessive. In this way, the market assessment of the full potential for returns is included in the stock value.

An examination of R&D budgets reported by Kleinknecht et al. (2002) indicated that R&D expenditures accounted for only one-quarter of the total corporate innovation investment. Additionally, one-half of the innovation expenditures were made for fixed assets. The service sector, which may not have a requirement to invest directly in new technology, still invests its innovation resources into fixed investments. The use of direct R&D expenditures, which is perhaps best suited for corporations producing physical innovations, does not allow the researcher to uncover the investment in the corporate innovation activity of low technology or service corporations (Kleinknecht et al.).

From a financial standpoint, there are other important measures of a firm's overall performance. One that captures, in financial terms alone, the performance of a firm's

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investment in its own operations is the *return on invested capital* (ROIC). This measure focuses on the long-term capital investments made by corporations (Anthony et al., 2007). In general, the management team garners the greatest benefit from this metric when the ROIC is part of the investment decision-making process. By comparing the ROIC to the weighted average cost of capital (WACC) of potential projects, a firm can make a better determination as to which projects to fund (Lloyd & Davis, 2007).

Descriptive Quantitative Inquiry

The current study is best put forth as a quantitative study, and more focused as a descriptive-quantitative study. This is due in large measure to the reliance on existing, well-defined data and the use of analysis to describe a phenomenon (Singleton & Straits, 2005). Singleton and Straits defined inquiries designed to test relationships, such as the present study, as explanatory studies. This idea was rejected in favor of the descriptive nomenclature since the measures are widely used and accepted. It would be perhaps more confusing to define the study as explanatory since there is no explanation of the phenomena related to innovation attempted in this study.

Trochim (2001) broke the nature of quantitative studies into three categories as well, using the terms descriptive, relational, and causal. These terms more clearly allow the present study to be cast as a descriptive study since Trochim used the idea that a descriptive study should, "describe what is going on or what exists" (2001, p. 5). Once again, the current study was not undertaken to define cause and effect related to innovation investment, but simply to describe the situation at hand. In this light, and

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referring back to Singleton and Straits (2005), a descriptive study should be designed more as an evidence-gathering exercise than a quest for cause and effect.

Another point considered during the development of this study was the focus on data correlation. This study was designed to understand the correlation between innovation inputs and their attendant outputs, particularly financial outputs. This idea falls squarely into the category of a correlation study (Leedy & Ormrod, 2005). Leedy and Ormrod noted that correlational studies are designed to find the relationship between particular characteristic or attribute variables.

The research problem might have been addressed through a qualitative methodology if the research had been skewed slightly toward a phenomenological light. A phenomenology may be described as an extension of a biographical effort. In both cases, the lived experiences of an individual (biography) and a group (phenomenology) is described (Creswell, 1998). Phenomenological studies are designed to understand the human social interactions or the participants' view of some social reality (Leedy & Ormrod, 2005). Since the roots of phenomenology are found in the world of psychology, the focus is generally on the consciousness of particular experience. This is in contrast to the goal of the present study, which is not concerned with the experience of innovation related activity, but with the financial outcomes.

The measures used in the study were found within the literature presented in the next chapter, and considering the impersonal nature of the research measures, the qualitative study methodologies are likely inappropriate for the nature of inquiry in this study. Additionally, the goal was not to understand the fundamental causes and effect

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relationships of the subject matter. This constraint aligned the current research with the quantitative methodology as espoused by Singleton and Straits (2005) and Trochim (2001). Further, using the definition of descriptive research put forth by Singleton and Straits, as well as Trochim, the present study falls into the category of descriptive research vice either explanatory or relational.

Conclusion

A manager who aspires to lead an innovative organization faces many challenges. Chief among these challenges is an understanding what being innovative really means. This chapter does not serve as a prescription either for innovative success, or to demonstrate the processes required for corporate success. Instead, the intent was to define innovation as a process, with discrete inputs, processes, and outputs; describe the economics environment in which innovation management exists; and to develop the need for a business model to exploit innovation activities. The overarching point to be carried away is that innovation is an organizational outcome, and a worthy management objective.

With the review of existing innovation literature concluded, the focus of the study will turn to developing the study data. Chapter 3 of this study will introduce the heart of the study, the data collection and analysis. Within the chapter will be the theoretical model, the accompanying hypotheses, the reseach methodology, and the procedures that will be used to analyze the data. These topics will serve the goal of helping to improve management's capacity to delivery consumer-pleasing products to the market in an effort to ensure profitability.

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CHAPTER 3: METHODOLOGY

This project was a descriptive quantitative study using a nonprobabalistic purposive sample of convenience containing an analysis of existing public financial data. The design of the present study allowed an examination of innovation-related data from across industrial segments in an attempt to develop potential correlations between innovation expenditures and financial outcomes. The analysis first focused on individual corporate performance followed by a comparison of the results across the sample. This methodology first established correlations within a single business entity, then correlations among businesses within a broader market. This study design was grounded in the research conducted by both the Rensselaer Polytechnic Institute’s Research Program on Radical Innovation (RPI; Leifer et al., 2000; O'Connor et al., 2008), and a separate study conducted by Klomp and Van Leeuwen (2001), although the final design is not taken directly from either study. Each of these two studies directly examined innovative organizations. In the next section, the research model used to accomplish the study objectives is introduced.

Research Model

Recall that, as applied to the economic theory put forth by Cobb and Douglas (1928), the general form of their production function is written as $Y = AL^{\alpha}K^{\beta}$. The Cobb-Douglas model therefore captures as the dependent variable, the output of its independent variables, which are rooted in both accounting and business performance metrics. This is consistent with the objective of the present study, which is to find the relationship between corporate inputs, in the form of internal investment, to the corporate financial output, in the form of the ratio of R&D expenditures to total expenditures (innovation

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intensity) and invested capital. The general form of the Cobb-Douglas production function was the preferred basis for the research model, although the model would not be subjected to the economic inputs limitations of capital and labor imposed by the team of Cobb and Douglas.

Further assessment of the study data demonstrated that a linear model would better fit the data. This also required that the data be assessed with due recognition that there was likely an interaction effect between innovation investment and invested capital, and that there was likely some influence of period, especially related to the data year. Using corporate earnings per share as the dependent variable, the linear model of the study was $Y = \beta_0 + \beta_1 XYEAR + \beta_2 XII + \beta_3 XIC + \beta_4\, XIIxIC$. The definition of each model variable is presented within this chapter.

Basis for the Model

One challenge common to both the engineering business manager and the accountant alike is properly reporting the firm's account values. Complicating the financial accounting activity is the requirement for the immediate costing of all R&D investment, and the prohibition of accounting for work-in-progress as an asset. Unfortunately, these two financial accounting requirements ultimately lead to a decrease in the firm's reported return on assets (ROA) and a potential drop in market valuation. On initial examination, one may see this market devaluation as a sign of poor managerial performance. The challenge before the management team then is to define a strategy, which will demonstrate increased value through internal investment while simultaneously satisfying stockholder demands for financial returns.

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From chapter 1, the following research questions were examined in the study.

1. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in innovation intensity?
2. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in invested capital?
3. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in the product of innovation intensity and invested capital?
4. What is the relationship between earnings per share and the year the data was collected?

The research model was developed to demonstrate the relationships required by the research questions, and led to the use of variables related to corporate financial output, research and development investment, invested capital, an interaction between R&D investment and overall invested capital, and a period variable. Each of these variables is further explained in this chapter.

Dependent Variable

Earnings per share (EPS). In the research model, this variable was *Y*. The corporate EPS is a benchmark of a corporation's economic output; determined by dividing the corporation's net income applicable to the corporation's common stock by its outstanding shares for the reporting period (Anthony et al., 2007). There are two varieties of EPS, basic (utilizes only outstanding shares) and diluted (captures the diluting effect of all stock issued or not). This study utilized the basic earnings per share, as

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reported by the sample corporation's on their annual SEC Form 10-K filings. This measure is the dependent variable in the study model. A corporation's EPS, although somewhat controversial (Frigo, 2003), is widely used as a measure of corporate performance (Reda & Schmidt, 2008). The EPS variable has a direct influence on the P/E ratio, which in turn is used by the investment community as a measure of expected future returns.

Unfortunately, there is currently no generally accepted measure of innovation output found within the literature (Parthasarthy & Hammond, 2002). The use of EPS as a performance metric within the current study is established by the its impact on both price-to-earnings and its use as a measure of shareholder value, a key goal of management (Christensen et al., 2008). This may be due to the differing and, at times, conflicting objectives within the research community.

Independent Variables

Innovation intensity (XII). In the research model, this variable was denoted XII and is defined as the logarithmic value of the participant companies' reported R&D expenditures divided by total expenditures. The variable was used to quantify the ratio of direct investment in a corporation's internal innovation activities, and is a measure of innovation process input; as such, it should have been a leading indicator of corporate economic output. Use of this variable to indicate R&D output is not appropriate since it does not relate to a corporate financial outcome.

Invested capital (XIC). The logarithmic value of study participant corporation IC was the dependent variable XIC in the model and was used as a measure of the impact of

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a corporation's internal investment. In the present study, the IC became important in that not all innovative companies reported R&D expenditures directly, and so the relationship between internal investment and the resulting EPS became an area of interest. The generally accepted accounting principles (GAAP) also allows generous interpretations of what constitutes an R&D expenditure, even though it is very strict about when such expenses are to be reported.

The use of the variable XIC is assumed correct because a company must use its own financing to perform the preliminary activities that lead to new products and the resulting returns. Additionally, had the researcher used the return on invested capital (ROIC), there would be a collinearity issue due to the use of net income in both the dependent variable (EPS) and its ROIC, which would call the study results into question. Cho and Pucik (2005) studied the effects present in their innovation-quality-performance model and found a positive relationship between innovativeness and firm performance as measured by ROA, return on investment (ROI), and growth. Of interest, Cho and Pucik used the metrics of market to book value and Tobin's q to identify the market performance of an innovative company.

Interaction between XII and XIC (XIIxIC). In the list of assumptions made for this study, one was that invested capital was used to fund R&D expenses. Accordingly, the independent variable XIIxIC was used to capture this effect. This variable was the product of the XII and XIC values.

Influence of annualized data (XYEAR). The model also included variable to assess the potential bias in the use of annual data. An assumption within the study was that the

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impact of using annual data would require some control variable to stabilize the dependent variable data. Accordingly, the term XYEAR was introduced to represent the year the data set was initially collected and reported on SEC Form 10-K.

Research Hypotheses

To evaluate the adequacy of the theoretical model used in this study, each of the independent variables was subjected to hypothesis testing. The full model was also tested to ensure accuracy. Accordingly, the following hypotheses were used to evaluate the model.

Hypothesis 1

Null hypothesis 1: There is no relationship between the corporate EPS and the variable XII. The alternative hypothesis is that there exists a relationship between EPS and XII.

H_{01}: $\beta_1 = 0$; H_1: $\beta_1 \neq 0$

Hypothesis 2

Null hypothesis 2: There is no relationship between the corporate EPS and the variable XIC. The alternative hypothesis is that there exists a relationship between EPS and XIC.

H_{02}: $\beta_2 = 0$; H_2: $\beta_1 \neq 0$

Hypothesis 3

Null hypothesis 3: There is no relationship between the corporate EPS and the variable XIIxIC. The alternative hypothesis is that a relationship exists between EPS and XIIxIC.

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H_{03}: $\beta_3 = 0$; H_3: $\beta_1 \neq 0$

Hypothesis 4

Null hypothesis 4: There is no relationship between the corporate EPS and the variable XYEAR. The alternative hypothesis is that a relationship exists between EPS and XYEAR.

H_{04}: $\beta_4 = 0$; H_4: $\beta_1 \neq 0$

Hypothesis 5

There is no relationship between a corporation's EPS and the variables XII, XIC, XIIxIC, and XYEAR. The alternative hypothesis is that a relationship exists between EPS and XII, XIC, XIIxIC, and XYEAR.

H_{05}: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$; H_{05}: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$

Research Design

This study was a non-experimental evaluation of innovative companies and their investments in innovation, conducted under the approval of the Institutional Review Board (02-13-09-0309834). The methodology used was rooted in contemporary applied social research as identified by Singleton and Straits (2005). Although the study is grounded in the work of the RPI team (Leifer et al., 2000) and of Klomp and VanLeewen (2005), the design is not taken directly from either study. The sample firm's financial performance was measured through the set of innovation-related metrics developed earlier in this study.

Zahra (1991) used a set of financial accounting variables to describe corporate entrepreneurship investments. The Zahra study demonstrated the effect of the variable

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contribution to the overall corporate financial performance. In that study, the accounting variables included earnings per share, return on investment, and return on assets. In the present study, the model included not only accounting measures, but also measures of direct R&D investment. The overall goal in the selection of the model variables was to capture the financial output of corporate internal investments associated with both R&D and investment performance.

The research design of this study was formulated to attempt an examination that looked beyond the effects of direct R&D investment as measured by the intensity variable. This study design avoided an examination of only those measures normally associated with products and their related manufacturing efforts, which tend to underestimate innovation within the service sector (Kleinknecht et al., 2002). A better picture of the financial output of innovation activity necessitated an examination of general corporate entrepreneurship and desire for positive financial reporting.

Data Sources

The primary sources of data were the corporate Securities and Exchange Commission Form 10-K filings for the most recent 6-year period (2003-2008) of the sample corporations. Both the primary and derived data necessary to answer the research hypotheses were collected through publicly available information as required to support the primary data analysis. These ancillary data sources were found in the corporate annual reports to their stockholders, and the corporate investor relations websites.

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Research Sample

The population for the current study was *innovative companies*. The companies selected for inclusion in the study sample were identified through a qualitative assessment of U. S. headquartered, publicly traded companies generally recognized as being representative of innovative industry leaders. This led to an original sample of 30 companies. To increase the sample size, additional companies were added through a comparison of the original sample, bringing the total sample to 51 companies. These admittedly simple qualifications ensured the sample companies were subject to a consistent set of economic forces related to a single national economic environment and accounting rules. The total study sample size was $N = 51$ companies, and included 306 data sets. This method of developing a research sample is consistent with a nonprobabalistic purposive sample (Trochim, 2001).

By using this method, the companies selected not only represented a cross-section of the American market, but also obviated the requirement to develop an inefficient or exclusionary definition to describe an innovative organization. By attempting to define an innovative company too narrowly, the researcher may have inadvertently segregated the overall population into inadequate clusters.

This technique for sample selection was used previously by the RPI research team for its longitudinal study of innovative companies (O'Connor et al., 2008). Additionally, Zahra (1991) used a similar approach in a study of corporate entrepreneurship, the Corporate Advisory Board (1998) used the Fortune 500 as its source, and yet another

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study focused on examining shareholder value and R&D investment (Kelm, Narayanan, & Pinches, 1995) used the Wall Street Journal to find appropriate participant companies..

Procedures

Data Collection

Data collection occurred through documentation generally available to the public. This collection effort principally used the Internet to search for and electronically collect data related to the hypotheses. This study utilized the tools commonly found within the Microsoft Excel 2007 program for data manipulation and storage. The source data for each company under study were preserved in a separate file for use by the researcher in the current study and for future reference.

The study data sets included:

1. Securities and Exchange Commission (SEC) filings (Form 10-K) for the fiscal years 2003 through 2008.
2. Annual Report to Shareholders for the sample corporations.
3. Ancillary corporate financial information available via the corporate website.

Data Analysis

To assess the appropriateness and validity of the hypothetical model, the following steps were taken.

1. The discrete data elements were collected for each sample corporation.
2. The study variables were calculated from the discrete data.
3. The resulting data were then analyzed according to the linear regression model $Y = \beta_0 + \beta_1$ XYEAR + β_2 XII + β_3 XIC + β_4 XIIxIC.

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4. Where data elements were negative, the data were entered as a percentage change from the previous year without taking the logarithm.
5. The regression output returned b, *t*, *p*, VIF and the derived multiple coefficient of determination (R^2), adjusted R^2, and standard error (ε) values.
6. The data were analyzed using analysis of variance (ANOVA).
7. Each independent variable of the model was analyzed for appropriateness using Student's *t* tests.
8. The *F*-distribution value and significance of the complete model was determined.
9. A stepwise regression model was used to improve the model fidelity.
10. The residual plots, collinearity, and variance inflation factors (VIF) were derived to confirm appropriateness of the model.

Data Management

The data repository was a researcher workbook containing compilations of both raw and manipulated data. The data analysis utilized the tools available within the SPSS Statistics GradPack v17 and Microsoft Office Excel 2007 (with the MegaStat add-in) programs, and included both descriptive and inferential statistics regarding the financial performance of the sample companies. The descriptive data included statistical sample mean, mode, median, variance, standard deviation, and the multiple coefficients of determination (R^2). The set of inferential statistics included an analysis of variance

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(ANOVA), Student's *t* tests, and multiple regression analysis. The data analysis was conducted at a significance level (α) of 0.05.

The data were analyzed first to assess the correlations within each company as a separate unit. The data were then aggregated to uncover potential correlations within the sample as a whole. Since the financial data set for each corporation encompassed 6 consecutive years of performance, each company served as a subsample within the study sample of 51 companies.

Summary

This chapter was devoted to the development of the research design and methodology. The theoretical model was introduced, as were the attendant hypotheses. The chapter included sections detailing the research design, sample selection rationale, data collection procedures, data analysis, and data management. This chapter of the study provided the details necessary to ensure a thorough, accurate analysis of the data to support the engineering manager in the quest to allocate precious corporate resources more efficiently. Chapter 4 follows and details the results of the study data collection and analysis. The chapter includes an assessment of the research model, a report of the hypothesis tests, and identifies the answers to the study research questions.

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CHAPTER 4: RESULTS

Introduction

The results identified in this chapter are presented to show the both the correlations between innovation-related expenditures and financial outcome, and the impact of the independent variables upon the dependent variable earnings per share (EPS). The dependent variable EPS was chosen as the top-level management metric since classical management training calls for maximization of shareholder value (Christensen, 2005; Drucker, 1985; Friedman & Friedman, 1982). The independent measures were chosen in acknowledgment of the calls from management researchers for innovation investment (e.g., Canner & Mass, 2005; Chesbrough, 2006; Lilien et al., 2002). The strength of corporate innovation investment was represented by the ratio of R&D expenditures to total expenditures, which was included as the explanatory variable innovation intensity (XII). Management's corporate investment strategy was included in the study as the independent variable XIC (IC) to capture the impact of corporate internal investment activities, which are critical to financing R&D efforts. Additionally, some corporations did not report direct R&D investment and so the metric of IC was used to assess the overall investment activities by management. The variable XIIxIC was introduced to capture any interaction effect between XII and XIC, which assumed to exist because IC would be used to fund R&D expenses. Additionally, XYEAR was introduced to include any effect of using annual data.

The study data were collected and analyzed at a significance level (alpha, α) of 0.05, using the procedures described in chapter 3. The results of the analysis are

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presented in this section, as are the answers to the research questions and the accompanying hypothesis tests.

The data were collected through an examination of public financial records related to the subject companies. The study variables were derived as noted in chapter 3, and a table of the resulting study data is contained within Appendix A (company names were omitted per IRB). Following the collection of raw data, a set of descriptive statistics was developed for each study company; these are presented in Appendix B. A multiple regression was also performed, and the research hypotheses were tested; the results of the regression and of the hypothesis testing are presented throughout this chapter.

Data Collection

The data collection effort was undertaken by accessing public financial documents related to the 51 companies used in this study through their corporate Internet websites and the Securities and Exchange Commission online database. The first objective was to collect the annual financial filing of SEC Form 10-K for each company over the most recent 6-year period, 2003-2008. The financial data required by SEC Form 10-K provided all necessary primary data to derive the study variables. In cases where neither the corporate website nor the SEC database provided the required-year Form 10-K data, or in cases in which final derivation of data was hindered in some way, the corporate annual report was used. Since the financial data contained within the Annual Report is consistent with the SEC Form 10-K, the reliance on Annual Report data did not degrade the quality of data collected.

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Incomplete Data Sets

With the exception of Google, all necessary corporate data was accessible, and afforded a complete set of the most recent 6 years of financial data. In the case of Google, the sixth year (2003) of accessible data was incomplete, due to the 2004 initial public offering of stock. This resulted in public disclosure forms that presented only a minimum set of required financial data. The missing corporate information represented a minimal loss of data, and did not affect the study results.

R&D Expenditure Reporting

A corporate investment in R&D was identified first by locating the dedicated accounting item in Part II, Item 8, of the Consolidated Statements of Income of the SEC Form 10-K. In several cases, the R&D investment was not shown in Part II, but was presented textually within the notes to Part II or within the Management's Discussion and Analysis section, Item 7, of the Form 10-K.

Complicating the data collection effort with regard to R&D investment was the absence of reported R&D investment by several of the study corporations. The result was a value of zero for innovation intensity. The companies reporting no R&D investment were primarily from, but not limited to, the financial services sector. This loss of data was unfortunate since most of the companies not reporting any R&D investment did mention such investments, particularly software development, within Item 7. Interestingly, two corporations, each known within the market as being particularly innovative, also did not report R&D investments.

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Also of note were the earnings per share for Company 12 (Appendix A). In the case of this corporation, there were large losses from 2005-2007. These losses led to severe outliers for the variables EPS and XIC. The three data points presented a skew in the data, but the information contained within these data were not excluded from the study analysis. The inclusion of this data was done to acknowledge that innovative companies are not immune to poor performance.

Analysis of Incomplete Data Sets

As noted, several companies reported no R&D or placed the R&D value within a general accounting line such as Property, Plant, and Equipment, addressing the actual R&D investment in the Management Discussion section of the Form 10-K or Annual Report. This is consistent with the finding that R&D expenses are sometimes viewed as minor accounting items (O'Brien, 2003). Although there was concern about using data from corporations that omitted R&D investments, dismissing the entire data for a company that did not report its R&D investment may have biased the results toward the more innovation intensive companies (Himmelberg, Hubbard, & Palia, 1999).

Descriptive Statistics

The descriptive statistics derived from the analysis of sample data included the mean, error, and curve-shaping statistics for each variable. Additionally, box plots for the various data sets are included in Appendix B. The independent variables related to financial ratios, XROA and XROIC, as well as the dependent variable EPS had much greater variance than the innovation related data in the form of XII and XRDI. These results are shown in Table B1.

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Multiple Regression Data Analysis

A multiple regression analysis was conducted on the full model and variations of the full model to derive the best-fit model using the data and methodology of this study. The results of these analyses are detailed in this section, and the accompanying tables are shown in Appendix C. The tables are not presented in the current chapter due to the potentially corrupting influence of their insignificant results. The results, in general, show unacceptable values that detract from the best-fit model identified later in this chapter.

Research Model Results

The results of the research model multiple regression are shown in Table C1. The regression analysis resulted in determination of the variable coefficients (*b* in the table), as well as both *t*- and *p*-values for each model variable. The two-tailed Student's *t test* critical value for 301 degrees of freedom (*df*) and a significance level (α) of 0.05 was estimated at ±1.97 (Aczel & Sounderpandian, 2006, p. 777; Lind et al., 2008, p. 786). The resultant *t*-values and *p*-values indicate that the only variable significant to the required α is XIC.

The analysis of variance (ANVOA) for the full model is shown in Table C2. The most significant values in the table are the values for *F* and the *p*-value of the full model. Since the model *F* was greater than the estimated critical value of 2.4 (Aczel & Sounderpandian, 2006, p. 782; Lind et al., 2008, p. 788), the model was determined to be valid. This statement of appropriateness must be tempered by the fact that results of a full-model global test using the *F* statistic indicates that there exists significance of at least one of the model variables (Aczel & Sounderpandian, 2006).

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Despite the significant finding through the model *F* test, the coefficient of determination (R^2, 0.035), and the adjusted coefficient of determination (adj R^2, 0.022) values indicated an unsatisfactory fit of the regression data to the research model. Accepting the initial multiple regression results and using the regression coefficients (*b* values) shown earlier in Table C1, the data returned a model that became

Y = 321.1 - 0.160 XYEAR + 2.674 XII + 0.000 XIC + 0.000 XIIxIC.

Model Adjustments

Recognizing the poor results of the model, a variety of attempts were made to improve the model, and to stabilize the independent variable XIC in particular. The first attempt at improvement was done by dividing each of the IC values by the largest IC value, to form the new variable XICratio, which represented the ratio of the IC to largest IC value. The ANOVA for this model included a global model *p*-value of 0.0312. This result, taken with the results shown in Table 4, indicated that there is one reliable model variable, and that is again the one tied to invested capital (XICratio). This provided no new data results or additional insights. In fact, these data results were sufficiently close to those derived using XIC that the two sets of data results were indiscriminant. The XICratio regression results are shown in Table C3.

A second attempt to stabilize the model data was by introducing the interaction between the year of the data and the invested capital, producing the variable X(YEARxIC). The model results are shown in Table C4. The data indicate the existence of an issue regarding the VIFs. The impact of this issue is covered in the next section.

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To determine if the R&D-related variable could be improved, an analysis was conducted using R&D expenditures without the scaling factor of total expenditures (II = R&Dexp / total exp). The new variable XRD was used to replace XII in the original model and was used in the new interaction variable XRDxIC. The ANOVA returned a global test p-value of 0.002, indicating a significant variable; however, the R^2 value was 0.070 and adjusted R^2 value was 0.058, indicating a generally poor model fit. These results are shown in Table 1.

Table 1

ANOVA Results with X(RD)

Source	SS	df	MS	F	p-value
Regression	448.885	4.000	112.221	2.693	0.031
Residual	12542.545	301.000	41.670		
Total	12991.429	305.000			

In this adjusted model, the XIC *t*-value was calculated at 4.479 and the corresponding *p*-value was 0.000 indicating that XIC remained significant at 95%. The new variable XRDxIC returned a *t*-value of -3.428, and a *p*-value of 0.001, which demonstrated the XRDxIC was also significant at 95%. Finally, the VIFs are again in the acceptable range. The model results are shown in Table 1. Overall, these results presented a better fit of the model results. Once again, the significant elements were tied to invested capital. Using these new results, the adjusted research model was reassessed as

Y = 335.41 - 0.17 XYEAR + 0.00 XRD + 0.00 XIC + 0.00 XRDxIC.

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Table 2

Summary of Multiple Regression Analysis Results with X(RD)

					confidence interval		
variables	coeff (*b*)	std. error	t (df=301)	p-value	95% lower	95% upper	VIF
Intercept	335.407	429.018	0.782	0.435	-508.848	1179.662	
XYEAR	-0.167	0.214	-0.779	0.437	-0.588	0.254	1.018
R&D exp	0.000	0.000	-0.081	0.936	0.000	0.000	1.039
IC	0.000	0.000	4.479	0.000	0.000	0.000	1.351
XRDxIC	0.000	0.000	-3.428	0.001	0.000	0.000	1.368

Multicollinearity and Correlation

When considering financial data, one should be cautious with regard to multicollinearity among the variables. This is due to the reuse of data elements for various financial accounting measures. Curto and Pinto (2007) wrote that strongly correlated dependent variables may lead to cases of inflated coefficient values or even coefficients with the incorrect signs. Using the Cobb-Douglas study as a backdrop, Farrar and Glauber (1967) also wrote of concerns regarding multicollinearity in regressions. Farrar and Glauber asserted that the existence of collinearity was a concern only when its presence corrupts the power of the independent variables to predict the dependent variable, and that the corrupting power of multicollinearity is not a general threat to the theoretical validity of a research model. Additionally, the authors noted that an indication of harmful multicollinearity could be found when the x-x' variable correlations are greater than the x correlations with the independent variable (x-y). Finally, Farrar and Glauber noted that the root of the multicollinearity discourse should not be constrained to the existence of the collinearity, but rather the degree of collinearity and its attendant power to corrupt a regression.

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One of the modern tools for detecting the existence of multicollinearity is the variance inflation factor (VIF) of the model variables (Aczel & Sounderpandian, 2006; Curto & Pinto, 2007; Lind et al., 2008). The VIF and its power to help identify the existence of multicollinearity must be tempered by the fact that the VIF does not specifically call into question the capacity of the research model to predict the dependent variable. Excessive VIFs do indicate a degradation in the explanatory power of the independent, or predictor, variables (Curto & Pinto, 2007; Lind et al., 2008).

The value of the VIF is determined by the equation VIF = 1 / (1- R^2), the impact of high correlation (the R^2) between variables can be seen mathematically. This equation is nonlinear and the results become generally unacceptable when the R^2 value is greater than 0.9 and the denominator begins to approach 0. At the point where R^2 equals 0.9, the VIF increases dramatically with even minor changes in R^2. In this light, a VIF greater than 10 is accepted as an indicator of a collinearity problem (Research Consultations, 2007). A graph of the VIF function is shown in Figure 2. From the figure, it is clear that at a VIF of approximately 10, the inflation associated with the VIF becomes unstable and the slope rapidly approaches infinity.

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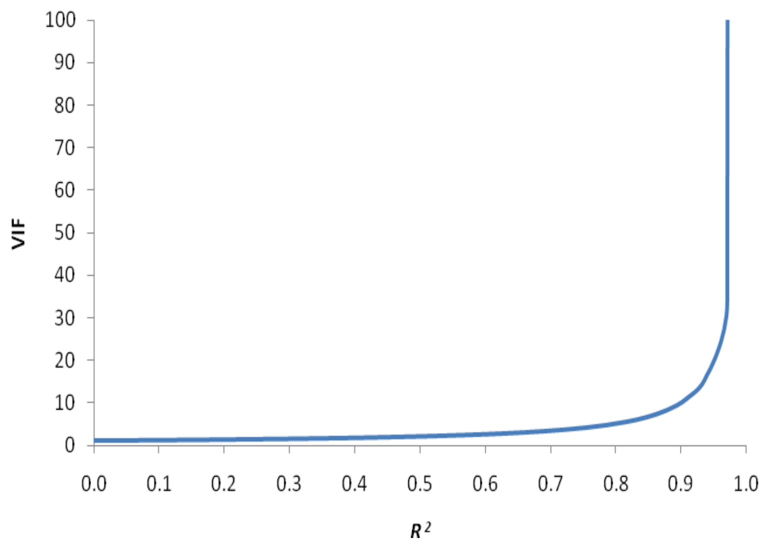

Figure 2. A graph of the VIF function.

Table 2 contained the VIF associated with each of the research model variables. While there is no specific quantitative limit for acceptability of VIFs, as related to multicollinearity, in general, a value of 10 is considered the point at which the data should be modified (Lind et al., 2008, p. 534). The VIFs in this study are all below 2, and so indicate that no unacceptable multicollinearity exists.

As in the case of VIFs, there is no clear demarcation between acceptable and unacceptable correlation values between independent variables. However, when examining the correlation between pairs of independent variables, values closer to zero are an indication that the variables are truly independent of the others (Aczel & Sounderpandian, 2006; Mansfield & Helms, 1982). In general, correlation values less than -0.7 or greater than +0.7 indicate the potential for collinearity (Lind et al., 2008). When performing simple linear regression, correlations outside ±0.7 indicate an acceptable model fit; however, the same correlation between independent variables

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within a multiple regression indicates that uncertainty has entered into the model, as evidenced by the variable VIFs. The correlation matrix developed for this study indicated no excessive correlations. The model correlation matrix will be further explained in the next section of this chapter.

Additional Data Analysis

The full, four-variable research model $Y = \beta_0 + \beta_1$XYEAR + β_2XII + β_3XIC + β_4 XIIxIC, was adjusted in a stepwise manner to uncover the best fit of the study data. The stepwise regression analysis utilized the best-fit approach, vice either the forward or the backward methods. The data presented in Table 7 shows the results of the stepwise regression, arranged in descending order according to the reduced model R^2 value. From Table C5, it is clear that in all cases that include XIC, the variable remains significant, with a p-value of 0.002. It is also clear that no other variable is significant at 95%

Analysis of Model Time Sensitivity

The data analysis of data such as that collected in the current study at should have been appropriate to a time-series analysis. To investigate the appropriateness of such analyses, each independent variable was assessed against the dependent variable (EPS) using scatterplots. This was done to determine if obvious trending was present. The results indicated no obvious trends and large data variability. The scatterplots are presented in Appendix D. A further analysis of potential time sensitivity was conducted by plotting the average annual data by year (e.g. year vs. EPS). This yielded good results for both the innovation intensity and invested capital, as seen in Figure 3. Interestingly,

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accompanying the 2007 and 2008 data were significant losses for automobile producers, two of which are included in the sample.

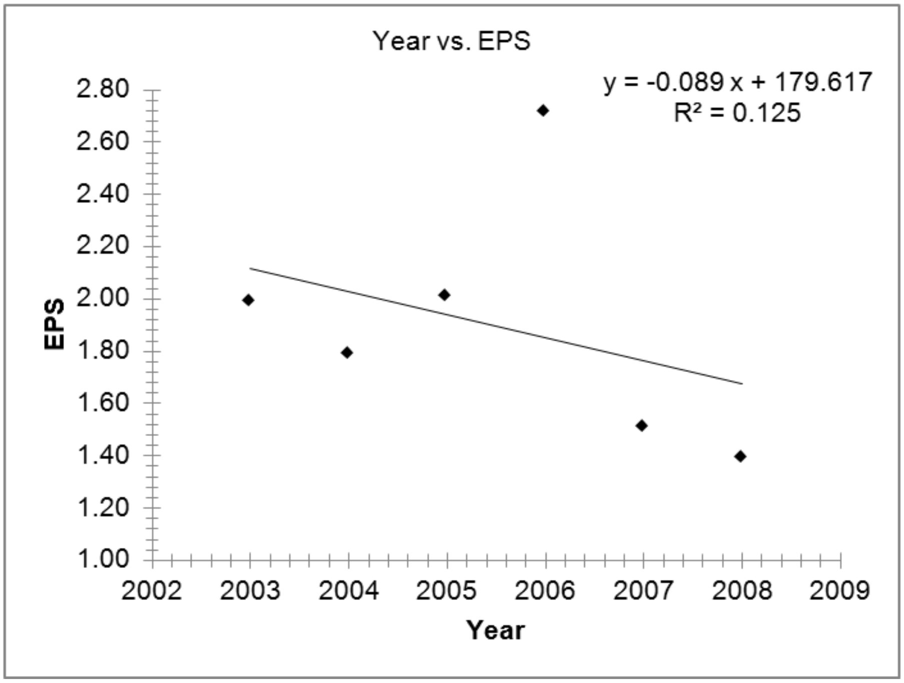

Figure 3. Scatterplot of EPS vs. YEAR.

Figure 4 depicts the nonlinear relationship of innovation intensity. While the shape of the curve would appear to be parabolic, there is too little data to make such a conclusion. The data also shows that, over time, the innovation investments appear to be cyclical, at least to the extent that expenditures rose over the first four years of data and then began a decline. Given the economic reality of that time period such a drop in R&D would not be unexpected.

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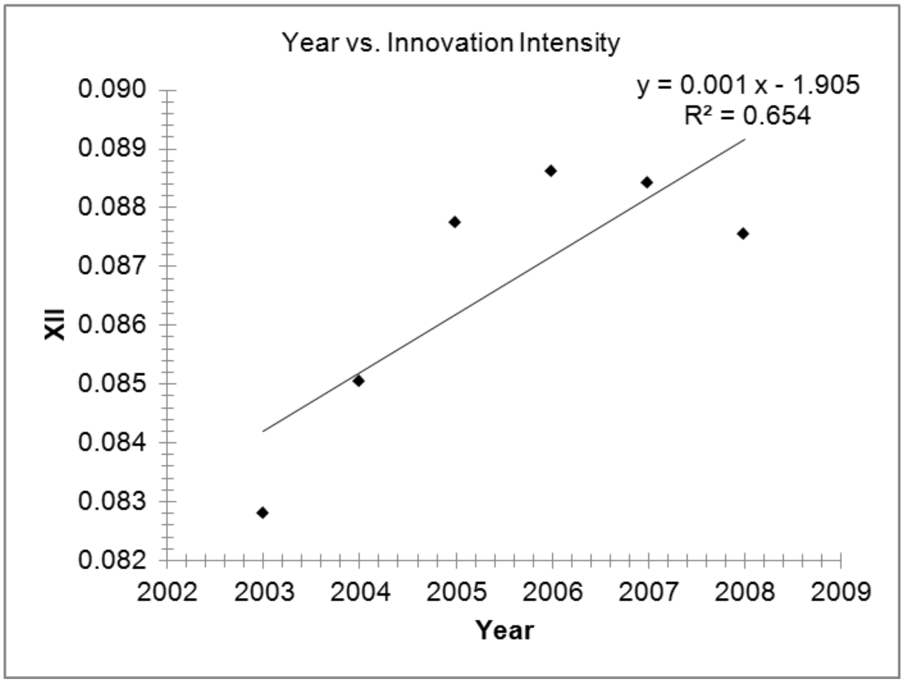

Figure 4. Scatterplot of XII vs. YEAR.

The shape of the data XIC over time was assessed in Figure 5. The data appears to be almost perfectly linear, as indicated by both the trend line and the R^2 of 0.991. This led to the general conclusion that invested capital has increased at a steady rate of time. This appeared to have been the case despite, or in spite of, the general economic trends seen in 2007 and 2008. Of note, there appears to have been no significant reduction of invested capital associated with the extraordinary losses in the automobile manufacturing segment.

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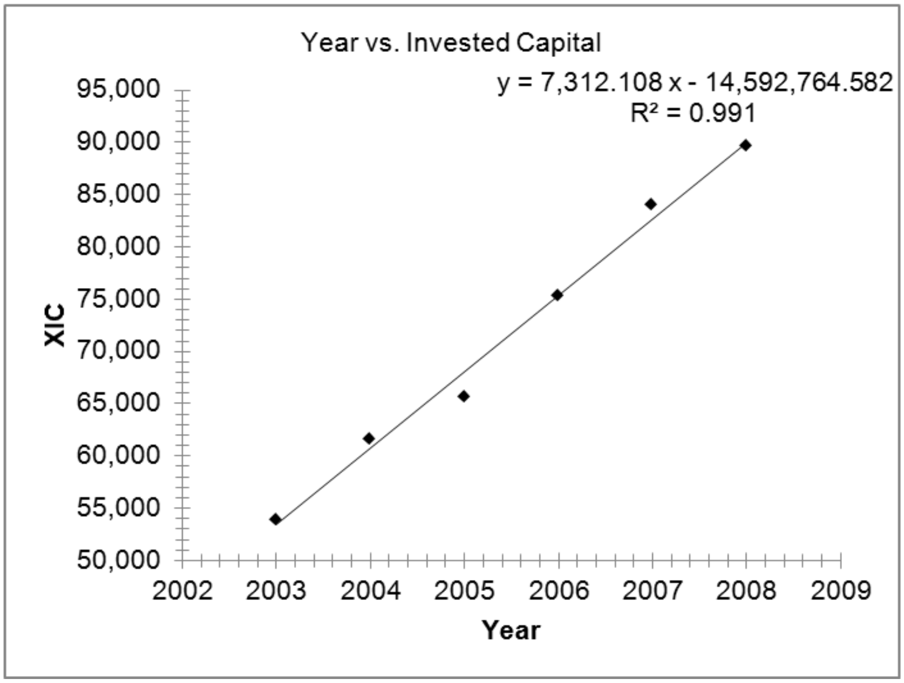

Figure 5. Scatterplot of XIC vs. YEAR.

As expected the interaction variable XIIxIC includes both the nonlinearity of innovation intensity and the linearity of invested capital. The result is a graph that appears to be semi-linear, one with a steady increase but also a cyclical aspect. This trend is shown in Figure 6.

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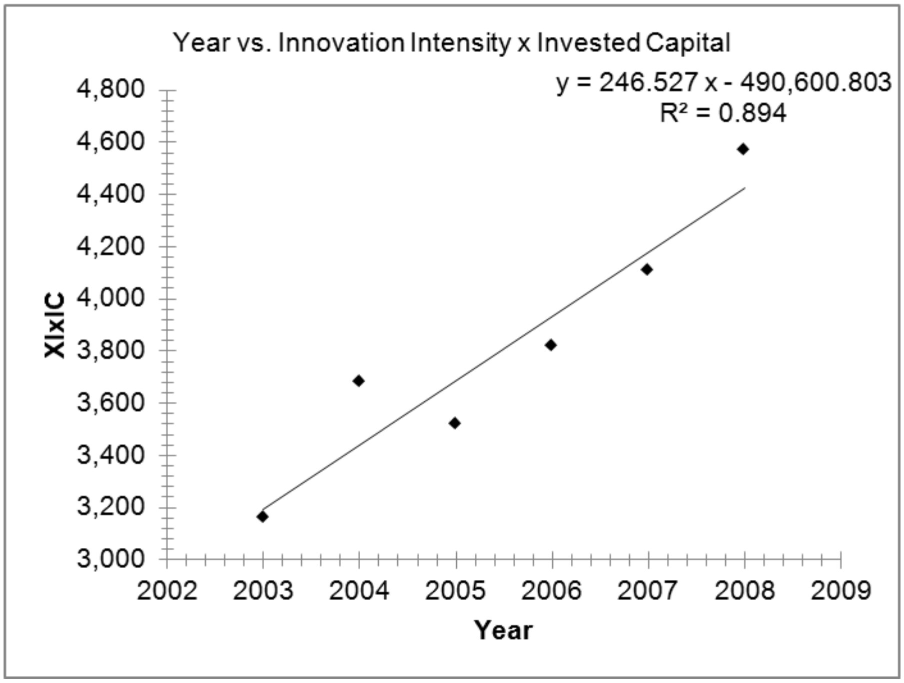

Figure 6. Scatterplot of XIIxIC vs. YEAR.

An additional analysis of the lagged variables was conducted by holding 2008 EPS data and lagging the independent variables XII, XIC, and XII*IC by 2, 3, 4, and 5 years (the variable XYEAR was removed). This yielded no significant returns and the R^2 values are generally below 0.04 and the resulting ANOVA F-Test *p*-values are all greater than 0.65. The specific results are shown in Table C6. Of note, the significance of the ANOVA did improve with each lag year except the p-value in the 5-year lag, which unexpectedly decreased. These results appear to indicate that at some point in the future there may be a significant time-related result. However, the data collected for this study is insufficient for such a longitudinal analysis.

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Although not an explicit study objective, analyses were conducted to attempt a definition of the time-to-return on investment and to forecast the returns. The data collection was focused on providing annual data for each company, and as such, the data set per company is limited to only 6 years. The time-series analysis would therefore be limited to only 1 data set per company, a situation which threatened (or negated) both internal and external validity. Additionally, the study did not include an objective of defining the time-to-return on investment or of forecasting the returns.

Given these data shortcomings and the objective of the study, it seemed that a time-series analysis was not the best analysis tool given the dissertation objectives and data structure. These analyses indicated that the data is not well-suited or modeled with regression of time-series models.

Research Model Correlations

To answer the research question answers completely, an examination of the correlations between sets of both dependent and independent variables was necessary. Therefore, the model correlations were developed into a matrix, presented as Table C7. This table shows the results of significance testing of the study's Pearson product-moment correlation coefficients (*r*).

From Table C7, it is clear that the independent variable XII is not correlated to the dependent variable EPS. The variable XIC is significantly correlated to EPS at the 99% level as seen by the value 0.174. There is a negative correlation between XII and XIC as identified by the value -0.174, this is an unexpected finding since one of the study assumptions was that invested capital (XIC) would be used to fund R&D investment

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(captured by XII). It is not surprising that the most significant correlation is found between the variables XIC and XIIxIC; this is likely due to the overpowering magnitude of the invested capital variable. In counterpoint to the most significant correlation, is the weakest, which is seen in the correlation between EPS and XIIxIC.

The model correlation matrix, Table C7, provided additional evidence that multicollinearity within the model did not exist. Had an examination of the data shown unacceptably tight correlation between the model's independent variables, there would have been further evidence of multicollinearity (Curto & Pinto, 2007).

Hypothesis Test Results

The hypothesis testing was first conducted using the results of the full research model $Y = \beta_0 + \beta_1 XYEAR + \beta_2 XII + \beta_3 XIC + \beta_4\ XIIxIC$. These results of a multiple regression using this model were shown in Table 2. Using *t*- and *p*-values from Table 2, only the variable XIC was significant at $\alpha = 0.05$. The results of each null hypothesis, H_{01} through H_{04}, were evaluated in light of the listed results, and the full model was evaluated globally using the ANVOA *F*- test. As shown in chapter 3 of this study, for *df*=306, the required Student's *t*-statistic was estimated at ±1.97, and the *F*-statistic required was estimates at 2.4.

Hypothesis 1

H_{01}: $\beta_1 = 0$; H_1: $\beta_1 \neq 0$. Null hypothesis 1: There is no relationship between the corporate EPS and the variable XII. The alternative hypothesis is that there exists a relationship between EPS and XII.

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The null hypothesis is not rejected at $\alpha = 0.05$. The *t*-value for the variable XII was 0.649, which is within the null hypothesis do not reject range for this study. Additionally, the *p*-value was 0.517, which exceeds the required α (0.05) and indicates that we should not reject the null hypothesis. Given these results, there appears to be no relationship between the corporate earnings per share and the corporation's innovation intensity.

Hypothesis 2

H_{02}: $\beta_2 = 0$; H_2: $\beta_1 \neq 0$. Null hypothesis 2: There is no relationship between the corporate EPS and the variable XIC. The alternative hypothesis is that there exists a relationship between EPS and XIC.

The null hypothesis is rejected at $\alpha = 0.05$. The *t*-value for the variable XIC was 3.154, which is within the null hypothesis rejection range for this study. Also, the *p*-value was 0.002, which is below the required α (0.05) and indicates that we should reject the null hypothesis. Given these results, there appears to be a relationship between the corporate earnings per share and corporate invested capital.

Hypothesis 3

H_{03}: $\beta_3 = 0$; H_3: $\beta_1 \neq 0$. Null hypothesis 3: There is no relationship between the corporate EPS and the variable XIIxIC. The alternative hypothesis is that a relationship exists between EPS and XIIxIC.

The null hypothesis is not rejected at $\alpha = 0.05$. The *t*-value for the variable XII was -0.845, which is within the null hypothesis do not reject range for this study. Additionally, the *p*-value was 0.399, which exceeds the required α (0.05) and indicates

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that we should not reject the null hypothesis. Given these results, there appears to be no relationship between the corporate earnings per share and the product of the corporate innovation intensity and invested capital.

Hypothesis 4

H_{04}: $\beta_4 = 0$; H_4: $\beta_1 \neq 0$. Null hypothesis 4: There is no relationship between the corporate EPS and the variable XYEAR. The alternative hypothesis is that a relationship exists between EPS and XYEAR.

The null hypothesis is not rejected at $\alpha = 0.05$. The *t*-value for the variable XII was -0.734, which is within the null hypothesis do not reject range for this study. Additionally, the *p*-value was 0.464, which exceeds the required α (0.05) and indicates that we should not reject the null hypothesis. Given these results, there appears to be no relationship between the corporate earnings per share and the year of the reported data.

Hypothesis 5

H_{05}: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$; H_{05}: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$. Null hypothesis 5: There is no relationship between a corporation's EPS and the variables XII, XIC, XIIxIC, and XYEAR. The alternative hypothesis is that a relationship exists between EPS and XII, XIC, XIIxIC, and XYEAR.

The model global test, using the *F*-test, showed that the null hypothesis is rejected at $F = 2.693$ using the data in Table 3 and an $F_{critical}$ value of 2.4. Additionally, the ANOVA returned a *p*-value of 0.031, which is lower than the required α and indicates that the null hypothesis should be rejected. Accordingly, at least one independent variable of the research model is significant at the study's significance level of 95%.

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Summary

The results obtained from the research data led to the general observation that invested capital was significant with regard to EPS and that corporate innovation intensity was not significant. The study results also indicated that the model, in general, is a poor fit. This was evidenced by considering the low values for both R^2 and adjusted R^2. While the ANOVA return was significant, this result indicated only that at least one variable in the model was significant. The ANOVA result was consistent with the regression table that showed the XIC *p*-value of 0.002; no other p-values were significant at 95% as required by chapter 3. A review of the model VIFs showed that they were acceptable, which indicated that any multicollinearity present in the model was acceptably low.

The data has been presented and the results explained. With the study results to this point, certain conclusions were drawn. Chapter 5 will present a study summary, recommendations, and conclusions reached.

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CHAPTER 5: SUMMARY, CONCLUSIONS, AND FURTHER RESEARCH

Summary of the study

Chapters 1 and 2 of this study demonstrated that the body of business management literature is vague with regard to innovation-related guidance and few studies deal directly with performance measurement (Adams et al., 2006). The extant literature provides the corporate executive with various, often incoherent, courses of action to implement innovative strategies and practices (e.g. Christensen et al., 1998; Cooper, 1998; Pande et al., 2000a; Utterback & Acee, 2005). As shown in chapter 2, the literature does little to provide the engineering manager with quantified benefits of innovation investments and does not provide the business leader with a foundation for innovation-related activities (Zahra, 1991). The focus of the sundry calls to action usually center on the need to assure a corporation that it will have a set of competitive goods and services for the market.

This study was undertaken in an attempt to help engineering business managers understand the potential impact of innovative investment on business profitability. The study was designed to help answer the management executive's question, "Is it worth our effort to undertake innovation-enhancing efforts?" To accomplish this objective, the study synthesized existing innovation-related literature and attempted to develop a quantified model of the correlation between innovation investments, management performance indicators, and financial outcomes. The ultimate goal of the present study was to help managers understand the impact of innovation expenditures better, potentially leading to a more efficient allocation of shareholder resources.

Recall that the research questions for this study were:

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1. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in innovation intensity?
2. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in invested capital?
3. How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in the product of innovation intensity and invested capital?
4. What is the relationship between earnings per share and the year the data was collected?

In order to answer these questions, the research design was a descriptive quantitative study containing an analysis of existing public financial data. The design allowed an examination of innovation related data from across industrial segments and developed correlations between innovation expenditures and financial outcomes.

The research model was $Y = \beta_0 + \beta_1 XYEAR + \beta_2 XII + \beta_3 XIC + \beta_4\ XIIxIC$. The collection of raw data was followed by the development of descriptive statistics for each study company; these are presented in Appendix B. The main data analysis efforts were the multiple regression and the research hypotheses tests, which were presented in chapter 4. The study data analysis not only provided the multiple regression and descriptive statistics, but resulted in a determination of the model coefficients such that the model was $Y = 321.1 - 0.160\ XYEAR + 2.674\ XII + 0.000\ XIC + 0.000\ XIIxIC$.

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Research Conclusions

This section provides the research conclusions. The conclusions are based on the literature review, found in chapter 2, and the data analysis, found in chapter 4. The first part of this section provides the direct answers to the study research questions. The second part expands the conclusions to include implications for engineering management and innovation investment.

Question 1

How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in innovation intensity? From the data analysis presented in chapter 4, it appears that innovation intensity does not factor significantly into the corporate EPS. The data showed that the null hypothesis should not be rejected and so there is likely no relationship between innovation intensity and EPS. Recall that the variable XII included direct investment in R&D, and so it appears that such changes in such investment do not lead to changes in EPS.

Question 2

How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in invested capital? The multiple regression and ANOVA results indicated that changes in invested capital do result in changes to corprote EPS. The data results showed that the alternative hypothesis, that there is a relationship between XIC and EPS, should be accepted at the expense of the null hypothesis that there is no relationship. From these results changes in invested capital so relate tochanges in EPS.

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Question 3

How will the performance of corporate management, as measured by corporate earnings per share, vary with changes in the product of innovation intensity and invested capital? The data demonstrated that the interaction effect of innovation intensity and invested capital had no significant impact on corresponding changes in corporate EPS. The null hypothesis, that there was no relationship between the interaction term and EPS, was not rejected. Accordingly, there appears to be no relationship between this interaction term and EPS.

Question 4

What is the relationship between earnings per share and the year the data was collected? Analysis of the study data indicated that the year in which the data was collected was not significant to changes in the corporate EPS. The null hypothesis, that there was no relationship, was not rejected. This led to the conclusion that year of data collection had no relationship with the EPS.

Final Question

Recall that this study was undertaken to find an answer to the question, "Does investment in innovation lead to increased financial output?"

Of prime importance is recognition of the study purpose, which was to help engineering business managers understand the potential impact of innovative investment on business profitability. Reflecting on the ideas presented in chapter 2 and the results presented in chapter 4, there are two sets of conclusions to present. The first ideas, rooted in the literature review, concerns the qualitative organizational concerns of corporations

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seeking to increase innovativeness. The second set is centered on the actual implications of innovation investment. These two areas of thought may appear to be disparate or disjointed, but they do coalesce in the arena of engineering management.

Qualitative Management Considerations

Innovation, in and of itself, does nothing to ensure the success of a corporation (Chesbrough, 2006). Additionally, attempts to evaluate the output of technical programs in terms of corporate sales or profits produces an evaluation of the effectiveness of the company as a whole (Finkelstein, 1963). There has been much work by management researchers to describe the organizational processes by which a company might become "innovative" (e.g. Christensen, 2005; Leifer et al., 2000; O'Connor et al., 2008), but there is much less in the literature a corporation can use to understand the relationship between innovation investment and financial outcomes.

Perhaps complicating the discourse on innovation is the idea that innovation defies rote definition; running along a qualitative continuum (MacKenzie, 2007). Innovations can vary from minor changes to existing products to dramatically disruptive innovations that change markets forever. Another characteristic of innovations, is their appearance in the form of a product or a service or a process (Adams et al., 2006). Additionally, innovation is really a process itself, vice an output of organizational processes (Parthasarthy & Hammond, 2002). With such disparate characteristics, accurately defining innovation has been a challenge for management researchers. The definition challenge was addressed within chapter 2 of the present study.

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Collins (2001) and Drucker (1985) each made a case for constraining the corporate quests for innovation to those within the existing corporate technology competency. This case was made to caution against undertaking innovation efforts in unfamiliar technology or process domains. A company reaching too far may expend resources that will never realize a viable product for the marketplace. In contrast, Kanter (2006) cautioned against to the idea of product portfolios. These portfolios could be used to constrain unnecessarily an exploitation of unfamiliar technology or knowledge. Once again, resolution of the dichotomous views may lie in the business model.

Within the present study was a collection of evidence related to the organizational realities necessary for innovative activity. This included the idea that corporations cannot be held hostage to the limited foresight of existing customers (Christensen, 2005; van der Panne et al., 2003). Such an approach may bias innovative efforts toward modest improvements of existing products, vice truly game-changing products. Worse, a company focusing on its current customers may find that its focus is on near term profitability at the expense of long term growth (Rappaport, 2005).

The quest for innovative output can follow one of two organizational models. The first model is a problemistic model, which has a company focused on solving an identified problem; the second model is a slack model, which has a company using some of its uncommitted funds to develop innovation products (Greve, 2003). Using either model, a critical organizational consideration is the separation of research from development activities. The former activity is the realm of scientists and inventors who seek new technology or knowledge, while the latter focuses on developing the discovery

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into a market-pleasing product or service (Chesbrough, 2006; O'Connor et al., 2008). The development activity is best removed completely from the research staff, freeing them from unproductive market focus.

Within chapter 2, the open model of innovation discovery was presented. In this model, the company actively seeks innovation both vertically and horizontally; from other companies and from within its own organization (Chesbrough, 2006). By using an open model, instead of relying on a closed proprietary system, the company can find complimentary ideas and increase the number of ideas considered. This may lead to an increase in the modularity of the design, which would facilitate simplified upgrades to solve consumer demands and allow out-sourcing of low-yield components. Coupled to the idea of an open innovation model, is that of a dominant design put forth by Utterback (Utterback, 1994).

This dominant design theory is based on the idea that the market will ultimately decide the preferred product design. A recent example of the dominant design model is the competition between high-definition digital video disk (HD DVD) and Blu-ray (blue-violet laser) technology (Katzmaier, 2008). For years, the two technologies competed within the high-definition video market. While there were certainly strong advocates for both technologies, ultimately the market chose the Blu-ray technology by virtue of sales, resulting in Toshiba's market surrender. This left Blu-ray as the market-chosen dominant design.

Innovation-related investments provide benefits that extend beyond the obvious increases in market share and profitability (Andrew & Sirkin, 2006; Chan et al., 2001;

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Deeds, 2001). Intangible returns to the corporation include organizational pride, brand strength, corporate status, process improvement, and corporate learning; however, none of these benefits can be capitalized as assets. In the end, neither these intangible benefits, nor the potential markets can be omitted from consideration in the innovation process.

Any product, innovative or not, requires a market of consumers. To address the needs of these consumers, and to reap the attendant profit, a company must have a viable business model (Chesbrough, 2006; Schumpeter, 1934/2008). In fact, some authors have asserted that there is no innovation without the accompanying business model (O'Connor et al., 2008). The need for a business model is clear in the arguments around the use of patents as an indicator of innovation output. This is due to the nature of patents themselves (e.g., Bessen & Meurer, 2008; Gittleman, 2008; Ziedonis, 2008). Drucker (1985) and Christensen (1997) both offered economic perspectives on innovation by removing any requirement for new technology from the definition of innovation. Additionally, both authors noted that almost by definition, market-changing products have no known existing market for comparison; this condition certainly complicates effort to value the innovation. In the end, the seemingly contradictory goals of corporate strategy and financial activity must be aligned to serve the common goal of corporate market success and growth (Christensen et al., 2008).

Quantitative Innovation Investment Considerations

Despite the manager’s struggle to uncover quantitative measures for R&D effectiveness, the literature remains inadequate (Adams et al., 2006; Cordero, 1990; Szakonyi, 1994). Far more literature is devoted to articulating the qualitative benefits of

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innovation than to prescriptions for measurable increases in R&D effectiveness. Some managers need quantified studies of R&D effectiveness to help guide the corporate business strategy. It should not be surprising then that traditional financial reporting does not support effective innovation valuation (Shapiro, 2006). The valuation is complicated by the idea that an accountant must debit R&D expenses when they are incurred, yet there is no concurrent capitalization of any asset until the resulting product becomes an asset, typically 3-5 years later (Leifer et al., 2000). In the end, one must remember that investment in innovation activities does not necessitate innovative output.

Traditional business training demands, as the primary goal of management, the maximization of shareholder value (Christensen, 1997; Friedman & Friedman, 1982). This may lead to an inappropriate focus on near-term profitability at the expense of long-term growth and success (Bushee, 1998; Rappaport, 2005). The resulting management performance metric readily found is the corporate earnings per share. This measure has become so endemic as the prime indication of management performance, it has become the top priority for many top managers (Reda & Schmidt, 2008). In fact, earnings per share has become the de facto measure of manager performance (Christensen et al., 2008).

One of the innovation-related accounting challenges mentioned early in this study was the idea that because of R&D debit requirements, the R&D investment is debited when the expense is incurred. While this GAAP requirement is not of particularly concern, it becomes problematic when there is no accompanying asset or capitalization. The net effect is to decrease ROA. When a company implementing the problemistic

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innovation investment model, which seeks solutions to identified problems, the RDI value may be negative when ROA is high. This condition is due to the solution of one problem without reinvestment in a new challenge (Greve, 2003).

The research model, $Y = \beta_0 + \beta_1 XYEAR + \beta_2 XII + \beta_3 XIC + \beta_4 XIIxIC$, was presented in chapter 3. Recalling chapter 4, the research model regression analysis gave the model results, $Y = 321.1 - 0.160\ XYEAR + 2.674\ XII + 0.000\ XIC + 0.000\ XIIxIC$.

Of greater concern is that the both the *t*- and *p*-values for XII were not significant at $\alpha = 0.05$. From these results, it is clear that innovation investment intensity does not affect the corporate EPS at the 95% level. R&D intensity (RDI) may be a better measure when it is used as a relative measure, in which the company's individual performance is measured against the industry as a whole (O'Brien, 2003). This would make RDI similar to the indirect P/E ratio, which requires consideration of the larger industry for proper interpretation, as opposed to a stand-alone direct measure of innovation input.

What should be of concern to the management researcher is the inability of innovation-related investment intensity to predict a change in corporate EPS. This is significant since the EPS was noted within the present study as a de facto management performance measure. A management researcher may be justified in asserting that a focus on near-term performance, measured by EPS, would suffer if the company undertook R&D investment. One researcher even asserted that we should reject quantification of innovation returns when defined by "the current all-to-popular practice among research executives of referring to what per cent of current sales or profits come from products originating in the R&D laboratories" (Finkelstein, 1963, p. 225).

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Drucker gave perhaps the most succinct social impact statement related to innovation when he wrote that "an innovation is a change in market or society" (1985, p. 252). Management professionals should be careful to ensure they provide the market with products that not only please the consumer, but also allow for efficient allocation of limited resources. Executive management teams should be able to use the results of this study to help determine the efficacy of investing in an innovation process. By examining the various definitions of innovation and the economic realities of the business environment, this study should lead the business manager to understand the nature of innovation and its corporate financial impacts.

The management team should understand that using innovation investment intensity as a single prediction variable for overall corporate financial performance comes with serious shortcomings. Although using innovation investment intensity does have merits, managers evaluating the information must fully understand and accept the inherent limitations of the data (Szakonyi, 1994, p. 29). The data analysis and conclusions found within the present study should help managers understand the impact of innovation expenditures better, and provide the managers with information to help them more efficiently allocate shareholder resources.

Recommendations for Future Research

The recommendations for further research from the present study results center on an expansion of the current work. Other management researchers should consider expanding the data set used in this study. By expanding the work, the body of knowledge related to innovation investments will deepen, providing engineering managers with the

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tools to evaluate their investment options properly. Any expansion of knowledge must come through public access to resultant information. Accordingly, these and any further results should be published in appropriate journals. The public release would also expand the audience by allowing access for the executive managers who these works are intended to help.

Continue as a Longitudinal Study

Continue to track the participant companies as a means to begin a longitudinal study of innovation investment. This would be a worthy project given the global economic downturn seen since this present study was undertaken. Within this longitudinal study should be a consideration for the lagging nature of financial returns on investment. The literature has shown that any return on innovation-related investment will lag by 3-5 years. The current study was not designed to capture a potential 3-year lag; however, the assumed variances in time to return on corporate innovation investments should be considered in the future. By revisiting the corporations in the future, and assessing their R&D investment intensity, the management research may uncover new and interesting items related to corporate innovation activities. This would certainly add to the richness of the management literature related to how companies perform and why they undertake innovation investment.

Incorporate Organizational Behavior Models

One important aspect of the study results was just how important the individual corporate structures can be. While the current study was deliberately constrained, there is merit to expanding the existing data to include organizational structures, hierarchies, and

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behaviors. In particular, executive compensation schemes may influence corporate investment strategies. The management body of knowledge would be enriched by folding together the business and organizational influences felt by executive management teams.

Expand the Model to Include Innovation Expertise Areas

Under the constraints of this study, the data related to the area of innovation expertise was not incorporated, for example, through creating subsets of the participants. Including such variables in the research model may uncover additional aspects of management behaviors not seen in the current study. One of the organizational characteristics not quantified in the model was the influence of the companies' industry segment and the associated shade or type of innovation. A telecommunications company may have a different strategy than an aerospace manufacturer, for instance.

Social Impact of the Study

Simplistically, it may be said that the objective of business is to make a profit. Regarding the public company, the literature presented in this study has shown that classical business training includes the call for a corporate goal of maximizing shareholder value (Friedman & Friedman, 1982). In order to accomplish the requisite profit and shareholder value maximization, the corporate manager may compromise long-term strategy for near-term profitability (Rappaport, 2005). This is what might be termed the "dark side of business." However, if a corporation is to enjoy the profitability and benefits of shareholder value maximization, the company must provide products and services the consumer will buy.

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Some businesses may appear to be stagnant; certainly, these businesses can improve the performance of products, services, or delivery mechanizations. Innovations need not be rooted in new technology or knowledge. In fact, Christensen (1997) reported that radical innovations, those that fundamentally change the market, are usually based on new applications of existing technology and knowledge. In this light, the belief that innovations exist only as the result of technology development is to overlook the social aspect of innovations. As noted earlier in this study, Drucker (1985) wrote that innovation might be identified as an economic or social activity revolving around the use of resources.

Considering Drucker's idea within the context of social change, companies serve a greater social good by providing the goods and services that allow consumers to enjoy the benefits of corporate investments in innovation. Corporate investments lead to new products, services, and delivery mechanizations, which then lead to positive social change. Take for instance the introduction of the World Wide Web and the power it has brought to electronic connectivity, or the proliferation of cellular phone technology, which has allowed social interactions previously unachievable. The corporate innovation investments allow society to progress and prosper. This study provides the corporation a better understanding of innovation investment.

Study Conclusion

As presented earlier in this study, today's business managers are beholden to earnings per share as their highest performance metric. Logically, use of this single indicator of corporate performance may lead the executive management team to focus on

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near-term profitability and earnings per share at the expense of innovation investments. One potentially significant reason for such a management state of mind may be the reported 3-5 year lag between the investment outlay and its financial return.

Organizations are assemblies of people who bring with them abilities, disabilities, biases, and energy. The success of one corporate model does not necessitate a replication with another random company. Management literature should not be viewed in isolation, because no single area of concern (accounting, administration, financial planning, etc.) will provide a complete picture of the management landscape. Only through synthesizing the work found within disparate subject categories can the engineering manager gain the breadth of understanding necessary to create a truly innovative organization. This study was designed to help the engineering manager take a single stride in the journey toward more effective management of innovation activities by obviating the common overreliance on innovation-related financial investment and attendant returns as the metrics of success.

The goal of the study was to help managers understand the impact of innovation expenditures better, potentially leading to a more efficient allocation of shareholder resources. To accomplish this data was collected, analyzed, and reported. The analysis and results show that there is more to the story of innovation-related management investments than just financial ratios. Additionally, the manager today is in a position based on accounting practices that seems to penalize R&D expenditures through a decrease in corporate return on assets and return on invested capital. Innovation can lead

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to such dramatic societal changes as electronic commerce, and the seamless exchange of digital data.

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APPENDIX A: STUDY DATA

Code	EPS	XYEAR	XII	IC	II*IC
1	5.48	2008	0.228	25,480	5,802
1	4.04	2007	0.209	16,067	3,355
1	2.36	2006	0.226	10,734	2,430
1	1.65	2005	0.223	8,067	1,800
1	0.74	2004	0.253	5,370	1,358
1	0.19	2003	0.276	4,458	1,229
2	4.95	2008	0.070	19,728	1,381
2	5.70	2007	0.075	19,332	1,448
2	5.15	2006	0.088	13,971	1,234
2	4.23	2005	0.077	15,275	1,174
2	3.83	2004	0.074	14,637	1,084
2	3.07	2003	0.076	12,518	950
3	13.46	2008	0.184	29,465	5,428
3	13.53	2007	0.184	23,300	4,292
3	10.21	2006	0.174	17,169	2,990
3	5.31	2005	0.145	9,526	1,386
3	2.07	2004	0.089	2,973	263
3	0.77	2003	0.081	622	51
4	1.52	2008	0.320	3,568	1,142
4	1.15	2007	0.303	2,771	840
4	0.46	2006	0.303	1,831	554
4	0.81	2005	0.281	1,767	497
4	1.45	2004	0.233	1,628	380
4	0.09	2003	0.276	909	251
5	2.48	2008	0.000	86,734	0
5	3.45	2007	0.000	80,273	0
5	2.98	2006	0.000	65,189	0
5	2.61	2005	0.000	51,877	0
5	2.79	2004	0.000	61,588	0
5	2.34	2003	0.000	49,310	0
6	2.17	2008	0.000	222,955	0
6	1.95	2007	0.000	236,370	0
6	1.89	2006	0.000	230,152	0
6	1.42	2005	0.000	120,214	0
6	1.50	2004	0.000	89,910	0
6	1.76	2003	0.000	85,933	0
7	3.68	2008	0.064	22,854	1,466
7	5.36	2007	0.072	27,448	1,979
7	2.88	2006	0.065	22,093	1,427
7	3.26	2005	0.048	31,870	1,521
7	2.27	2004	0.042	33,128	1,383
7	0.90	2003	0.033	34,587	1,140
8	1.35	2008	0.321	44,827	14,399
8	1.21	2007	0.328	39,972	13,112

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
8	0.91	2006	0.346	31,996	11,074
8	0.88	2005	0.359	24,362	8,745
8	0.73	2004	0.361	26,801	9,684
8	0.50	2003	0.375	28,803	10,813
9	1.25	2008	0.085	11,641	994
9	1.33	2007	0.074	8,941	663
9	1.15	2006	0.077	7,733	597
9	1.49	2005	0.083	7,182	593
9	1.21	2004	0.097	9,079	883
9	1.03	2003	0.116	8,415	974
10	8.78	2008	0.004	178,952	656
10	7.36	2007	0.004	183,770	808
10	6.68	2006	0.004	170,198	648
10	5.76	2005	0.003	162,028	502
10	3.89	2004	0.004	152,275	651
10	3.16	2003	0.005	135,892	639
11	1.79	2008	0.018	540,202	9,986
11	2.21	2007	0.021	541,220	11,144
11	1.99	2006	0.020	469,147	9,432
11	1.76	2005	0.021	460,340	9,747
11	1.62	2004	0.018	527,896	9,570
11	1.58	2003	0.024	465,173	10,990
12	-53.32	2008	0.047	14,500	681
12	-76.52	2007	0.044	71,148	3,107
12	-3.50	2006	0.031	105,603	3,242
12	-18.50	2005	0.032	148,435	4,746
12	4.97	2004	0.034	150,415	5,083
12	5.10	2003	0.031	151,022	4,716
13	4.67	2008	0.000	795,661	0
13	26.34	2007	0.000	714,416	0
13	20.93	2006	0.000	566,423	0
13	11.73	2005	0.000	463,267	0
13	9.30	2004	0.000	315,199	0
13	6.15	2003	0.000	250,569	0
14	3.35	2008	0.033	60,392	1,983
14	2.76	2007	0.038	49,439	1,868
14	2.23	2006	0.043	46,131	2,001
14	0.83	2005	0.042	45,857	1,923
14	1.16	2004	0.046	47,550	2,203
14	0.83	2003	0.052	48,078	2,502
15	9.07	2008	0.219	67,088	14,688

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
15	7.32	2007	0.226	76,122	17,195
15	6.15	2006	0.244	63,143	15,438
15	4.99	2005	0.240	70,596	16,968
15	5.04	2004	0.236	69,385	16,398
15	4.42	2003	0.229	66,557	15,260
16	0.93	2008	0.481	42,897	20,644
16	1.20	2007	0.492	47,080	23,182
16	0.87	2006	0.467	39,854	18,627
16	1.42	2005	0.469	39,080	18,347
16	1.17	2004	0.497	40,137	19,943
16	0.86	2003	0.456	40,264	18,361
17	3.83	2008	0.000	25,924	0
17	1.96	2007	0.000	24,893	0
17	2.33	2006	0.000	26,016	0
17	2.06	2005	0.000	25,953	0
17	1.81	2004	0.000	24,317	0
17	1.19	2003	0.000	23,039	0
18	1.90	2008	0.215	72,793	15,669
18	1.44	2007	0.218	39,417	8,611
18	1.21	2006	0.237	47,155	11,164
18	1.13	2005	0.245	53,938	13,222
18	0.76	2004	0.280	77,420	21,663
18	0.70	2003	0.246	65,597	16,111
19	1.82	2008	0.000	53,126	0
19	2.09	2007	0.000	54,849	0
19	1.69	2006	0.000	50,276	0
19	1.36	2005	0.000	48,043	0
19	1.23	2004	0.000	61,246	0
19	1.02	2003	0.000	56,360	0
20	3.80	2008	0.000	9,121	0
20	2.96	2007	0.000	8,104	0
20	5.37	2006	0.000	7,246	0
20	4.61	2005	0.000	6,794	0
20	3.59	2004	0.000	5,883	0
20	2.80	2003	0.000	4,699	0
21	3.86	2008	0.082	113,034	9,253
21	3.22	2007	0.082	107,297	8,837
21	2.79	2006	0.090	115,710	10,454
21	2.83	2005	0.103	36,488	3,756
21	2.46	2004	0.105	34,901	3,671
21	3.90	2003	0.119	31,348	3,743
22	0.24	2008	0.000	11,402	0
22	0.85	2007	0.000	11,934	0

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
22	0.63	2006	0.000	16,347	0
22	0.70	2005	0.000	10,370	0
22	0.40	2004	0.000	9,195	0
22	0.56	2003	0.000	8,155	0
23	0.43	2008	0.001	3,483	3
23	0.90	2007	0.001	3,188	3
23	0.74	2006	0.001	2,493	2
23	0.63	2005	0.002	2,287	4
23	0.99	2004	0.001	2,545	3
23	0.69	2003	0.001	2,121	3
24	2.87	2008	0.016	33,594	528
24	3.37	2007	0.017	32,778	542
24	3.23	2006	0.020	26,232	526
24	2.73	2005	0.020	25,407	514
24	2.09	2004	0.018	24,073	422
24	2.02	2003	0.018	23,078	416
25	2.26	2008	0.214	139,247	29,829
25	1.90	2007	0.225	129,930	29,255
25	1.88	2006	0.229	128,187	29,318
25	2.67	2005	0.254	116,313	29,560
25	2.62	2004	0.228	117,776	26,847
25	1.27	2003	0.197	115,050	22,671
26	3.36	2008	0.000	108,039	0
26	3.17	2007	0.000	105,060	0
26	2.92	2006	0.000	99,439	0
26	2.68	2005	0.000	89,361	0
26	2.41	2004	0.000	77,335	0
26	2.03	2003	0.000	104,912	0
27	2.34	2008	0.003	50,906	148
27	2.33	2007	0.004	49,537	182
27	1.68	2006	0.003	49,788	169
27	1.25	2005	0.004	43,990	172
27	1.14	2004	0.005	42,843	227
27	0.65	2003	0.007	41,319	289
28	2.95	2008	0.000	11,726	0
28	2.42	2007	0.000	10,956	0
28	2.35	2006	0.000	9,613	0
28	2.24	2005	0.000	9,846	0
28	1.92	2004	0.000	8,863	0
28	1.58	2003	0.000	8,054	0
29	1.37	2008	0.171	11,887	2,036
29	0.26	2007	0.117	12,266	1,435
29	0.80	2006	0.150	10,976	1,650
29	0.79	2005	0.143	10,304	1,475

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
29	0.59	2004	0.151	6,906	1,040
29	0.70	2003	0.142	5,173	736
30	0.56	2008	0.000	445,344	0
30	3.35	2007	0.000	344,311	0
30	4.66	2006	0.000	281,272	0
30	4.10	2005	0.000	202,381	0
30	3.71	2004	0.000	197,351	0
30	7.27	2003	0.000	123,323	0
31	11.74	2008	0.005	129,142	656
31	8.83	2007	0.007	114,988	806
31	7.84	2006	0.008	104,219	798
31	6.58	2005	0.004	100,822	433
31	6.30	2004	0.005	74,413	385
31	3.48	2003	0.005	65,359	343
32	-0.40	2008	0.000	1,332	0
32	1.45	2007	0.000	1,516	0
32	-3.76	2006	0.000	1,254	0
32	1.74	2005	0.000	2,236	0
32	1.96	2004	0.000	1,576	0
32	1.98	2003	0.000	2,190	0
33	4.62	2008	0.268	64,060	17,147
33	3.67	2007	0.255	61,117	15,614
33	3.76	2006	0.301	51,395	15,464
33	3.38	2005	0.276	46,229	12,773
33	2.87	2004	0.247	39,390	9,719
33	2.42	2003	0.242	34,815	8,411
34	0.73	2008	0.006	617	4
34	0.65	2007	0.008	99	1
34	1.70	2006	0.008	574	5
34	2.48	2005	0.006	544	3
34	4.39	2004	0.002	531	1
34	3.32	2003	0.000	445	0
35	3.79	2008	0.047	23,201	1,093
35	3.20	2007	0.047	21,864	1,020
35	2.54	2006	0.049	20,806	1,028
35	1.93	2005	0.042	21,203	896
35	1.49	2004	0.038	22,323	856
35	1.52	2003	0.035	22,561	789
36	0.50	2008	0.301	8,672	2,615
36	0.54	2007	0.337	10,387	3,502
36	-0.25	2006	0.315	8,917	2,807
36	-0.03	2005	0.359	9,424	3,387
36	-0.12	2004	0.338	9,390	3,169
36	-1.07	2003	0.240	8,856	2,122

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
37	2.46	2008	0.091	46,833	4,249
37	1.64	2007	0.084	6,823	574
37	1.70	2006	0.097	6,207	600
37	1.51	2005	0.094	3,464	327
37	1.17	2004	0.115	2,694	310
37	1.53	2003	0.116	2,154	249
38	-0.57	2008	0.225	1,271	286
38	-0.22	2007	0.303	1,511	458
38	-0.26	2006	0.210	1,390	292
38	-0.51	2005	0.216	1,283	277
38	-0.92	2004	0.164	1,514	248
38	-0.79	2003	0.175	1,723	301
39	-6.46	2008	0.046	202,361	9,228
39	-1.38	2007	0.042	257,011	10,844
39	-6.72	2006	0.029	253,846	7,311
39	0.78	2005	0.028	245,427	6,877
39	1.91	2004	0.044	270,288	11,903
39	0.27	2003	0.045	278,331	12,391
40	8.05	2008	0.032	22,897	734
40	7.29	2007	0.032	18,889	605
40	5.91	2006	0.031	18,678	588
40	4.15	2005	0.030	18,316	550
40	2.86	2004	0.029	16,988	487
40	2.34	2003	0.030	17,282	523
41	-5.54	2008	0.000	8,230	0
41	4.53	2007	0.000	7,675	0
41	3.28	2006	0.000	7,353	0
41	-0.96	2005	0.000	7,130	0
41	-6.19	2004	0.000	7,252	0
41	0.43	2003	0.000	7,755	0
42	-0.98	2008	0.000	51,971	0
42	-10.27	2007	0.000	55,193	0
42	0.45	2006	0.000	87,363	0
42	0.87	2005	0.000	88,462	0
42	-0.71	2004	0.000	34,172	0
42	0.91	2003	0.000	35,952	0
43	-1.39	2008	0.000	2,588	0
43	-2.90	2007	0.000	2,728	0
43	-3.48	2006	0.000	2,896	0
43	-1.43	2005	0.000	3,221	0
43	-5.23	2004	0.000	3,348	0
43	-0.90	2003	0.000	4,219	0
44	0.42	2008	0.000	16,830	0
44	5.71	2007	0.000	17,835	0

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
44	9.57	2006	0.000	20,014	0
44	5.63	2005	0.000	20,223	0
44	-2.37	2004	0.000	13,277	0
44	11.86	2003	0.000	13,964	0
45	2.03	2008	0.003	4,805	17
45	1.74	2007	0.004	5,126	22
45	3.02	2006	0.004	4,629	18
45	2.66	2005	0.004	4,174	17
45	2.54	2004	0.003	4,320	14
45	2.10	2003	0.004	4,159	15
46	1.38	2008	0.000	1,518	0
46	2.13	2007	0.000	1,660	0
46	2.31	2006	0.000	1,700	0
46	2.17	2005	0.000	1,651	0
46	2.08	2004	0.000	1,976	0
46	2.30	2003	0.000	2,380	0
47	0.31	2008	0.293	11,985	3,510
47	0.49	2007	0.316	9,929	3,134
47	0.54	2006	0.297	10,040	2,978
47	1.35	2005	0.277	9,628	2,670
47	0.62	2004	0.232	7,997	1,858
47	0.19	2003	0.213	5,224	1,115
48	1.41	2008	0.099	437,567	43,405
48	4.51	2007	0.091	322,231	29,200
48	4.16	2006	0.095	261,420	24,946
48	2.43	2005	0.094	227,097	21,288
48	1.59	2004	0.108	211,371	22,774
48	3.32	2003	0.130	100,936	13,152
49	1.54	2008	0.035	230,713	7,974
49	3.13	2007	0.033	246,499	8,151
49	7.38	2006	0.055	204,770	11,171
49	4.57	2005	0.060	156,482	9,365
49	4.15	2004	0.072	137,142	9,868
49	3.52	2003	0.064	103,385	6,642
50	2.51	2008	0.000	26,741	0
50	2.59	2007	0.000	30,044	0
50	2.16	2006	0.000	21,073	0
50	2.04	2005	0.000	19,591	0
50	2.00	2004	0.000	20,308	0
50	1.77	2003	0.000	19,456	0
51	1.60	2008	0.237	22,842	5,414
51	0.88	2007	0.215	17,528	3,769
51	0.81	2006	0.201	19,079	3,830
51	1.53	2005	0.187	21,248	3,972

table continues

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Code	EPS	XYEAR	XII	IC	II*IC
51	1.23	2004	0.167	20,592	3,441
51	1.60	2003	0.163	19,987	3,260

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APPENDIX B: DESCRIPTIVE STATISTICS

Table B1

Summary of Descriptive Statistics Results

Statistic	*EPS*	*XYEAR*	*XII*	*XIC*	*XIIxIC*
count	306	306	306	306	306
mean	1.90	2006	0.09	71,667.84	3,809.97
sample variance	42.59	2.93	0.01	13,899,288,157.93	47,404,209.00
sample standard deviation	6.53	1.71	0.12	117,895.24	6,885.07
minimum	-76.52	2003	0.00	98.87	0.00
maximum	26.34	2008	0.50	795,661.00	43,404.63
skewness	-7.50	0.00	1.39	3.07	2.43
kurtosis	85.28	-1.27	1.13	11.01	6.41

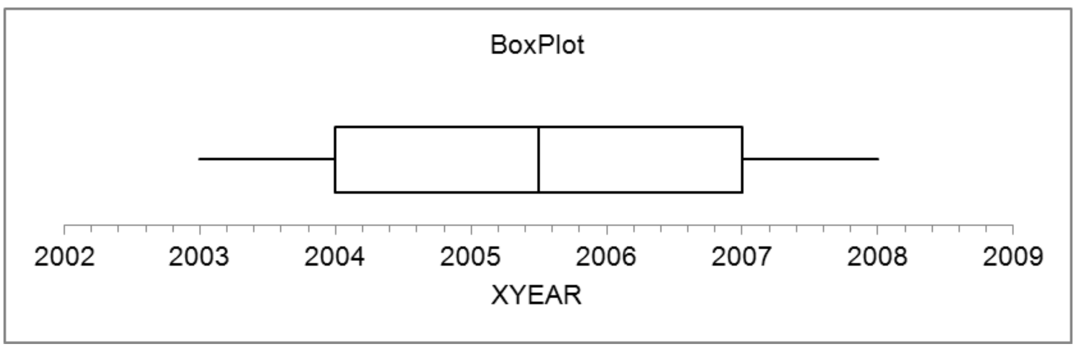

Figure B1. Box plot of XYEAR.

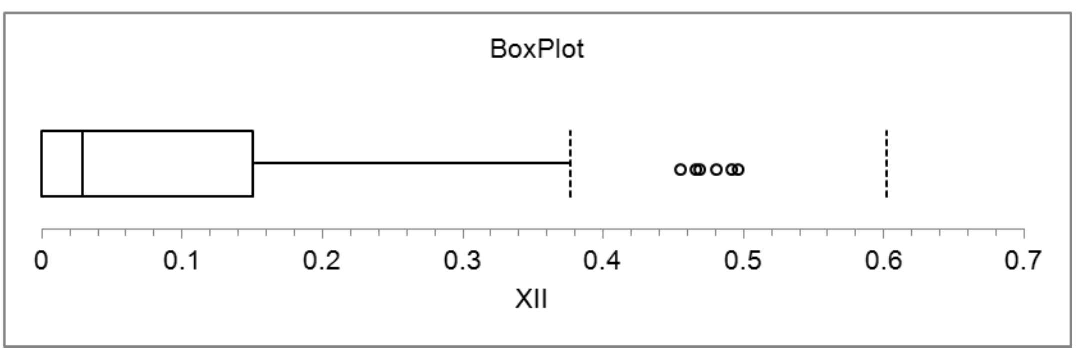

Figure B2. Box plot of XII.

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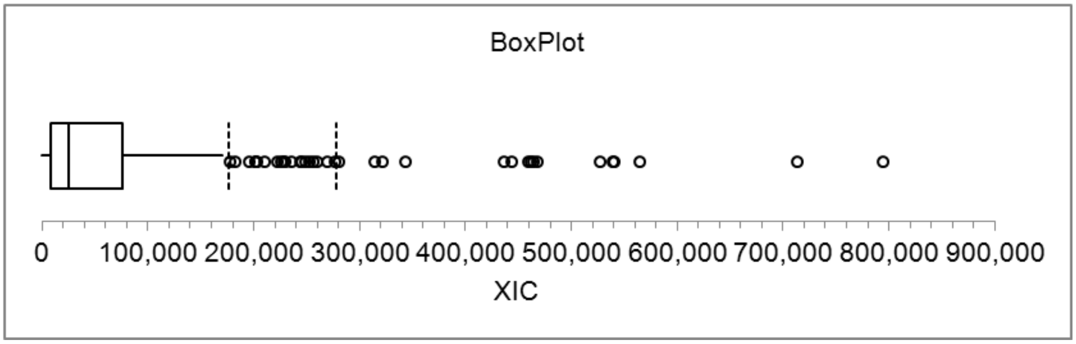

Figure B3. Box plot of XIC.

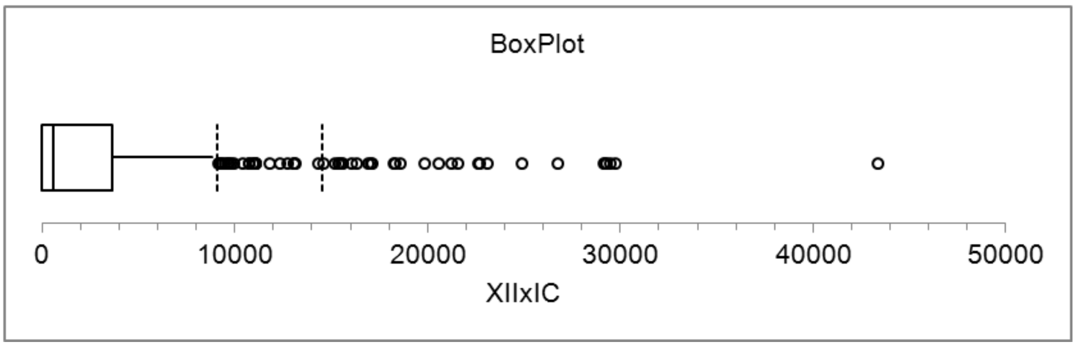

Figure B4. Box plot of XIIxIC.

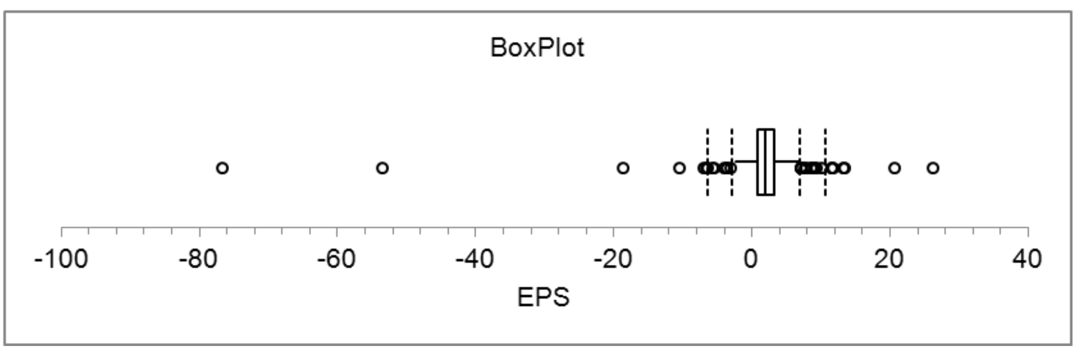

Figure B5. Box plot of EPS.

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APPENDIX C: REGRESSION RESULTS

Table C1

Summary of Multiple Regression Analysis Results

					confidence interval		
variables	*coefficients*	*std. error*	t-value	*p-value*	*95% lower*	*95% upper*	*VIF*
Intercept	321.132	436.053	0.736	0.462	-536.966	1179.230	
XYEAR	-0.160	0.217	-0.734	0.464	-0.587	0.268	1.013
XII	2.674	4.117	0.649	0.517	-5.429	10.776	1.719
XIC	0.000	0.000	3.154	0.002	0.000	0.000	1.331
XIIxIC	0.000	0.000	-0.845	0.399	0.000	0.000	1.822

Table C2

Full-Model Analysis of Variance Table

Source	SS	df	MS	F	p-value
Regression	448.885	4.000	112.221	2.693	0.031
Residual	12542.545	301.000	41.670		
Total	12991.429	305.000			

Table C3

Summary of Multiple Regression Analysis Results with XICratio

					confidence interval		
variables	*coeff (b)*	*std. error*	*t (df=301)*	*p-value*	*95% lower*	*95% upper*	*VIF*
Intercept	321.132	436.053	0.736	0.462	-536.966	1179.230	
XYEAR	-0.160	0.217	-0.734	0.464	-0.587	0.268	1.013
XII	2.674	4.117	0.649	0.517	-5.429	10.776	1.719
XICratio	9.077	2.878	3.154	0.002	3.414	14.740	1.331
XIIxICrat	-48.745	57.657	-0.845	0.399	-162.207	64.717	1.822

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Table C4

Summary of Multiple Regression Analysis Results with X(YEARxIC)

variables	coeff (*b*)	std. error	t (df=301)	p-value	confidence interval 95% lower	confidence interval 95% upper	VIF
Intercept	341.637	507.333	0.673	0.501	-656.731	1340.005	
XYEAR	-0.170	0.253	-0.671	0.503	-0.668	0.328	1.37
XII	0.470	3.194	0.147	0.883	-5.816	6.756	1.03
IC	0.000	0.004	-0.057	0.955	-0.008	0.007	1520970.54
Yr xIC	0.000	0.000	0.059	0.953	0.000	0.000	1521119.63

Table C5

Summary Results of all Possible Stepwise Regressions

p-values for the coefficients: XYEAR	XII	XIC	XIIxIC	s	Adj R^2	R^2	Cp	p-value
		0.002		6.437	0.027	0.030	0.286	0.002
0.458		0.002		6.442	0.026	0.032	1.737	0.007
		0.002	0.559	6.444	0.025	0.032	1.944	0.008
	0.902	0.002		6.447	0.024	0.030	2.271	0.009
0.470		0.002	0.575	6.449	0.024	0.033	3.422	0.017
	0.524	0.002	0.393	6.450	0.023	0.033	3.539	0.018
0.456	0.882	0.002		6.452	0.023	0.032	3.715	0.019
0.464	0.517	0.002	0.399	6.455	0.022	0.035	5.000	0.031
	0.683			6.535	0.000	0.001	9.602	0.683
0.686				6.535	0.000	0.001	9.604	0.686
			0.739	6.536	0.000	0.000	9.658	0.739
	0.482		0.508	6.541	0.000	0.002	11.150	0.739
0.690	0.688			6.544	0.000	0.001	11.438	0.850
0.671			0.720	6.545	0.000	0.001	11.472	0.864
0.659	0.477		0.491	6.550	0.000	0.003	12.949	0.849

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Table C6

Results of Time-Lagged Regressions

Lag	R^2	Adj R^2	*F*-value	*p*-value
2-year	0.009	0.000	0.137	0.938
3-year	0.016	0.000	0.250	0.861
4-year	0.022	0.000	0.360	0.782
5-year	0.034	0.000	0.550	0.651

Table C7

Research Model Correlation Matrix

Variable	EPS	XYEAR	XII	XIC	XIIxIC
EPS	1.000				
XYEAR	-0.023	1.000			
XII	-0.023	0.014	1.000		
XIC	0.174	0.106	-0.174	1.000	
XIIxIC	0.019	0.061	0.545	0.291	1.000

Note: ± 0.112, α=0.05 (two-tail) ; ± 0.147, α=0.01 (two-tail)

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APPENDIX D: VARIABLE SCATTERPLOTS

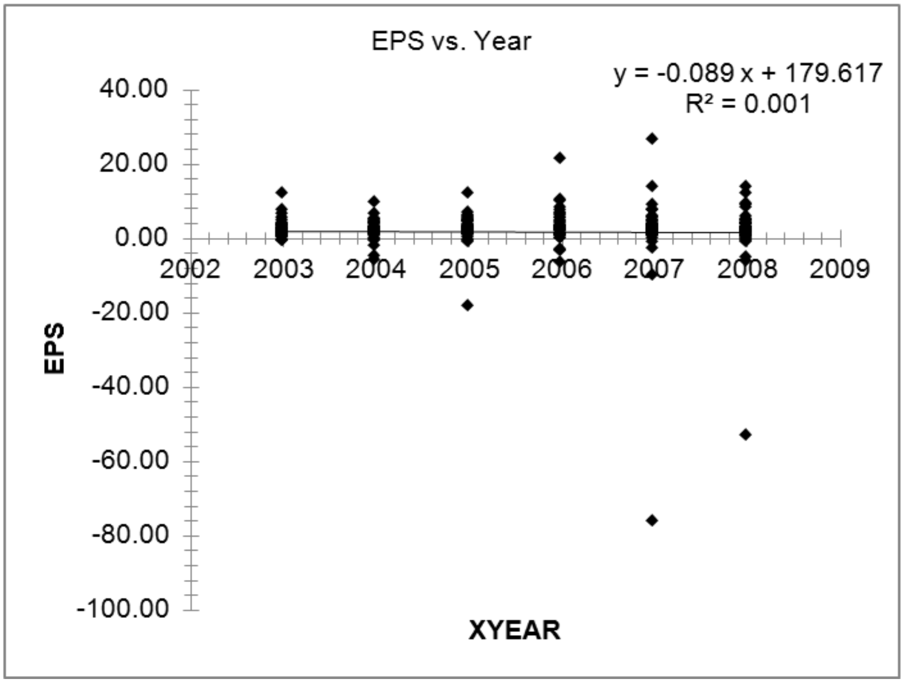

Figure C1. Scatterplot of EPS vs. XYEAR.

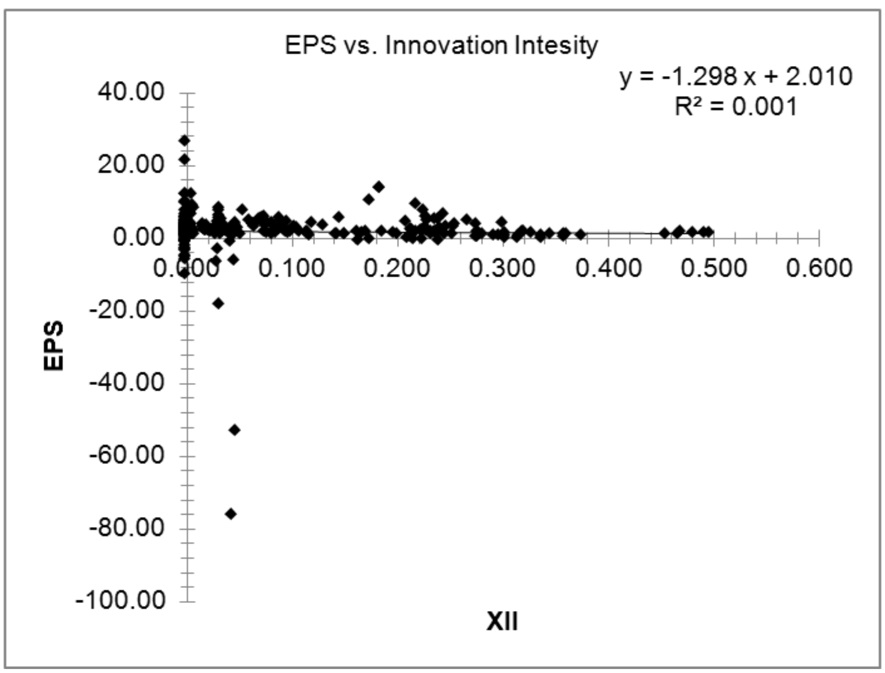

Figure C2. Scatterplot of EPS vs. XII.

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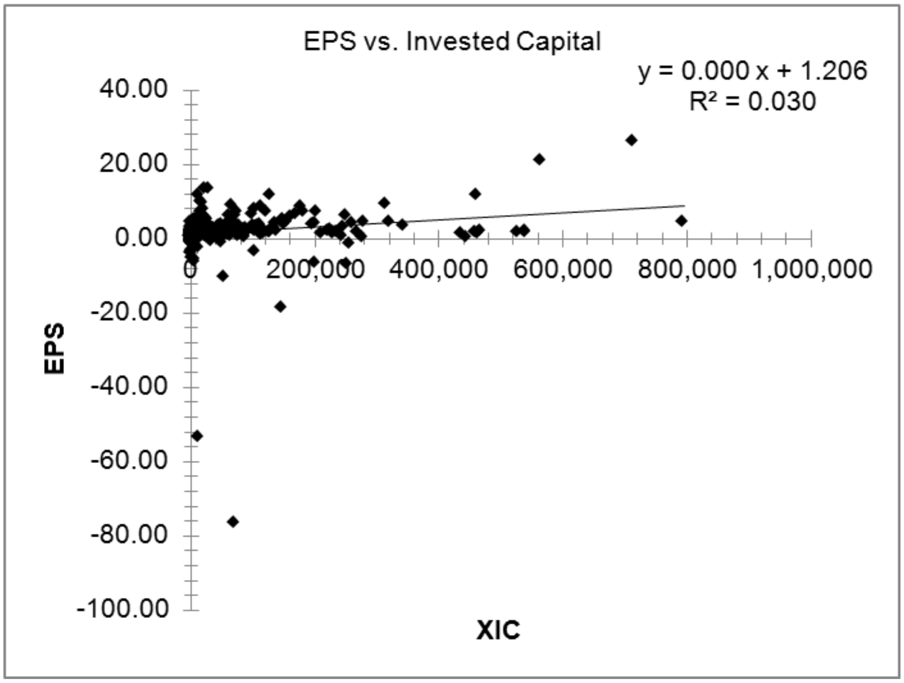

Figure C3. Scatterplot of EPS vs. XIC.

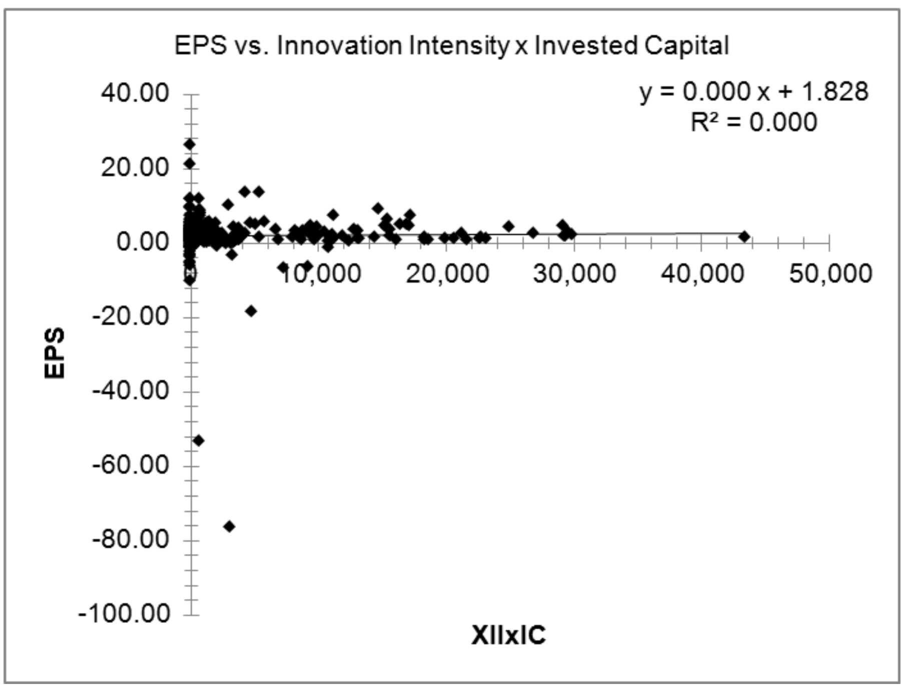

Figure C4. Scatterplot of EPS vs. XIIxIC.

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CURRICULUM VITAE

John Selby is a 1992 graduate of the University of Southern California where he was awarded a Bachelor of Science degree in Public Administration. In 2002, he graduated from the United States Naval Test Pilot School Rotary Wing Course with Class 121. He was awarded a Master of Science degree in Systems Engineering by the Johns Hopkins University in May of 2005. A Lieutenant Colonel in the U. S. Marine Corps, he serves with the Naval Air Systems Command. John is also faculty member in the Johns Hopkins University's Engineering for Professionals program teaching System Engineering courses, and mentoring students undertaking their final Master's project.

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