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**CROSS-SECTIONAL VARIATION IN THE
MARKET VALUATION OF R&D SPENDING
IN THE PREPACKAGED COMPUTER SOFTWARE INDUSTRY**

by

CHIICHAO CATHERINE CHIANG

A dissertation submitted to the Graduate Faculty in Business in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2001

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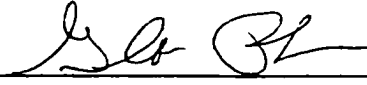
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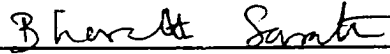
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Abstract**CROSS-SECTIONAL VARIATION IN THE MARKET VALUATION OF R&D SPENDING IN THE PREPACKAGED COMPUTER SOFTWARE INDUSTRY**

by

Chiichao Catherine Chiang**Adviser: Sudipta Basu**

This dissertation examines the cross-sectional variability in the market valuation of R& D expenditures in the prepackaged software industry. Prior research has often assumed that R&D spending by different firms is valued homogeneously by the stock market. This dissertation argues and empirically demonstrates that this assumption is invalid. Built on the economic literature on technological innovation, hypotheses are derived regarding the determinants of the cross-sectional heterogeneity in the market valuation of R&D. Empirical tests of the hypotheses use an extensive database containing information at a product level of the software firms between 1994 and 1997, along with accounting and stock price data in the same period.

The test results, consistent with my hypotheses, show that R&D spending is more valuable for firms with larger market shares, more frequent introductions of product innovations and upgrades, higher percentage of technical employees, and those that have diversified into different product categories. The results also indicate that market valuation of R&D spending is a function of product life cycle.

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TABLE OF CONTENTS

List of Tables		x
Chapter		
1. Introduction		p. 1
2. Prior Research		5
2.1 R&D Research in Economic Literature		5
2.2 Accounting Research on R&D		5
2.3 Research on the Determinants of Innovation		9
2.4 Deficiencies in Prior Research		10
3. Institutional Setting of Prepackaged Computer Software Industry		12
3.1 The Market Structure of the Computer Software Industry		12
3.2 The Accounting Environment		14
4. Hypotheses Development and Empirical Research Design		16
4.1 Heterogeneity of the Cross-sectional Market Valuation of R&D Spending – the Role of R&D Productivity		17
4.2 Heterogeneity of the Cross-sectional Market Valuation of R&D Spending – A Model that Includes the Effect of Competition		18
4.3 Impact of Product Life Cycle on the Heterogeneity of the Cross-sectional Market Valuation of R&D Spending		19
4.4 Other Determinants of Cross-sectional Variation in Market Valuation of R&D Spending		21
4.5 Empirical Models		24
4.5.1 Independent Analyses		24
4.5.2 Joint Analyses		30
5. Data Source and Operational Measures		33

5.1	Data Source	33
5.2	Variable Measurement	33
5.2.1	R&D Capital	33
5.2.2	Measuring R&D Productivity	34
5.2.3	Market Structure Variables	37
5.2.4	Definition of “Loss”	39
6.	Sample Selection and Summary Statistics	40
6.1	Sample Selection	40
6.2	Descriptive Statistics	41
7.	Empirical Findings	44
7.1	Is market valuation of software development cost a positive function of a firm’s productivity?	44
7.2	What market structure variables explain the cross-sectional variation in market valuation of software development cost?	48
7.3	Do the factors combined together explain the cross-sectional variation in the market valuation of R&D spending?	52
8.	Summary and Conclusions	56
8.1	Summary and Conclusions	56
8.2	Contribution of this dissertation	56
8.3	Limitation of this study	58
8.4	Future research	58
Appendix A – The Effect of Market Competition on the Expected Profit of a Firm Engaging in R&D Activities: the Derivation		83
Appendix B – List of the 44 Firms Used in Testing Hypotheses that Require Product Market Variables		90

References

LIST OF TABLES

Table 1: Summary Statistics of the Software Industry	p. 60
Table 2: Sample Selection Process	61
Table 3: Summary Statistics of the 44 Software Firms Used in Testing Most of the Hypotheses	62
Table 4: Descriptive Statistics on Variables	
Panel A: Summary Statistics of the Product Market Variables	64
Panel B: Correlation of the Product Market Variables	65
Table 5: Effect of R&D Productivity on Market Valuation of R&D – Returns Regressions	
Panel A: Results using Frequency of Product Innovation as Productivity Measure	67
Panel B: Results using Percentage of Technical Employees as Productivity Measure	68
Panel C: Results using Changes in Hiring of Technical Employees as Productivity Measure	69
Panel D: Results using Changes in Capital Expenditure as Productivity Measure	70
Table 6: Effect of R&D Productivity on Market Valuation of R&D – Price Regressions	
Panel A: Results using Frequency of Product Innovation as Productivity Measure	71
Panel B: Results using Percentage of Technical Employees as Productivity Measure	71
Panel C: Results using Changes in Hiring of Technical Employees as Productivity Measure	72

Panel D: Results using Changes in Capital Expenditure as Productivity Measure	72
Table 7: Effect of Market Competition on Market Valuation of R&D – Returns Regression Results	73
Table 8: Effect of Product Life Cycle Stage on Market Valuation of R&D – Returns Regression Results	74
Table 9: Effect of Product Diversification on Market Valuation of R&D – Returns Regression Results	75
Table 10: Effect of Market Structure Variables on Market Valuation of R&D – Price Regression Results	
Panel A: Hypothesis on Market Competition	76
Panel B: Hypothesis on Product Life Cycle	76
Panel C: Hypothesis on Product Diversification	77
Table 11: Stock Returns Regressed on all Hypothesized Variables (Full Model)	78
Table 12: Stock Price Regressed on all Hypothesized Variables (Full Model)	80
Table 13: The Effect of the Common Factor on the Market Valuation of R&D Spending – the Results of Returns Regressions (Reduced Model)	81
Table 14: The Effect of the Common Factors on the Market Valuation of R&D Spending – the Results of Price Regressions (Reduced Model)	82

1. Introduction

In this dissertation, I explore empirically the value-relevance of research and development (R&D) accounting in the prepackaged computer software industry. Specifically, I ask the following two questions: (1) Is the market valuation of R&D spending cross-sectionally constant, as assumed by prior studies? and (2) If the market valuation of R&D spending is *not* cross-sectionally constant, what are the key determinants of the cross-sectional variation in the market valuation of R&D expenditure?

In recent years, several arguments have been made concerning the shortcomings of the traditional accounting reporting model in the high technology sector (e.g., Lev and Zarowin 1999). The conceptual argument against the traditional accounting model is that, developed as it was for a traditional manufacturing economy, it has severe limitations in situations where intellectual properties (intangibles) predominantly form the basis for wealth rather than tangible assets. Recognizing this limitation, the American Institute of Certified Public Accountants (AICPA) Special Committee on Financial Reporting (Jenkins Committee) recommended in 1994 that companies disclose more non-financial data in addition to conventional accounting data.

The conceptual arguments against the traditional accounting reporting model are bolstered by empirical research. Several recent studies (Amir and Lev 1996; Lev and Zarowin 1999) have found that accounting information reported by high technology companies is not value-relevant for investors.¹ Moreover, Amir and Lev (1996) find that, in high technology sectors, non-financial information explains stock price variation better than traditional accounting information.

¹ These findings, however, are not supported by Francis and Schipper (1999).

Although the case for the inadequacy of traditional financial statements for high technological companies has been made, the extent to which the proposed non-accounting data are useful for predicting the future performance of these companies is still unclear.² Questions also arise as to how investors weigh non-accounting information when making investment decisions, and how such non-accounting data help investors to form unbiased expectations of a high technology firm's future profits. Given these unresolved questions, Lev and Zarowin (1999) have called for additional research on what additional kinds of information should be included in financial reports and how these reports can be made more informative.

Most previous studies that examine the value relevance of R&D outlays treat each dollar of R&D spending the same cross-sectionally. However, one dollar of R&D expenditure is not likely to produce the same incremental profit for each company. Market valuation of R&D expenditures is likely to reflect the market expectations of the productivity of R&D investment. If the market valuation of R&D spending is not cross-sectionally constant, the invalidity of the constancy assumption may jeopardize standard setters' ability to determine what changes (if any) in the accounting model are needed to make accounting information more value-relevant. Thus, examination of this assumption is important.

If the assumption of the cross-sectionally constant market valuation of R&D spending is invalid, the identification of the factors contributing to the cross-sectional variation and an examination of how data on these factors are viewed and used by investors can provide valuable insight for setting future accounting standards for R&D

² For example, how much more revenue can be earned by a one percent increase in customer satisfaction or in a certain quality score.

expenditures. Such studies can also guide us on whether the current accounting systems can be enhanced to produce more value-relevant information, or whether additional reporting systems must be developed.

In this dissertation, I examine the validity of the cross-sectional constancy assumption and hypothesize that the frequency of product introductions, market shares, product diversification, product life cycle stages, and percentage of technical employees contribute to cross-sectional heterogeneity in the market valuation of R&D expenditures. I use stock price, accounting and non-accounting data reported by the prepackaged computer software companies, and an extensive database containing product level information for these firms to examine the empirical relationship between market valuation of R&D and the variables that are hypothesized to affect its cross-sectional variability.

The prepackaged computer software industry offers a fertile environment to test empirically a theoretical model because (1) R&D is a critical factor to a computer software company's success; (2) there are numerous software products in the market (product diversification); (3) software firms have very dissimilar market shares; and (4) the software industry is known for the frequency of its product innovations.

My empirical results show that software development cost is not cross-sectionally constant. It is more valuable for firms with larger market shares, more frequent introductions of product innovations and upgrades, higher percentage of technical employees, and those that have diversified into different product categories. The results also indicate that market valuation of R&D spending is a function of product life cycle

stage, and that these factors are used together in determining the market valuation of R&D spending by different companies.

The relevant prior research on the market effects of R&D is summarized in Chapter 2. Chapter 3 presents the institutional setting of the computer software industry, while the hypotheses development and research models are presented in Chapter 4. Sample selection and summary statistics are reported in Chapter 5. Variable measurements are described in Chapter 6. Chapter 7 provides the empirical results and implications. The summary and conclusions, with contributions of the research, are outlined in the final chapter.

2. Prior Research

Both the economics and accounting literature contain research relevant to this dissertation. In this chapter, I first briefly summarize the relevant findings in the economic literature on R&D in section 2.1, followed by a review of accounting research on R&D in section 2.2. The extant research on the determinants of innovation, appearing both in the economic and the accounting literature is described in section 2.3. Section 2.4 summarizes the deficiencies in prior research.

2.1 R&D Research in Economics Literature

The economics literature primarily concentrates on studying the contribution of technological innovation on economic growth at the micro- and macro- economic levels and finds that R&D contributes to productivity growth (see Griliches 1995 for a survey of the relevant studies). The major findings are: (1) R&D contributes to productivity growth, (2) basic research contributes more to productivity growth than other types of research, (3) company-financed R&D contributes more to productivity growth than government-financed R&D, (4) an individual firm's productivity growth benefits not only from its own research but also from R&D of other firms in the same industry (knowledge spill over), and (5) knowledge also spills over from one industry to another.

2.2 Accounting Research on R&D

Accounting research on R&D has concentrated on issues relating to the capitalization of R&D, such as capitalization versus expensing and methods of capitalization. In addition, research on earnings management posits that R&D accounting is being used to manage investors' perception of firm performance.

2.2.1 Accounting Treatments of R&D Spending – Debate on Capitalization vs. Expensing

Under current U.S. GAAP, investment in intangible assets (such as R&D and advertising) is expensed as incurred. Investment in R&D differs from investment in a factory or long-term investment because it lacks physical existence as an asset, and because the benefit of investment in R&D often comes much later when the projects are completed and successfully commercialized. Because of the uncertainty of the outcomes, the eventual return on such investment cannot be determined immediately. Prior studies that support the expensing of R&D expenditures center on the difficulty of finding a reliable relationship between the funds invested in such activities and their future benefits (e.g. Johnson 1967). On the other hand, earlier empirical research providing support for capitalization of R&D uses market valuation as the criterion and finds that market value is positively related to R&D expenditures. Abdel-khalik (1975) finds a positive relation between operating income and lagged advertising expenditures. Grabowski and Mueller (1978) observe a positive relation between market value and lagged R&D expenditures. Ben-Zion (1978) shows that the difference between market value and book value is positively related to R&D expenditure. Hirschey and Weygandt (1985) find that Tobin's Q is positively related to R&D intensity (R&D divided by sales).³ Chan *et al.* (1990) find that market reactions to announcements of an increase in R&D investment differ for high technology and low technology firms. They find that the stock market reacts positively to the announcement of an increase in R&D spending by high technology

³ Tobin's Q, developed by James Tobin in 1968, is a ratio of the market value to the replacement cost of assets. It has been found to be a measure of a firm's monopoly rent (Lindenberg & Ross 1982; Smirlock, Gilligan and Marshall 1984)

companies and reacts negatively to a similar announcement by low technology companies. Shevlin (1991) examines the valuation of firms that form R&D limited partnerships as funding vehicles. Viewing a R&D limited partnership as a call option by the firm, he calculates the value of R&D limited partnerships and finds that capital market investors view R&D limited partnerships as increasing both the assets and liabilities of the firms.

More recent studies all provide support for R&D capitalization.⁴ Not only do researchers establish a positive relation between R&D expenditure and its future benefits, such as subsequent operating income and earnings (Lev and Sougiannis 1996, Aboody and Lev 1998), but they also find that capitalized R&D is value-relevant to investors (Aboody and Lev 1998, Chambers, Jennings, and Thompson 1998). In a simulation study on the pharmaceutical industry, Healy, Myers, and Howe (1999) also provide support for R&D capitalization. They find that performance reported under a successful efforts method explains much higher variation in economic returns than that reported under the cash method or a full-cost method. They also find that the difference in explanatory power arises from the information contained in R&D asset write-downs under the successful efforts method. However, when the managers can choose when the decline in R&D assets is reported, the value-relevance of accounting performance under successful efforts also decreases. Chambers, Jennings, and Thompson (1998) adjust R&D-related accounts by arbitrarily imposing different capitalization and amortization accounting rules to all sample firms. They find a small but statistically significant

⁴ An exception is Kothari, Laguerre, and Leone (1998), who find that investment in R&D contributes significantly more to future earnings variability than investment in PP&E, suggesting that future benefits from R&D investment is much more uncertain.

improvement in the value relevance of the adjusted R&D-related numbers over the unadjusted reported numbers.

Finally, alternative accounting methods for R&D spending such as setting up a contra-equity account have also been proposed (Johnson 1976).

2.2.2 Studies on Capitalization Methodologies

Studies aimed at finding alternative methodologies to straight-line to amortize R&D capital include Hirschey and Weygandt (1985) and Lev and Sougiannis (1996). Assuming a constant growth rate of R&D expenditures over time, Hirschey and Weygandt (1985) derive a normalized amortization rate by analyzing the relation between intangible capital and R&D expenditure. Instead of suggesting a normalized amortization rate, Lev and Sougiannis (1996) empirically establish industry-year-specific amortization rates by regressing current operating income on current tangible assets, advertising expenses, and past time-series of R&D expenditures for the years 1975 to 1990. Using the obtained industry-year coefficients, they then calculate firm-year-specific R&D capital by multiplying the coefficients and firm-specific R&D expenditures. The calculated R&D capital is found to be positively related to contemporaneous and subsequent stock prices and returns.

2.2.3 Manipulation of R&D Spending

The earnings management research argues that because R&D spending is a discretionary expense, it is often used to manage investors' perception of the firm's performance. Two competing hypotheses exist in this area. One hypothesis posits that

managers have the tendency to underinvest in R&D in order to increase the current earnings. For example, Dechow and Sloan (1991) hypothesize that CEOs whose incentive compensation is based on earnings will reduce R&D spending in their final years in office. Their empirical findings are consistent with the hypothesis of managerial myopic behavior. The other hypothesis posits management's tendency to increase R&D spending because higher R&D spending conveys positive information about the firm's prospects (Trueman 1986). Darrough and Srinivasan (1999) test the competing hypotheses by correlating R&D spending around the initial public offering (IPO) with managerial selling around the IPO. Their empirical results show that the percentage of managerial selling during the IPO is negatively correlated with the level of R&D in the offering year. They interpret the results as suggesting that managers are focusing more on investors' perception of earnings than investors' perception of R&D

2.3 Research on the Determinants of Innovation

Another line of research on R&D has centered around the factors leading to innovation. This line of research dates back to Schumpeter (1942) in the industrial organization literature. Industrial organization theory (Scherer and Ross 1990) suggests that the market structure in which a firm operates affects its conduct, which in turn determines its ultimate economic performance. Schumpeterians posit that market structure affects the rates of R&D investment (see Cohn and Levin 1989 for a survey of the relevant literature). Accounting research on the determinants of innovation examines the level of R&D spending in an agency paradigm. Francis and Smith (1995) posit that innovation is positively related to the level of ownership concentration. They find that,

relative to CEO- or insider-held firms, diffusely-held firms have fewer patents awarded, spend more money on each patent, and focus more on acquisitions than internally developed R&D projects. Holthausen, Larcker and Sloan (1995) study the interdependence between the structure of divisional executive compensation and the subsequent innovation at the business unit level. They find modest evidence that the percentage of total compensation tied to long-term accounting performance measures has a positive relation with future innovation. Cardinal and Opler (1995) test whether more diversified firms are less efficient innovators than undiversified firms. They find that efficiency of innovation as measured by new products per R&D dollar is not a function of corporate diversification. Anthony and Ramesh (1992) test whether the stock market response to sales growth and capital investment is a function of firm life cycle stage. They find that, from the growth to the stagnant stage, the market response coefficients of unexpected sales growth and unexpected capital investment decline monotonically.

Finally, research has also found that firm size (information environment) and growth (investment opportunity) contribute to cross-sectional differences in market reaction to accounting performance measures, as shown, for instance, in Collins, Kothari and Rayburn (1987) and Smith and Watts (1992).

2.4 Deficiencies in Prior Research

The extant accounting literature on valuation of R&D has demonstrated the value-relevance of R&D expenditures and suggests capitalization. However, to date, the literature has neither examined the role of R&D productivity in the capital market's valuation process nor explored the determinants of cross-sectional variation in the capital

market's valuation of R&D spending. Moreover, research on the relationship between life cycle stages and market valuation only analyzes the impact of *firm* life cycle, not *product* life cycle. In a market where technology advances rapidly, product life cycle may have more significant and direct impact on the market valuation. Finally, while most studies in the literature still use patent counts or patent citation as the measure of R&D output, market valuation is more likely to focus on the innovation efficiency and expected future profits than on the number of patent grants.⁵

⁵ An exception is Cardinal and Opler (1995), who study the relationship between number of new products per R&D dollar and firm diversification.

3. The Institutional Setting of the Computer Software Industry

3.1 The Market Structure of the Computer Software Industry

The prepackaged computer software industry (SIC = 7372) is relatively new, with only one company thus classified prior to 1979 in COMPUSTAT, and has experienced rapid growth (from 24 firms in 1979 to 445 in 1997). Its financial importance has also increased rapidly: the market value of the average company grew from \$80.83 million in 1979 to \$1.587 billion in 1998. Table 1 reports the average assets and market value of the industry since 1979.

The industry is intensively competitive. The 1997 annual report of Activision Inc. discusses the competitiveness of the industry: "The consumer software industry is undergoing rapid changes, including evolving industry standards, frequent new platform introductions and changes in consumer requirements and preferences. The introduction of new technologies, ... could render the Company's previously released products obsolete or unmarketable." Software developers compete with their peers on price, product functions, speed, compatibility, ease of use, and many other product qualities (Liebowitz and Margolis 1999). Technological progress of computer hardware can also change the competitive environment virtually overnight. For instance, a software product designed to improve the running speed of a computer operating system can easily be replaced by a higher-speed computer chip. To stay competitive in the market, it is essential for a firm to develop new technologies, upgrade its existing products, and introduce new products on a timely basis. Investment in R&D is crucial to a software firm's success in the industry.

However, unlike a perfectly competitive market, entry into the prepackaged computer software market is not free. One entry barrier is the entry cost. Prepackaged computer software is a market for differentiated products where the firms in the industry produce a number of similar but not identical products. Consumers in this market are aware of product differentiation and have varied preferences. Marketing surveys and advertising expenditures are critical to ensure that consumers' needs and preferences are met and that the product differentiation is recognizable. The largest cost of entry into the market is perhaps the labor cost of skilled software designers. Although patent is not the most effective way of deterring entry into this industry, incumbent software developers hide their source codes so that their programs cannot be easily altered.⁶ Potential entrants will have to hire people to design new products from scratch. Highly skilled software engineers are costly to find as the competition for skilled software engineers is also intensive due to the already competitive product market environment.

Another entry barrier is the cost advantage of the established firms. Liebowitz and Margolis (1999) attribute software market's unique market structure to the following two characteristics (1) instant scalability and (2) independence of product quality and marginal cost. Because the reproduction of a software product requires no more than disk/CD-ROM duplicators, output can be expanded almost instantly (instant scalability). Moreover, incorporating additional features of a software product sometimes only requires transporting/altering program codes from another existing product. Improving

⁶ Patent is not as important in the computer software industry as in other high-tech industries largely because software products have relatively short economic lives. Statements such as the following, quoted from Advance Technologies Inc.'s 1996 annual report, are prevalent in the annual reports of computer software companies: "The Company believes that patents are of less significance in its industry than factors such as innovation, technological expertise, and distribution strength."

product quality does not add much cost (independence of quality and marginal cost). Therefore, it is much easier for the incumbent firms than for the potential entrants to introduce new and/or improved products in an inexpensive and efficient manner. Because of these two characteristics of this industry, market domination is not uncommon and firms that eventually enjoy disproportionate larger market shares are often not the original creator of a product/product idea but those who can develop products with the best designs at lower cost.⁷

3.2 *The Accounting Environment*

Statement of Financial Accounting Standards No. 86 (SFAS 86) '*Accounting for the Costs of Computer Software to be Sold, Leased or Otherwise Marketed*' (FASB, 1985) mandates that software development costs be expensed until technological feasibility is established; any subsequent expenditures may then be capitalized but must be written off if the software is deemed obsolete. Development costs, once capitalized, can be amortized at the greater of the following two rates: a straight-line basis over the product's economic life⁸ or at a ratio of current sales revenue over the expected total revenue derived from sales of the product. However, the point at which technological feasibility can be established is ambiguous (see Fox and Ramsower 1989 for a

⁷ For example, Graphic User Interface (GUI) computer operating system was an idea created in the Xerox laboratory to make operating systems user-friendly. Apple Computers adopted the GUI idea and applied it to its Macintosh Computers. Macintosh Computers' success in the consumer market in the 1980s can be largely attributed to its GUI operating system – Macintosh OS. However, the operating system that currently dominates the operating systems market in personal computers is Microsoft's Windows, although introduced 5 years later than Macintosh OS.

⁸ In my sample, the average software product on the (retail) market is 15.4 months old, the median is 15.9 months old. The longest-lived software products in my sample have been on the retail market for 73 months. They are Clipper by Computer Associates, SimCity by Electronic Arts, Turbo Pascal by Inprise, and Norton AntiVirus by Symantec.

discussion) and is subject to management discretion. Consequently, SFAS 86 is not followed consistently by software developers.⁹ In this dissertation, the R&D expenditures include both the capitalized portion and the portion that is expensed as incurred.

⁹ For example, Microsoft expenses all of its software development costs as incurred. Of the 44 firms in the final sample for market structure analyses, 24 firms are expensers and 13 firms are capitalizers, while the information for the remaining 7 firms is not available via Edgar Online.

4. Hypotheses Development and Empirical Research Design

A firm's ability to innovate is among the most important factors in the market valuation of R&D spending. Other factors, such as the marketing and timing of its product introductions, can also affect a firm's commercial success (Christensen 1997). If new products are expected to bring significant profits to the company, investors will pay a premium to buy the firm's shares, pushing the stock price upward. On the other hand, if new products are expected to fail, the stock price will be adjusted downward, reflecting pessimism over the future cash flows resulting from the R&D investment. As such, depending on investors' *expectation of the success* of the projects under development, software development costs in a given period can be deemed as "probable future economic benefits" and priced as *assets*, or as "using up of assets" and be priced as an *expense/loss*. In other words, market valuation of R&D spending reflects investors' perceptions about the probability and expected payoff to successful introduction of innovations.

There are many reasons to expect that market valuation of R&D spending is not cross-sectionally constant. In the next section, I argue that heterogeneity in expectation can result if firms' past R&D performance is used by the market to value R&D spending. I then analyze, in Section 4.2, the direct effect of market structure on the expected profit of innovation, and show that the heterogeneity in the cross-sectional market valuation of R&D can be caused by market competition. In Section 4.3, I examine the impact of product life cycle stage on the heterogeneity in the cross-sectional market valuation of R&D. Other economic factors that contribute to the heterogeneity, as suggested by

previous research are discussed in Section 4.4. Finally, the empirical models for testing these hypotheses are presented in Section 4.5.

4.1 Heterogeneity in the Cross-sectional Market Valuation of R&D Spending – the Role of R&D Productivity

No two firms have the same innovation efficiency. Intuitively, R&D spending should be more valuable for more efficient firms. Prior empirical research that suggests heterogeneity in the cross-sectional market valuation of R&D spending can be found in Chan *et al.* (1990). They find that the stock market reacts positively to the announcement of an increase in R&D spending by high-technology companies and reacts negatively to a similar announcement by low-technology companies.¹⁰ It is reasonable to assume that this differential reaction results from investors' different expectations for R&D productivity of high- and low-technology firms.

Consider two firms: A and B, identical in every aspect other than the productivity of previous R&D expenditures. Suppose that, based on historical experience, Firm A on average produces four times as much revenue from its inventions as Firm B, although it incurs the same level of R&D expenditures. One would expect that the market valuation of one dollar of R&D expenditure by Firm A exceeds that of the same dollar R&D expenditure by Firm B, *ceteris paribus*.

Further consider firms C and D, identical in every aspect other than the development projects currently being undertaken. Suppose Firm C's research laboratory

¹⁰ According to the authors, the definitions of high-technology and low-technology are based on the classification in *Business Week's* annual R&D Scoreboard. Among those categorized as "high-technology" industries are pharmaceuticals, semiconductors, and information processing. Food and beverage, electrical equipment, and automotive, among others, are classified as "low-technology."

is designing products that are expected to have substantially more impact on the market place than Firm D's. It is reasonable to believe that market valuation of Firm C will be higher than that of Firm D. Consequently, cross-sectional differences in market valuation are expected to reflect both the productivity of prior R&D spending, as well as the expected productivity of current R&D spending.

The above discussion suggests the following research hypothesis:

H1: Market valuation of R&D spending is not cross-sectionally constant, but is a positive function of expected R&D productivity.

4.2 Heterogeneity of the Cross-Sectional Market Valuation of R&D Spending- A Model that Includes the Effect of Competition

In a perfect competitive market, the equilibrium condition is that no firm in the market can make above normal profit. However, when there are barriers to entry, firms can make above normal profit. As discussed in Section 3.1, prepackaged computer software industry fits this description. In this section, I argue that in an industry where there are barriers to entry, market competition can cause heterogeneity in the cross-sectional market valuation of R&D spending.

Consider a market where only one firm engages in innovative activities. The firm will have positive returns on R&D investment if it has successful innovation, and will suffer loss at least equal to the R&D spending if it fails to innovate. However, when many firms compete in an innovation race, returns on R&D investment will be considerably reduced for two reasons. First, if more than one firm discovers successfully, market revenue has to be shared by more than one innovator. Second, if firms are

competing for experienced R&D employees as a result of the innovation race, competition is likely to drive up labor costs and consequently drive down the potential returns on R&D.

When competition becomes really intense, some firms may not survive. Agarwal (1997) finds that firms' survival rates consistently decline with competition intensity. In the context of software development, if a product fails to survive its competition, the liquidating value of its related software development cost will be close to zero.¹¹ Depending on the variety of product lines and the intensity of competition in each market, each software firm's survival rate differs, and so does the liquidating value of its R&D investment. The difference in the liquidating value of R&D, in turn, is likely to contribute to the heterogeneity in the cross-sectional market valuation of R&D spending.

In Appendix A, I model the expected profit of a firm engaging in R&D activities in a competitive market. The model I develop shows that, *ceteris paribus*, the marginal contribution of R&D spending of a firm is positively related to its market share and is negatively related to its competitors' gross R&D spending. The above discussion and the derivations in Appendix A suggest the following hypothesis:

H2: The market valuation of R&D spending is not cross-sectionally constant, but is positively related to a firm's market share.

4.3 Impact of Product Life Cycle on the Heterogeneity in the Cross-Sectional Market

Valuation of R&D

¹¹ Berger, Ofek, and Swary (1996) find that specialized assets create less abandonment option value than unspecialized assets.

The life cycle of a computer software product begins after a successful innovation and ends when its demand recedes: when it is replaced by a later version or by a competitor product, or when the hardware that supports the product becomes obsolete. Between its arrival and termination, the software product goes through an introduction period, followed by a growth in demand either due to increased scope of application or due to the creator's marketing effort. The demand growth, in turn, invites competition from imitators, who create more supply that may saturate the market, and from other innovators, whose new innovations may eventually replace the product.

Most product life cycle research documents a bell shaped revenue line across four stages of a product's life - introduction, growth, mature, and decline, with a peak at the stage of maturity (Rink and Swan 1979). Greenstein and Wade (1999) examine the product life cycle in the commercial mainframe computer market and find that a product's failure rate is a function of product life cycle stage.

In the case of a software product, much of the R&D precedes its introduction, before any income is generated. In the introduction and growth stages, R&D effort is devoted to product enhancement, fixing problems, and resolving conflicts with newly developed equipment. If the development team is not able to resolve major problems, the product will exit the market. For products that survive the growth stage, most income is earned in the mature stage, at which point, little R&D is needed on the product because most of the problems were encountered and fixed in the earlier stages and product features have been enhanced to a satisfactory level. In other words, return to R&D investment is the highest at the mature stage. If the market anticipates the highest return to R&D at the mature stage and reacts early, the market valuation of R&D should be

highest before the product reaches maturity. However, sometimes fixing software problems takes longer time than creating the original codes. Considering the intensity of the competition in the software industry and the speed of technological innovation, if a developer is unable to fix a problem in a timely manner, either one of the following situations may occur. The potential customers may switch to a competitor product or newly developed technology would require drastically different product features and functions. As a result, the developer itself may decide to pull the product out of the market. For these reasons, I expect that the market would react positively to a new product only after the major problems are resolved. Therefore, I hypothesize that the market valuation of R&D should be highest for firms whose average product is somewhere between the growth and early part of the mature stage. Once the product sales start to decline, the product is likely to exit the market soon. R&D spending on a product at the decline stage is not expected to bring significant future cash flows.

In short, because the average product of each software firm is in a different life cycle stage, I do not expect the market valuation of R&D spending to be cross-sectionally constant. R&D should be more valuable in the middle part of a product's life cycle than in other stages. Hence, the following hypothesis:

H3: Market valuation of R&D expenditures is a function of the firm's average product life cycle stage.

4.4 Other Determinants of Cross-sectional Variation in Market Valuation of R&D Spending

In this section, I explore other factors that are hypothesized to determine the cross-sectional variation in the market valuation of R&D spending in the literature. These factors are level of diversification and firm size.

Diversification

The level of diversification of a firm has been hypothesized to affect innovation efficiency (Cardinal and Opler 1995). Those who posit a positive effect of diversification on innovation efficiency argue that, in a diversified firm, R&D divisions can share their technological innovations, taking advantage of economies of scale in the innovation effort (Teece 1980). In the case of software development, a technology advance in one area can significantly benefit development in other areas. For instance, advancement in the object-oriented paradigm has been applied in the development of many software products such as databases, word processors, and web browsers. If innovation efficiency can be achieved across products and divisions, investments in software development will be valued more for a diversified firm than a non-diversified firm.

On the other hand, there is also growing empirical evidence suggesting that firm value is a negative function of industrial diversification (Berger and Ofek, 1995; Bodnar, Tang, and Weintrop 1997).¹² Those who posit a negative effect of diversification on innovation efficiency argue that ROI-based compensation to divisional managers in a diversified firm is likely to result in myopic behavior, sacrificing investment of a longer-term nature,

¹² The evidence to date is limited to the effect of industrial diversification and geographic diversification. I am not aware of any study on the value impact of product line diversification.

such as innovative activities (Hoskisson *et al.* 1993). However, such managerial myopic behavior is not likely to affect the innovation efficiency in the software industry.

Software products have relatively short life cycles; therefore, one would expect the financial return to R&D investment to be sooner than research in other industries, reducing the possibility of underinvestment in R&D. In addition, because of the low correlation between earnings and the firm value created by R&D managers, accounting-based bonus plans are not expected to be frequently used by software firms (Watts and Zimmerman 1986, Barclay, Gode, and Kothari 2000). In fact, stock options are used prevalently among software firms to compensate employees, which should mitigate the effect of myopic behavior caused by predominantly ROI-based compensation, if used.¹³ Moreover, the empirical evidence documenting a negative effect of industrial diversification on firm value is limited to diversification from one industry to an unrelated industry, not for one product category to another category within the same industry. Therefore, I do not expect the negative effect to have much impact on the market valuation of R&D in the software industry.

Putting it together, since technological advancement in the software industry can be easily transferred from one area to another with minimal marginal cost, and because the use of stock options for compensation is prevalent in the industry and the documented negative effect of diversification on firm value is limited to diversification into unrelated industries, I predict that the positive effect of diversification on innovation efficiency will

¹³ Of the 44 firms in my sample, the median value of stock option as a percentage of net income is 29%. All firms in the sample grant stock options to employees, and the median firm issues employee stock options worth 2.6 cents per dollar of sales.

dominate. That is, R&D spending is generally more valuable for a diversified firm than a non-diversified firm.

H4: Market valuation of R&D spending is a function of product diversification. R&D is more valuable for firms that diversify into different product categories (within the same industry) than those who do not diversify.

Firm Size

A sizable literature exists on the effect of firm size on market valuation. In general, larger firms have smaller earnings response coefficients than smaller firms. In the R&D context, Holthausen *et al.* (1995) argue that centralization is necessary for large firms to control employee managers, and that a more centralized firm tends to inhibit innovation due to its more bureaucratic control mechanisms. To the extent that firm size proxies for centralization, firm size could show a negative correlation with the market valuation of R&D spending. However, firm size is also related to the availability of financial resources. If the availability of financial resources can facilitate innovation efficiency, firm size will be positively correlated with the market valuation of R&D. Since the size effect on the market valuation of R&D investment is ambiguous but the effect of size in firm valuation is well documented, I use firm size only as a control variable in the study.

4.5 Empirical Models

4.5.1 Independent Analyses

In the accounting literature, the market valuation of R&D investment is studied empirically either by regressing stock returns on changes in R&D expenditure as in equation (1) below, or regressing market value on R&D capital as in equation (2) below:

$$R_{it} = \alpha_0 + \alpha_1(RD_{it}) + \alpha_2(\Delta RD_{it}) + \alpha_3(\Delta E_{it}) + \alpha_4(E_{it}) + \alpha_5(SIZE_{it}) + \varepsilon_i \quad (1)$$

$$V_{it} = \beta_0 + \beta_1(TA_{it}) + \beta_2(RDC_{it}) + \beta_3(ADVC_{it}) + \beta_4(DEBT_{it}) \quad (2)$$

where

R_{it} is the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm i ;

E_{it} is the earnings per share before R&D for the period t for firm i ;

RD_{it} is the R&D expenditure for firm i in period t ; in this study it includes R&D expense and capitalized R&D;

ΔRD_{it} is the change in annual R&D spending per share;

ΔE_{it} is the changes in earnings per share before R&D for firm i in the period t ;

$SIZE_{it}$ is the natural log of the market value of firm i at the end of the period t ;

V_{it} is the market value of the common stock of firm i at end of period t ; in this study, it is the share price three months after the firm's fiscal year end;

TA_{it} is the book value of tangible assets of firm i at the end of period t ;

RDC_{it} is the R&D capital of firm i at the end of period t ;

$ADVC_{it}$ is the advertising capital created by marketing activities of firm i for the period t ;

$DEBT_{it}$ is the book value of the debt of firm i at the end of period t ,

and all variables except the intercept, R_{it} , and $SIZE$ are scaled by the market value at time $t-1$.

Equation (1) is a returns model where stock return is explained by both earnings level and change in earnings and firm size. In equation (2), the market value of a firm is represented by the sum of the market value of its tangible and intangible (R&D capital and advertising capital) assets minus the market value of its liabilities.

In the cross-sectional empirical studies, investment in R&D (software development cost) is incrementally value-relevant to investors if the coefficient of ΔRD , α_2 , in equation (1) or the coefficient of RDC , β_2 , in equation (2) are positive and statistically significant.

Implicitly, both equations (1) and (2) assume a constant cross-sectional contribution of R&D expenditure to market value. To test the heterogeneity of cross-sectional market valuation of R&D, I modify equations (1) and (2) into equation (3), a returns model, and equation (4), a price model as below:

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(D_i) + \gamma_4(D_i)(\Delta RD) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(D_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i \quad (3)$$

$$V_{it} = \lambda_0 + \lambda_1(TA_{it}) + \lambda_2(RDC_{it}) + \lambda_3(D_{it}) + \lambda_4(D_{it})(RDC_{it}) + \lambda_5(ADVC_{it}) + \lambda_6(DEBT_{it}) \quad (4)$$

where D is a factor dummy, which equals to one for firms of a certain characteristic, zero for the others. Specifically, the value of D under each hypothesis is as follows:

H1 (productivity hypothesis):

$D = 1$ for firms with high R&D productivity; $D = 0$ otherwise.

H2 (market competition hypothesis):

$D = 1$ for firms with larger market share; $D = 0$ for smaller market share.

H3 (life cycle hypothesis)

$D = 1$ for firms whose average product is in mature stage; $D = 0$ for other stages.

H4 (product diversification hypothesis)

$D = 1$ for diversified firms; $D = 0$ for non-diversified group.

In models such as (3) and (4), the group that is assigned $D = 0$ is the base group. A significantly nonzero λ_3 (γ_3) shows how much the group with the characteristic ($D = 1$) differs in average stock price (average annual stock returns) from the base group after controlling for other factors.¹⁴ A significantly nonzero λ_4 or γ_4 would validate the heterogeneity hypotheses. The magnitude of λ_4 or of γ_4 reflects how much more (if λ_4 or γ_4 is positive) or less (if λ_4 or γ_4 is negative) valuable the other group's R&D spending is, relative to the base group. Based on such models, the cross-sectional difference in market valuation of R&D is examined primarily by testing the statistical significance of λ_4 and γ_4 , the coefficients on the interaction terms.

For Hypothesis 1, a firm's productivity measure is calculated for each firm-year observation. Based on its productivity measure, each observation is then put into one of two groups: productive ($D = 1$) and less productive ($D = 0$). If market valuation of R&D is higher for firms with higher productivity, as predicted by Hypothesis 1, γ_4 in model (3) and λ_4 in model (4), the interaction term, should be positive.

¹⁴ Because the dummy may also influence how the market prices earning surprises, I add an interaction term of change in earnings and the dummy, $\Delta E * D$, in equation (4) to control for any effect the dummy may have on stock returns through earnings.

Similarly, for Hypothesis 2, each observation is put into one of two groups based on market share. If market valuation of R&D is higher for firms with more market share, γ_4 in model (3) and λ_4 in model (4), the interaction term, should be positive.

For the life cycle hypothesis, R&D is expected to be most valuable in the middle part of the product's life. Letting $D = 1$ for firms whose average product is in the middle stage and $D = 0$ for others, I expect λ_4 and γ_4 to be positive. For the hypothesis on product diversification, a significantly positive λ_4 and γ_4 would indicate that R&D is valued more for diversified firms than for non-diversified firms when D is set to 1 for the diversified companies.

I do not predict signs for λ_2 , the coefficient of R&D capital, and γ_2 , the coefficient of changes in R&D for the following reason. The sign of λ_2 should be considered along with the sign of λ_4 and γ_2 with γ_4 . A positive λ_2 and a positive γ_1 would suggest that R&D spending is priced as assets in general. However, if γ_2 (λ_2) is non-positive but γ_4 (λ_4) is positive, it would suggest that incremental R&D spending is priced as assets/benefits only for firms showing evidence of productivity (Hypothesis 1), for firms with larger market share (Hypothesis 2), for firms whose average product has reached mature stage (Hypothesis 3), and for diversified companies (Hypothesis 4).

The other predictions are that $\gamma_5, \gamma_6, \gamma_7$ the coefficient of earnings change, the interaction between earnings change and the dummy, and earnings level, are indeterminate in the returns model, and that λ_1 , the coefficient of tangible assets, is positive, λ_3 , the coefficient of advertising outlay, indeterminate, and λ_6 , the coefficient of liabilities, negative in the price model. The reasons are discussed below.

Several returns-earnings relationship studies (e.g. Easton and Harris 1991, Ali and Zarowin 1992) have shown that both the current earnings level and the earnings change variables are positively associated with stock returns. Aboody and Lev (1998) decompose net income into R&D components and net income before R&D and still find a significantly positive association between the stock returns and the net income before R&D in the pooled regression. However, Black (1998) argues that earnings are not value-relevant for start-up and growth firms because earnings persistence is lower for these firms and a large portion of these firms' value consists of their growth opportunities. His empirical findings, consistent with his prediction, show that earnings of start-up and growth firms are not positively correlated with market value. Hayn (1995) also shows that reported losses are less informative about firm's future prospects and are more weakly associated with returns than profits. Since the prepackaged computer software industry is relatively young, I expect the majority of my sample firms to be in the start-up and growth stages. I also expect the sample firms to report more losses than firms in more mature industries. If the earnings effect of start-up and growth firms and/or the effect of losses dominate, γ_5 and γ_6 may not be positive in equation (3). Thus, I do not have a sign prediction for earnings. In addition, I will also conduct two separate regressions for the loss group and for the profit group to control for losses.

The empirical findings about the contribution of advertising outlay to firms' market value are inconclusive. Using price regression to study the market value of advertising, Hirschey and Weygandt (1985) conclude that advertising outlay is long-lived and should be capitalized. Abdel-khalik (1975) finds a positive relation between operating income and lagged advertising expenditures. However, Bublitz and Ettredge

(1989) did not find a positive association between cumulative abnormal stock returns and unexpected advertising expense and conclude that advertising expenditure is short-lived. If advertising expense is priced as an asset, the coefficient of advertising expense, λ_5 , should be positive; if not, it may be insignificant or negative.

Since equities are the residual claims of the stockholders against a company's assets, the market value of a firm's equity should be equal to the market value of its assets minus the market value of its liabilities. Therefore, in equation (4), the coefficient of *TA*, λ_1 , which measures the contribution of a firm's tangible assets to its market value, is expected to be positive. The coefficient of *DEBT*, λ_6 , which measures the market value of each dollar of liabilities, should be negative.

In short, the predictions for equation (3) are: $\gamma_1 > 0$, $\gamma_4 > 0$, and the predictions for equation (4) are: $\lambda_1 > 0$, $\lambda_4 > 0$, $\lambda_6 < 0$.

4.5.2 Joint Analysis

In addition to the univariate analyses, these hypotheses can be jointly tested in the following returns and price models:

$$\begin{aligned}
 R_{it} = & \sigma_0 + \sigma_1(RD_{it}) + \sigma_2(\Delta RD_{it}) + \sigma_3(E_{it}) + \sigma_4(\Delta E_{it}) + \sigma_5(INNO_{it} * \Delta RD_{it}) \\
 & + \sigma_6(MKSH_{it} * \Delta RD_{it}) + \sigma_7(LIFE_{it} * \Delta RD_{it}) + \sigma_8(LIFESQ_{it} * \Delta RD_{it}) \\
 & + \sigma_9(DVS_{it} * \Delta RD_{it}) + \sigma_{10}SIZE_{it}
 \end{aligned} \tag{5}$$

$$\begin{aligned}
 V_{it} = & \theta_0 + \theta_1(TA_{it}) + \theta_2(RDC_{it}) + \theta_3(INNO_{it} * RDC_{it}) + \theta_4(MKSH_{it} * RDC_{it}) \\
 & + \theta_5(LIFE_{it} * RDC_{it}) + \theta_6(LIFESQ_{it} * RDC_{it}) + \theta_7(DVS_{it} * RDC_{it}) \\
 & + \theta_8(ADV_{it}) + \theta_9(DEBT_{it})
 \end{aligned} \tag{6}$$

where

INNO is a measure of innovation efficiency;

$MKSH_{it}$ is the aggregate and weighted average product market share of firm i in period t ;

$LIFE_{it}$ is the (simple) average product life, measured in months, of firm i in period t ;

$LIFESQ_{it}$ is the square of $LIFE_{it}$;

DVS_{it} is the reciprocal of modified Herfindahl Index,

and the other variables are as defined earlier.

Equations (5) and (6) test whether heterogeneity in the cross-sectional market valuation of R&D are incrementally explained by the cross-sectional differences in innovation productivity, competition intensity, product life cycle stages, and level of diversification. The variable $LIFESQ$ is included to test whether the R&D-return and R&D-price response coefficients are non-linear with respect to life cycle stage of the products.

One problem with equations (5) and (6) is that several independent variables could be highly correlated, making precise coefficient estimation difficult (Gujarati 1995).¹⁵ For example, intuitively, larger firms ($SIZE$) tend to be more diversified (DVS) and have larger market share ($MKSH$). In the study of industrial organization, a market is decomposed into structure, conduct, and performance. Industrial organization economists believe that a firm's performance is affected by market structure and its conduct. In equations (5) and (6), competition intensity ($MKSH$) and firm size ($SIZE$) are factors that can define how a firm interacts with other participants in the market. In addition, as discussed in Section 4.4, a firm's decision to diversify and the level of its

¹⁵ The consequences of high multicollinearity are that OLS estimators have large variances, covariances and wide confidence intervals, resulting in statistically insignificant t ratios and making it easier to accept the null hypothesis.

diversification (*DVS*) may affect innovation efficiency (*INNO*), which in turn, can influence product life cycle (*LIFE*). Since some of these variables define market structure and firms' conduct and some measure firm performance, I expect them to be highly correlated.

Gujarati (1995) suggests several ways to correct the near multicollinearity problem, one of which is factor analysis. Factor analysis is a set of statistical techniques aimed at representing a larger number of variables by a smaller number of clusters. Therefore, in the joint analysis, I will use factor analysis to isolate a better proxy for the observed variables and examine the extent to which the extracted common factors affect the market valuation of R&D spending.

5. Data Source and Operational Measures

5.1 Data Sources

The following information sources are used in constructing the operational measures of the variables: companies' 10-K reports, Center for Research in Security Prices (CRSP), COMPUSTAT, and PC Data Retail Sales Report for 1994-1998.

CRSP and COMPUSTAT are widely used databases in finance and accounting research. The stock prices and number of shares in CRSP provides necessary data for calculating market value. COMPUSTAT contains information on the reported value of assets, liabilities, R&D spending, earnings, capital expenditure, and fiscal year end month. From 10-K reports, I collect the information on number of technical employees.

PC Data is a market research company that collects monthly sales data from computer software wholesalers, distributors, and retailers across the United States. To compile its Retail Sales Report, PC Data asks the contracted software retailers to provide information about their monthly sales in units and in dollars for each software title. The market share of each product and the date of its first appearance are also collected in the report. PC Data tallies the information from each retailer and sells the information to its clients.

5.2 Variable Measurement

5.2.1 R&D capital

In accounting research, R&D capital is defined as the part of the cumulated R&D investment that is still contributing to a company's revenue. In other words, it is the sum of the R&D spending over time minus the amortization of R&D capital. Most studies

calculate R&D capital as the weighted average of past R&D spending, where the weights are obtained by making different assumptions about the depreciation of intangible R&D investment:

$$RDC_t = \sum_0^k (1 - \lambda_k) r_{t-k}$$

where

λ_k is the amortization rate of R&D spent k years ago

r_t is the research and development outlays for period t

Empirically, many different assumptions about the amortization rates have been used; some assume exponentially declining rates going backward in time (Grabowski and Mueller 1978), while others assume a normalized rate (Herschey and Weygandt 1985, Hall 1993), and some allow the depreciation rate to vary over time (Sougiannis 1994, Lev and Sougiannis 1996). In addition to using the cumulative R&D investment to calculate R&D stock, Hall (1993) also uses current R&D expenditure as a proxy for R&D stock, due to findings that R&D expenditures, when expressed in constant dollars, vary little over time within a firm.

Following Hall (1993), I measure the R&D stock using current R&D expenditure in this dissertation. The methodology suggested by Lev and Sougiannis (1996) is not used in this paper because the software industry is relatively young and does not have sufficient time series data to produce statistically efficient estimates.

5.2.2 Measuring R&D productivity (PD)

Several methods have been used to measure the output of R&D. For example, patent counts and patent citations are widely used in the economic literature. However, I

do not use patent-related statistics to measure R&D output in this study for two reasons. First, good patent statistics have not been successfully linked to financial performance (Pakes and Simpson 1989, Griliches 1990). Second, as discussed in Section 3, patents are not as important in determining returns to R&D in the software industry as in other industries because of the relatively short life cycle of software products. Instead of using patent statistics, I calculate R&D output measures using information found in the annual reports and PC Data Sales Reports. The construction of the measures is discussed below.

5.2.2.1 Measures of historical R&D productivity

Frequency of new product introductions and product upgrades (INNO)

Frequent introductions and upgrades of products in the computer software industry are necessary to meet consumers' needs in the rapidly changing technological environment. The ability of a software developer to deliver new products and upgrades *on time* is crucial to the survival of the products and the developer. In fact, financial analysts consider significant delays in product delivery an indication of poor R&D quality.¹⁶ In this study, the number of new products and upgrades (i.e. products released in the current fiscal year) scaled by number of existing products on the market is used as a productivity measure.¹⁷

¹⁶ The importance of timely product delivery to a software developer is best illustrated by the following news about Corel and comments from a financial analyst regarding Oracle's second delay in a product release. 'Corel yesterday reported ... a net loss of \$3.2 million for the quarter, which ended Aug. 31. The company blamed the loss on shipping delays for its Office Professional software suite.' (Information Week, September 26, 1998) 'Bradley (an analyst at Meta Group Inc. at Stamford Connecticut) said any further delay should raise a warning flag. "If they push it back again, it will indicate that there are significant problems they can't fix," he said.' (Computer World Online News, January 7, 1999)

¹⁷ As PC Data Monthly Retail Report only provides information on software products sold in the retail market, the assumption made here is that the frequency of *all* products developed in a firm can be proxied for by the frequency of *retail* products developed in the firm.

$$INNO = \frac{(\# \text{ of } _ \text{ new } _ \text{ products}) + (\# \text{ of } _ \text{ upgrades})}{\# \text{ of } _ \text{ products } _ \text{ on } _ \text{ the } _ \text{ market}}$$

5.2.2.2 *Forward-looking R&D productivity measures*

(1) *Percentage of R&D staff*

A high technology company can only survive and thrive if it keeps up with the latest development in technology. Keeping up with the pace of technological development requires the work of many scientists and engineers. Entwistle (1999) reports that high-tech firms devote significant portions of their annual reports discussing the people involved in R&D, suggesting that managers consider information about R&D staff an important signal about their development efforts. The percentage of R&D staff to total employees indicates how serious a company regards its product development and how likely the company will be able to keep rolling out new products to the market.

(2) *Increase in the hiring of R&D staff (HIRE)*

As people involved in R&D are an important factor in R&D, hiring more R&D staff may signal an anticipated strong demand for the products under development. The following variable measures the percentage increase in recruiting of R&D staff.

$$HIRE_t = \frac{STAFF_t - STAFF_{t-1}}{STAFF_{t-1}}$$

where $STAFF_t$ is the number of R&D staff in year t.

(3) *Increase in capital investment (NEWC)*

Increase in capital investment is necessary to support growth. An unexpected change in the capital expenditure signals the firm's positive net present value projects (Kerstein and Kim 1995). Therefore, an increase in the capital investment by a software company may indicate that the company is optimistic about the revenue potential of its software products under development.

5.2.3 Market Structure Variables

To test Hypotheses 1 to 4, I first calculate all market structure variables in continuous numbers and then transform them into categorical data, so that the sample can be partitioned to examine the difference in market valuation of R&D between groups.

(1) Market Share

I use two measures to calculate *Market Share* - aggregate market share and weighted average market share across different product categories. Aggregate market share of a firm is the sum of the firm's annual revenue from all product categories divided by the total market revenue. The weighted average market share is the weighted average of the market shares in six different product categories, where the weight is the percentage of revenue generated from each category. The aggregate market share represents the overall market share of the company; whereas the weighted average market share gives greater weight to the firm's specialized area(s). The smaller the firm's market share, the more competition the firm is operating under. In this study, firms with aggregate market share of less than 0.05% (sample median) are defined as firms of smaller market share; those with market share equal to or greater than 0.05% are defined

as firms with higher market share. To test for sensitivity of the results, partition is also done at 1% (sample mean).

(2) Life Cycle Stage

Firm's product's life cycle stage is measured as the simple average age of the firm's products, where the age of a product is measured as the number of months since the product was first released to the market. A smaller number indicates that the firm's average product is younger in the life cycle stage. Based on this number, the sample is then partitioned into three groups representing different life cycle stages: introduction, growth/mature, and stagnant. In the empirical part of the study, a firm is placed in the introduction stage if the average age of its products is less than 12 months.

Growth/mature stage is when the average product has been on the market for more than a year but less than 20 months. A firm reaches the stagnant stage, as defined in this study, when its average product has been out for more than 20 months.

(3) Level of Diversification

I adopt the modified Herfindahl Index in Holthausen *et al.* (1995) to measure *level of diversification*; however, the diversification in this study is measured across product categories as follows. Each software product in the sample is classified (by PC Data) into one of the following six categories: business, education, finance, game, personal productivity, and reference software. The total sales amount of each product category of each firm is first summed and then squared. The sum of square of each category divided by the squared total firm sales forms the firm's modified Herfindahl index. With six

categories under consideration, the modified Herfindahl index should fall between 0.167 and 1 (inclusive). A score of 1 indicates a firm's non-diversification status. The closer a score is to 0.167, the more diversified the firm is.

In the univariate analysis, a dichotomous measure is used and diversified firms (score <1) take $D=1$ and non-diversified group (score=1) takes $D=0$. In the joint analyses, for both the full model and the reduced factor model, I will use the reciprocal of the modified Herfindahl Index as input, so that all variables used as input to the factor analysis have the same (positive) relationship with regard to the market valuation of R&D, making the factor coefficient easier to interpret.

(4) Firm Size

Firm Size is the natural log of the market value of the common equity at the beginning of the year.

5.2.4 Definition of "Loss"

In this dissertation, a firm is put in a "loss" group if the earnings per share *after* deducting R&D expenses and including extraordinary items is negative. When a negative earnings per share *before* deducting R&D expenses and including extraordinary items is used as a definition for loss, the loss group often consists of fewer than 20 observations, which results in low power tests; therefore, it is not used.

6. Sample Selection and Summary Statistics

6.1 Sample Selection

I began the sample selection process from the firms listed in the computer software industry in “Yahoo! Finance” as of February 20, 1998.¹⁸ A firm in the final sample must satisfy at least the following two selection criteria: (1) SIC code is 7372 (prepackaged computer software industry), (2) its relevant data for fiscal years 1993 to 1998 must be available in the 1998 COMPUSTAT file and the 1998 CRSP daily and monthly files.

For tests that require product market information, an additional requirement is that the data about a firm’s monthly sales of each retail software product for the years 1994 to 1997 must be available from PC Data Retail Sales Report. Table 2 presents the sample selection process for this sample. This final sample consists of 44 software developers (see Appendix B for the companies’ names and their dates of incorporation) and 155 firm-year observations for the years between 1994 and 1997.

For tests that require number of technical employees as an input, the sample is not limited to the firms listed in the “Yahoo! Finance”. However, an additional requirement (beyond (1) and (2)) is that the firm must disclose number of technical employees on its 10-K report for years between 1994 and 1998. Final sample size for these tests consists of 166 (for returns model) and 196 (for price model) firm-year observations.

For the tests that require the amount of capital expenditure as an input, I use all data that satisfy selection criteria (1) and (2). As a result, 260 firm-year observations are included in the final sample for these analyses.

¹⁸ “Yahoo! Finance” is a division of Yahoo that provides financial news, stock quotes, and other financial services to viewers on the Internet.

6.2 *Descriptive Statistics*

The summary statistics of the 44 software firms used in testing Hypothesis on market competition, product life cycle, product diversification, and product innovation are provided in Table 3. Two sample statistics reveal the importance of R&D in the prepackaged computer software industry: (1) on average, three out of every ten employees in these companies worked in the software development division, and (2) the average firm in the sample spends 28% of its net sales on R&D (R&D intensity). The R&D intensity ranges from less than 1% to more than 300%. The average firm increases annual R&D spending by 23.6 million dollars during the sample period. The annual operating income of the sample firms ranged from a loss of \$64 million to a gain of \$7.468 billion. Market capitalization of the firms ranged from \$6.588 million to \$273.837 billion with a median at \$309 million. Except for Computer Associates, which was traded on the New York Stock Exchange, all other firms were traded on the National Association of Securities Dealers Automated Quotation System (NASDAQ) during the sample period.

The sample statistics for the market structure variables are presented in Panel A of Table 4. Evidence of dissimilar market shares and market domination is clearly present. Between 1994 and 1997, the aggregate market share of the sample firms ranges from less than 0.001% to 22% with the mean at 1.33% and a median at 0.15%. Only one firm has aggregated market share of more than 10%. As expected, Microsoft is the dominant software developer with market share (22% in 1994) that dwarfs the other players in the retail market for all four years. However, the weighted average market share, ranging

from less than 0.001% to 82.48%, tells a slightly different story. With the percentage of sales from each product category being the weight, Intuit has the largest (82.48% in 1997) presence in the finance software category, giving it the highest weighted average market share. Only 4 firms have weighted average market share at above 10% level.

The modified Herfindahl index measures the degree of diversification of a firm across different product categories. As discussed in Section V in this study, the index should fall between 0.167 and 1 (inclusive). As shown in Panel A of Table 4, the median of 1 suggests that more than 50% of the sample firms only produce products in one product category. The mean of 0.89 implies that most firms are not very well diversified into the six product categories defined by PC Data.

Statistics on the software products' age and percentage of new products on the market reveal the speed of product innovation in the computer software sector. The average firm's products on the market have an average age around 16 months old. At average age of 1-month old, the minimum indicates that either some new company just roll out new products or some firm just entered the retail market; no one is selling products that average more than 3 years old. The average firm has equal number of new products and old products on the market (50%) with more than 20 firm-year observations having 100% new products on the market.

The Spearman correlations of the product market structure variables are reported in Panel B of Table 4. Market share, product age, product diversification, and product innovation measure are correlated with one another at 5% significance level or better.¹⁹ Firm size is correlated with market share at 1% level. The evidence of high correlation

¹⁹ Except for the correlation between product innovation and product diversification, which is correlated at 10% significance level.

among the variables provides justification for employing reduced models for the joint analysis.

7. Empirical Findings

Independent (Univariate) Analyses

7.1 *Is market valuation of software development cost a positive function of a firm's productivity?*

Table 5 presents the results of the effect of R&D productivity on the heterogeneity of cross-sectional market valuation of R&D spending. Hypothesis 1 predicts that R&D spending is more valuable for firms exhibit higher productivity. Panel A presents the results using the frequency of product innovation as a productivity measure. A company is placed in the “more productive” group if its current products on the market consist of more than 50% new products and upgrades. The other companies are categorized as “less productive.” 111 observations are used in the returns regression estimation; 53 are “more productive,” 58 are “less productive.” The empirical result contrasting these two groups is provided in Panel A of Table 5. The top row reports the baseline regression results without the productivity dummy. The bottom row presents the regression with the productivity dummy. It shows that at 5% significance level, R&D is valued 4.5% more in annual stock returns for more productive firms than for other firms. The pivotal point, 50%, is the sample median, but the result still holds at 5% significance level when the top one third is compared to the bottom one third (in terms of the productivity measure).²⁰

Table 5 Panel B reports the results using percentage of technical employees as the expected R&D productivity measure. 196 observations have no missing value for the variables and are divided approximately at the sample median. Firms that are in the top

²⁰ Although 50% is the sample median, the two groups are not of the exact same size because more than six observations have the same measure of 50%, making one group slightly larger in size than the other group.

half (96 observations) in terms of percentage of people working in the development divisions is compared to the bottom half (100 observations). The interaction term of change in R&D and the productivity dummy is 4.45 at 5% significance level, suggesting that R&D is valued 4.45% more in annual returns for firms having higher percentage of people working in the R&D divisions than for other firms. The dummy variable is not statistically significant, suggesting that having higher percentage of people working in the development divisions doesn't add firm value, but it influences how R&D increment and earnings surprises are valued by the investors. I also perform analysis by dividing groups at the mean. The results are not qualitatively different. Compare to the baseline regression without the dummy, percentage of technical employees adds explanatory power to the returns regression.

Panel C of Table 5 presents the results using change in hiring technical employees as the expected R&D productivity measure. The interaction term is not statistically significant and the dummy as an independent variable is negative at 10% significance level, implying that hiring more technical employees reduces firm value and is not relevant in the market valuation of R&D. Suspecting that percentage change in hiring of technical employees may produce the hypothesized results, I also conduct analysis using percentage *change* as a measure. However, the results remain the same. These results are inconsistent with the implication of the previous empirical evidence (Table 5, Panel B) on percentage of technical employees. A possible reason for such results is a lack of control for merger activities. A good number of firms have on-going merger activities throughout the sample period. It is possible that an increase in number of technical employees is actually a reduction in technical work force for the merged company.

Unfortunately, merger and acquisition has a whole different set of literature and is beyond the scope of the study; therefore, I will leave it for future research.

Results using capital expenditure as the productivity measure are reported in Panel D of Table 5, firms that increase capital expenditure are compared with those that decrease capital expenditure. Of the 260 observations used in the returns regression analysis, 147 observations increased capital investment, and 113 decreased capital investment in the sample period. The coefficient on the dummy variable is 0.169 at 10% significance level, indicating that incremental capital investment adds firm value, consistent with Kerstein and Kim (1995). However, the interaction term of the dummy and change in R&D does not have the expected sign and is not statistically significant at 10% level, implying that change in capital investment is not relevant to the market valuation of R&D spending in the software industry. The result is not surprising - considering that output of software can be inexpensively expanded almost instantly and that improving product quality does not add too much cost - capital investment is not a critical component in succeeding in the software market.

Again, the coefficients of change in R&D in the above regressions are either not significant or negative. Incremental R&D spending is more valuable only when a firm demonstrates its efficiency in churning out new products or when the firm has higher percentage of technical employees. The coefficient of R&D level ranges from 3.2 to 4.9 and remains statistically significant in baseline regressions and regressions with the dummies, displaying the importance of R&D in the software industry.

Results of separate returns regressions for loss group and for profitable group for the above regressions are not presented here. Regressions for these two groups do not

produce different (in terms of significance of the parameter) results concerning earnings level or earnings change.

All four panels show that including the R&D productivity dummy adds the explanatory power beyond the baseline return regressions.

In price regressions, variable ADV (marketing expenses) is dropped from the model for two reasons. First, the advertising expenses provided by COMPUSTAT are different from the marketing expenses found in the annual reports. Second, information on this item for many companies is missing from COMPUSTAT. If ADV were kept in the model, number of observations used in the analyses would be significantly reduced. The results of price regressions are provided in Table 6. Except for the parameter estimate for DEBT in Panel A, the coefficients of total assets and liabilities across all panels have the expected sign and the magnitude at around 1 for assets and -1 for debt. The interaction term either has a wrong sign or is not statistically significant in any Panel. Parameter estimates for R&D are insignificant except when the frequency of product introduction is used as the productivity measure. The insignificance of R&D spending may be due to the general econometric problems with price regressions. It is found that price regression suffers from correlated omitted variable problem, which, if not properly controlled for, will lead to incorrect inference (Christie 1987, Ahmed and Takeda 1995). There are also other problems with ordinary least square regressions of price models. For example, price models are non-stationary and heteroskedastic, both of which violates the assumptions of ordinary least square regression. Another evidence the price regression is not well-specified is that most of the adjusted R-squares are also much smaller for price regressions (Table 6) than for returns regressions (Table 5).

In sum, the regression analyses support Hypothesis 1. The cross-sectional variation in the market valuation of R&D can be explained by R&D productivity - when properly measured.

7.2 What market structure variables explain the cross-sectional variation in market valuation of software development cost?

Because the market structure information used in this study is compiled based on software developers' performance in the retail market, the regression results reported here are weighted by percentage of sales derived from retail sales.

Regarding market competition, Hypothesis 2 predicts that market valuation of R&D is positively related to market share. Table 7 shows the results on the market competition hypothesis. Again, the baseline regression with the market share dummy is reported first, followed by the regression including the dummy. 110 observations having valid market share data and no missing values for other variables are used in the regression analysis. Firms with aggregate market share of less than 0.05% (53 observations) are compared to firms with aggregate market share of more than 0.05% (57 observations). 0.05% is the sample median.²¹ I divide the sample approximately at the median, so that two groups are similar in size. Splitting the sample at its mean (1%) produces similar results. The coefficient on the interaction term is 17.22 at 5% significance level, which suggests that R&D spending is valued approximately 17% more in annual return for firms which have larger market share. The coefficient on the market share dummy is not significant, implying that higher market share itself does not add firm

²¹ Recall that in Panel A of Table 4, the sample median of aggregated market share is 0.15%, based on 145 observations. The reason for the difference in the sample medians is that the 0.05% is based on the actual observations used in this regression analysis.

value. Interestingly, the coefficient on the change in R&D spending is not significant, suggesting that incremental R&D spending does not add firm value. Increase in R&D is viewed as beneficial to a firm only if the firm has larger market share. Although the regression with dummy does not outperform the baseline regression in terms of improved adjusted R-square, it tells a very different story regarding how an increase in R&D spending is priced in the market. Without factoring in the market competition environment, a study may mistakenly conclude that incremental R&D is always priced positively by the market, but in fact, it is not so, as the result has shown here. The analysis using weighted average market share, although not reported, produces similar results.

Table 8 reports the returns regression results of the Life Cycle Hypothesis. This hypothesis predicts that the market valuation of R&D expenditure is a function of the age of the software products and that the function is a bell-shaped curve that peaks at the middle part of its life cycle stage. As discussed in Section 5.2.2, the product life cycle stages are defined as introduction stage, growth/mature stage, and stagnant stage. 114 observations have valid product life measures and no missing values for the other variables; 32 are classified in the introduction stage; 56 in the growth/mature stage; 26 in the stagnant stage. The purpose of the regression is to examine the extent to which being in the middle part of product life cycle stage (relative to the other stages) adds to the market value of software development cost. The empirical result shows that software development cost adds 10% *more* in annual return for firms whose average product reaches the growth/mature stage (between 12 months and 20 months) than for firms whose average product is still in the introduction stage (less than 12 months) or has

already past the mature stage (more than 20 months). Again, the coefficient on change in R&D spending is not positive, suggesting that increase in R&D spending is not valued as assets unless the average product is in the growth/mature stage. The baseline regression without the product life dummy is provided as a reference again. In this case, the regression with the product life dummy adds explanatory power.

Table 9 reports the results for the diversification hypothesis using the returns regression. The hypothesis predicts that R&D spending is more valuable for a diversified firm than a non-diversified firm. 110 observations have no missing value for any variables and are used in the regression estimate; 59 firms are non-diversified firms, and 51 firms have some level of diversification. The coefficient on the interaction term of change in R&D and diversification measure is 12.244, significant at 10% level, which suggests that R&D expenditure contributes 12% more to annual stock returns for diversified firms than for non-diversified companies. The coefficient on R&D increment is not significant, implying that increase in R&D spending only adds firm value for diversified firms, not for non-diversified firms.

Notice that the coefficient for SIZE in all the returns regressions is statistically significantly positive, indicating that in the computer software industry, firm size is positively related to firm value. Suspecting that Microsoft Corporation alone causes the positive coefficient on firm size, I did the outlier tests including R-student, Hat, and Dfbetas. Microsoft Corporation is not identified by any test as an influential observation in any year.²²

²² One firm-year is identified as an influential observation in some regression models and is consequently dropped from those analyses; however, its firm size is not identified as the influential factor.

Notice also that when the market structure dummy is included in the regression, both earnings level and earnings change do not show any statistical significance in Table 7, 8, or 9. Separate regressions for the loss group and the profit group (results not provided here) do not generate different (in terms of the significance of the parameters) results in regard to earnings. Only when the observations are equally weighted (i.e. when regressions are not weighted by the percentage of retail sales), does the coefficient on earnings change become statistically significantly positive at below 3% levels for all regressions. This result implies that, in terms of market valuation, earnings surprises are not as important as the market competition environment (i.e., market share, product's shelf life, and diversification) for those firms that derive their sales largely from retail sales. For firms that depend less on retail sales, earnings changes are still value-relevant.

The results of price regressions are provided in Table 10. Signs on the interaction terms are not significant in any Panel. Parameter estimates for R&D Capital are insignificant except for life cycle hypothesis test. All price regressions have relatively small (less than 10%) adjusted R-square. As discussed in Section 7.1, the insignificance of the parameters and low adjusted R-square could result from misspecification and econometric problems with price regression models in general.

Other than the problems with price regressions, results of the univariate analyses are consistent with the predictions of the four hypotheses. The results show that increase in R&D is more valuable for firms that are more productive, firms with larger market share, diversified companies, and whose average product age lies between 12 and 20 months old. Comparing across Tables 5, 7, 8, and 9, R&D level is statistically significantly positive in all the returns regression and its coefficient ranges from 3.7 to 6,

suggesting that R&D is viewed as critical in the computer software industry. However, incremental R&D spending alone does not add firm value unless the firm has the above mentioned characteristics.

Joint Analyses

7.3 Do the factors combined together explain the cross-sectional variation in the market valuation of R&D spending?

For this part of the analyses, I first conduct a regression analysis on the full model using equations (5) and (6), where all the observed variables are used as independent variables. The results of full model returns regression are reported in Table 11. Only one coefficient (earnings change) shows statistical significance. The results are as expected. As discussed in Section 4.5.2, given the high correlation among the hypothesized factors, it is difficult to make precise estimate of the parameters using the full model. The results of full model price regression are provided in Table 12. The only variable showing statistical significance is total assets, whose coefficient is 1.3, similar to the other price regression results reported in this dissertation. The adjusted R-squares for the price regressions are still low - less than 10% variations are being explained.

I then conduct factor analyses to extract the common factors from among the observed variables, so that they can be used to run the reduced models. For the returns regression, one common factor is extracted.²³ The extracted common factor, denoted as F in Table 13, loads high on all variables, with positive loadings on product life cycle,

²³ I used three statistical techniques in identifying the underlying structure(s): principal component analysis, common factor analysis with orthogonal rotations, and common factor analysis with oblique rotations. All three techniques suggest that one common factor be extracted.

product diversification, and market share, and negative loading on the innovation efficiency measure.²⁴ For the price regression, two common factors are extracted: one factor, denoted as MKTSTR in Table 14, has large and positive loadings on market share and firm size; while the other factor, denoted as PDT in Table 14, has high (in terms of absolute value) loadings on product diversification (positive), product life (positive), and product innovation (negative).²⁵ As sensitivity tests, I measure market share using both weighted average market share and aggregated market share. I also measure product diversification using modified Herfindahl Index, reciprocal of the modified Herfindahl Index and a dichotomous that assigns 1 to diversified firms and 0 to other firms. The results of the factor analyses are not sensitive to how the variables are measured.²⁶

The results of the reduced returns regression using factor scores obtained through factor analysis with oblique rotation are presented in Table 13. The regressions are still weighted; firms that derive more than 30% of the sales from the retail market are given 100% weight; firms that derive less than 10% of the sales from the retail market are weighed 50%; firms in between are weighed at 75%. The weights are chosen arbitrarily. I assign weights at least 50% to all the observations, so that most information is retained in the regression.²⁷ The first row reports the baseline regression results without the factors. The second row presents the results that include the factor in the interaction terms. The bottom row provides results when the factor is added as an independent

²⁴ Factor loadings are the correlation of the variables with a factor.

²⁵ Again, all three techniques make the same suggestion with only a slight difference in the scoring coefficients.

²⁶ Except that when modified Herfindahl Index is used, the common factor has negative loading on this measure, as expected.

²⁷ When an observation is assigned a weight of 0, the observation is omitted from the regression analysis.

variable in addition to the interaction terms. 81 observations have no missing values for any of the variables and are used in the analysis. As the extracted factor has three positive loadings and one negative loading on the observed variables, I do not have a sign prediction for the interaction term. The interaction term is statistically significant at 10% level in row 2 and row 3, suggesting that the underlying structure of the four hypothesized variables is used in determining the cross-sectional variation in market valuation of R&D. Because the regression uses factor score as a proxy for the observed variable, I make no attempt to interpret the magnitude of this coefficient. Except for the baseline regression, both R&D level and change are statistically significant at 6% level. The coefficient on R&D level maintains at around 3, similar to the results of the other returns regressions reported in this dissertation. The coefficient on the common factor as an independent variable is not statistically significant, indicating that the factor by itself has no effect on firm value; rather, it influences how R&D increment is valued by the investors. Looking across the three rows in Table 13, adjusted R-square is around 13 points (40.2% - 26.5% and 39.4% - 26.5%) higher when the common factor is included in the model, suggesting that adding the common factor in the regression adds substantial explanatory power.

Some additional tests are done to check for the robustness of the results. Here are the findings. The results are not sensitive to factor scores generated through different factor analysis techniques. Regression analyses using different weighting scales based on retail sales percentages produce similar results with one exception: as less weight is given to firms that have smaller presence in the retail market, earnings change variable becomes insignificant. Again, I interpret this result as implying that, at least from the market

valuation perspective, earnings changes are not as important as the underlying retail market structure for firms focusing highly on the retail market, but earnings changes are still value-relevant for other firms.

Table 14 provides the results of the reduced price regression. 80 observations are used in the analysis. Although the interaction term of R&D with the market structure common factor has the expected sign at 1% significance level, R&D has a negative sign and DEBT is not significant. When the two common factors, PDT and MKTSTR, are included as independent variable, the interaction terms and the factors by themselves all show moderate statistical significance; however, the coefficient on R&D still has a negative sign and DEBT is still not statistically significant. I suspect that the insignificance in DEBT and the unexpected sign on R&D are partly due to the general econometric problems with price models, as discussed in Section 7.1.

Overall, the joint analyses support the hypothesis that the market valuation of R&D is not cross-sectionally constant and that market share, product diversification, product life cycle, and the frequency of product innovation together are used in determining the heterogeneity in cross-sectional valuation of R&D.

8. Summary and Conclusions

8.1. Summary and Conclusions

The dissertation studies the cross-sectional variability in the market valuation of R&D spending in the prepackaged software industry. Previous research often assumes that R&D spending by different firms is valued homogeneously by the stock market. I argue and empirically demonstrate that this assumption is invalid. Based on economic literature on technological innovation, hypotheses are developed regarding the factors that help determine this cross-sectional heterogeneity.

I test the hypotheses in regression models using accounting data, stock price, and an extensive database that contains retail sales information at a product level of the software firms between 1994 and 1997. Empirical evidence, consistent with my hypotheses, suggests that R&D is more valuable for firms with more frequent introduction of product innovation, higher percentage of technical employees, larger market share, and firms that have diversified into developing products in different categories within the software industry. Test results are not sensitive to how the variables are measured.

8.2. Contributions of this dissertation

The dissertation has potential contributions in many areas, as discussed below. In a letter to the American Accounting Association dated August 1999, the Chief Accountant of SEC explicitly called for accounting research that can provide insight about the “information regarding intangible assets investors believe is useful and necessary in making investment decisions,” and about “financial data investors and

analysts use that is not currently provided in filings with the SEC.” First, current accounting standards are perceived as failing to capture the value of assets arising from intellectual properties. For standard setters to adequately consider alternative to expensing R&D, an examination of value related factors is critical. The dissertation directly responds to this need by studying factors (market share, innovation efficiency, life cycle stage of products, and product diversification) that would provide guidance as to when capitalization might be appropriate. In addition, the value relevance of factors not yet required for disclosure in SEC filings (product line market share and innovation efficiency) is assessed here.

Statement of Financial Accounting Standards No. 121 ‘Accounting for Impairments of Long-Lived Assets’ (FASB, 1995) suggests that companies review events and changes in circumstances to determine whether impairment has occurred. The factors studied in this dissertation can be used in the impairment tests on capitalized R&D to determine whether to check for impairment. For example, a significant decrease in market share of a software product may indicate possible impairment of its capitalized R&D and a recoverability test should follow.

The factors studied in this dissertation can also guide auditors in the auditing of capitalized R&D. For instance, an increase in the amount of capitalized R&D coupled with a sudden drop in a firm’s R&D productivity should warrant some further analyses or examination regarding the capitalized R&D account.

Finally, like the contribution of the earnings response coefficient study to the returns-earnings research (e.g. Collins and Kothari 1989, Collins *et al.* 1994, and Easton and Zmijewski 1989), the factors studied in this dissertation should be considered in the

cross-sectional model in future intangibles research, so that valid inference about the market valuation of intangible assets can be made.

8.3. Limitations of this study

The dissertation examines the value-relevance of R&D accounting in the prepackaged software industry. Factors that help determine the market valuation of R&D in this industry can be different from other industries. Furthermore, the empirical tests use only product sales information from the retail sector. Sales to corporate, other institutions, or through other distribution channels are not included. Although the regressions have used percentage of retail sales as a control, the natures of the sales through the other channels are still different. Caution should be exercised when drawing inference from this study.

8.4. Future research

A number of extensions of this dissertation may prove to be fruitful. For example, researchers can investigate whether the same set of factors are used by stock analysts in forming their estimates about the R&D performance of computer software companies. Second, computer software industry has observed very vigorous merger and acquisition activities in recent years. Researchers can also examine whether these factors or other R&D performance measures are used in scouting targets. Third, some of the measures used in this study to group the observations are relatively crude, just to demonstrate the variability in the market valuation of R&D spending by different companies. To further examine the relationship between R&D valuation and each

variable, the sample can be divided into more groups or to use more refined measures to see, for example, whether all types of diversification are priced positively. Finally, similar studies on other high-tech industries should be done to further our understanding of the market valuation of R&D expenditure and other intangible assets.

Table 1: Summary Statistics of the Prepackaged Computer Software Industry

year	Number of firms	Average Assets (\$MM)	Average Market Value (\$MM)
Prior to 1979	1		
1979	24	40.83	80.84
1980	29	52.96	159.49
1981	37	63.85	147.66
1982	63	52.07	178.23
1983	84	58.51	193.17
1984	94	63.34	124.75
1985	116	58.18	105.59
1986	128	64.94	129.31
1987	127	80.91	156.48
1988	125	96.25	182.35
1989	129	106.64	200.94
1990	140	104.43	240.62
1991	165	109.30	385.10
1992	202	102.29	475.03
1993	229	107.31	480.18
1994	307	106.51	531.90
1995	416	106.78	694.79
1996	447	127.14	651.32
1997	445	156.78	943.43
1998	331	265.70	1586.65

Table 2: Sample Selection Process

	<u>Number of firms</u>
Firms appearing in the Yahoo Finance computer software industry on 2/20/1998	314
minus: foreign firms (ADRs)	-10
firms with no "permno" on CRSP	-157
SIC not 7372 ¹ on CRSP/Compustat	-25
10-K not available on EDGAR	-5
monthly sales not available in PCDATA Sales Report	<u>-73</u>
The Final Sample that Requires Product Market Data	<u>44</u>

¹ SIC 7372 represents the prepackaged computer software industry.

Table 3: Summary Statistics of the 44 computer software firms used in testing most Hypotheses*
 For the Years 1993 –1998
 (in thousands of dollars except percentages)

	Number of Observations	Mean	Median	Std. Dev.	Minimum	Maximum
Total Assets	206	732,622	86,790	2,332,000	601	22,357,000
Market Value of Common Equity	217	4,757,098	309,399	23,038,895	6,588	273,836,744
Operating Income	204	199,854	10,749	798,171	-64,467	7,468,000
R&D Spending	197	103,642	20,033	295,527	342	2,502,000
Change in R&D Spending	173	23,608	4,983	135,921	-672,680	1,085,000
R&D Intensity (=R&D Spending / Sales)	197	28.41%	19.09%	35.50%	0.09%	302.17%
Percentage of employees working in the R&D department (1994-1998)*	84	31.62%	30.61%	13.74%	9.62%	75.68%
Annual Stock Returns	182	49.72%	16.67%	143.93%	-85.63%	1,047.6%

* Expanded samples are used when testing Hypotheses that do not require product market information.

* Percentage of technical employees based on an expanded sample of 386 observations ranges from 4% to 90.9%, with a median at 28% and averages 31%.

Table 3 (continued)

Note:

R&D spending is taken from COMPUSTAT annual tape, item #46.

Percentage of employees working in the R&D department is number of employees working in the development division divided by total number of employees. Both numbers are taken from 10-K and are voluntarily disclosed by each firm.

Operating Income is operating income before depreciation and R&D expenses, item #13 from COMPUSTAT annual tape.

Total Assets is item #6 on COMPUSTAT annual tape.

Market Value of Equity is obtained from CRSP by multiplying the total number of shares outstanding by share price three months after the fiscal year end.

Annual Stock Returns are 12-month raw returns cumulated from nine months before to three months after the fiscal year end.

Table 4 Descriptive Statistics on Variables

Panel A: Sample Statistics of Product Market Structure Variables

Sample period: 1994 –1997

Variable*	Number of Observations	Mean	Median	Std. Dev.	Minimum	Maximum
Aggregate Market Share	145	1.33%	0.15%	3.56%	<0.0001%	22.1%
Weighted Average Market Share	145	13.64%	0.39%	13.46%	<0.0001%	82.48%
Modified Herfindahl Index	145	0.891	1	0.204	0.282	1
Age of the Sample Firm's Average Product on the market since its first release (in months)	155	15.4	15.9	7.0	1	33
Ratio of New Products to Total Products on the Market	143	0.533	0.5	0.279	0	1

* Variable Definitions:

Aggregate Market Share of a firm is the firm's total sales divided by total industry sales.

Weighted Average Market Share of a firm is the sum of its market share in a product category multiplied by percentage of its revenue derived from that product category.

Modified Herfindahl Index, used as a diversification measure in this study, is the sum of square of a firm's sales in each product category divided by the square of its total sales.

Table 4 Descriptive Statistics on Variables

Panel B: Spearman Correlation of Product Market Structure Variables

(P-value in parentheses)

	Aggregate Market Share	Weighted Average Market Share	Modified Herfindahl Index	Average Product Age	Product Innovation
Weighted Average Market Share	0.988 (0.0001) N=145	1			
Modified Herfindahl Index	-0.603 (0.0001) N=145	-0.596 (0.0001) N=145	1		
Average Product Age	0.317 (0.0001) N=140	0.337 (0.0001) N=140	-0.313 (0.0001) N=140	1	
Product Innovation	-0.240 (0.018) N=96	-0.258 (0.011) N=96	0.192 (0.061) N=96	-0.552 (0.0001) N=107	1
Firm Size	0.359 (0.0001) N=135	0.339 (0.0001) N=135	-0.110 (0.202) N=135	-0.037 (0.662) N=142	-0.048 (0.592) N=129

Table 4 Panel B (continued)

Aggregate Market Share of a firm is the firm's total sales divided by total industry sales.

Weighted Average Market Share of a firm is the sum of its market share in a product category multiplied by percentage of its revenue derived from that product category.

Modified Herfindahl Index, used as a diversification measure in this study, is the sum of square of a firm's sales in each product category divided by the square of its total sales.

Product Innovation is the ratio of new products to all products on the retail market.

Firm Size is measured as the natural log of the market value of common equity.

Table 5: The Effect of R&D Productivity on the Market Valuation of R&D Spending – Returns Regression Results

Panel A: R&D Productivity Measure - Frequency of Product Innovation

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(PD_i) + \gamma_4(PD_i)(\Delta RD) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(PD_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^*$$

$PD_i = 1$ if more than 50% of products on the market are new innovations (More Productive); $n = 53$

$PD_i = 0$ if 50% or less products on the market are new innovations (Less Productive); $n = 58$

Variables	Intercept	RD	ΔRD	PD	$(\Delta RD)(PD)$	ΔE	$(\Delta E)(PD)$	E	$SIZE$	Adjusted R^2
Prediction		+			+					
Parameter Estimate (P-value)*	-1.291 (0.002)	3.268 (0.000)	2.841 (0.014)			0.448 (0.333)		2.913 (0.000)	0.071 (0.023)	47.8% (N = 111)
Parameter Estimate (P-value)*	-1.611 (0.000)	4.134 (0.000)	-0.083 (0.968)	-0.164 (0.157)	4.527 (0.029)	0.108 (0.824)	2.014 (0.061)	3.096 (0.001)	0.094 (0.004)	49.3% (N = 111)

- * R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the t th fiscal year end for firm i ;
 RD_{it} = the R&D expenditure per share for firm i in period t ;
 ΔRD_{it} = the annual change in R&D spending per share;
 E_{it} = the earnings per share before R&D for the period t for firm i ;
 ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;
 All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.
 $SIZE$ = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 5: The Effect of R&D Productivity on the Market Valuation of R&D Spending – Returns Regression Results

Panel B: R&D Productivity Measure – Percentage of Technical Employees

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(PD_i) + \gamma_4(PD_i)(\Delta RD) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(PD_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^{\diamond}$$

$PD_i = 1$ if more than 28% (sample median) of employees work in the Development Division (More Productive); $n = 96$

$PD_i = 0$ if less than 28% of employees work in the Development Division (Less Productive); $n = 100$

Variables	Intercept	RD	ΔRD	PD	$(\Delta RD)(PD)$	ΔE	$(\Delta E)(PD)$	E	$SIZE$	Adjusted R^2
Prediction		+			+					
Parameter Estimate (P-value)*	-3.198 (0.000)	4.476 (0.000)	-0.686 (0.567)			-0.025 (0.021)		0.678 (0.075)	0.243 (0.000)	17.9% (N = 196)
Parameter Estimate (P-value)*	-2.933 (0.000)	4.291 (0.000)	-2.906 (0.087)	-0.021 (0.881)	4.45 (0.030)	-0.042 (0.001)	0.054 (0.013)	0.775 (0.055)	0.223 (0.000)	20.5% (N = 196)

$\diamond R_{it}$ = the annual common stock return per share cumulated beginning nine months before to three months after the t th fiscal year end for firm i ;
 RD_{it} = the R&D expenditure per share for firm i in period t ;
 ΔRD_{it} = the annual change in R&D spending per share;
 E_{it} = the earnings per share before R&D for the period t for firm i ;
 ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;
 All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.
 $SIZE$ = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 5: The Effect of R&D Productivity on the Market Valuation of R&D Spending – Returns Regression Results

Panel C: R&D Productivity Measure –Change in Hiring of Technical Employees

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(PD_i) + \gamma_4(PD_i)(\Delta RD) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(PD_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^*$$

$PD_i = 1$ if the firm hires more technical employees (More Productive); $n = 67$
 $PD_i = 0$ if the firm reduces number of technical employees (Less Productive); $n = 99$

Variables	Intercept	<i>RD</i>	ΔRD	<i>PD</i>	$(\Delta RD)(PD)$	ΔE	$(\Delta E)(PD)$	<i>E</i>	<i>SIZE</i>	Adjusted R^2
Prediction		+			+					
Parameter Estimate (P-value)*	-3.075 (0.000)	3.930 (0.000)	-1.422 (0.299)			-0.028 (0.017)		0.595 (0.137)	0.238 (0.000)	15.3% (N = 166)
Parameter Estimate (P-value)*	-2.897 (0.000)	3.732 (0.001)	-2.129 (0.221)	-0.283 (0.076)	1.899 (0.481)	-0.056 (0.001)	0.054 (0.012)	1.004 (0.032)	0.230 (0.000)	18.4% (N = 166)

* R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the t th fiscal year end for firm i ;
 RD_{it} = the R&D expenditure per share for firm i in period t ;
 ΔRD_{it} = the annual change in R&D spending per share;
 E_{it} = the earnings per share before R&D for the period t for firm i ;
 ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;
 All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.
 $SIZE$ = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 5: The Effect of R&D Productivity on the Market Valuation of R&D Spending – Returns Regression Results

Panel D: R&D Productivity Measure –Change in Capital Expenditure

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(PD_i) + \gamma_4(PD_i)(\Delta RD) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(PD_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^*$$

$PD_i = 1$ if the firm increases capital expenditure (More Productive); $n = 147$

$PD_i = 0$ if the firm decreases capital expenditure (Less Productive); $n = 113$

Variables	Intercept	<i>RD</i>	ΔRD	<i>PD</i>	$(\Delta RD)(PD)$	ΔE	$(\Delta E)(PD)$	<i>E</i>	<i>SIZE</i>	Adjusted R^2
Prediction		+		+	+					
Parameter Estimate (P-value)*	-3.143 (0.000)	4.333 (0.000)	-0.526 (0.584)			-0.021 (0.033)		0.578 (0.091)	0.238 (0.000)	18.5% (N = 260)
Parameter Estimate (P-value)*	-3.271 (0.000)	4.978 (0.000)	0.330 (0.785)	0.169 (0.095)	-2.798 (0.106)	-0.003 (0.823)	-0.032 (0.075)	0.347 (0.342)	0.239 (0.000)	19.3% (N = 260)

- * R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the t th fiscal year end for firm i ;
 RD_{it} = the R&D expenditure per share for firm i in period t ;
 ΔRD_{it} = the annual change in R&D spending per share;
 E_{it} = the earnings per share before R&D for the period t for firm i ;
 ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;
 All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.
 $SIZE$ = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-value reported is for one-tailed test if there is a predictions, two-tailed test if no prediction is made.

Table 6: The Effect of R&D Productivity on the Market Valuation of R&D Spending – Price Regression Results

$$V_{it} = \lambda_0 + \lambda_1(TA_{it}) + \lambda_2(RDC_{it}) + \lambda_3(PD_{it}) + \lambda_4(PD_{it})(RDC_{it}) + \lambda_5(DEBT_{it})^\#$$

Variables	Intercept	TA	RDC	D	(D)(RDC)	DEBT	Adjusted R ²
Prediction		+	+		+	-	
Panel A: R&D Productivity Measure - Frequency of Product Innovation <i>PD_i</i> = 1 if more than 50% of products on the market are new innovations (More Productive); n = 54 <i>PD_i</i> = 0 otherwise (Less Productive); n = 60							
Parameter Estimate (P-value)*	0.720 (0.001)	1.503 (0.006)	2.183 (0.086)			-1.251 (0.136)	10.3% (N=114)
Parameter Estimate (P-value)*	0.443 (0.011)	1.204 (0.004)	3.418 (0.036)	0.463 (0.055)	-3.780 (0.037)	-0.876 (0.131)	22.7% (N = 114)
Panel B: R&D Productivity Measure – Percentage of Technical Employees <i>PD_i</i> = 1 if more than 28% (sample median) of employees work in the Development Division (More Productive); n = 98 <i>PD_i</i> = 0 otherwise (Less Productive); n = 101							
Parameter Estimate (P-value)*	0.981 (0.000)	1.016 (0.003)	1.213 (0.170)			-1.299 (0.021)	5.7% (N=199)
Parameter Estimate (P-value)*	0.956 (0.000)	1.015 (0.003)	1.488 (0.225)	0.053 (0.826)	-0.418 (0.420)	-1.323 (0.025)	4.8% (N=199)

Table 6 (continued)

Panel C: R&D Productivity Measure –Change in Hiring of Technical Employees							
<i>PD_i</i> = 1 if the firm hires more technical employees (More Productive); n = 67 <i>PD_i</i> = 0 if the firm reduces number of technical employees (Less Productive); n = 99							
Parameter Estimate (P-value)*	0.942 (0.000)	1.286 (0.001)	-0.825 (0.300)			-1.018 (0.069)	6.0% (N=166)
Parameter Estimate (P-value)*	1.050 (0.000)	1.279 (0.001)	-0.887 (0.309)	-0.243 (0.373)	0.277 (0.452)	-1.073 (0.060)	5.8% (N=166)
Panel D: R&D Productivity Measure –Change in Capital Expenditure							
<i>PD_i</i> = 1 if the firm increases capital expenditure (More Productive); n = 148 <i>PD_i</i> = 0 if the firm decreases capital expenditure (Less Productive); n = 113							
Parameter Estimate (P-value)*	0.935 (0.000)	1.045 (0.000)	0.495 (0.318)			-1.013 (0.024)	6.8% (N=261)
Parameter Estimate (P-value)*	0.743 (0.000)	1.006 (0.000)	1.204 (0.170)	0.283 (0.083)	-0.308 (0.432)	-1.023 (0.024)	7.4% (N=261)

* Variable Definitions:

V_{it} the common share price three months after firm *i*'s fiscal year (*t*) end;

TA_{it} the book value of tangible assets of firm *i* at the end of period *t*;

RDC_{it} the R&D capital, measured as R&D spending per share, for firm *i* in period *t*;

$DEBT_{it}$ the book value of the debt per share of firm *i* at the end of period *t*;

All the above variables are scaled by market value per share at the beginning of the year.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 7: The Effect of Market Competition on the Market Valuation of R&D Spending -the Results of Returns Regression

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(D_i) + \gamma_4(D_i)(\Delta RD_i) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(D_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^{\diamond}$$

$D_i = 1$ for firms with aggregated market share >0.05% (Larger Market Share); $n = 57$

$D_i = 0$ for firms with aggregated market share <0.05% (Smaller Market Share); $n = 53$

Variable	Intercept	<i>RD</i>	ΔRD	<i>D</i>	$(\Delta RD)(D)$	ΔE	$(\Delta E)(D)$	<i>E</i>	<i>SIZE</i>	Adjusted R ²
Prediction		+			+					
Parameter Estimate (P-value)*	-2.605 (0.042)	4.716 (0.031)	10.228 (0.004)			3.560 (0.008)		-0.249 (0.909)	0.197 (0.036)	25.4% (N = 110)
Parameter Estimate (P-value)*	-2.538 (0.013)	4.767 (0.031)	-4.812 (0.625)	-0.096 (0.899)	17.223 (0.05)	5.456 (0.527)	-1.515 (0.860)	-0.819 (0.713)	0.198 (0.036)	25.2% (N = 110)

♦ Variable Definitions:

R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm *i*;

RD_{it} = the R&D expenditure per share for firm *i* in period *t*;

ΔRD_{it} = the annual change in R&D spending per share;

E_{it} = the earnings per share before R&D for the period *t* for firm *i*;

ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;

All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.

SIZE = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 8: The Effect of Product Life Cycle Stage on the Market Valuation of R&D Spending – Returns Regression Results

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(D_i) + \gamma_4(D_i)(\Delta RD_i) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(D_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i$$

$D_i = 1$ for firms whose average product is in the market for ≥ 12 months but < 20 months (growth/mature stage); $n=56$
 $D_i = 0$ otherwise (introduction stage or the stagnant stage); $n=58$

Variable	Intercept	<i>RD</i>	ΔRD	<i>D</i>	$(\Delta RD)(D)$	ΔE	$(\Delta E)(D)$	<i>E</i>	<i>SIZE</i>	Adjusted R ²
Prediction		+			+					
Parameter Estimate (P-value)*	-1.938 (0.048)	3.708 (0.018)	0.449 (0.825)			4.568 (0.002)		1.422 (0.458)	0.139 (0.047)	22.5% (N = 114)
Parameter Estimate (P-value)*	-3.327 (0.062)	6.023 (0.015)	3.973 (0.509)	-0.214 (0.574)	10.133 (0.089)	2.634 (0.399)	1.552 (0.590)	-0.646 (0.772)	0.254 (0.017)	25.3% (N = 114)

• Variable Definitions:

R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm *i*;

RD_{it} = the R&D expenditure per share for firm *i* in period *t*;

ΔRD_{it} = the annual change in R&D spending per share;

E_{it} = the earnings per share before R&D for the period *t* for firm *i*;

ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;

All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.

SIZE = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 9: The Effect of Product Diversification on the Market Valuation of R&D Spending – the Results of Returns Regression

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(D_i) + \gamma_4(D_i)(\Delta RD_i) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(D_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^{\bullet}$$

$D_i = 1$ for firms whose Herfindahl Index <1 (Diversified firms); $n = 51$
 $D_i = 0$ for firms whose Herfindahl Index =1 (Non-diversified firms); $n = 59$

Variable	Intercept	<i>RD</i>	ΔRD	<i>D</i>	$(\Delta RD)(D)$	ΔE	$(\Delta E)(D)$	<i>E</i>	<i>SIZE</i>	Adjusted R ²
Prediction		+			+					
Parameter Estimate (P-value)*	-2.605 (0.042)	4.716 (0.063)	10.228 (0.004)			3.560 (0.008)		-0.249 (0.909)	0.197 (0.036)	25.4% (N = 110)
Parameter Estimate (P-value)*	-3.150 (0.018)	4.133 (0.058)	-0.005 (0.999)	0.496 (0.301)	12.244 (0.071)	0.614 (0.897)	3.320 (0.488)	-0.870 (0.696)	0.211 (0.024)	26.0% (N = 110)

• Variable Definitions:

R_{it} = the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm i;

RD_{it} = the R&D expenditure per share for firm i in period t;

ΔRD_{it} = the annual change in R&D spending per share;

E_{it} = the earnings per share before R&D for the period t for firm i;

ΔE_{it} = the annual change in earnings per share before R&D but including extraordinary items;

All the above variables except for R_{it} are scaled by market value per share at the beginning of the year.

SIZE = the size of the firm, measured as the natural log of the firm's market value of equities at year-end.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 10: The Effect of Product Market Structure on the Market Valuation of R&D Spending - Price Regression Results

$$V_{it} = \lambda_0 + \lambda_1(TA_{it}) + \lambda_2(RDC_{it}) + \lambda_3(D_{it}) + \lambda_4(D_{it})(RDC_{it}) + \lambda_5(DEBT_{it})^\#$$

Variables	Intercept	TA	RDC	D	(D)(RDC)	DEBT	Adjusted R ²
Prediction		+	+		+	-	
Panel A: Hypothesis on Market Competition							
<i>D_i</i> = 1 for firms with market share >0.05% (Larger Market Share); n = 60 <i>D_i</i> = 0 for firms with market share <0.05% (Smaller Market Share); n = 55							
Parameter Estimate (P-value)*	0.720 (0.001)	1.503 (0.006)	2.183 (0.086)			-1.251 (0.136)	9.9% (N=115)
Parameter Estimate (P-value)*	0.716 (0.400)	1.493 (0.013)	0.797 (0.451)	0.008 (0.993)	1.493 (0.410)	-1.261 (0.136)	8.4% (N = 115)
Panel B: Life Cycle Hypothesis							
<i>D_i</i> = 1 for firms whose average product is in the market for >= 12 months but <20 months (growth/mature stage); n=58 <i>D_i</i> = 0 otherwise (introduction stage or the stagnant stage); n=62							
Parameter Estimate (P-value)*	0.700 (0.001)	1.659 (0.003)	2.153 (0.084)			-1.521 (0.094)	10.6% (N=120)
Parameter Estimate (P-value)*	0.575 (0.037)	1.550 (0.007)	3.735 (0.083)	0.273 (0.483)	-2.271 (0.232)	-1.443 (0.108)	9.5% (N=120)

Table 10 (continued)

Panel C: Hypothesis on Product Diversification							
<i>D_i</i> = 1 for firms whose Herfindahl Index <1 (Diversified firms); n = 52							
<i>D_i</i> = 0 for firms whose Herfindahl Index =1 (Non-diversified firms); n = 63							
Parameter Estimate (P-value)*	0.720 (0.001)	1.503 (0.006)	2.183 (0.086)			-1.251 (0.136)	9.9% (N=115)
Parameter Estimate (P-value)*	0.743 (0.119)	1.503 (0.006)	1.728 (0.370)	-0.026 (0.959)	0.489 (0.464)	-1.256 (0.138)	8.3% (N=115)

Notes:

* Variable Definitions

V_{it} the common share price three months after firm i's fiscal year (t) end;

TA_{it} the book value of tangible assets of firm i at the end of period t;

RDC_{it} the R&D capital, measured as R&D spending per share, for firm i in period t;

DEBT_{it} the book value of the debt per share of firm i at the end of period t;

All the above variables are scaled by market value per share at the beginning of the year.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 11: Stock Returns Regressed on all Hypothesized Variables (Full Model)

$$R_{it} = \sigma_0 + \sigma_1(RD_{it}) + \sigma_2(\Delta RD_{it}) + \sigma_3(E_{it}) + \sigma_4(\Delta E_{it}) + \sigma_5(INNO_{it} * \Delta RD_{it}) \\ + \sigma_6(MKSH_{it} * \Delta RD_{it}) + \sigma_7(LIFE_{it} * \Delta RD_{it}) + \sigma_8(LIFESQ_{it} * \Delta RD_{it}) \quad \# \\ + \sigma_9(DVS_{it} * \Delta RD_{it}) + \sigma_{10}SIZE_{it}$$

Explanatory Variables	Predicted Sign	Parameter Estimate (P-value)*	Parameter Estimate (P-value)*
Intercept		-1.889 (0.092)	-1.603 (0.232)
<i>RD</i>	+	3.307 (0.057)	2.276 (0.167)
ΔRD		2.678 (0.287)	2.073 (0.913)
<i>E</i>		1.175 (0.576)	-0.543 (0.841)
ΔE		4.461 (0.003)	6.053 (0.000)
<i>INNO * ΔRD</i>	+		-0.125 (0.215)
<i>MKSH * ΔRD</i>	+		-0.217 (0.478)
<i>LIFE * ΔRD</i>			0.666 (0.697)
<i>LIFESQ * ΔRD</i>			-0.012 (0.834)
<i>DVS * ΔRD</i>	+		2.535 (0.327)

Table 11: Full Model Returns Regression (continued)

<i>SIZE</i>		0.138 (0.087)	0.119 (0.114)
Adjusted R ²		21.9% (N = 81)	24.5% (N = 81)

*** Variable Definitions:**

R_{it} is the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm i ;

E_{it} is the earnings per share before R&D for the period t for firm i ;

RD_{it} is the R&D expenditure for firm i in period t ; in this study it includes R&D expense and capitalized R&D;

ΔRD_{it} is the change in annual R&D spending per share;

ΔE_{it} is the changes in earnings per share before R&D for firm i in the period t ;

$SIZE_{it}$ is the natural log of the market value of firm i at the end of the period t ;

$INNO$ is the frequency of product innovation;

$MKSH_{it}$ is the aggregate or weighted average product market share of firm i in period t ;

$LIFE_{it}$ is the (simple) average product life, measured in months, of firm i in period t ;

$LIFESQ_{it}$ is the square of $LIFE_{it}$;

DVS_{it} is the reciprocal of modified Herfindahl Index,

All the above variables except for $SIZE$ are scaled by the market value at the beginning of the year.

*P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 12: Stock Price Regressed on all Hypothesized Variables (Full Model)

$$V_{it} = \theta_0 + \theta_1(TA_{it}) + \theta_2(RDC_{it}) + \theta_3(INNO_{it} * RDC_{it}) + \theta_4(MKSH_{it} * RDC_{it}) + \theta_5(LIFE_{it} * RDC_{it}) + \theta_6(LIFESQ_{it} * RDC_{it}) + \theta_7(DVS_{it} * RDC_{it}) + \theta_8(DEBT_{it})$$

Variable	Intercept	TA	RDC	INNO*RDC	MKSH*RDC	LIFE*RDC	LIFESQ*RDC	DVS*RDC	DEBT	Adjusted R ²
Prediction		+	+	+	+			+	-	
Parameter Estimate (P-value)*	0.860 (0.000)	1.325 (0.009)	0.189 (0.444)						-0.639 (0.271)	5.3% (N = 80)
Parameter Estimate (P-value)*	0.686 (0.001)	1.304 (0.006)	-2.032 (0.298)	0.008 (0.402)	0.650 (0.129)	0.108 (0.391)	0.001 (0.950)	-0.501 (0.346)	-0.535 (0.294)	8.1% (N = 80)

- * V_{it} is the common share price three months after firm i's fiscal year (t) end;
 TA_{it} is the book value of tangible assets of firm i at the end of period t;
 RDC_{it} is the R&D capital, measured as R&D spending per share, for firm i in period t;
 $INNO$ is the frequency of product innovation;
 $MKSH_{it}$ is the aggregate or weighted average product market share of firm i in period t;
 $LIFE_{it}$ is the (simple) average product life, measured in months, of firm i in period t;
 $LIFESQ_{it}$ is the square of $LIFE_{it}$;
 DVS_{it} is the reciprocal of modified Herfindahl Index,
 $DEBT_{it}$ is the book value of the debt per share of firm i at the end of period t;
 All the above variables except for PDT_{it} and $MKTSTR_{it}$ are scaled by market value per share at the beginning of the year.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 13: The Effect of the Common Factor on the Market Valuation of R&D Spending – Returns Regression Results

$$R_i = \gamma_0 + \gamma_1(RD_i) + \gamma_2(\Delta RD_i) + \gamma_3(F_i) + \gamma_4(F_i)(\Delta RD_i) + \gamma_5(\Delta E_i) + \gamma_6(\Delta E_i)(F_i) + \gamma_7(E_i) + \gamma_8(SIZE_i) + \varepsilon_i^*$$

Variables	Intercept	<i>RD</i>	ΔRD	<i>F</i>	$(\Delta RD)(F)$	ΔE	$(\Delta E)(F)$	<i>E</i>	<i>SIZE</i>	Adjusted R ²
Prediction		+								
Parameter Estimate (P-value)*	-1.897 (0.112)	2.811 (0.095)	2.068 (0.459)			4.995 (0.001)		1.241 (0.611)	0.133 (0.122)	26.5% (N = 81)
Parameter Estimate (P-value)*	-1.829 (0.093)	3.422 (0.043)	10.017 (0.053)		0.522 (0.073)	3.640 (0.022)	-0.623 (0.000)	-0.568 (0.811)	0.125 (0.111)	40.2% (N = 81)
Parameter Estimate (P-value)*	-1.859 (0.091)	3.321 (0.051)	10.740 (0.055)	-0.006 (0.748)	0.568 (0.082)	3.753 (0.023)	-0.608 (0.000)	-0.622 (0.796)	0.124 (0.115)	39.4% (N = 81)

- * R_{it} the annual common stock return per share cumulated beginning nine months before to three months after the fiscal year end for firm i;
 RD_{it} the R&D expenditure per share for firm i in period t;
 ΔRD_{it} the annual change in R&D spending per share;
 F_{it} the common factor score extracted from product innovation measure, market share, product life cycle stage, and product diversification measure of firm i in period t;
 E_{it} the earnings per share before R&D for the period t for firm i;
 ΔE_{it} the annual change in earnings per share before R&D but including extraordinary items;
 All the above variables except for R_{it} and F_{it} are scaled by market value per share at the beginning of the year.
 $SIZE$ the size of the firm, measured as the natural log of the firm's market value of equities at year end

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Table 14: The Effect of the Common Factors on the Market Valuation of R&D Spending – Price Regression Results

$$V_{it} = \theta_0 + \theta_1(TA_{it}) + \theta_2(RDC_{it}) + \theta_3(PDT_{it}) + \theta_4(PDT_{it} * RDC_{it}) + \theta_5(MKTSTR_{it}) + \theta_6(MKTSTR_{it} * RDC_{it}) + \theta_7(DEBT_{it})^{\diamond}$$

Variables	Intercept	TA	RDC	PDT	PDT*RD C	MKTSTR	MKTSTR *RDC	DEBT	Adjusted R ²
Predicted Sign		+	+				+	-	
Parameter Estimate (P-value)*	0.879 (0.000)	1.278 (0.009)	0.069 (0.474)					-0.667 (0.252)	4.8%
Parameter Estimate (P-value)*	0.579 (0.006)	1.221 (0.007)	-8.366 (0.017)		-0.030 (0.757)		1.755 (0.009)	-0.554 (0.274)	14.1% (N=80)
Parameter Estimate (P-value)*	-0.203 (0.649)	1.025 (0.021)	-1.058 (0.424)	-0.043 (0.040)	0.345 (0.045)	0.063 (0.102)	1.210 (0.104)	-0.517 (0.569)	17.3% (N=80)

- [♦] V_{it} the common share price three months after firm i's fiscal year (t) end;
 TA_{it} the book value of tangible assets of firm i at the end of period t;
 RDC_{it} the R&D capital, measured as R&D spending per share, for firm i in period t;
 PDT_{it} the common factor extracted from product innovation measure, product life cycle stage, and product diversification measure of firm i in period t;
 $MKTSTR_{it}$ the common factor score extracted from market share measure, and firm size measure of firm i in period t;
 $DEBT_{it}$ the book value of the debt per share of firm i at the end of period t;
 All the above variables except for PDT_{it} and $MKTSTR_{it}$ are scaled by market value per share at the beginning of the year.

* P-values reported are for one-tailed test if there is a prediction, two-tailed test if no prediction is made.

Appendix A: Derivation of the Effect of Competition on the Expected Profit of a Firm Engaging in R&D Activities

In this appendix, I model the expected profit of a firm engaging in R&D activities in a competitive market. The purpose of this model is to derive the effect of competition on the expected profit from R&D and to show that market competition can lead to heterogeneity in the cross-sectional market valuation of R&D. Hypothesis 2 is based on the derivation.

First, consider the expected profit of firm i , assuming firm i is the *only* firm in the product market. Let p be the probability of a successful discovery, Ω be the revenue (net of commercializing and production costs) of the innovation for the entire market, D_i be R&D expenditure of firm i , and O_i be other general and administrative expenses of firm i . Firm i 's expected profit from this innovation is the probability of successful innovation multiplied by the potential market revenue minus the expenses. It can be stated as

$$E(\pi_i) = p\Omega - D_i - O_i \quad (\text{A1})$$

where π_i is the profit resulting from the successful innovation, of firm i

Next, consider the expected profit of firm i , assuming that two firms, i and j , compete in the product market, and that both firms engage in innovation activities in the same area. Also assume that each firm has a different probability of successful discovery, p_i and p_j , and that each firm has fifty percent market share. The expected profit of firm i is the sum of (1) the expected profit if firm i discovers and firm j does not, and (2) the expected profit of firm i if both firms discover. Mathematically, the expected profit of firm i can be expressed as:

$$E(\pi_i) = p_i(1 - p_j)\Omega + p_i p_j \frac{\Omega}{2} - D_i - O_i \quad (\text{A2})$$

The first term on the right-hand side represents the expected profit of firm i if firm i discovers (probability p_i) and the other firm (firm j) does not (probability $1-p_j$), in which case firm i grabs the entire market revenue, Ω . The second term is the expected profit of firm i if both firms discover, in which case, the firms share the market revenue equally.

Further consider the expected profit of firm i , with the same assumptions as in the previous case, except that each firm has a different market share, w_i and w_j . Assume that the market shares are not expected to change after the innovation. The expected profit of firm i from this innovation can be stated as:

$$E(\pi_i) = p_i(1 - p_j)\Omega + p_i p_j w_i \Omega - D_i - O_i \quad (\text{A3})$$

The first term on the right-hand side still represents the expected revenue of firm i if only firm i discovers and grabs the entire market. The second term represents the expected revenue of firm i if both firms discover, but firm i only has market share of w_i .

The models presented above indicate that a higher probability of successful discovery leads to higher expected profit. As share price is the present value of expected future profits, and expected profit is positively associated with the probability of success, a perceived higher probability of success would lead to higher equity price. The models presented above also reveal that R&D expenditure has a dollar for dollar *negative* effect on the expected profit of a firm (i.e. $\frac{\partial E(\pi)_i}{\partial D_i} = -1$). However, in recent empirical studies (Lev and Sougiannis 1996, Sougiannis 1994), it has been shown that R&D expenditure is valued as an intangible asset in the stock market. How could an expenditure that has negative contribution to expected profit be valued as an asset? It must be the case that

investors associate higher R&D spending with higher expected value ($p_i \Omega$) of successful innovation. Assuming that the expected revenue (Ω) is independent of R&D spending, investors must associate higher R&D spending with higher probability of successful innovation.²⁸ In other words, the probability of successful discovery is viewed as a positive function of R&D spending. Stated differently, investors must assume that $p_i = f(D_i)$ and $\frac{\partial p_i}{\partial D_i} > 0$. It is difficult to specify ex-ante the exact functional form of the relation between p_i and D_i . It is possible that the real function may fall into, but is not restricted to, either of the following forms: (i) The probability of success is viewed as a positive linear function of R&D; (ii) The probability of success is a function of R&D intensity²⁹.

In the paragraphs that follow, I derive the relationship between a firm's expected profit and its R&D spending and the necessary condition for a R&D expenditure to make a positive contribution to the expected profit of a firm, under the two stylized functional assumptions above.

A.1 Derivation of the necessary condition under Assumption 1: The probability of success is a positive linear function of R&D expenditure.

²⁸ The assumption of independence between R&D spending and expected revenue is not unreasonable. According to an empirical study by Liebowitz and Margolis (1999), in the application software industry, products that dominate the market (reap the most revenue) are the ones with the highest quality. Improving software product quality, in turn, does not affect software developer's marginal (R&D) cost function, according to the study's finding. Taken together, in the application software market, a firm's future payoff may be independent of its R&D spending.

²⁹ R&D intensity is the ratio of R&D expenditure to sales revenue.

Under this assumption, $p_i = f(D_i)$, and $p_i = c * D_i$, where c must satisfy the following condition

$$0 \leq p_i = c * D_i \leq 1 \quad \text{or} \quad 0 \leq c \leq \frac{1}{D_i}.$$

The expected profit of firm i from engaging in such innovation activities can be stated as

$$\begin{aligned} E(\pi_i) &= p_i(1 - p_j)\Omega + p_i p_j \omega_i \Omega - D_i - O_i \\ \Rightarrow E(\pi_i) &= cD_i\Omega - c^2 D_i D_j \Omega (1 - \omega_i) - D_i - O_i \end{aligned}$$

The marginal contribution of R&D expenditure to firm i 's profit can be written as

$$\frac{\partial E(\pi_i)}{\partial D_i} = c\Omega - c^2 D_j \Omega + \omega_i c^2 D_j \Omega - 1$$

The sign of ω_i indicates that the **marginal contribution of firm i 's R&D expenditure to its expected profit is positively associated with its market share.**

Take one step further, given $0 \leq c \leq \frac{1}{D_i}$, the boundaries of the marginal contribution of

R&D are

$$-1 \leq \frac{\partial E(\pi_i)}{\partial D_i} \leq \frac{\Omega}{D_i} \left[1 - \frac{D_j}{D_i} (1 - \omega_i) \right] - 1$$

As we can see from the above inequality, for the marginal contribution of R&D to be

positive, the right-hand side of the inequality, $\frac{\Omega}{D_i} \left[1 - \frac{D_j}{D_i} (1 - \omega_i) \right] - 1$ must be greater than

0. That is,

$$\frac{\Omega}{D_i} \left[1 - \frac{D_j}{D_i} (1 - \omega_i) \right] - 1 > 0$$

$$\Rightarrow \frac{D_i}{D_j} > \frac{1 - \omega_i}{1 - \frac{D_i}{\Omega}} > 1 - \omega_i$$

$$\Rightarrow D_i > (1 - \omega_i) D_j$$

Let j represent all competitors of firm i . We can see from the above inequality if the probability of success is a positive linear function of R&D spending, a positive marginal contribution of R&D is possible only **if firm i 's R&D spending is more than the product of what its competitors are spending on R&D and their market share**. The above derivation proves that the *contribution of R&D to expected profit is not cross-sectionally constant*. **Market share** and the level of **competitors' R&D spending** are two important factors in determining the contribution of R&D spending.

A.2 Derivation of the necessary condition under Assumption 2: The probability of success is a linear positive function of R&D intensity.

Suppose R&D intensity can be proxied by R&D expenditure divided by expected future sales and assume that

$$p_i = c_2 \frac{D_i}{\Omega_i} \text{ and } p_j = c_2 \frac{D_j}{\Omega_j}$$

Where c_2 is a constant such that $0 \leq p_i = c_2 \frac{D_i}{\Omega_i} \leq 1$ and $0 \leq p_j = c_2 \frac{D_j}{\Omega_j} \leq 1$

$$\Rightarrow 0 \leq c_2 \leq \frac{\Omega_i}{D_i}, \quad 0 \leq c_2 \leq \frac{\Omega_j}{D_j}$$

The expected profit of firm i from engaging in such innovation activities is

$$E(\pi_i) = c_2 \frac{D_i}{\Omega_i} \Omega - c_2^2 \frac{D_i}{\Omega_i} \frac{D_j}{\Omega_j} \Omega (1 - \omega_i) - D_i - O_i$$

The marginal contribution of R&D spending is

$$\frac{\partial E(\pi_i)}{\partial D_i} = c_2 \frac{\Omega}{\Omega_i} - c_2^2 \frac{D_j}{\Omega_j} \frac{\Omega}{\Omega_i} (1 - \omega_i) - 1$$

Again, the sign of ω_i indicates that the **marginal contribution of R&D spending is a positive function of market share.**

Take one step further, given that $0 \leq c_2 \leq \frac{\Omega_i}{D_i}$, we obtain the following boundaries for the

marginal contribution of R&D spending:

$$-1 \leq \frac{\partial E(\pi_i)}{\partial D_i} \leq \frac{\Omega}{D_i} - \frac{\Omega}{D_i} \frac{\Omega_i}{D_i} \frac{D_j}{\Omega_j} (1 - \omega_i) - 1$$

For the marginal contribution of R&D to be positive, $\frac{\Omega}{D_i} - \frac{\Omega}{D_i} \frac{\Omega_i}{D_i} \frac{D_j}{\Omega_j} (1 - \omega_i) - 1$ must be

greater than 0. That is,

$$\Rightarrow \frac{D_i / \Omega_i}{D_j / \Omega_j} > 1 - \omega_i$$

The above inequality suggests that if the probability of success is a positive linear function of R&D intensity, a positive marginal contribution of R&D is possible only if the ratio of firm i 's R&D intensity to the combined R&D intensity of its competitors is greater than the combined competitors' market share. In this derivation again, I show that **market share and competitors' R&D intensity** are two important factors in

determining the contribution of R&D spending and that *contribution of R&D spending to expected profit and firm value is not cross-sectionally constant.*

Appendix B: List of the 44 Firms Used in Hypothesis Tests that Require Product Market Information (in alphabetical order)

Company	The Average of Total Sales derived from Retail Market Between Fiscal Years 1994-1997	Date Found/Incorporated
ACTIVISION INC	35.48%	1979
ADOBE SYSTEMS	15.84%	1982
AUTODESK INC	2.53%	1982
BORLAND INTL (INPRISE)	12.01%	1983
BRODERBUND SOFT	81.83%	1980
CITRIX SYSTEMS INC	n. a.	1989
CODA MUSIC TECH	8.01%	n.a.
COMPUTER ASSOCIATES	0.14%	1976
DATASTREAM SYS	0.42%	1986
ELECTRONIC ARTS INC	16.57%	1982
EXPERT SOFTWARE	100.00%	1992
FTP SOFTWARE	0.22%	1986
FOREFRONT GROUP	n. a.	n.a.
GT INTERACTIVE	32.02%	1992
INSO CORP	0.69%	n.a.
INTL MICRO COMP	58.49%	1982
INTERSOLV INC	0.01%	1982/1985
INTUIT INC	40.30%	1983
LEGATO SYSTEMS	0.02%	1988

LOGIC WORKS	0.13%	1985
MACROMEDIA INC	27.62%	1992
MANUGISTICS GP	0.04%	1986
MAPINFO CORP	0.10%	1986
MATHSOFT INC	6.99%	1984
MICROSOFT CORP	11.83%	1975/1981
MYSOFTWARE CO	90.40%	1986
NETSCAPE COMM	7.92%	1994
ON TECHNOLOGY	1.16%	1985
ORACLE CORP	<0.01%	1977
QUARTERDECK CP	44.85%	1982
RATIONAL SOFTWARE	n. a.	1982
SPSS INC	0.80%	1968/1975
7TH LEVEL INC	54.26%	1993
SMITH MICRO SOF	3.66%	1983
MICROPROSE INC	n. a.	n.a.
STAC INC	21.51%	1983
STATE OF ART	0.60%	1981
STERLING SOFTWR	0.01%	1981
SYBASE INC	0.12%	1984
SYMANTEC CORP	39.10%	1982
SYSTEMSOFT CORP	0.26%	1990

VERITY INC	0.19%	1988
VISIO CORP	12.81%	n.a.
WALL DATA INC	0.44%	1982

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