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CORPORATE GROWTH OPPORTUNITIES AND CAPITAL STRUCTURE OF EMERGING FIRMS: THEORY AND EMPIRICAL EVIDENCE

By

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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.

1998

UMI Number: 9830748

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This manuscript has been read and accepted by the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

5/4/98

Date

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ABSTRACT

CORPORATE GROWTH OPPORTUNITIES AND CAPITAL STRUCTURE OF EMERGING FIRMS: THEORY AND EMPIRICAL EVIDENCE

By

Richard E. Ottoo

Advisor: Professor Linda Allen

If firms are viewed as portfolios of real investment opportunities, then the most successful are those with access to the most lucrative projects. However, real growth options are not endowed on companies but are instead acquired through competitive investments. Rather than assuming an exogenously specified distribution of positive net present value projects across firms, this dissertation examines the process of allocation of investment opportunities across firms by modeling basic R&D investment. In my model, a firm gains access to productive technology by successfully completing basic R&D projects before its competitors, thereby procuring patent protection to guarantee indefinite flows of monopoly rents. The valuation of growth opportunities that a firm acquires by being first in making a breakthrough innovation and introducing a new product into the market is modeled as a compound real option. In my model, the firm uses its level of basic R&D investment strategically to impact the speed of innovation.

In order for the firm to generate expected benefits by the time of discovery, it must exercise the real option by paying the manufacturing costs, the strike price of the option, which are unknown a priori. Both project value and the exercise price are considered stochastic. The existence of competition lowers the expected time of discovery.

The model determines that growth opportunities are a function of R&D outlays of the firm and its rivals; the expected manufacturing capital and the cost of hedging its volatility; the risk-free rate of interest; the expected monopoly rents and its volatility; the conditional probability of innovation; the correlation between capital expenditures and R&D project value; and advertising spending.

I apply the "excess market value" approach in estimating growth opportunities. The empirical study analyzes a sample of 208 publicly traded U.S. companies of which 107 are emerging and 101 are well established firms, over the period 1987 to 1993. A company is defined as emerging if it has never issued any cash dividends.

Emerging firms are found to be more reliant on internal capital markets, in high R&D industries, less concentrated, more volatile with less free cash flow and greater growth opportunities. R&D has positive and significant impact on growth opportunities. However, when controlled for other variables, R&D of mature firms are found to be significantly negative. I suggest this may reflect investors' preference for mature firms to purchase ready technology rather than engage in risky basic R&D investments during the sample period. I find that emerging firms have lower debt ratio, but this difference is not significant. There is evidence that surprises in capital expenditures have a negative impact on growth opportunities for emerging firms but not for mature firms.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Overview

The increased attention of industry and academia in corporate valuation issues in recent years has been spurred by a surge in the number of startup firms, realized gains in market value, and the ever-increasing speed of global roll outs of products of technology companies. In 1980, the biotech industry hardly existed. Now it is a multibillion dollar business and may well be the industry of the next century. The New York Stock Exchange now boasts about 3,000 listed companies, even after accounting for companies lost due to mergers, acquisitions, and tremendous cash flow problems. Of these, two-thirds were listed within the last twelve years alone, the period with the largest number of new listings ever since the organization was founded in 1792[1]. Interestingly, most of these newcomers are young companies with limited histories to evaluate.

And consider the epicenter of global technology, the Silicon Valley meritocracy, where eleven companies are being created every week and in 1996, on average, a Valley company went public every five days[2]. Netscape Communications Corporation, for instance, went public just sixteen months after it was founded.

Finance literature offers on-going enterprises a guide to value-enhancing capital budgeting decisions. However, in a competitive market marked by rapid change and uncertainty, still very little is known about actual determinants of corporate growth

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[1] New York Stock Exchange Fact Book (May 1997).

[2] BusinessWeek (August 25, 1997, page 66). Not all are successes, though. BusinessWeek reports that only one in ten startups hits it big, six limp along, and the rest are destined to implode...

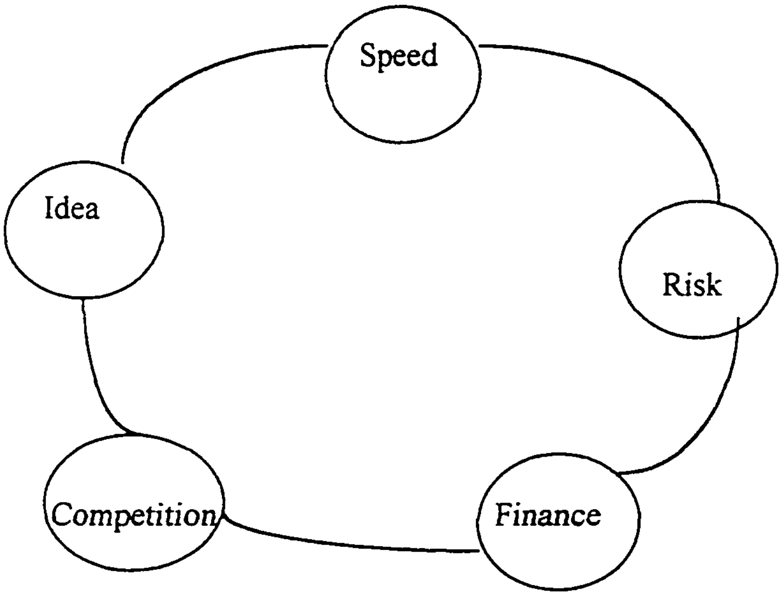
opportunities especially for startup and emerging firms. This dissertation aims at developing and testing a model that incorporates key corporate growth drivers. It rests on the premise that a firm's objective is to offer quality product or service to the market. However, that process begins with a unique *idea* and concept which must be nurtured or *financed*, all within a very *competitive* and *risky* environment. The introduction of the product to the market requires winning the "race" (*time*) to innovate.

Inventions and technological change are the major driving forces of economic and industrial growth. At the individual firm level, this takes the form of investing in positive net present value projects. If firms are viewed as portfolios of real investment opportunities, then the most successful are those with access to the most lucrative projects. However, growth opportunities are real growth options whose values are affected by management's strategic investment decisions. Real growth options are not endowed on companies but are instead acquired through competitive investments. Rather than assuming an exogenously specified distribution of positive net present value projects across firms, my dissertation examines the process of allocation of investment opportunities across firms by valuing basic R&D investment.

The firm is composed of assets-in-place plus real options[3]. It is the real options component of firm value that is the focus of this study. Growth options are strategic in nature. They may have positive value because they open up the way for profitable future investment opportunities. These options are especially important to start-up and emerging firms, whereas assets-in-place are more important in determining the value of established firms.

Few studies have investigated theoretical and empirical determinants of growth opportunities mainly because of the inherent gaps in valuation models resulting from the difficulty in pricing real options embedded in corporate investments. This dissertation examines growth opportunities by employing key determinants of innovation: *original idea*, *risk*, *speed*, *competition* and *finance*, factors that spawn that real option. In particular, I measure firm value for established firms as distinct from emerging firms because of the qualitative differences between growth options and assets-in-place. The purpose of this study is to demonstrate the distinction between emerging firms, whose firm value consists mainly of real options in intangible investment opportunities as opposed to mature firms, with relatively greater value in existing assets.

Figure 1: Determinants of innovation



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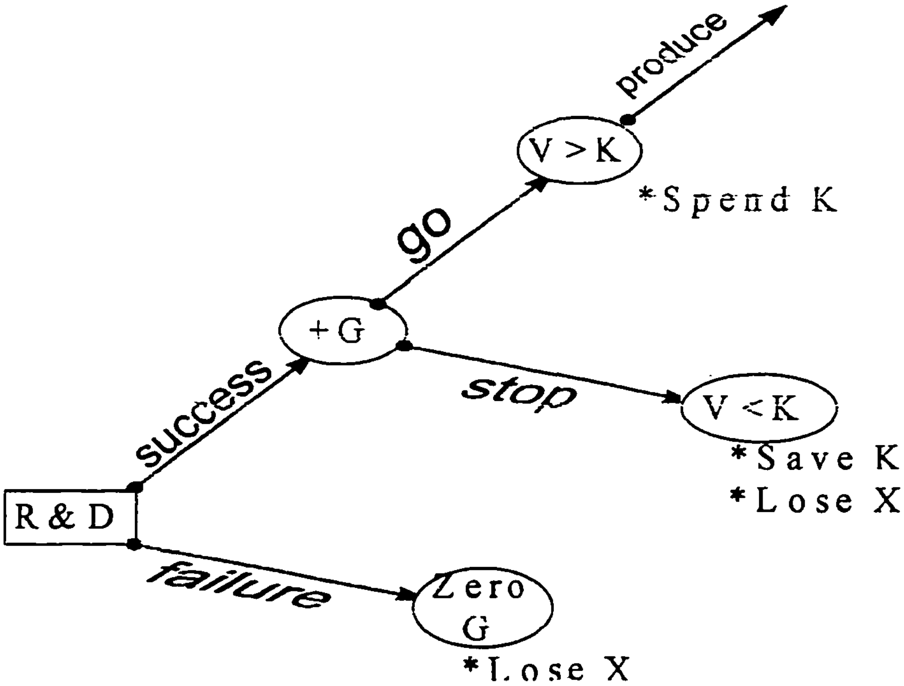
[3] See Myers (1977), Kester (1984) and Pindyck (1988).

In the study, I model the interaction between current real options and future growth opportunities. Innovation is a result of strategic investments in basic R&D, whose direct output is measured by product improvements and the number and type of patents granted to individuals and companies in different periods (Griliches 1981). In the model, a firm gains access to productive technology by successfully completing basic R&D projects before its competitors, thereby procuring patent protection to obtain access to monopoly rents. Thus, the firm's success depends upon winning a basic R&D "race" to secure access to these monopoly rents. The role of R&D investment is to impact the speed with which the firm propels itself to being first in making a breakthrough innovation and introducing a new product into the market. A participating firm is uncertain about the date of discovery by itself or by the competitors. The discovery time, a function of the level of R&D investment, is modeled as an exponential distribution with the instantaneous probability of innovation as its hazard rate. Winning the competitive race is signaled by the patents awarded. In a system with effective patent protection, acquiring a patent basically creates barriers for rival firms. Each firm's basic R&D will be affected by the actions of competitive firms.

In order for the firm to generate expected benefits by the time of discovery, it must exercise the real investment option by incurring manufacturing costs (modeled as the strike price of the option) which are unknown a priori. Basic R&D outlays are essentially the premiums paid to hold that option. The magnitude of the strike price is critical in determining the exercise decision of the firm. In my model, the strike price has two parts. An anticipated component which represents the premium paid to purchase the expected flow of monopoly rents, and the stochastic component which potentially affects the amount of manufacturing investment to the extent that the option may not be exercised. There are two implications of capital expenditure. On one hand, it must be paid otherwise all the expected benefits are lost. On the other hand, too high a level may substantially diminish the value of the real growth option. Thus, at $\tau = 0$, the option premium, the basic R&D expenditure is paid. At an uncertain date $\tau = t > 0$, the strike price, the cost of the manufacturing investment is paid. Consequently, monopoly rents which are a function of the size of the premium and patent awarded, are earned. The rents which are positive if the firm wins but zero if it loses are valued as an American call option.

Figure 2: Investment and production decision tree.



1.2 Growth Opportunities

A firm may tap internal and external sources of growth for purposes of enhancing its market value or achieving diversification. Internally, various options available include R&D investments to roll out new breakthrough products; expansion of distribution and manufacturing capacity to boost sales volume and market share; product pricing to undercut competitors and lift sales; human resource development to position personnel ready for possible new markets, products or techniques; re-invention and brand extension of core products; and restructuring including asset sale, downsizing, and spinoffs to free the company of excess capacity and labor and focus on core operations. Externally, a firm may opt for geographical or global expansion; strategic acquisitions and synergistic mergers.

Whether the source is internal or external, a firm experiences essentially two types of growth in its operating life. The first termed "contractual" or "self-sustaining" refers to opportunities arising from ironclad obligations the firm is required to make in order to earn rates of return above their cost of capital. In essence, contractual growth relates to contributions from assets-in-place. Prominent adjusted discounted cash flow models, for instance, Miller and Modigliani (1961) and Gordon (1955, 1967), that incorporate the component of self-sustaining growth in valuation suggest that if a firm has an opportunity to invest in a project with above normal returns, such investments increase value. Although still generally acceptable, the models fail to recognize that some of these investments are discretionary and so the value of real growth options embedded in real assets of the firm are ignored.

The second type is "strategic growth" generated from real options acquired by making investments that offer potential for future value. Strategic growth offers a firm the ability to truncate downside risk while preserving and enhancing upside potential. However, the value of a real growth option can only be captured if the option is exercised. Growth opportunity is considered a real call option, the right but not the obligation the firm possesses to buy the underlying asset by a certain date for a certain price. Take a real option acquired by investing in a basic R&D project. The option's exercise price is the level of future investment needed to acquire the expected project benefits. The underlying asset would be the value of the firm or completed project. Time to expiration is the date the decision to commit manufacturing outlays is made. Exercising the option implies that the flexibility available to a manager or an investor is valuable, a feature lacking in traditional discounted cash flow valuation models[4]. Such models seem to focus exclusively on the "stand-alone" value of a firm, taking as given the expectation of continued future investments by the firm. Thus, self-sustaining and strategic growth are ambiguously lumped together and contributions from financing, investing and operating flexibilities are ignored.

For start-up and emerging firms, internal sources of growth seem to be the only feasible option. Because of age and size of operating capacity as well as financial constraint, an emerging firm may not have the capability to purchase and integrate outside technology or business, or engage in extensive expansion geographically as a viable means of achieving growth. None of the options are readily available except

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[4] See Myers(1977), Hayes and Garvin (1982), Brennan and Schwartz (1985), Mason and Merton (1985), Trigeorgis and Mason (1987), and Pindyck (1988). Also, Berksund and Ekern (1990), Brealey and Myers

engaging in basic R&D investments in order to introduce a new product or process to the market. For this reason, I model basic R&D spending as the premium of the real growth option of an emerging firm.

Myers' (1977) pioneering work on real growth options has greatly motivated my dissertation. He values growth opportunities as call options, but takes the existence of growth opportunities as given. Myers acknowledges that "the development of a theory of the firm which treats real options as endogenous is a challenging subject for future research."[5] This work attempts to respond to that challenge. In particular, my contribution is to model basic R&D investment as a strategic, competitive process. That is, each firm's real option payoff is determined by its own basic R&D investment as well as the level of investment in basic R&D by its competitors. If a competitor wins the race to develop the product and obtains a patent, the value of the firm's real option will be lost.

Consideration of an endogenously determined distribution of real investment opportunities yields interesting insights regarding emerging firms. Real option values depend on the pace of basic R&D investment, which must be paid out at time $\tau = 0$ in the form of a premium. Thus, the firm must finance the premium, relying on both internal and external sources of capital. But capital markets may be reluctant to provide this financing because of information asymmetries that make basic R&D projects difficult to evaluate. Since the discovery time is a function of R&D investment, limited access to external capital markets and a paucity of past retained earnings may restrict emerging

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(1991), Kemna (1993), and Trigeorgis (1993) further demonstrate that DCF techniques assume projects hold assets passively.

[5] Page 164.

firms' success in the competitive race to innovation and the financing of manufacturing investments. This process further entrenches developed firms leading emerging firms to rely more on internally generated funds to support basic R&D investments.

1.3 Existing Literature

None of the available real options literature examines the interactions among operating, investment and financing determinants of growth opportunities in a competitive environment. My dissertation develops and tests a model which is able to address the endogeneity issue in growth options lacking in most finance literature. In particular, I present a comprehensive framework, allowing for a stochastic process for project value and investment costs as well as possible correlation between them.

Other studies have either only looked at the underlying asset or the exercise price of the real growth options, or failed to incorporate the uncertainty components of these variables. Thomadakis (1977) formulates growth opportunities as the capitalized value of monopoly rents (referred to as excess value) which the firm is expected to appropriate throughout the future, and focuses on the market structure effect on the excess firm value. Following McDonald and Siegel (1986), Chung and Charoenwang (1991) model a project value as following a stochastic process but assume the investment cost and the time the cost is made are known, also taking the existence of growth opportunities as given, not showing, for example, whether they are acquired via purchase of real assets or direct investments in R&D.

In Willner (1995), the discovery nature of a start-up venture follows a jump process whose occurrence is governed by a Poisson process. However, it is not clear whether the investment date is related to the discoveries made, or how it is determined. Willner argues that the date is the time when funding runs out. Broyles and Cooper (1981) price growth opportunity as a call option but arbitrarily set the asset value, the investment components, and the maturity date.

Other related studies include Baldwin (1982) who examines the interactions of search technology and investment and models valuation of a mineral mine exploration program; Margrabe (1978) and Fischer (1978) demonstrate how making current investments for future value can be priced as European exchange options; while Carr (1988) models them as American exchange options.

The exercise price of the real call option is one of the key influencing variables. For some projects, the cost of investment is more uncertain than the future payoff. In capital investments, there is evidence that unexpected increases in expenditures may lead to termination of otherwise worthwhile projects. Pindyck (1993) finds that in the 1980s considerable cost uncertainty led to the cancellation of many nuclear power plant construction projects in the U.S. even when some were 5% to 90% completed. Weitzman, Newey and Rabin (1981) cite wide variation in estimates of coal liquefaction costs (from $24 to $80 per barrel) as evidence of cost uncertainty in the synfuel industry.

There is reason to believe that cost uncertainty could be a crucial factor in determining growth opportunities of firms engaged in basic R&D investments. Geczy, Minton and Schrand (1997) examine a sample of *Fortune 500* non-financial firms in 1990 and find that firms with greater growth opportunities and tighter financial constraints are more likely to use derivative instruments to reduce cash flow variation that might otherwise preclude them from making these valuable investments. Shapiro and Titman (1986), Stulz (1990), Lessard (1990), and Froot, Scharfstein, and Stein (1993) argue that hedging strategies mitigate the under-investment problem of Myers (1977). It is likely that emerging firms may experience more cost uncertainty than established companies whose cash flows are more stable and who supposedly already have some manufacturing facilities in place that may be adaptable.

My approach is distinctly different from other studies because I consider both the future payoff and the cost of investment as being uncertain in a competitive industry environment. McDonald and Siegel (1986) take a similar view but show that the optimal investment rule is to wait until potential benefits from a project are at least double the investment costs. Roberts and Weitzman (1981) analyze an R&D investment as a sequential development project with benefits uncertain at each step and received only at termination. They further assume that the standard deviation of estimated terminal benefits decline progressively as project completion nears, and show that at any stage the uncertainty is proportional to the expected costs remaining to complete the project.

In Weitzman, Newey and Rabin (1981), uncertainty over terminal costs is eliminated by a subsidized sequential development program. Each stage of development, including the learning that has taken place, is indexed by the amount of subsidy paid so far. As development of the project proceeds, subsidy outlays are concurrently made, and the information revealed is translated into progressively less uncertain estimates of that ultimate cost. The model assumes the project is continuously re-evaluated and each stage, a decision of whether to continue subsidization and investment is made.

In Majd and Pindyck (1987), the value of a completed project also evolves as a geometric Brownian motion but the total required investment is assumed to be known.

The focus is on the option implicit on the construction phase and the option value of being able to delay an investment. Majd and Pindyck show how the value of an investment program and the decision to invest depend on the maximum rate at which expenditures can productively be made. The treatment of uncertainty here is different from others. The randomness of the future value of the project is independent of the proportion of the project already completed. Thus, there is no learning, as in Roberts and Weitzman (1981). There is also no waiting as a means of resolving this uncertainty, as in Majd and Siegel (1987).

Another aspect of this inquiry is Grossman and Shapiro (1986). They incorporate the analysis of project risk and study the effects of uncertainty on R&D expenditures of a single firm. The payoff is modeled as a Poisson distribution and the hazard rate of the process is specified as a function of the cumulative effort expended. They conclude that an optimal investment program involves ever-increasing levels of outlays as progress is made. Under cost uncertainty, a firm is shown to prefer a risky research project to a safe one requiring on average the same amount of progress for completion.

In a related work by Pindyck (1993), projects that take time to build are subject to two types of cost uncertainty: technical uncertainty over the physical difficulty of completing a project which can only be resolved as the investment proceeds; and input cost uncertainty which is external to what the firm does and is partly non-diversifiable. Pindyck finds that a project can have an expected cost that makes its conventional NPV negative but can still be economical to initiate. Likewise, a project with positive conventional NPV might still be uneconomical to undertake. Because costs of construction inputs change whether or not investment is taking place, there is a value of waiting for new information before committing resources. In the model, the expected cost to completion is stochastic but the process is controlled by an assumed maximum rate of investment. Pindyck thus develops a decision rule which is to invest as long as the expected cost to complete the project is below a critical number.

Although similar to our approach, the models of Roberts and Weitzman (1981), Weitzman, Newey and Rabin (1981), and Pindyck (1993) are essentially timeless in the sense that consideration of optimal timing and speed of development, which are critical elements of my model, are suppressed. As in many other studies, these authors also never examine inter-firm effects. My contribution is to show that each firm's R&D is affected by other competitors' levels of R&D.

1.4 Financing Growth Opportunities

If stock market investors are not myopic and focus on long-term performance then it would seem that the intangible assets are valued by the market and are reflected in the measured capital of the firm. Basic R&D projects are by definition uncertain. A firm is simultaneously uncertain whether it or its competitors will succeed in making the innovation. By sustaining R&D investments, competing firms hope to acquire better estimates of future states of nature that would determine their resulting payoffs. However, at each stage, managers of a firm may have more information than competitors and capital markets, and different firms may have different information about which states will occur.

It is highly likely that the extent to which real growth options constitute the market value of the firm may influence its mode of financing. However, puzzling as capital structure issues still are, it is unclear if there is an optimal financing policy for growth options. It may be implied from Diamond (1989) that start-ups and emerging firms with little reputation have less access to debt than are well established firms. This conforms with Jensen and Meckling (1976), Myers (1977), and Stulz (1990) who show that leverage is expected to be negatively associated with the extent of growth opportunities. The view of Stulz (1990) is that volatility of cash flows has a strong effect on financing policy of a firm since it increases the agency costs of managerial discretion. Managerial discretion induces two cost components. One is an over-investment cost caused by management investing too much in some circumstances, and the other is the under-investment cost that arises because of management's lack of credibility when it claims available internal funds are not sufficient to exhaust all positive NPV projects.

Stulz argues that a solution to the agency problem of managerial discretion is to make it less likely that resources available to management will differ significantly from the resources stockholders expect management to have. The desire to achieve a decrease in the dispersion of cash flow and to re-align the expectation of investors with the investment and financing strategies of management may explain why some firms, especially young ones, defer making dividend payments.

Also, because of informational heterogeneity across investor groups, the capital markets will fail to instantaneously aggregate information about a firm. Thus, investors cannot properly identify the relative performance of firms engaged in a competitive race to innovate merely by observing their market prices. Because information acquisition is a costly activity, investors will consequently price their own capital very highly for any needy firm that approaches the market. This may lead some firms to pass up positive net present value projects.

Management of an established company realizes this and would desire to separate itself from the rest. It will choose to use an unambiguous signal to convey to the market that it has a stable expected set of cash flows sufficient to meet debt obligations as well as dividend payments without triggering undue stress on the financial condition of the firm. One such unique signaling device is dividend payment. Start-up firms cannot mimic this signal because they lack the stability and necessary level of cash flows to back it up. In addition, mimicking a mature firm would be expensive since higher costs of issuing equity or debt to pay cash dividends must be incurred[6]. Also, seeking external capital brings with it the amount and intensity of capital markets scrutiny which a start-up firm may not desire.

A firm will know more about the prospect of its R&D investment than the investors. Due to the resulting information asymmetry, credit rationing may ensue and the market may fail to finance basic R&D of emerging firms to the levels needed to compete for the monopoly rents. Access to internal sources of financing, as in Myers' "Pecking-Order" theory (1984) and Myers and Majluf's benefit of financial slack (1984), become a binding constraint for these companies, even though internal cash flows might

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[6] For an excellent exposition on signaling theory, see Ross (1977), Bhattacharya (1979), Myers and Majluf (1984), Miller and Rock (1985), and John and Williams (1985). Jensen and Meckling (1976) argue that because of the agency cost of equity, firms may shy away from using equity just for the sake of raising funds to pay dividends. Tax-based dividend signaling models postulate that dividends only convey information about a firm's values because of the higher tax they impose on shareholders. Using data on Germany where dividends are not tax-disadvantaged, Amhiud and Murgia (1997) find that stock price response to dividend news in Germany is similar to that documented in the U.S., suggesting that besides taxes, dividends are informative. It is agreed that where corporate managers have greater discretion in accounting reporting, financial statement variables may even be less informative about current and potential earnings of the firm

generate Jensen's (1986) free cash flow problems. If internal funds are lacking, then there is no access to external capital either, and the firm fails to enter the strategic growth competition. Therefore, internally generated cash flow is a more important determinant of firm value for emerging than for mature firms.

In this study, we recognize dividend payment as a signaling device and utilize it to distinguish an emerging from a mature firm[7]. Thus, an emerging firm is defined as one that had never issued cash dividends over its entire life.

1.5 The Organization of the Dissertation Project

The organization of this study is as follows. After the introduction, the theoretical model is presented in chapter 2. Chapter 3 discusses comparative static analyses. A scenario analysis with particular reference to a case of a biotechnology company is conducted in chapter 4. This is followed by empirical design and analysis of results in chapter 5. Chapter 6 concludes with an overall summary of the study and discussion of extensions of the model and possible weaknesses.

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than signaling devices like dividends. To new suppliers of capital, for instance, audited financial statements may not adequately communicate every relevant information, especially "adverse" news about the firm.

[7] Masulis and Trueman (1986) state that firms with many growth opportunities will use all their internally generated funds without paying dividends, but established firms will pay out dividends because not all internal resources will be exhausted by investment opportunities. Pilotte (1992) also employs this criterion in an event-study of stock price reaction to new financing.

CHAPTER 2

THE THEORETICAL MODEL

2.1 R&D Investment Decision

I model an emerging firm as one purchasing a basic R&D option to develop a new technology or product. By basic R&D option I mean that the option to make positive NPV investments will be received by the firm if and when the R&D project is successfully completed. The purpose here is not to draw a formal distinction between "basic" R&D and "applied" R&D (see Schmitt (1985)). My assumption is that the innovation the firm would make is not an end-use product but a product or process that will lead to further generic or targeted product or process developments. In my model, the potential value resulting from additional products, markets, and opportunities is captured by the granting of patents that provide monopoly rents to the firm exercising the real option.

I begin with an investment decision. I assume the basic R&D project is finitely lived since such opportunities can be captured by a competitor or diminished by introduction of a substitute. I develop the noncooperative game model of Kamien and Schwartz (1972), Loury (1979), and Lee and Wilde (1980) to determine R&D choice. I suppose that there are N firms in the market that are competing to reap a flow of benefits from R&D investments which become due only to the first firm to succeed in making the innovation. Later, I explore possible variations of these investment strategies under monopoly and cartel forms of market structure. R&D investments are initiated at time $\tau = 0$. The first firm is expected to succeed at some time before $\tau = T$. I assume that if no discovery is made by time T then all benefits related to the R&D investments will vanish. Each firm, however, is uncertain about the date of innovation $(t < T)$ by itself or by the competitors. R&D investments span over time $\tau = 0, 1, 2, \ldots t, \ldots, T$, where t represents the innovation date of the first firm and T denotes the maximum time to innovation.

Once the R&D is successful and the new product is tested and introduced, the successful firm must decide whether to manufacture the product or not. At time t the firm decides to incur a manufacturing cost $K(t)$, in order to realize V_1, the present value of the stream of uncertain future cash flows generated by this investment. For firm i, V_1 represents the market value of a claim on the stream of net cash flows that arise from installing the manufacturing plant subsequent to the discovery at time t. It is recognized that if $K(t) > V_1$, the firm will not manufacture the product and the growth value will be lost.

A participating firm can assess $K(\tau)$, the required capital investments, at $\tau = 0$. However, $K(t)$ *is* uncertain since new information is revealed over the basic R&D investment period between dates $\tau = 0$ and t. In an approach similar to Fischer (1978) and Pindyck (1993), we consider the manufacturing investments, the strike price of the option, a stochastic variable. R&D investment is thus a real growth option on the value of a completed manufacturing project as the underlying asset; the capital cost $K(t)$, as exercise price; time of innovation t, as maturity date; and the R&D expenditures x, as the cost of or premium on this option. Thus, at t, the firm's investments payoff is $max[V_1 - K(t), 0]$.

Assume a market in which there are N identical firms competing for an amount of benefit $B(t)$, that can only be available to the firm that first introduces a new technology or product at some date t. The firm that "beats the market" would immediately receive a patent protection to guarantee to it the flows of benefits indefinitely. I rule out the possibility of spillovers and assume that a belated rival innovator would get zero benefit.

In order to reap the expected benefits, firm *i* must commit to a level of R&D Investment x. Similarly, each of the (N-1) firms makes an R&D investment y. I assume that the investment costs are non-contractual, and will be incurred until any one of the firms succeeds.

At $\tau = 0$ firm *i*, just like firm *j* ($1 \leq j \neq i \leq N$), is faced with two kinds of uncertainty. First, it does not know the exact date it will succeed in completing the R&D project. Usually by making an R&D expenditure a firm seeks to invest in personnel and facilities that can both produce efficiently and introduce a product sooner. This serves to mitigate the uncertainty underlying the relationship between the investment decision and the date of project completion. Essentially, for firms *i* and *j*, the R&D expenditure is purchasing a random variable $\tau(x)$ and $\tau(y)$, respectively, representing an uncertain date at which the R&D project would be successful.

Second, firm *i* is uncertain about the introduction date of any of the other firms. I denote this uncertainty, from firm *i*'s perspective, by a random variable $\tau_i(y)$, where $\tau_i(y) = \min \tau_j(y)$ and $\tau_j(y)$ is a random variable representing the uncertainty a firm *j* also faces about when it will successfully make the innovation.

I assume rational expectations, that the firm's expectations are correct, so that

$$\tau_i(y) = \min\ \tau_j(y) = \tau(y) \tag{1}$$

Thus, the challenge facing firm *i* is to ensure that $\tau(x) < \min(\tau(y), T)$. This follows since, for firm *i* to earn V_1 by time t, it must have succeeded previously and on condition that no other firm overtook it to make that innovation. Let each firm's discovery time t follow an exponential distribution. Thus, for firm *i*,

$$Prob(\tau(x) \leq t) \;=\; 1\text{-}e^{-f(x)t} \tag{2}$$

The expectations of this random variable can be derived by applying the procedure of integration by parts as follows:

$$F_{\tau(x)}(\tau(x)) \;=\; F(\tau(x)) \;=\; \text{Prob}(\tau(x) \leq t) \;=\; 1\text{-}e^{-f(x)t}$$

$$\Rightarrow \quad f_{\tau(x)}(\tau(x)) \;=\; f(\tau(x)) \;=\; F'(\tau(x)) \;=\; f(x)\, e^{-f(x)t}$$

$$\Rightarrow \quad E(\tau(x)) \;=\; \int_0^\infty \tau f(x)\, e^{-f(x)t}\, d\tau \;=\; \int_0^\infty v du.$$

Let $v = \tau$ and $du - f(x)\, e^{-f(x)t}\, d\tau$, implying $u = -e^{-f(x)t}$.

Therefore,

$$\int_0^\infty \tau f(x)\, e^{-f(x)t}\, d\tau \;=\; [-\tau e^{-f(x)t}]_0^\infty + \int_0^\infty e^{-f(x)t}\, d\tau$$

$$= [-\tau e^{-f(x)t}]_0^\infty + \left[-\frac{1}{f(x)} e^{-f(x)t}\right]_0^\infty$$

$$= [-\tau e^{-f(x)t}]_0^\infty + \left[-\frac{1}{f(x)} e^{-f(x)t} + \frac{1}{f(x)}\right]_0^\infty$$

$$= 0 + 0 + \frac{1}{f(x)}$$

$$\therefore \; \mathrm{E}(\tau(x)) = \frac{1}{f(x)} \tag{3}$$

is the expected time of innovation. Here, $f(x)$ is the conditional probability that firm i will introduce a new product to the market at any subsequent date. It is the hazard rate of success for firm i. Assume that the function $f(x)$ is twice continuously differentiable and that it satisfies the following boundary conditions:

$$f(0) = 0$$

$$f'(x) = 0, x \to \infty,$$

$$f''(x) < 0, \tag{4}$$

allowing for initially increasing returns to x, with possibly diminishing returns eventually. f is only a function of x and is considered a constant hazard rate.

From (1) and (2) it follows that if τ_n, $n = 1, \ldots, N$, are taken as independent, then

$$Prob(\tau_i(y) \leq t) = 1 - Prob(\tau(y) > t) = 1 - \mathrm{e}^{-\lambda t}, \tag{5}$$

where $\lambda = \sum f(y)$, $j \neq i$.

Therefore, the probability that firm i introduces the product by time t, and that no other firm has done so, may be computed as follows:

Let $x = \tau(x) \sim \exp(\pi = f(x))$, and

$y = \tau(y) \sim \exp(\lambda = \Sigma f(y))$.

$$\therefore \ \text{Prob}(x \le y \wedge t) = \int_0^t \text{Pr}\,ob(x \le y)dF_y(y) + \text{Prob}(y > t).\text{Prob}(x \le t)$$

$$= \int_0^t (1 - e^{-\pi y})\,\lambda e^{-\lambda y} dy + e^{-\lambda t}[1 - e^{-\pi t}]$$

$$= 1 - e^{-\lambda t} - \left(\frac{\lambda}{\lambda + \pi}\right)\left(1 - e^{-(\lambda+\pi)}\right) + e^{-\lambda t} - e^{-(\lambda+\pi)t}$$

$$= (1 - e^{-(\lambda+\pi)t}) - \left(\frac{\lambda}{\lambda + \pi}\right)\left(1 - e^{-(\lambda+\pi)}\right)$$

$$= \left(1 - \frac{\lambda}{\lambda + \pi}\right)\left(1 - e^{-(\lambda+\pi)}\right)$$

$$= \left(\frac{\pi}{\lambda + \pi}\right)\left(1 - e^{-(\lambda+\pi)}\right)$$

$$= \left(\frac{f(x)}{\lambda + f(x)}\right)\left(1 - e^{-t[\lambda + f(x)]}\right) \qquad (6)$$

Thus, from (4) and (6), the present value of the benefits $B(t)$ that firm i will receive on successfully completing the R&D project before any firm j has, is given as:

$$E[B(t) \mid \{\tau(x) \le (\tau(y),\ t)\}]$$

$$= \int_0^\infty B(t)dP\left[x \le y \wedge t\right]e^{-rt}dt$$

$$= \int_0^\infty B(t)\left[f(x_i)e^{-t(\lambda + f(x_i)}e^{-rt}\right]dt$$

$$= \frac{B(t)f(x)}{\lambda + f(x) + r} \tag{7}$$

where r is the discount rate and t is the conditional expectation of $\tau(x)$.

To determine the value of t, we know that

$$\mathrm{F}(\tau) = \left(\frac{f(x)}{\lambda + f(x)}\right)\left(1 - e^{-t(\lambda + f(x))}\right)$$

$$\Rightarrow \quad \mathrm{F}'(\tau) = \frac{d}{dt}\left(\frac{f(x)}{\lambda + f(x)}\right)\left(1 - e^{-t(\lambda + f(x))}\right)$$

$$= [\lambda + f(x)]\mathrm{e}^{-(\lambda + f(x))}\left(\frac{f(x)}{\lambda + f(x)}\right)$$

$$= f(x)\mathrm{e}^{-t(\lambda + f(x))}.$$

Therefore, the expectation of $\tau(x)$ is given as:

$$\mathrm{E}[\tau(x) \mid \{\tau(x) \leq (\tau(y), t)\}]$$

$$= \int_0^\infty \left[t f(x) e^{-t(\lambda + f(x))}\right] dt$$

$$= \underbrace{\int_0^\infty t(\lambda + f(x)e^{-t(\lambda+f(x))}dt}_{Q} - \underbrace{\int_0^\infty \lambda t e^{-t(\lambda+f(x))}dt}_{R}$$

For part Q, let $v = t$ and $u = -e^{-t(\lambda + f(x))}$, so that $dv = dt$ and $du = (\lambda + f(x))e^{-t(\lambda + f(x))}dt$.

$$\therefore \int_0^\infty t(\lambda + f)e^{-t(\lambda+f(x))}dt \equiv \int vdu = uv - \int udv$$

$$= \left[-te^{-t(\lambda+f(x))}\right]_0^\infty + \int_0^\infty e^{-t(\lambda+f(x))}dt$$

$$= \left[-te^{-t(\lambda+f(x))}\right]_0^\infty + \left[-\frac{1}{(\lambda+f(x))}e^{-t(\lambda+f(x))}\right]^\infty - \left[-\frac{1}{(\lambda+f)}e^{-t(y+f(x))}\right]^0$$

$$= 0 + 0 + \frac{1}{(\lambda+f(x))} = \frac{1}{(\lambda+f(x))}.$$

For part R, let $v = t$ and $u = -\frac{1}{(\lambda+f)}e^{-t(\lambda + f(x))}$, such that $dv = dt$ and $du = e^{-t(\lambda + f(x))}dt$.

$$\therefore \lambda\int_0^\infty e^{-t(\lambda+f(x))}dt \equiv \lambda\int vdu = \lambda uv - \lambda\int udv$$

$$= \left[-\frac{\lambda t}{(\lambda+f(x))}e^{-t(\lambda+f(x))}\right]_0^\infty + \lambda\int_0^\infty \frac{e^{-t(\lambda+f(x))}}{(\lambda+f(x))}dt$$

$$= \left[-\frac{\lambda t}{(\lambda+f(x))}e^{-t(\lambda+f(x))}\right]_0^\infty + \left[-\frac{e^{-t(\lambda+f(x))}}{(\lambda+f(x))^2}\right]_0^\infty$$

$$= (0\text{-}0) + (-\lambda.0) + \frac{\lambda}{(\lambda + f(x))^2} = \frac{\lambda}{(\lambda + f(x))^2}.$$

$$\therefore\ E(\tau) = Q - R = \frac{1}{(\lambda + f(x))} - \frac{\lambda}{(\lambda + f(x))^2} = \frac{f(x)}{[\lambda + f(x)]^2}. \qquad \text{Q.E.D. (7a)}$$

Equation (7a) states that the expected time of discovery for firm *i* is a function of both the probability of the firm as well as the probability of rival firms succeeding in making the innovation at any subsequent date. In other words, from firm *i*'s perspective, the expected time of discovery depends on its own probability of winning conditional on the probability of winning of its rivals, which are in turn a function of R&D expenditure of each firm in the competitive race.

We apply the exponential distribution which permits determination of the minimum time to make a discovery. In practice, an exponential distribution arises as being the distribution of the amount of time until some specific event occurs (see Ross (1994)). A unique property of an exponential random variable is that it is *memoryless*. For instance, if a firm has not yet made a discovery by time *t*, the probability that it would succeed any time between *t* and the maximum date *T*, is the same as its initial probability of success before *t*. In other words, the distribution of R&D investments after time *t* is the same as the original distribution, if no innovation is observed by that date.

R&D project has been assumed to be finite. This assumption is relaxed while determining the conditional expected time of innovation, without loss of results. Rational expectations hypothesis is also assumed to hold such that each firm's expectations about the action of the competitor is correct. Furthermore, R&D investments are observable and are assumed to be equally valuable.

2.2 Production Decision

We need to determine $B(t)$, the present value of the benefits that firm i will receive at time t. Suppose the firm wins, the R&D expenditure level x would be the optimal level required to be successful. At that date when the new product is tested and introduced, firm i faces a production decision. In order to receive the present value of cash flows V_1 resulting from its R&D efforts, it must go ahead and invest in new capital to manufacture the new product and incur an expenditure of $K(t)$. Its payoff would be:

$$max\,[V_1(t) - K(t),\ O]. \tag{8}$$

This is a call option on the value of the investment, V_1, with capital expenditure $K(t)$ as strike price. Assume that the project value V_1 follows a diffusion process:

$$dV_1 = \alpha_v V_1 dt + \sigma_v V_1 dz_v \tag{9}$$

where:

α_v is the instantaneous expected return on the project,

$\sigma^2{}_v$ is the instantaneous variance of the return, and

dz_v is the Gauss-Wiener process, defining the uncertainty underlying the process (9).

It is reasonable to assume that V_1 will depend on x, σ, t and s, the state of nature[8]. We define V_1 as:

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[8] V_1 is modeled as in Myers (1977).

$$V_1 = V_1(x, \sigma, t, s) = \int_t^\infty \left[e^{-rt} \int_0^t q(s)\{V_1(x,\sigma,t,s)\}ds \right] dt. \tag{10}$$

The manufacturing costs, the strike price of the call option at $\tau = 0$, is assessed as $K(0)$ and is known. However, the option will be exercisable at t, when the actual strike price is $K(\mathrm{t})$. At any time before t occurs, $K(t)$ is uncertain. Again, note that t is the observed value of τ. Thus, the payoff from undertaking this production depends on the increase in value of the project as well as on changes in the uncertain strike price, itself correlated with the process of V_1. We, therefore, assume the exercise price has the dynamics

$$dK = \alpha_k K dt + \sigma_k K dz_k \tag{11}$$

where: α_k is the instantaneous expected rate of increase of the stated exercise price,

$\sigma^2{}_k$ is the instantaneous variance of the exercise price, and

dz_k is the standard Wiener process.

Let the Wiener processes, dz_v and dz_k, have an instantaneous correlation coefficient σ_{vk}, where $dz_v dz_k = \sigma_{vk} dt$. I wish to obtain the call value on an asset with a stochastic exercise price. This could be achieved by purchasing a hedge security to hedge against changes in the exercise price. This hedge provides an insurance against unanticipated changes in $K(t)$. It is required that for this to be appropriate the stochastic percentage changes in the value of the hedge security be perfectly correlated with the stochastic component of the percentage changes in the strike price. It follows that the option value would depend on V_1, $K(t)$, the parameters of the processes (9) and (11), as well as on the cost of hedging.

The expected rate of return, α_h, on the hedge security is equivalent to the risk-free rate of interest plus the risk premium on the hedge security. If capital asset pricing model (CAPM) holds, the risk premium on the hedge security can easily be derived (see Fischer (1978)). Under perfect capital market assumptions, the expected rate of return on this hedge security equals the cost of hedging. The net benefits for firm *i*'s R&D is thus:

$$B = V_1 \mathrm{N}(\mathrm{d}_1) - K(0)\mathrm{N}(\mathrm{d}_2)e^{-t(\alpha_h - \alpha_k)} \tag{12}$$

where:

$$\mathrm{d}_1 = \frac{\ln \frac{V_1}{K(0)} + (\alpha_h - \alpha_k + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

$$\mathrm{d}_2 = \mathrm{d}_1 - \sigma\sqrt{t}$$

$$\sigma^2 = \text{Variance}\left(\frac{d[(\frac{V_1}{K(\tau)})]/(\frac{V_1}{K(\tau)})}{dt}\right) = \sigma^2_v + \sigma^2_k - 2\sigma_{vk}\sigma_v\sigma_k$$

and N(.) is the cumulative standard normal density function.

I then substitute (12) in (7) for $B(t)$ to get the present value of the expected benefits firm *i* will receive from successful innovation.

R&D costs x and y will be incurred so long as no firm has made a breakthrough or until any of the firm has succeeded. For firm *i* this flow of expenditure will occur with a probability density $[\lambda + f(x)]\, e^{-t(\lambda + f(x))}$. Hence, the expected value of outlays is given by

$$\int_0^{\infty}\left[(\lambda+f(x)e^{-t(\lambda+f(x))}(\int_0^{t} xe^{-r\tau}d\tau)\right]dt.$$

$$= \frac{x}{[\lambda+f(x)+r]} \tag{13}$$

That is, the present value of R&D investment is computed as the R&D spending discounted by the sum of the relative probabilities of innovation and the risk-free rate of interest.

The problem of firm *i* is to choose the level of R&D investment which maximizes the net present value of expected benefits from the new product. Thus, its objective function is to:

maximize [present value(R&D project) - present value (R&D cost)]

$$\equiv \textit{maximize}\ \frac{B(t)f(x)-x}{(\lambda+f(x)+r)}. \tag{14}$$

The first order condition with respect to x, dropping the subscripts and taking λ as given, becomes

$$f'(x)B(t) + \frac{xf'(x)}{\lambda+r} - \frac{\lambda+f(x)+r}{\lambda+r} = 0 \tag{14'}$$

and the second order condition is

$$f''B(t) - 2f'B(t) - \frac{2xf'}{\lambda + r} + \frac{3f'(\lambda + f(x) + r)}{\lambda + r} < 0 \qquad (14'')$$

where f' and f'' are the first and second derivatives of $f(x)$ with respect to x, respectively.

Suppose $x = x^*$ is the solution for (14), x^* would then be the level of R&D investment that guarantees the optimal net benefits. Equation (14), therefore, defines x^* as a function of y, N, r and B. I will denote this as $x^* = x^*(y, N, r, B(t))$. From (14') and (14"), we have

$$x^* = \frac{(\lambda + f(x) + r)}{f'} - f(x)B(t)(\lambda + r) \qquad (15)$$

Suppose we make a Cournot assumption, that each firm expects no reaction from the other competitors in response to a change in its investment strategy. If their expectations are all rational, then (15) provides a Cournot-Nash equilibrium of R&D investment. Differentiate (15) totally with respect to λ to obtain:

$$\frac{dx^*}{d\lambda} = \frac{1 + f'}{f} - \frac{f''(\lambda + f + r)}{f'} - fB - f'B(\lambda + r) > 0$$

implying that as competition increases, firm *i* will spend more on R&D. Also,

$$\frac{dx^*}{dB(t)} = \frac{f' - f''(\lambda + f + r)}{f'} - f(\lambda + r) - f'B(\lambda + r) > 0,$$

indicating that the larger the value of the expected real growth option, the higher the potential for increased investments in R&D for a particular firm.

Suppose G is the value of the real R&D growth opportunity given by (7). Substituting for $B(t)$ from (12) and using the optimal R&D investment level x^*, we have:

$$G = \frac{f}{\lambda + f(x) + r}\left\{V_1 N(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha)}\right\} \tag{16}$$

The effect of each of the parameters in (16) on G can be analyzed. It is easy to see that $dG{\cdot}d\lambda < 0$, meaning that more intense competition eventually leads to reduced expected value of the growth opportunity firm i will reap. Putting it differently, *ceteris paribus*, a higher probability of success for one or more of the competing firms is bad news for firm i.

2.3 The Monopoly Case

Consider a monopolist making R&D investment of x in order to receive benefit B_m at time t when the R&D is successful. The monopolist is protected by barriers to entry and the probability that it would make the innovation by that time is $1 - e^{-f(x)t}$. Thus it would seek to maximize the present value of the expected net benefit from the discovery:

$$max\ \frac{B_m f(x) - x}{f(x) + r}. \tag{17}$$

The solution for (17) requires that the first and second order conditions be satisfied which are, respectively,

$$x = \frac{(f + r) - rB_m f'}{f'}, \tag{17'}$$

$$\text{and} \quad rB_m f'' - xf'' < 0. \tag{17''}$$

2.4 The Case of Collusion

Suppose these N firms now collude to undertake the R&D investment. Under the terms of the cooperation they will share the receipts of total benefits from the innovation so long as any one of them succeeds by time t. This would occur with a probability density function of $[\lambda + f(x)]\ e^{-t(\lambda + f(x))}$. Let $(\lambda + f) = (N\text{-}1)f + f = Nf$, assuming the existence of Cournot-Nash equilibrium. Therefore, the objective in this case is to maximize total expected net benefit with respect to x and N:

$$max\ \frac{B_c Nf - Nx}{Nf + r} \tag{18}$$

The necessary conditions for x to be a solution are

$$x = \frac{(Nf + r) - rB_c f'}{Nf'} \tag{18'}$$

$$\text{and} \quad rBcf'' \div Nxf'' < 0. \tag{18''}$$

Also, for N to be a solution to (18) requires the following first and second order conditions:

$$N = \frac{rB_c f + x(f - r)}{xf} \tag{18'a}$$

and $-xf < 0.$ (18''a)

Equation (18'a) gives some interesting results. More firms are attracted to join a cartel the larger the value of expected growth option ($\frac{dN}{dB} > 0$). Furthermore, suppose N *is* continuous, it can be shown that as N increases the R&D expenditure of each firm declines ($\frac{dN}{dx} < 0$). However, there is an optimal size of the cartel if the participating companies maximize total net benefit.

By examining (15), (17') and (18) we find firms pursue different R&D investment strategies under different market structures. Suppose $B = B_m$, equations (15) and (17') imply that a rival competitive firm invests more in R&D than a monopolist especially if $f < \frac{1}{B}$. It would seem that factors on which B depends influence the over-investment or under-investment of a rival firm in R&D. For example, a higher strike price will result in over-investment in a comparable project since the option value is lower. Alternatively, if optimal R&D investments are equal, then $B < B_m$. The implication is that a firm under rivalry would need to spend more in R&D in order to be able to reap sufficient potential benefits to match a monopolist. We also note that the expected benefits a successful firm receives under collusion is larger than that under rivalry ((15) and (18')). Again, this depends on the parameter values. A firm is attracted to enter a collusive agreement especially if $(xf'+f) > \frac{r(\lambda + r)}{\lambda}$. On the other hand, if $B = B_c = B_m$, there would always be an over-investment under competitive rivalry. Given equal net research and development investments, the expected benefits accruing to a monopolist is often larger than those due to collusion or perfect competition ($B < B_c < B_m$).

2.4 Marketing Decision

To capture a wider consumer market and subsequently generate larger revenues from this new product, we assume that the firm must commit to additional expenditures on advertising and developing the distribution network. The reason is that even if a product has already been developed, its market has not. Prices and other conditions in the factor and product markets may change as news of the new product is analyzed. As a result, the firm may have to commit some funds for advertising and marketing in order to make and facilitate the market. The firm can only choose to incur marketing costs if the benefit it generates consequently is higher than the benefit it would have earned without this additional expenditure. Here, we adopt with modifications, the valuation approach of Margrabe (1978) and Carr (1988) that price the options to exchange one risky asset for another.

I suppose that the firm would spend m in expectation of receiving a higher present value of cash flows of V_2, where $V_2 > V_1$. V_2 is defined as in (10). Certainly, V_2 depends on V_1 and hence, on the success of the R&D investment. I assume that V_2 also follows a stochastic process with return α_2, volatility σ_2, and dz_2 as its Wiener process. I further assume that there is a correlation between the Wiener processes, dz_v and dz_2, which is denoted by σ_{v2} since V_1 and V_2 are correlated. By paying *m* in marketing costs, firm *i* effectively purchases the option to exchange V_2 for V_1. *m* is the cost of this option. Suppose V_1 and V_2 are lognormally distributed, then

$$\text{Variance}\left(\frac{d[(V_2/V_1)]/(V_2/V_1)}{dt}\right) = \sigma^2{}_v + \sigma^2{}_2 - 2\sigma_{v2}\sigma_v\sigma_2 = \rho^2 \tag{19}$$

where ρ^2 measures the total uncertainty underlying this subsequent marketing investment. The option to exchange V_2 for V_1, when exercised at some specific maturity date t_2 will yield $V_2 - V_1$, and zero if unexercised. This exchange option is equivalent to a call option on an asset of value V_2 with a strike price V_1. The exercise decision implies

$$M(V_2, V_1, \rho, t) = max\,[V_2 - V_1,\ 0] \tag{20}$$

where *M* is the intrinsic value of the call. When adjustments are made to the standard Black-Scholes pricing formula, the value of the exchange call option can be obtained (See Carr (1978) and Margrabe (1978)). Thus, we have:

$$M(V_2, V_1, \rho, t) = V_2N(d_3) - V_1N(d_4) \tag{21}$$

$$\text{where: } d_3 = \frac{\ln\left(\frac{V_2}{V_1}\right) + \rho(t_2 - t)}{\rho\sqrt{(t_2 - t)}}$$

and $d_4 = d_3 - \rho\sqrt{(t_2 - t)}$

2.5 Overall Value of the Growth Opportunity

In sum, the market value of the growth opportunity, G_v, due to the basic R&D investment is the real growth option value G plus an exchange option on this growth value M pertaining to additional investments in advertising and marketing. That is,

$$G_v = G - Me^{-rt}$$

$$= \frac{f}{\lambda + f + r}\left\{V_1 N(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\right\} + e^{-rt}[V_2N(d_3) - V_1N(d_4)] \quad (22)$$

CHAPTER 3

COMPARATIVE STATIC ANALYSIS

I carry out comparative static analysis of the model presented in chapter two. The relationship between any two variables is determined each time, holding other variables constant. For the purpose of this dissertation, only the parameters of interest and relevance are examined.

3.1 R&D with Competition.

Under the assumption of perfect collusion, equation (18) leads us to express R&D expenditure of a firm (x) and the number of competitive firms in a collusion (N), as in equation (18'):

$$x = \frac{(Nf + r) - rB_c f'}{Nf'}$$

Thus,

$$\frac{dx}{dN} = \frac{fNf' - f''(Nf + r) - f'' rB_c f'}{N^2 f'^2} > 0$$

since, from equation (4), $f(0) = 0$, $f'(x) = 0, x \rightarrow \infty$, and $f''(x) < 0$. The result implies that as competition increases, a firm is likely to spend more on R&D.

3.2 R&D of a Firm with Rival R&D

Assuming x^* is the optimal level of R&D of a firm and y is the R&D of a rival company. Equation (15) expresses a link between the two:

$$x^* = \frac{(\lambda + f(x) + r)}{f'(x)} - f(x)B(\lambda + r), \text{ where } \lambda = f(y).$$

Differentiate the above equation totally with respect to *y* to obtain:

$$\frac{dx^*}{dy} = \frac{f'(x)f'(y)}{[f''(x)]^2} - f(x)f(y)B.$$

The sign of this derivative is not obvious. It will be positive if the first term on the right hand side is larger than the second term on the same side. It would be negative otherwise. It is likely that, because of the size of B, the sign would be negative.

3.3 Growth Opportunities with R&D

The fundamental model of this study is given by equation (16):

$$G = \frac{f}{\lambda + f + r}\left\{V_1 N(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\right\}$$

Thus,

$$\frac{dG}{dx} = \frac{\lambda f' + rf'}{(\lambda + f + r)^2}\left\{V_1 N(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\right\} > 0,$$

implying that R&D contributes positively to growth opportunities.

3.4 Growth Opportunities with Rival R&D

The derivative of growth opportunities with respect to rival R&D (*y*) is expressed (from equation 16) as follows:

$$\frac{dG}{dy} = \frac{-f(x)f'(y)}{[f(x)+f(y)+r]^2}\left\{V_1N(d_1) - K(0)N(d_2)e^{-t(\alpha_h-\alpha_l)}\right\} < 0,$$

meaning, larger investments in R&D of rivals have a negative impact on a firm's growth opportunities.

3.5 Growth Opportunities with Size of Monopoly Rent

Given,

$$G = \frac{f}{\lambda+f+r}\left\{V_1N(d_1) - K(0)N(d_2)e^{-t(\alpha_h-\alpha_l)}\right\}$$

and the expressions of d_1 and d_2 from equation (12), the derivative of G with respect to V_1 is:

$$\frac{dG}{dV_1} = \left[\frac{f}{\lambda+f+r}\right]\left[N(d_1)N'(d_1) - N'(d_2)\left\{K(0)N(d_2)e^{-t(\alpha_h-\alpha_l)}\right\}\right] > 0,$$

since as $V_1 \to \infty$, $d_1 = d_2 = +\infty$ and $N(+\infty) = 1$. $N'(d_1)$ and $N'(d_2)$ are derivatives. Thus, the larger the monopoly rent to be derived from a successful innovation, the greater the size of growth opportunities.

3.6 Growth Opportunities with Strike Price

The derivative of G with respect to K is as follows:

$$\frac{dG}{dK} = [\frac{f}{\lambda + f + r}][-N'(d_1) - N(d_2)(-)N'(d_2)\ \{K(0)N(d_2)e^{-t(\alpha_h-\alpha)}\}] = 0,$$

since if $K \to \infty$, then $\ln\frac{V_1}{K} \to -\infty$, and $d_1 = d_2 = 0$. It implies that increasing level of strike price, other factors held constant, causes the value of the real growth option to be worthless.

3.7 The Impact of R&D on the Expected Time of Discovery

We find that the effect of the incremental change in R&D investment on the expected time for successful completion of the R&D project is given as:

$$\frac{dt}{dx} = \frac{f'(x)[f(y) - f(x)]}{[f(x)+f(y)]^3} < 0 \text{ if } f(x) > f(y).$$

That is, increasing levels of R&D lowers the expected time of innovation if a firm's success rate is higher than the rival's.

3.8 Growth Opportunities and the Expected Time of Innovation

The derivative of G with respect to t, the maturity date for the real growth option, follows:

$$\frac{dG}{dt}=\left(\frac{1}{2}\right)\left[\frac{f(x)}{f(x)+f(y)+r}\right]*$$

$$\left[V_1 N(d_1)N'(d_1)\frac{\alpha_h-\alpha_k+\frac{\sigma^2}{2}}{\sigma\sqrt{t}}+N(d_2)N'(d_2)(\alpha_h-\alpha_k)K^{-t(\alpha_h-\alpha_k)}\left(\frac{\alpha h-\alpha k+\frac{\sigma^2}{2}}{\sigma\sqrt{t}}-\frac{\sigma}{\sqrt{t}}\right)\right]=0$$

as $t \rightarrow +\infty$. Therefore, as time of discovery drags further into the future, the value of growth opportunities vanishes.

3.9 Growth Opportunities with Return on Hedge Portfolio

The derivative of G with respect to α_h is as follows:

$$\frac{dG}{d\alpha_h} = \left[\frac{f}{\lambda+f+r}\right]\left[tV_1 N'(d_1) + (\alpha_h - \alpha_k)t(\sigma\sqrt{t})^{-1}N'(d_2)\ \left\{K(0)N(d_2)e^{-t(\alpha_h-\alpha_k)}\right\}\right] > 0$$

since $d_1 = d_2 = +\infty$, as $\alpha_h \rightarrow +\infty$ and $N'_1 = N'_2 = 1$. Thus, the value of the growth option increases with the cost of hedging volatility in the strike price.

CHAPTER 4

SCENARIO ANALYSIS: A CASE STUDY OF A BIOTECHNOLOGY COMPANY

4.1 Company Background

In the Fall of 1995, John Anderson and Jane McCarthy launched Othogen Incorporated[9], a New York start-up biotechnology laboratory located in Long Island. The name Othogen will soon become synonymous with weight-loss if the company succeeds in obtaining a patent on its unique gene-splicing technique that has the potential to deliver a cure for obesity. It would revolutionize an industry that is in urgent need for a safe cure but has patients now skeptical of all claims by companies making obesity drugs because of ineffectiveness and worries of side effects. In September 1997, American Home Products Corporation made a surprise recall of Redux and Fenfluramine, two leading drugs in that market, because of new evidence showing they are linked to serious heart-valve problems[10].

Othogen's dream is to identify genetic markers for obesity by splicing genes from affected people into bacteria and studying the strands of DNA (deoxyribonucleic acid) that these patients have uniquely in common[11]. The approach is to identify defective genes and match them with their specific functions in the cell. The bad genes are believed to set on a type of enzyme which inhibits the function of serotonin, a chemical

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[9] Othogen Inc. is a hypothetical company.

[10] The Wall Street Journal, November 25, 1997, page B1.

[11] A gene is the element or unit of a chromosome that carries and transfers an inherited characteristics from parent to offspring and determines the development of some particular character or trait in the offspring. Chromosomes are structures in the cell nucleus containing DNA. DNA is the material of which genes are made.

substance which causes muscles contraction and whose deficiency affects mental activity. So the challenge is not only to slow down the enzyme but to switch off the genes that set the enzyme to work. Because defective genes simply can't be snipped out, Othogen's technique will deactivate them by inserting copies of the genes made in reverse.

Othogen Inc. is among a growing list of firms that believe identifying human genes will provide important new leads to medicines against a wide range of diseases that continue to defy adequate treatment. John Anderson, a renowned research neurologist, left academia to seize the opportunity. He adds that at this point in his career, he is interested in finding "cures," not just causes of diseases, and "only companies do that, not universities." John has teamed up with Jane McCarthy, a former graduate student who has been with Spectra Biomedical Inc., a Menlo Park, California company until the firm was acquired by Glaxo Wellcome PLC.

4.2 Market Trend

According to a report in the Journal of the American Medical Association[12], some 58 million people in the U.S. weigh at least 20% more than their ideal body weight- making them, in the terminology of dietary science, obese. The report shows that the percentage of teens who are overweight, which held steady at about 15% through the 1970s, rose to 21% by 1991. Despite a plethora of diet and fitness programs since the 1980s, Americans have actually put on more weight that they have lost. The average weight gain between the ages 30 and 39 is 4 pounds for men and 9 pounds for women.

Of the estimated 80 million Americans who go on a diet each year, 95% gain it back within five years.

Results from a long-term study conducted by the Center for Disease Control (CDC)[13] show that the number of Americans who are seriously overweight, after holding steady for 20 years at about a quarter of the population, jumped to one-third in the 1980s, an increase of more than 30%. A survey across the country indicates there are deep pockets of obesity, especially in rural areas and among certain racial and ethnic groups. The CDC study found that the prevalence of obesity was nearly 50% for black and Mexican-American women - compared with 33.5% for white women. In some Native American communities, up to 70% of adults are dangerously overweight.

In all gender, income and racial groups, genetic factors play a role. Scientists now know that body weight control is linked to the function of the brain which regulates the rate of metabolism. However, what has never been determined was how that process is biologically triggered and if the elements that create it could be identified, isolated and blocked. The discovery of defective genes responsible for obesity and the technique to switch them off for good will revolutionize the industry. Othogen believes they will not just control the disease but conquer it.

It is estimated that the overweight industry is about $80 billion a year. Othogen plans to initially target the seriously obese patients. This is an $800 million niche. The company hopes the technique will eventually catch on to include people under 20% overweight, or even those who desire cosmetic weight loss. And the possibility of opening up the global market appears to have great potential.

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[12] Time Magazine, January 16, 1995, pages 58-65.

4.3 Industry Competition

Othogen faces stiff competition in the industry. The Food and Drug Administration (FDA) in November approved Meridia which acts on the brain to produce a feeling of fullness. The obesity drug which could hit the market sometime in 1998 is made by Knoll Pharmaceutical Company, a unit of Germany's BASF AG. However, besides its less dramatic weight loss effects, the drug has some side effects including dry mouth, constipation, high blood pressure, headache and insomnia.

American Home Products Corporation in September withdrew Redux and Fenfluramine from the market after the FDA determined that patients who were on these obesity drugs had developed primary pulmonary hypertension, a rare lung disease. Like Meridia, Redux and Fenfluramine act to boost the level of serotonin chemical in the brain in order to curb the appetite by helping a person feel full and satisfied.

Still, more competition could come soon from Roche Holding Ltd. The company recently resubmitted its application for approval of its widely awaited obesity drug Xenical, whose clearance had been delayed because of breast-cancer concerns. Experts say Xenical works by a different mechanism and, if approved, could be used in combination with Meridia.

Othogen is confident that their work would be the first of its kind to really introduce a cure for the disease. The firm says the approach of all other obesity drug companies has been to view obesity as a chronic disease, much like high blood pressure, that requires life-long therapy. Moreover, the products of these companies deliver short-

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[13] Ibid.

lived results and their effects on brain chemicals are apt to produce harmful side effects. Othogen's gene technology would essentially get rid of the defective genes and enhance good ones, freeing the body of any side effects. In addition, no patient with a history of any serious complications like stroke, coronary artery disease, congestive heart failure or uncontrolled hypertension would be excluded from this treatment.

Othogen, nevertheless, knows that there is a tough competition to face. Many research laboratories in academia, pharmaceutical and biotechnology companies are increasingly using gene-hunting technology as a way of looking for drugs. Thanks to the Human Genome Initiative, an international project partly funded by the U.S. government, to map the nearly 100,000 genes found on human chromosomes. The project hopes that by the year 2010 the structure and function of almost all human genes will be understood.

And there is Eli Lilly & Company, the architect of Prozac, the world's leading antidepressant. There is word that Eli Lilly that has been in the forefront of research on central-nervous-system (CNS) receptors is looking for appetite suppression drugs, now that the patent protecting Prozac is expiring in five years. Also, Glaxo Wellcome PLC, Pfizer Inc., Du Pont, Ciba-Geigy, General Electric, Upjohn, Dow Chemical, Merck & Co., Genentech and SmithKline Beecham PLC that have bet huge investments in genetic engineering technology are cited as competitors.

Othogen is aware that to capture the market they must win this competitive race to innovate. John and Jane still recall the words of Steve Paul, Eli Lilly's director of research and development. "CNS research is a game of probabilities. If you have a lot going on, the probability of one compound becoming a breakthrough drug is much higher."[14] Othogen believes they are in what they are best at, with a concept which when adequately financed could be a blockbuster. Competition in their view merely serves to build primary demand.

4.4 Risks

Some industry experts caution that biotech firms are overly futuristic, gambling with investments whose payoffs are elusive. Basic R&D investments are by nature uncertain. It may be truly a game of probability. While Othogen is not certain about the date it would win the race to innovate, it is at the same time uncertain about when any of its competitors would instead be first in making the discovery.

More expensive equipment and more insidious diseases have driven the average cost of developing a new drug at big pharmaceutical and biotechnology companies to $231 million, more than doubled the inflation-adjusted cost a decade ago[15]. A firm that wants to build leadership position in such highly competitive and risky markets must develop innovative products and techniques through a painful process, often willing to swallow heavy loses along the way.

Othogen also must face the public perception of genetic engineering, or gene transfer. According to a survey conducted by Prof. Thomas Hoban at North Carolina State University, two-thirds of consumers believe they will personally benefit from biotechnology, and almost 75% believe biotechnology will have a positive effect on food quality and nutrition[16]. However, survey respondents seem unwilling to accept gene

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[14] Burton, T.M., *The Wall Street Journal*, June 12, 1996

[15] BusinessWeek, July 1, 1991.

[16] Genetic Engineering: Oppcsing Viewpoints, Greenhaven Press, Inc., San Diego, 1996.

transfers between plants and animals or between humans and farm animals. This poses a threat to Othogen's plans to use plant genes instead of human genes which are much more expensive to extract. After all, they thought, humans can incorporate plant genes and vice versa, because all living organisms read the same genetic language.

Othogen is troubled that it will unfairly get the taint of biotechnology research from groups including religious organizations concerned about the sanctity of life, environmentalists worried about the release of genetically altered organisms, farmers anxious about paying patent royalties for their animals, and animal protectionists concerned about the increased exploitation and suffering of animals.

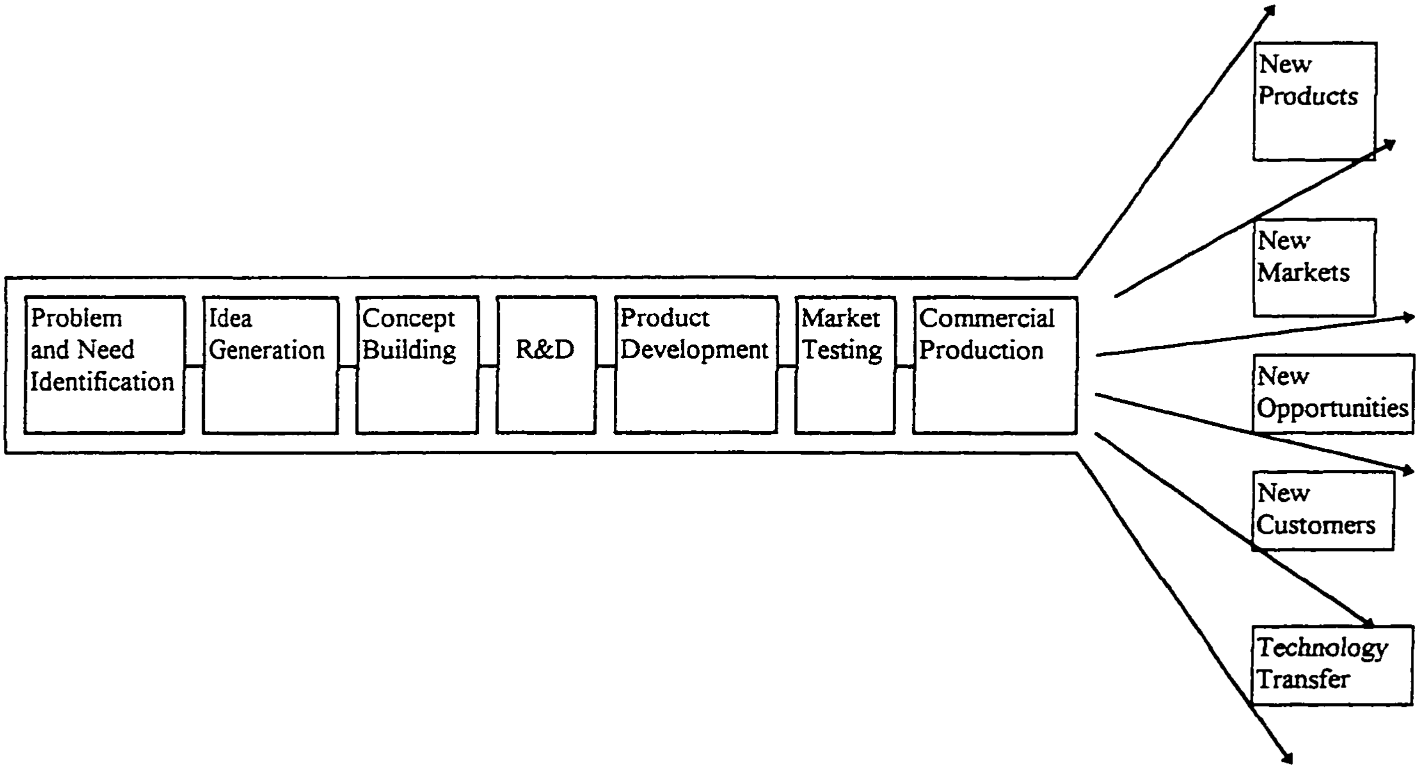
There are significant regulatory hurdles also to overcome stemming from the need to assure the public that the products are safe. Each biotech product currently requires an extended regulatory approval period which, unfortunately, does not take into account the time dimension of capital invested.

Product liability cases is another risk area. Richard Mahoney, Chairman & CEO of Monsanto Company recently warned, "wait until start-up companies see what larger companies have been facing for years in tort cases. Monsanto can handle it, we have the staying power to deal with these obstacles and we have had to face them before. But can the many superb science-based start-up companies do it with their funding limitations? May be - may be not."[17]

At one point, Othogen mulled over the idea of teaming up with other firms to carry out this project. The goal of such a collaborative deal would be to defray costs, spread risks and promote the cross-fertilization of ideas. Jane McCarthy experienced such an arrangement in the industry before. Bio Chem Pharma of Canada hatched an AIDS therapy, Glaxo Holdings of U.K. shepherded its clinical trial, and Burroughs Wellcome of U.K. did the marketing. However, alliances are not without drawbacks. They are hard to manage. Turf battles, miscommunication and mistrust often emerge among members. Worse still, lack of commitment and what to offer to the alliance may develop.

Othogen is aware that in order to survive, they must go beyond research and development into production and marketing. They are now ready to see how, given the idea, speed, risk and competition, the payoff stacks up.

Figure 3: Innovation Flow Chart



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[17] Bender, David and Bruno Leone, ibid, pp35

4.5 Investment Analysis

4.5.1 *Expected Time of Innovation*

R&D investment is crucial in impacting the speed at which Othogen or any other competitive firm could win the competitive race to innovate. The conditional probability of success for a monopoly firm is given in chapter 2 by equation (3), $E[\tau(x)] = \frac{1}{f(x)}$, and for a competitive firm by equation (7a), $E[\tau(x)] = \frac{f(x)}{[\lambda + f(x)]^2}$. Suppose Othogen's success rate is denoted by $f(x)$, and that of a competitor, say Genentech's, is represented by $\lambda = f(y)$, both expressed as percentages . The expenditures on R&D for each firm is assumed to be known and every dollar invested is assumed to be equally valuable.

Table 1A shows that if Othogen were a monopolist, its expected time to innovate would decline systematically as the probability to succeed increases. Suppose Othogen now competes with Genentech. The introduction of a competitor drastically lowers the discovery time as in table 1B. However, increasing number of firms lowers the expected value per unit of R&D that each firm receives (figure 5, assuming collusion). It appears an improvement in the success rate for Genentech is also good for Othogen, especially if Othogen has a higher probability. Now consider Genentech at 30% success rate. It is clear that the expected time of innovation first rises as Othogen's probability to succeed goes up, reaching a peak when the rate for Othogen also hits 30%, then it declines thereafter. Does it imply Othogen should settle for a success rate below Genentech's for the sake of achieving a shorter time to innovate? Certainly not if it wants to reap a larger share of the resultant payoff.

Table 1A: The impact of probability of success (f(x)) on the expected time of discovery, $[E(\tau)] = \frac{1}{f(x)}$. Othogen as a monopoly firm.

f(x)	5	10	15	20	25	30	40	45	50	60	75
E(τ)	20.0	10.0	6.7	5.0	4.0	3.3	2.5	2.2	2.0	1.7	1.3

Figure 4: Impact of success rate on expected time to innovate [Source: Table1A]

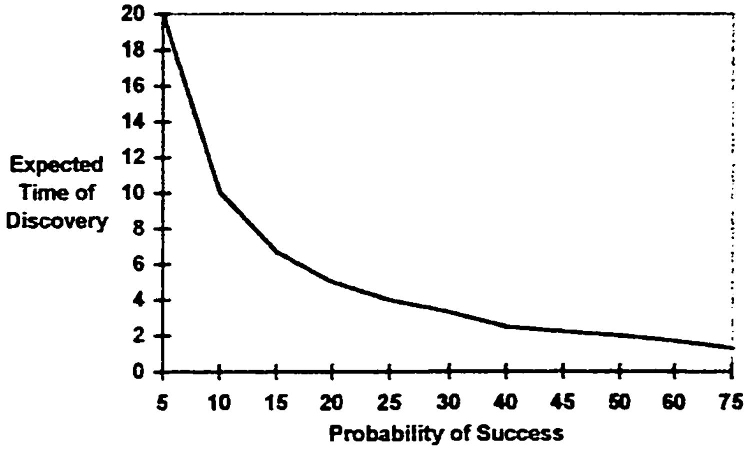
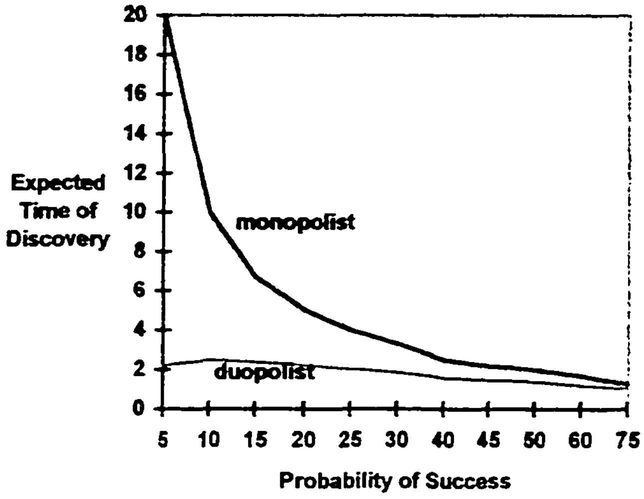


Table 1B: The effect of the conditional probability of success on the expected time of discovery. Othogen as a duopoly firm, E[$\tau(x)$]=$\frac{f(x)}{(\lambda+f(x))^2}$. $f(x)$ is the conditional probability for Othogen, and $\lambda = f(y)$ is the conditional probability for Genentech.

	λ	5	10	15	20	25	30	40	45	50
$f(x)$	5	5.00	2.22	1.25	0.80	0.56	0.41	0.25	0.20	0.17
	10	4.44	2.50	1.60	1.11	0.82	0.63	0.40	0.33	0.28
	15	3.75	2.40	1.67	1.22	0.94	0.74	0.49	0.42	0.36
	20	3.47	2.22	1.63	1.25	0.99	0.80	0.56	0.47	0.41
	25	2.78	2.04	1.56	1.23	1.00	0.82	0.59	0.51	0.44
	30	2.44	1.88	1.48	1.20	0.98	0.83	0.61	0.53	0.47
	40	1.98	1.60	1.32	1.11	0.95	0.82	0.63	0.55	0.49
	45	1.80	1.49	1.25	1.07	0.92	0.80	0.62	0.56	0.49
	50	1.65	1.39	1.18	1.02	0.89	0.78	0.61	0.55	0.50
	60	1.38	1.22	1.07	0.94	0.83	0.74	0.60	0.54	0.49
	75	1.17	1.04	0.93	0.83	0.75	0.68	0.57	0.52	0.48

Figure 5: The impact of competition on discovery time [Source: Table 1B]



4.5.2 *Determining R&D Expenditure Levels*

The framework is based on the model of biotechnology firms under collusion (equation 18'a), $N = \dfrac{rB_c f + x(f - r)}{xf}$, and any drawback to the alliance is assumed away. $f(x)$ represents the instantaneous probability of success for Othogen, and if the collusion is efficient then individual success rates would be indistinguishable, and each firm's probability would equal $f(x)$. B denotes the present value of the cash flows from the completed project, r represents the risk-free rate and N is the number of companies in the cartel. R&D spending is in million of dollars.

Table 2A shows that as the number of firms increases, the amount of R&D expenditure per firm declines, other factors held constant. Assume that Othogen is the sole company pursuing this type of project. As observed earlier, in order for the firm to make a faster discovery it must have a high probability of success. Table 2B implies that the firm must incur larger amounts of R&D spending to realize this. Also, the risk-free rate which reflects the cost of capital in the market, is positively related with the size of R&D (table 2D). Doubling of the risk-free rate leads to almost double the required amount of R&D. Table 2C indicates that R&D increases with both the level of expected benefits of the project and the success rate.

Table 2A: R&D (x) with changing N, the number of firms competing in the industry. $N = \frac{rB_c f + x(f - r)}{xf}$. $f(x) = 15\%$, is the success rate for a firm (for simplicity here assumed equal for all firms). The risk-free rate of interest, $r = 7\%$. And $B = \$800$ million is the project value. R&D is in millions of dollars.

n	1	2	4	8	16	32	50	75	100	120
R&D	120	38.18	16.15	7.5	3.62	1.78	1.13	0.75	0.56	0.47

Table 2B: R&D (x) with changing $f(x)$, the conditional probability of making the innovation. $N = \frac{rB_c f + x(f - r)}{xf}$. $N = 4$, is the number of firms competing in the industry. $r = 7\%$, is the risk-free rate of interest. And $B = \$800$ million is the project value. R&D is in millions of dollars.

$f(x)$	2	5	10	15	20	25	30	35	40	50
R&D	8.62	12.73	15.14	16.15	16.71	17.07	17.32	17.50	17.64	17.83

Table 2C: R&D (x) with changing $f(x)$, the conditional probability of making the innovation. $N = \frac{rB_cf + x(f-r)}{xf}$. B is the project value, in millions of dollars. $N = 4$, is the number of firms competing in the industry. $r = 7\%$, is the risk-free rate of interest.

	f((x)	**5**	**15**	**25**	**35**	**50**	**60**
B	**50**	0.795	1.009	1.067	1.094	1.115	1.123
	100	1.591	2.019	2.134	2.187	2.229	2.245
	200	3.783	4.179	4.268	4.375	4.458	4.491
	500	7.955	10.096	10.670	10.937	11.146	11.229
	1000	15.909	20.192	21.341	21.875	22.292	22.459
	1200	19.091	24.230	25.609	26.250	26.751	26.952
	1500	23.863	30.288	32.012	32.812	33.439	33.689

Table 2D: R&D (x) with changing r, the risk-free rate of interest.. $f(x) = 15\%$, is the conditional probability of success. $N = \frac{rB_cf + x(f-r)}{xf}$. $N = 4$, is the number of competing firms. And $B = \$800$ million is the project value. R&D is in millions of dollars, and r is in percentage.

r	5	7	9	11	13	15	17
R&D	12.00	16.15	20.00	23.57	26.89	30.00	32.90

4.5.3 *Computing the Value of Growth Opportunities*

Equation (16) is the model for determining the value of growth opportunities (G) that Othogen will derive if it succeeds in winning the competitive race to discover a breakthrough cure for obesity, $G = \frac{f}{\lambda + f(x) + r}\{VN(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\}$. Given a market potential value (V) of \$800 million, it is assumed that the company expects total cost ($K(0)$) of manufacturing, promotion and marketing to be \$250 million. However, the company strongly feels that the actual cost may change by the time the R&D project is completed. The expected return on this cost structure (α_k) is estimated to be 10% with a standard deviation (σ_k) of 30%. It is possible that Othogen could hedge this uncertainty and the cost of this operation (α_h) is estimated to be 12% annually. The production project is highly correlated (σ_{vk} = 60%) with the R&D project. The risk-free rate (r) is 7%.

Othogen is not a diversified entity. Analysts believe it is in the 20% risk (σ_v) class. Industry experts put the company's probability of making a breakthrough discovery at 25%, compared with Genentech's 10%, its only known competitor. Market research estimates a test parameter (∇) of 1.25 is reasonable for this industry sector, given the potential of this company. This parameter accounts for FDA approval period and any clinical trials once the innovation is successful. The market test parameter tends to be higher whenever competing products already exist in the market.

Given all the parameter values, table 3A shows that Othogen would generate growth opportunities (G) valued at \$337,281,000. Figure 6 depicts the call option nature of growth opportunities. It is also clear that growth opportunities increase with expected return on the hedge security (table 3B), decrease with expected return on the strike price (table 3C), increase with volatility of the strike price (table 3D), and increase with volatility of the R&D project (table 3E). However the magnitudes of the impact of these variables on the growth option differ. When growth elasticity constants are computed, the hedge security return is found to have the greatest influence, followed by the expected rate of return on the strike price, volatility of the strike price and volatility of the R&D project with the least impact. Table 3F presents a summary of the influence of each of the variables on growth opportunities.

Table 3A: Valuation Worksheet. An analysis of the model specified by $G = \frac{f}{\lambda + f(x) + r}\{VN(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\}$. The value of the growth opportunities (G) that can be assigned to Othogen is computed using the parameter values explained in the table. d_1 and d_2 are Black-Scholes constants expressed in equation (12), $d_1 = \frac{\ln\frac{V}{K(0)} + (\alpha_h - \alpha_k + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$ and $d_2 = d_1 - \sigma\sqrt{t}$. The conditional volatility of the real option is $\sigma^2 = \sigma^2_v + \sigma^2_k - 2\sigma_{vk}\sigma_v\sigma_k$. G, V and $K(0)$ are in millions of dollars.

Variable	**Notation**	**Value**
Hedge Security Rate of Return	α_h	12.00%
Risk-free Rate of Interest	r	7.00%
Exercise Price Rate of Return	α_k	10.00%
Exercise Price Volatility	σ_k	30.00%
Volatility of Project Value	σ_v	20.00%
Correlation Coefficient (V, K)	σ_{vk}	60.00%
Conditional Variance of R&D Project	σ^2	0.20606
Othogen's Probability of Success	$f(x)$	25.00%
Genentech's Probability of Success	$f(y) = \lambda$	10.00%
Expected Expiration Date	$E(\tau) = t$	2.04082
Market Test Parameter	∇	1.25
Gross Project Value	V	800.00
Expected Exercise Price	$K(0)$	250.00
d_1		2.47325
d_2		1.74822
Cumulative Standard Normal (d_1)		0.99331
Cumulative Standard Normal (d_2)		0.95979
Value of Growth Opportunity	G	**337.2812**

Figure 6: Intrinsic value of growth opportunities. The strike price = $250 million, and all other parameters are assumed constant at values as in table 3A.

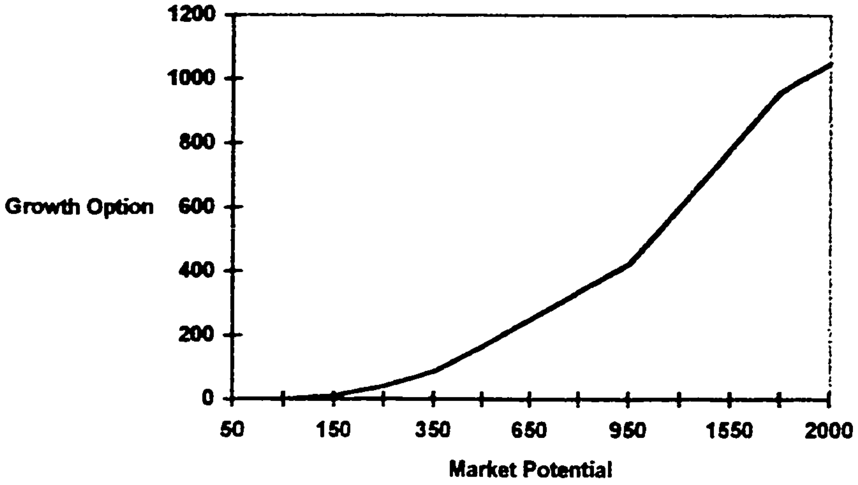


Table 3B: Effect of hedge security return (α_h) on growth opportunities $G = \frac{f}{\lambda + f(x) + r}\left\{VN(d_1) - K(0)N(d_2)e^{-t(\alpha_h-\alpha_k)}\right\}$. All other parameters are held constant at values as in table 3A. G is in millions of dollars, and α_h is in percentage.

α_h	5	7	9	12	14	16	18	20	25	30
G	312.2	319.7	326.9	337.3	343.8	350.1	356.2	361.9	375.3	387.2

Table 3C: Effect of exercise price return (α_k) on $G = \frac{f}{\lambda + f(x) + r}\left\{VN(d_1) - K(0)N(d_2)e^{-t(\alpha_h-\alpha_k)}\right\}$. All other parameters are held constant at values as in table 3A. G is in millions of dollars, and α_k is in percentage.

α_k	4	6	8	12	14	18	20	22	26	28
G	356.2	350.7	342.9	337.3	323.3	308.3	300.4	292.3	275.2	266.3

Table 3D: Effect of the variance of strike price (σ_k) on $G = \frac{f}{\lambda+f(x)+r}\{VN(d_1)-K(0)N(d_2)e^{-r(\alpha_n-\alpha)}\}$. All other parameters are held constant at values as in table 3A. G is in millions of dollars, and σ_k is in percentage.

σ_k	5	8	12	18	20	22	25	32	35	38
G	335.3	335.2	335.3	335.7	335.9	336.1	336.4	337.6	338.2	338.9

Table 3E: Effect of the project volatility (σ_v) on $G = \frac{f}{\lambda+f(x)+r}\{VN(d_1)-K(0)N(d_2)e^{-r(\alpha_n-\alpha)}\}$. All other parameters are held constant at values as in table 3A. G is in millions of dollars, and σ_v is in percentage.

σ_v	5	8	12	15	18	25	30	32	35	40
G	337.2	336.8	336.8	336.9	337.1	337.8	338.5	338.9	339.4	340.5

Figure 7: Effect of size of cartel on growth value and R&D.

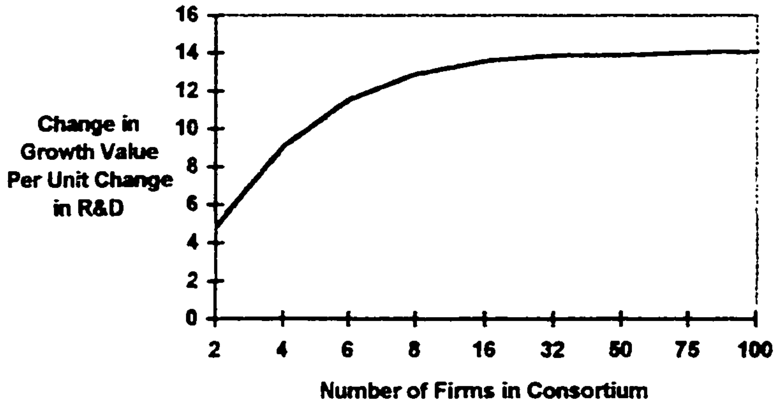


Table 3F: Summary of the effects of changes in the relevant parameters on Othogen's real growth option, $G = \frac{f}{\lambda + f(x) + r}\{VN(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)}\}$. As the level of a variable increases, other factors held constant at values as in Table 3A, G may rise (+), fall (-), vanish (0), or remain undetermined (?).

Variable	**Notation**	**Impact**	**Comment**
Hedge Security Rate of Return	α_h	+	
Risk-free Rate of Interest	r	-	
Exercise Price Rate of Return	α_k	-	
Exercise Price Volatility	σ_k	+	*G* first falls as σ_k rises but starts to increase at about 10%. But when both σ_k and σ_v rise, G always increases.
Volatility of Project Value	σ_v	+	*G* declines as σ_v rises but starts to increase at about 14%. But when both σ_k and σ_v rise, *G always increases.*
Correlation Coefficient (V, K)	σ_{vk}	-	*G* is highest with perfectly negative σ_{vk}.
Othogen's Probability of Success	$f(x)$	+	
Genentech's Probability of Success	λ	-	
Expected Expiration Date	t	-	But $G = 0$ as $t \to +\infty$.
Market Test Parameter	∇	+	
Present Value of Project Cash Flows	V	+	*G* is worthless at about V = \$100m. However, when V=K=\$250m, *G* is still positive at \$41m.
Expected Exercise Price	$K(\tau)$	-	G=0 as $K(\tau) \to +\infty$, especially when K is more than double V. *G* is still positive (\$112m) even when V=K=\$800m.

4.6 Conclusion

Growth opportunities is valued as a call option. It is evident that Othogen can boost its probability of succeeding in making a breakthrough discovery by investing more in R&D, the only observable input. Some competition is good for Othogen. It motivates efficient and speedy R&D investments and builds primary demand. As in an option pricing framework, the expected monopoly rent (underlying asset) and its volatility have positive effect on the real growth option. The strike price and its return rate have a negative impact on growth option but its variance has a positive relationship. The return rate on the hedge security has a positive impact.

I have shown that the growth option model can be conveniently applied in making strategic investment decisions and determining the values of intangible assets. It could be a vital tool for a company like Othogen if all relevant parameters are properly estimated.

CHAPTER 5

EMPIRICAL ANALYSIS

5.1 Data Sources and Empirical Design

5.1.1 Hypothesis

The model presented in chapter 2 provides the basis for the hypothesis to be tested. The purpose of the empirical tests is to examine the impact and relevance of identified variables as determinants of real growth options. Rather than lumping companies together and evaluating their competitive investments in acquiring growth opportunities, we divide the sample into two sub-samples of emerging and mature firms in order to avoid obscuring important qualitative differences that exist between assets-in-place and intangible real growth options. Emerging companies are expected to have predominantly real options in their market value, as opposed to established firms with relatively more assets-in-place.

I have argued that information asymmetry introduces a capital markets constraint on emerging firms making them more dependent on internal capital as a means of accessing strategic growth opportunities. Access to internally generated funds is thus a binding constraint for emerging firms and not for mature firms. One should expect growth in assets, the net investment component of internal capital, to have a positive effect on real growth options of an emerging firm more than they would have on a mature firm. Similarly, the number of patents and R&D spending are variables measuring outcomes of the competitive race for basic R&D. I test if they are valuable, and determine how different their impact on the sub-samples are, together with rival R&D.

For emerging firms, investments in the real options are expected to exhaust internal cash flows. Thus, operating cash flows should have a negative correlation with growth opportunities.

Options pricing theory tells us that volatility of an underlying asset is positively related to the value of the option written on that asset. We therefore expect volatility of potential benefits of innovation to have a positive effect on growth opportunities. Similarly, monopoly rent is expected to have a positive correlation with real growth options. I posit that growth in sales is a good industry indicator of the potential rents to be captured through competitive investments. A measure of industry concentration is also included. However, it is not clear whether a high level of industry concentration signifies available rents.

I hypothesize that due to the nature of the basic R&D investments, capital expenditure is an essential price to pay in order to produce the product and capture the expected benefits resulting from the success of the R&D investments. However, uncertainty of capital requirement levels may be undesirable since it potentially increases the cost of acquiring the benefits and the option value is lowered. A mature company that supposedly has a reservoir of retained earnings and easier access to the capital markets may be better positioned to hedge volatility in capital requirements than an emerging firm.

A number of control variables are incorporated in the analysis. It is conceivable that an old company may capitalize on its long presence in a market, rather than an emphasis on idea generation and new concept building, to compete for potential benefits. I include the age of a company to control for such influences plus incidences like "being-first" advantage. We also include a measure for labor capital to account for contributions to growth due to labor productivity.

Growth opportunities, *G*, is related to a number of relevant parameters (see equation (16)) and is represented as a function:

$$G = G(V, P, K, X, Y, \sigma_v, \sigma_k, \alpha, D, CF, ET, L), \tag{23}$$

where *V* represents the expected monopoly rents to be derived once the R&D is successful and the manufacturing investments are in place; *P* denotes the relative probability of innovation of firm *i*; *K* stands for the level of capital expenditures of the firm; *X* denotes the firm's R&D investment; *Y* is the rival firms' R&D; σ_v and σ_k represent the volatilities of the project value and capital expenditures, respectively; α is the second measure of volatility of capital outlays and denotes the premium required to hedge uncertainty in the strike price; *D* represents the debt-equity ratio; *CF* is operating cash flows; *ET* denotes age of the company; and *L* represents labor productivity.

Cross-sectional regressions, year-by-year and across firms, are conducted to analyze the linear form of the growth function above. We present the results for each year, rather than manipulating time-series averages, in line with Stulz's (1990) suggestion that the distribution of cash flows matters to shareholders period-by-period because shareholders want to optimize resources under managerial control each period to maximize their wealth. The view of Fama (1990) is also that the longest into the future the market can predict is two years.

Besides current values, I also include past and future expected values of these variables because I believe they interact in some way in influencing growth opportunities. For example, to investigate the influence of R&D on growth opportunities, I apply all current, past change and future change in R&D as explanatory variables. In a one-year regression, scaled past change in R&D is represented as $\Delta X_{t-1} = (X_t - X_{t-1})/A_t$. Similarly, $\Delta X_{t+1} = (X_{t+1} - X_t)/A_t$ denotes future change in R&D of the firm.

The final form of the least-squares regression equation (not showing stock or change variables) for testing the hypothesis expresses growth opportunities G, as the dependent variable:

$$\begin{aligned} G &= \gamma + \beta_1 V + \beta_2 P + \beta_3 K + \beta_4 X + \beta_5 Y + \beta_6 \sigma_v + \beta_7 \sigma_k \\ &\quad + \beta_8 \alpha + \beta_9 D + \beta_{10} CF + \beta_{11} ET + \beta_{12} L + \hat{e} \end{aligned} \tag{24}$$

where γ is the intercept coefficient of the regression; β_1, β_2, ..., β_{12}, are the coefficients of the independent variables fully described below; and $\hat{e}$ is the error term.

5.1.2 Overview of Empirical Studies

My contribution to the empirical literature stems from the sample construction and the broad scope of empirical methodology used. The sample design into emerging and mature panels enhances a rich observation of the influence of growth opportunities on investment and financing strategies that firms adopt as a result of the qualitative differences between assets-in-place and real growth options in their asset structures. My methodology is able to examine capital structure and investment decisions of a firm simultaneously, and is able to identify firm characteristics that have not been previously considered. It also enables us distinguish between expenditures on growth opportunities and outlays to maintain assets-in-place. The inclusion of a set of control variables is unique. For instance, I assume that every unit of R&D expenditure is equally valuable and recognize that research and development process entails learning. However, I believe that a company must not be rewarded or penalized in this process because of sheer age, and thus include age as a control variable.

Numerous studies have empirically investigated investment opportunities very restrictively, by only looking at the investment variables like R&D (Morbey (1989), Morbey and Reithner (1990), Shevlin (1991), Hall (1993)); R&D and patents (Griliches (1981), Bound, Cummins, Griliches, Hall, and Adam (1984), Ben-Zion (1984), Jaffe (1986), Cockburn and Griliches (1988), Austin (1993), Megna and Klock (1993)); or advertising and R&D (Lustgarten and Thomadakis (1987), Morck and Yeung (1991), Chauvin and Hirschey (1993)). Others have explored financing and the effects of risk (Chung and Charoenwong (1991)); risk and market structure (Thomadakis (1977)); and capital expenditures (McConnell and Muscarella (1985), Beranek, Cornwell and Choi (1995)).

My sample covers seven industries in contrast with others including Austin (1993), and Megna and Klock (1993) which are industry-specific. Industry-specific empirical analyses tend to miss the cross-sectional variation in some firm characteristics that are predicted to be associated with growth opportunities.

Several authors have applied the event-studies methodology which have become standard in finance literature in testing financing, investment and operating decisions on the returns of a firm (McConnell and Muscarella (1985), Chan, Martin and Kensinger (1990), Szewczyk, Tsetsekos, and Zantout (1996), Blose and Shieh (1997)). As pointed out by Fama and French (1997), the periods surrounding the announcements of identifiable events in event-studies tend to be short. Thus, the value effects measured by testing for abnormal stock returns may be small and less reliable. I apply Fama-French cross-sectional methodology which may be more informative since it examines cumulative effects of longer-term (one and two years) valuation.

5.1.3 Description of Variables

The relative excess value procedures of measuring capitalized market value is employed to proxy the value of growth opportunities. The market value of the firm (MV) is composed of the value of assets already in place (A) and the present value of growth opportunities (G). The relative excess value of the firm is thus measured as the market value of common plus the book value of debt (MV) minus the book value of assets (A) normalized by assets (A). I compute the market value of common as closing stock price times the number of shares outstanding. In my regression equation, growth opportunities $\left(\frac{G}{A}\right)$, is the dependent variable. In the event that data points for computing replacement costs are very limited, especially for emerging firms, I believe that $\left(\frac{G}{A}\right)$ proxies average Tobin's Q, which has been widely applied in finance literature, reasonably well by using book assets as a proxy for replacement costs.

Industry is defined by the two-digit Standard Industrial Classification (SIC) code. All variables are normalized by total assets unless otherwise specified. The description of the explanatory variables follows:

V: represents the expected monopoly rents and is proxied by two variables. One is the growth rate of sales derived by applying a simple exponential trend regression of net sales. In the year-by-year cross-sectional regression, I instead use expected change to represent growth rate of sales. For example, the expected change (value) in sales over the next one year is expressed as $\frac{Sale_2 - Sale_1}{Asset_1}$. The other variable is the Herfindhal-Hirschman index (*HH*) calculated by expressing market share of each firm (using sales) in the industry as a percentage, squaring these figures, and summing them up.

***P*:** denotes the relative probability of innovation and is proxied by the number of patents divided by the industry number of patents. I also include *PP*, the stock of patents obtained by dividing cumulative patents within the past 17 years by industry stock of patents (until 1995, an inventor in the United States had exclusive right to a patent for 17 years). Both *P* and *PP* are scaled by the ratio of firm assets to industry assets.

***K*:** the strike price is estimated by the levels of capital expenditures.

***X*:** represents current R&D spending.

***Y*:** denotes rival R&D expenditures and is computed as R&D of the industry less R&D of the firm.

σ_v: project volatility, is measured by the Chauvin and Herschey (1993) methodology using the natural logarithm of the ratio of the 52-week high and low stock prices for each firm, an index that is proportional to the Garman and Klass (1980) "ideal" volatility estimator. I choose this approach over equity beta estimation due to limitation of scope of data availability especially for emerging companies.

σ_k: represents uncertainty underlying the strike price and is determined by the standard deviation of capital expenditures.

α: denotes a second measure of uncertainty in the strike price and represents the cost of hedging that uncertainty (α_h - α_k). It is proxied by the "surprise" or the unanticipated change in the exercise price, and is obtained by ordinary least squares by subtracting the actual percentage change in capital expenditures from the predicted percentage change. In the cross-sectional regression, I don't use this time-series form of the variable. Instead, I derive the "surprise" in capital expenditures as the difference between the natural logarithm of $\left(\frac{K_{t+1}}{K_t}\right)$ and that of $\left(\frac{K_t}{K_{t-1}}\right)$ where t is current year. Here is the rationale: As of time t, the future change (variance) in capital expenditures is expressed as $ln\left(\frac{K_{t+1}}{K_t}\right)$. And as of time t-1, the future change is expressed as $ln\left(\frac{K_t}{K_{t-1}}\right)$. It turns out that any future change in capital expenditures as of time t that was not captured at time t-1 is an unexpected change, and represents information at time t that was not available at t-1, since

(actual change) = (expected change) ÷ (unexpected change).

***D*:** is debt ratio, the sum of debt in current liabilities and long-term debt divided by total assets, scaled by the industry's debt ratio.

***CF*:** denotes operating cash flow measured by operating income plus R&D expenditures which is meant to proxy internal capital. Another variable used is ΔA, the expected change in assets, a proxy for the net investment component of internal cash flows.

ET*:** represents the natural logarithm of the number of years the company has lived since it was established. And ***L is a measure of labor productivity, the ratio of total output (net sales) to labor inputs (number of employees).

5.1.4 Data Sources and Sample Design

All active U.S. public firms with a record of R&D spending were extracted from the Disclosure CD-ROM. This first sample is restricted to companies within the industries with SIC codes 3000 through 3829. The range covers rubber and miscellaneous plastic products (3000); primary metals (3300); fabricated metals (3400); industrial and commercial machinery and computer equipment (3500); electrical and electronics (3600); transportation equipment (3700); and measuring and controlling devices (3800). Leather and leather products (3100); and stone, clay, glass, concrete products (3200) are excluded.

The companies are then traced as to whether their R&D efforts have turned up any patented innovations. Patent counts come from the Classification and Search Support Information System (CASSIS) CD-ROM, managed by the Patent and Trademark Office of the U.S. Department of Commerce. The database contains bibliographic citations of U.S. patents assigned to individuals, private and public organizations and firms, from 1969 to the present. For our purpose, an entity is considered to have patented if the patent is issued to its subsidiary, division, or to the parent firm itself. In most cases CASSIS database would not distinguish a subsidiary from a parent company. For instance, it would list a subsidiary company like Lumec, Inc. and its parent, Thomas Industries, Inc. under completely different assignee codes, often not indicating that Lumec is a subsidiary of Thomas Industries. This is carefully and appropriately checked.

Information on subsidiaries and divisions of these firms are assembled from several sources for verification purposes: the National Register Publishing's Directory of Corporate Affiliations CD-ROM, Dun and Bradstreet Directory, Walker's Corporate

Directory of U.S. Public Companies, and CorpTech Directory of Technology Companies. CASSIS also does not record assignees distinctly as private or public firms. I resolve this problem by cross-checking the CorpTech Directory whose listings identify private and public technology firms as well as foreign-owned companies. Firms that are not cited by CASSIS from 1969 to end of 1993 are not included in the sample. As it turned out, all the companies excluded based on this criterion did not have adequate financial data to analyze and would have again been disqualified.

All data of financial nature are retrieved from the Standard & Poor's annual industrial and full coverage COMPUSTAT tapes. My study period covers 1987 to 1993. The final selection of 208 firms constitute a sample that must have all years of financial data for the period 1987-1993. Year of incorporation (founding) is accessed from Disclosure CD-ROM, Dun and Bradstreet, and CorpTech Directories. The sample is further divided into two panels: established firms and emerging firms. A firm is classified as emerging if it had never issued cash dividends by the end of 1993.

5.1.5 Industry Classification

Table 1 presents industry classification of the companies to be analyzed. A total of 208 firms make up the final sample of which 107 (51.44%) are emerging and 101 (48.56%) are established firms. Seven major industries are formed according to the two-digit SIC codes. Electrical and Electronics industry accounts for the largest share of the sample with 38.94% of the companies, followed by Measuring Instruments and Devices (21.64%) and Industrial and Computer Equipment (21.15%). No emerging company is classified under Rubber and Miscellaneous Plastics (1.44%), and Primary Metals

(1.92%), the two industries with the lowest number of firms. The majority of emerging firms (42.99%) are in the Electrical and Electronics industry. Only 1 emerging company compared with 25 mature firms are in the transportation industry which includes automotive, aircraft and defense. The Measuring Instruments industry is fairly balanced, with 23 emerging and 22 mature firms, respectively.

Table 5.1: Sample Distribution by Industry Classification

Industry is classified by the two-digit Standard Industrial Classification (SIC) code. Only firms followed by Compustat and cited in CASSIS CD-ROM are included. A company is defined as emerging if it has never issued cash dividends as of December 1993. The sample period is from 1987 to 1993.

2-Digit SIC	Industry	Emerging Firms	Mature Firms	Total	(Percent)
30	Rubber & Miscellaneous Plastics	0	3	3	(1.44)
33	Primary Metals	0	4	4	(1.92)
34	Fabricated Metals and Parts	3	2	5	(2.41)
35	Industrial and Computer Equipment	34	10	44	(21.15)
36	Electrical and Electronics	46	35	81	(38.94)
37	Transportation	1	25	26	(12.50)
38	Measuring Instruments	23	22	45	(21.64)
Total		**107**	**101**	**208**	**(100.00)**

5.1.6 Descriptive Statistics

Figures 8 to 13 graph some key variables, and descriptive statistics are given in table 5.2. Mature firms are relatively much older, with 1931 being their median year of founding compared with 1975 for emerging companies. Emerging firms on average employ 871 people, ranging from the smallest company with 19 to the largest company with 30,240. On the other hand, mature firms have a mean number of employees of 26,791 ranging from 68 to 354,508.

Total assets are about 63 times larger for established firms ($4,975 million with a standard deviation of $22,765 million) than emerging firms ($78 million with a standard deviation of $208 million). Mature firms also generate almost 52 times as much net sales as emerging firms, $4,217 million against $81 million. However, they have a much lower rate of growth in sales (4.94%) than emerging firms (11.35%). Emerging companies generally spend less in capital expenditures ($8.03 million) and R&D ($9.39 million), compared to mature firms' capital expenditures ($272.14 million) and R&D ($176.71 million). Mature companies experience lower levels of unanticipated changes (surprise) in capital expenditures (-15.94%) than emerging firms (-52.76%).

On average, there are 3 patents procured by an emerging firm per year compared to 39 by a mature company. For each patent assigned, a mature firm spends $4.5 million in R&D. This is higher than $2.9 million incurred by an emerging firm.

Debt ratios don't appear to be significantly different between the two subsamples, 21.51% and 18.87% for mature and emerging firms, respectively. In terms of investment volatility, emerging companies are much riskier, with the natural logarithm of the ratio of the 52-week high to 52-week low of stock price of 0.422 compared to 0.267 for mature firms. Established companies enjoy higher levels of operating cash flows ($492 million) compared to that of emerging firms ($13 million). On average, emerging companies register a much higher ratio of excess value (growth opportunities) to book value of assets (61%) than established companies (7%). Mature firms tend to operate in more highly concentrated industries with Herfindhal-Hirschman index of about 2200 while emerging companies are in more diffused industries at about 1500 level of the same index.

Figure 8: Number of patents granted to emerging and mature firms: 1969-1995.

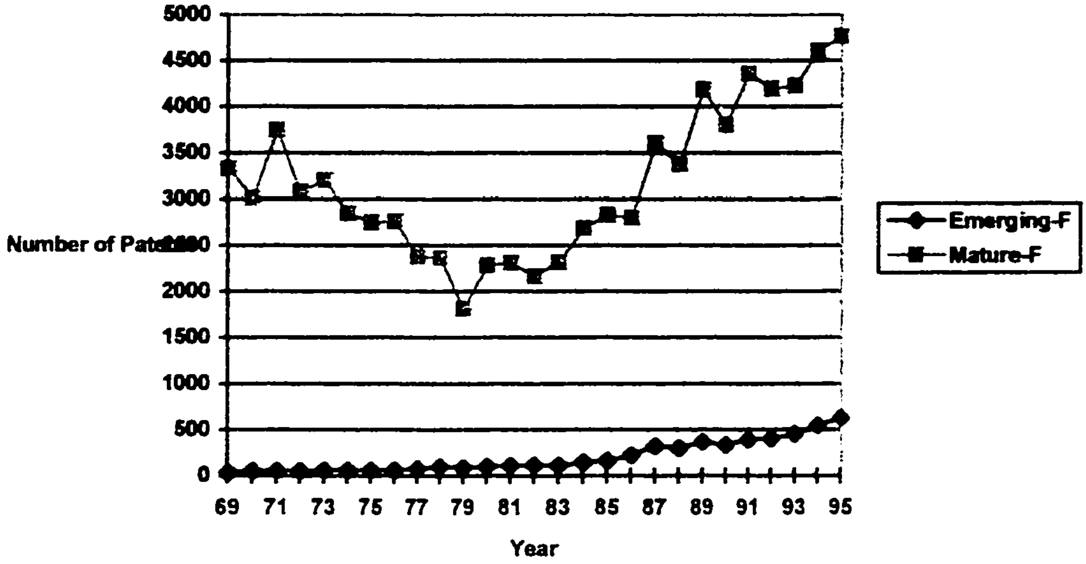


Figure 9: Mean sales at 1987 dollars (in millions).

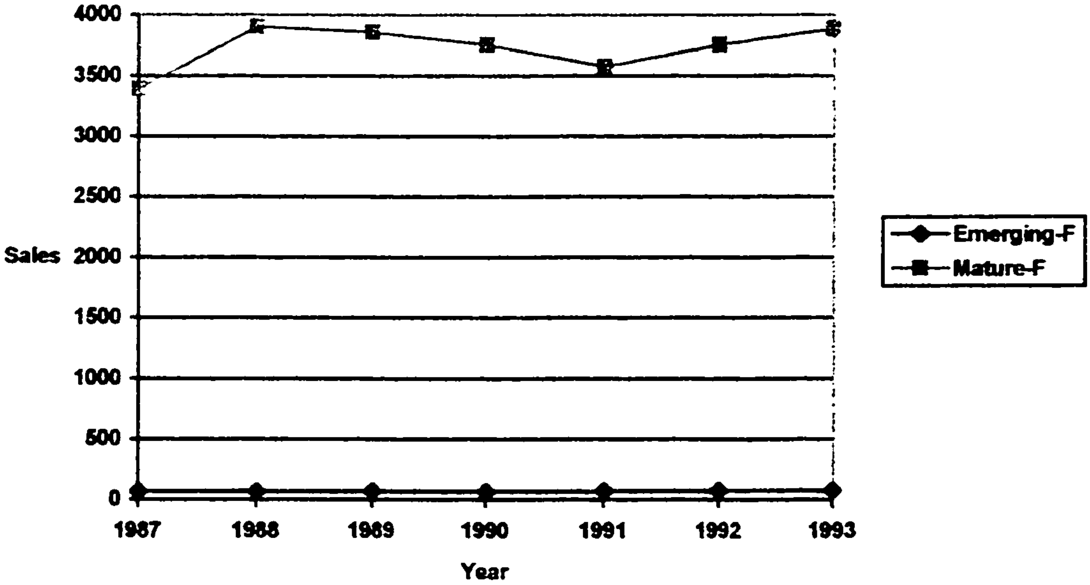


Figure 10: Net sales (at 1987 dollars (in millions)) per employee.

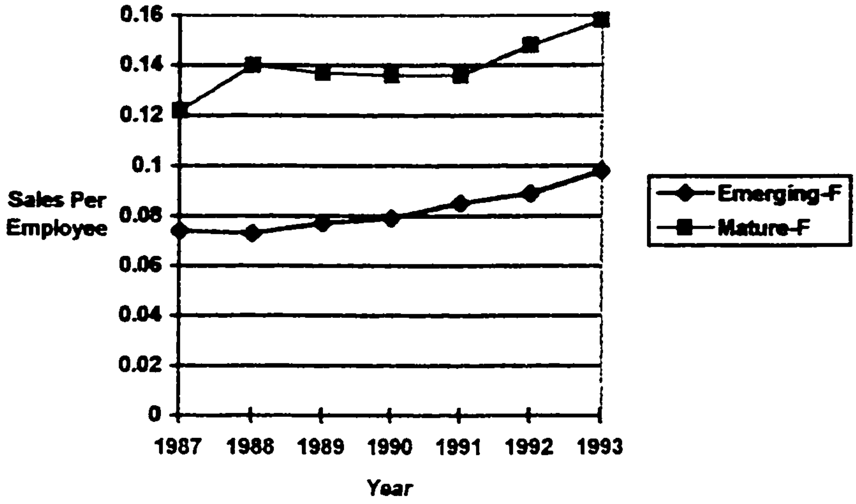


Figure 11: R&D expenditure at 1987 dollars (in millions).

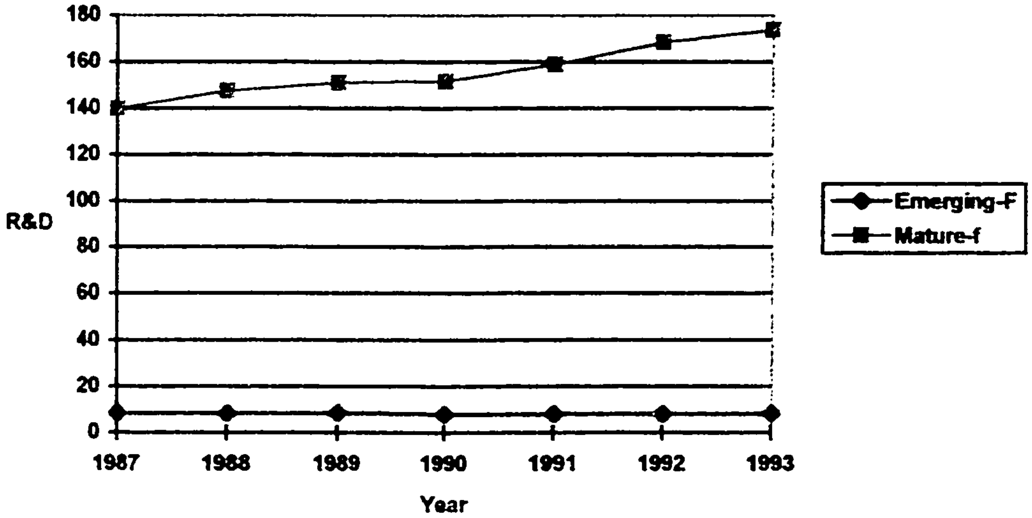


Figure 12: Mean capital expenditure at 1987 dollars (in millions).

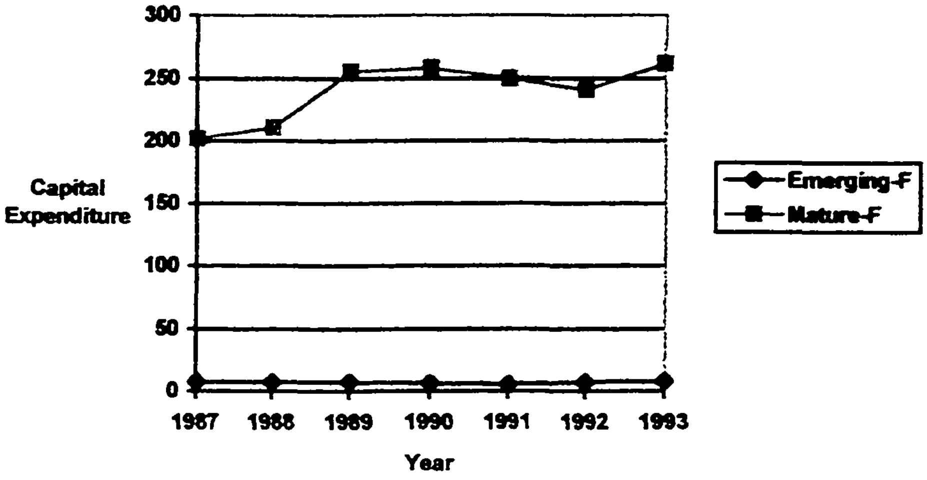


Figure 13: R&D (at 1987 dollars (in millions)) per patent granted.

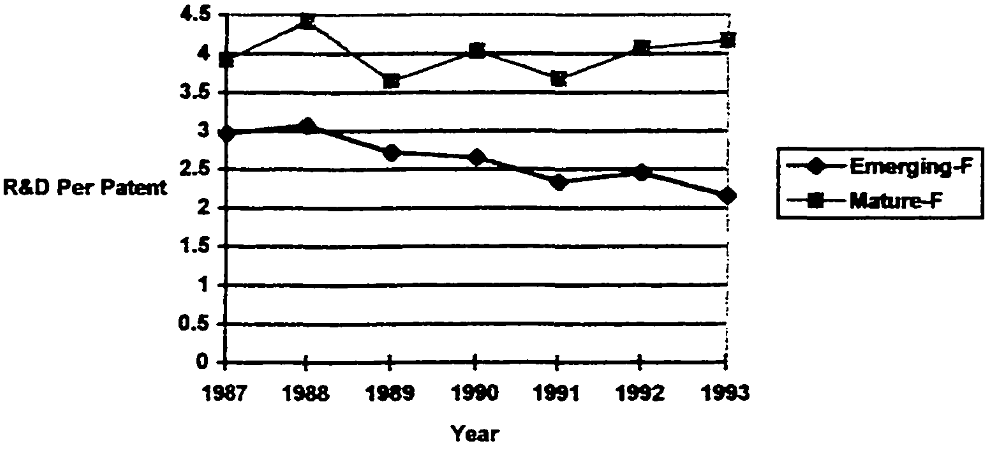


Table 5.2: Descriptive Statistics for Selected Variables

Time-series means of variables computed over the period 1987 to 1993 (standard deviation in parenthesis). Year of incorporation is median year. Patents are in units. Employees are in thousands. Volatility of the growth option is computed as the natural logarithm of the ratio of the 52-week high to 52-week low of the stock price as in Chauvin & Hirschey (1993) following Garman & Klass (1980). Growth rates of sales and R&D are derived by simple exponential trend regression and are percentages. "Surprise" is the unanticipated change in capital expenditures obtained by ordinary least squares by subtracting the actual from predicted percentage change. Rival R&D is obtained by subtracting firm R&D from industry R&D. Operating cash flow is measured by operating income plus R&D expenditures. Debt ratio is the sum of debt in current liabilities and long-term debt divided by total assets. Herfindhal-Hirschman index, a measure of industry concentration, is calculated by summing the squares of percent market share of each firm (using sales) in the industry. Growth opportunities is the excess market value over replacement cost of the firm, computed as the sum of the market value of equity and total debt less total book assets. Net sales, total assets, capital expenditures, R&D, rival R&D, operating cash flow and growth opportunities are in millions of dollars. Industry is classified by the two-digit SIC code.

Variable	Emerging Firms	Mature Firms	All Firms
Year Founded	1975	1931	1964
Employees	0.871	26.791	13.458
	(3.219)	(87.533)	(62.252)
Net sales	80.884	4216.591	2089.088
	(232.298)	(15811.640)	(11184.700)
Growth Rate of Sales	11.354	4.943	8.241
	(23.378)	(9.323)	(18.226)
Total Assets	78.160	4975.058	2455.981
	(208.248)	(22764.980)	(16012.520)
Capital Expenditures	8.028	272.141	136.275
	(29.737)	(1128.795)	(795.932)
Surprise in Capital Exp.	-52.762	-15.938	-34.881
	(80.366)	(28.160)	(63.488)
R&D Expenditures	9.393	176.714	90.640
	(32.441)	(665.688)	(470.790)
Growth Rate of R&D	7.762	6.856	7.322
	(16.399)	(13.182)	(14.895)
Rival R&D	1987.139	4648.871	3279.615
	(1806.186)	(4880.103)	(3867.023)
Patents	3.215	39.122	20.153
	(10.832)	(91.468)	(66.524)
Stock of Patents	21.965	467.440	238.278
	(68.358)	(1035.636)	(755.208)
Debt Ratio	18.874	21.507	20.153
	(19.056)	(14.312)	(16.931)
Operating Cash Flow	12.780	491.506	245.239
	(42.632)	(1879.365)	(1328.436)
Project Volatility	0.422	0.267	0.347
	(0.116)	(0.090)	(0.130)
Herfindhal-Hirschman Index	1521	2205	1853
Growth Opportunities	3.809	-817.555	-395.026
	(52.908)	(10000.600)	(6963.168)

5.2 Empirical Results

In table 5.3 I present tests of significance of the mean difference of selected variables in the two subsamples. Both t-Tests and Wilcoxon nonparametric approximations are performed. The results are very similar employing both methods. I find 8 of the 14 variables (without their change components) considered are significantly different between the emerging and mature firm groups. In particular, the difference in growth opportunities (G_t) is highly significant, strongly supporting the hypothesis that emerging firms have distinctively larger real options than mature firms. On average, 63% of the market value of emerging firms compared to 6% for mature firms is accounted for by the present value of growth opportunities. Mean differences of stock of patents (PP), R&D (X), rival R&D (Y), project risk (σ_v), capital expenditures (K), operating cash flows (CF), and industry concentration (HH) are all significant. I infer that emerging firms are in high R&D industries, less concentrated, more volatile with less free-cash-flow and higher Tobin's Q ratio.

Cross-sectional regressions are then conducted. I regress excess market value on relevant predictor variables as indicated and present results for the one-year change regressions in table 5.4 and 5.5. I also run regressions with current patents as dependent variable and present results in tables 5.6 and 5.7. It is apparent that the impact and signs of some predictor variables in explaining the changes in the dependent variable do change from period to period. However, an overall picture of the power of a particular factor can be discerned.

There is evidence that current (X_t), past (ΔX_{t-1}) and future (ΔX_{t-1}) expected values of R&D for emerging firms are positively significant. On the contrary, current and future expected R&D expenditures for mature firms are negative and significant for the most part. Although they lose their power in some periods, patents (P_t) have value.

Current (Y_t) and past (ΔY_{t-1}) rival R&D tend to be positive, but future rival R&D (ΔY_{t-1}) are negative for emerging firms. For mature firms, rival R&D are generally positive.

One salient result is the influence of internal cash flows. For emerging companies, the net investment components of internal capital (ΔA_{t-1} and ΔA_{t+1}) are positive and significant. Current (CF_t) and future values (ΔCF_{t+1}) of operating cash flows are significantly negative, and past values (ΔCF_{t-1}) are positive. These results strongly support our internal capital markets hypothesis. High Tobin's Q firms are high investment firms. And since for emerging companies investments must be financed internally, it implies that high Q emerging firms would have less cash flow left over after investments.

The negative sign of current operating cash flows for emerging firms also tends to support Jensen's (1986) assertion that after all positive NPV projects are considered and financed, and shareholders paid, the remaining "free cash flows" are often "wasted" by management. On the other hand, operating cash flows for mature firms are positive and highly significant, but the net investment component is negative for most of the sample period. There could be additional explanations for our results. Gompers (1995) documents a surge in venture capital financing in the U.S. throughout the 1980s and 1990s which may have been a critical catalyst for funding emerging firms and introducing them to the capital markets. Compared to other financial markets, the U.S. is the most efficient and liquid. The U.S. stock markets, especially the Initial Public Offerings (IPOs), have recorded substantial growth in the last 10 to 15 years[18].

For emerging firms, capital expenditure (*K*) signs are mixed, but generally show a negative relationship with growth opportunities in the two-year regressions. Unexpected values have positive signs in two of three regressions. Mature firms show a positive relationship of capital expenditures and their unexpected values with growth opportunities, overall.

Volatility of the underlying investments (σ_v) has positive relationship in both subsamples for most of the study period. Debt ratio (*D*) has a negative sign for emerging firms, but the signs are mixed for the established firms.

In tables 5.6 and 5.7, we find that the change in innovation, measured by the current number of patents (P_t) is significantly explained by the stock of patents (PP_t), R&D (X_t), and research-in-progress as proxied by expected future changes in the number of patents (ΔP_{t+1}). Operating cash flows (CF_t) and rival R&D (Y_t) have greater impact on innovation in emerging than in mature firms.

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[18] BusinessWeek, August 18, 1997.

Table 5.3: t-Tests and Non-Parametric Comparisons of Mean Differences

The non-parametric procedure is the Wilcoxon Normal Approximation. Industry is defined by the 2-digit SIC code. ΔA and CF are meant to proxy for internal capital. CF denotes operating cash flow measured by operating income plus R&D expenditures. ΔA is the annual change in total assets, a proxy for the net investment component of internal capital. ΔS is annual change (expected growth) in net sales. HH represents the Herfindhal-Hirschman index, calculated by summing the squares of percent market share of each firm (using sales) in the industry. Both ΔS and HH are meant to proxy for the expected value of the monopoly rents. P denotes the relative probability of innovation derived as the number of patents divided by the industry number of patents, and PP is stock of patents, computed by dividing cumulative patents within past 17 years by industry stock of patents, both scaled by the ratio of firm assets to industry assets. σ_v represents volatility of the growth option, computed as the natural logarithm of the ratio of the 52-week high to 52-week low of the stock price as in Chauvin & Hirschey (1993) following Garman & Klass (1980). K denotes capital expenditure, and α_k is the "surprise" or unexpected change in capital expenditures derived as the difference between $\mathrm{Log}(K_{t-1}/K_t)$ and $\mathrm{Log}(K_t/K_{t-1})$ where t is current year. X represents R&D. Y denotes rival R&D obtained by subtracting firm R&D from industry R&D, normalized by industry assets. Labor productivity, L, is the ratio of total output (net sales) to labor inputs (number of employees). Debt ratio, D, is the sum of debt in current liabilities and long-term debt divided by total assets, scaled by industry debt ratio. G denotes the excess market value over replacement cost of the firm, a proxy for growth opportunities, and is computed as the sum of the market value of equity and total debt less total book assets. ΔA, CF, ΔS, X, K, and G are all normalized by assets.

Variable	Emerging Firms	Mature Firms	t-Statistic	Z-Statistic
ΔA	0.0990	0.0735	-0.5452	0.4076
ΔS	0.1442	0.0814	-1.2472	-0.4889
P	2.5000	1.5403	-1.3429	1.1848
PP	1.8119	1.8588	0.2132	2.1655**
X	0.1302	0.0543	-5.7884***	-7.0179***
Y	0.0707	0.0577	-5.1853***	-4.8589***
K	0.0602	0.0607	0.0929	1.8790**
α_k	-0.0461	-0.0034	0.3527	0.6159
L	11.8264	11.0063	-0.9725	-1.1410
D	0.9682	0.9029	-0.4804	0.7226
CF	0.0791	0.1437	2.3884**	1.3895
HH	1552	2216	3.5576***	3.8258***
σ_v	1.0017	0.6375	-6.5193***	-6.8092***
G	0.6262	0.0566	-2.9683***	-2.4006**

*** Significance at the 0.01 level in a two-tailed test.
** Significance at the 0.05 level in a two-tailed test.
* Significance at the 0.10 level in a two-tailed test.

Table 5.4: One-year Change Cross-sectional Regression Analysis with Excess Value, G_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. *INT* denotes intercept and *ET* is the natural logarithm of the number of years of life of a firm since establishment. All other variables are as defined in table 5.3. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (one-year) in R&D is expressed as: $\Delta X_{t+1} = (X_{t+1} - X_t)/A_t$. Past change (one-year) in R&D is expressed as: $\Delta X_{t-1} = (X_t - X_{t-1})/A_t$. Changes (expected values) in all other variables are computed similarly and scaled as defined in table 3, except for *L*, *α*, and *HH* which are ratio changes.

	Panel A: Emerging Firms										**Fama-MacBeth Regression**	
Variable	1988		1989		1990		1991		1992			
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
INT	-7,273	-0,254	105,722	3,893***	0,241	0,012	-8,087	-0,437	-9,701	-0,905	16,180	1,081
ET	-0,424	-2,612***	-0.753	-3.098***	-0,355	-1,318	-0,260	-1,069	-0,334	-1,303	-0,425	-3,409
ΔA_{t+1}	1,060	1.677*	1,000	1.127	0,594	1,371	1,608	1,714*	0,779	1,350	1,008	2,759
ΔA_{t-1}	3,656	5,413***	3,417	3,479***	-0,192	-0,208	3,207	3,843***	1,348	1,545	2,287	5,925
ΔS_{t+1}	0,864	1.457	-0,594	-0.640	0,456	0,753	-1,116	-1,536	0,384	0,673	-0,001	0,283
ΔS_{t-1}	-1,004	-1,732**	-0,101	-0,114	0,349	0,469	0,685	1,314	-0,509	-0,641	-0,116	-0,072
P_t	-0,018	-0,562	-0,038	-0.926	-0,005	-0,262	0,038	0,859	-0,015	-0,373	-0,008	-0,505
PP_t	-0,016	-0,256	0,073	1,092	-0,010	-0.143	-0.006	-0,121	-0,004	-0,112	0,007	0,184
ΔP_{t+1}	0,025	0,820	-0,028	-0,856	0,004	0,086	-0,013	-0,308	-0,031	-0,725	-0,009	-0,394
X_t	3,148	1,810**	1,765	0,845	1,814	1,185	4,954	3,003***	7,044	3,683***	3,745	4,210
ΔX_{t+1}	-5,138	-2,710***	19,041	5,357***	1,656	0,376	9,783	2,305**	6,365	1,190	6,342	2,895
ΔX_{t-1}	5,674	1,464	5,087	1,309	7,890	2,271**	-2,789	-1,074	8,346	2,042**	4,842	2,404
Y_t	37,179	0,375	-407,6	-3,727***	25,451	0,178	26,565	0,255	142,63	1,094	-35,154	-0,730
ΔY_{t+1}	-446,43	-0,966	912,3	3,255***	-283,7	-0,528	322,95	0,650	-859,9	-1,548	-70,96	0,345
ΔY_{t-1}	607,99	0,935	-1190	-2,636***	228,2	0,643	-190,61	-0,346	-341,9	-0,507	-177,3	-0,765
K_t	-0,113	-0,045	-2,857	-0,884	0,365	0,113	-2,251	-0,774	0,570	0,193	-0,679	-0,559
ΔK_{t+1}	1,478	0,719	-0,439	-0.132	-1,429	-0,343	-1,872	-0,524	-7,895	-1,647	-2,031	-0,771
ΔK_{t-1}	-0,770	-0,246	8,893	2,075**	3,658	1,071	-3,764	-0,999	4,375	1,193	2,478	1,238
α_t	-0,104	-1,752*	0,525	3,151***	0,081	0,527	-0,087	-0,699	0,189	1,492	0,121	1,087
L_t	0,009	1,792*	-0,005	-0,726	0,002	0,390	-0,004	-0,854	0,000	0,027	0,000	0,252
ΔL_{t+1}	-0,007	-1,613	0,008	1,300	-0,001	-0,323	-0,002	-0,314	0,003	0,732	0,000	-0,227
ΔL_{t-1}	-0,003	-0,891	-0,004	-0,485	-0,002	-0,285	0,009	2,494**	0,001	0,236	0,000	0,427

D_t	0.057	0.395	-0.127	-0.718	-0.293	-1.434	-0.043	-0.290	-0.044	-0.350	-0.090	-0.958
ΔD_{t+1}	-0.644	-4.067***	-0.333	-1.004	-0.796	-1.661*	0.241	0.923	0.153	1.050	-0.276	-1.903
ΔD_{t-1}	-0.505	-2.728***	-0.037	-0.166	0.446	1.365	-0.630	-1.731*	-0.219	-0.673	-0.189	-1.573
CF_t	-3.550	-4.728***	-5.618	-6.042***	-3.312	-3.308***	-2.702	-2.299**	-6.378	-5.095***	-4.312	-8.589
ΔCF_{t+1}	-1.114	-1.517	-0.398	-0.274	-2.322	-2.096**	1.390	0.750	-2.838	-2.496**	-1.057	-2.253
ΔCF_{t-1}	0.876	0.855	-2.201	-2.179**	2.255	2.292**	-0.728	-1.044	3.651	2.420**	0.771	0.937
HH_t	0.003	0.229	-0.049	-3.644***	-0.001	-0.059	0.004	0.513	0.002	0.756	-0.008	-0.882
ΔHH_{t+1}	0.005	0.131	-0.290	-2.999***	0.010	0.231	-0.008	-0.611	0.093	1.557	-0.038	-0.677
ΔHH_{t-1}	0.007	1.057	-0.037	-1.902*	-0.020	-0.291	0.012	0.538	-0.031	-1.424	-0.014	-0.809
σ_t	0.035	0.083	0.272	0.588	-0.252	-0.489	0.327	0.836	-0.087	-0.209	0.059	0.324
$\Delta\sigma_{t+1}$	-0.050	-0.184	-0.768	-2.179**	0.129	0.315	0.469	1.488	-0.109	-0.349	-0.066	-0.364
$\Delta\sigma_{t-1}$	0.440	0.297	-0.413	-1.250	-0.368	-0.986	0.568	1.681*	0.192	0.084	0.084	0.134
Adj. R^2	0.674		0.815		0.475		0.507		0.613			
F-Stat.	7.63***		15.2***		3.90***		4.30***		6.1***			
											7.42***	

*** Significance at the 0.01 level in a two-tailed test.
** Significance at the 0.05 level in a two-tailed test.
* Significance at the 0.10 level in a two-tailed test.

Table 5.5: One-year Change Cross-sectional Regression Analysis with Excess Value, G_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. *INT* denotes intercept and *ET* is the natural logarithm of the number of years of life of a firm since establishment. All other variables are as defined in table 5.3. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (one-year) in R&D is expressed as: $\Delta X_{t+1} = (X_{t+1} - X_t)/A_t$. Past change (one-year) in R&D is expressed as: $\Delta X_{t-1} = (X_t - X_{t-1})/A_t$. Changes (expected values) in all other variables are computed similarly and scaled as defined in table 5.3, except for *L*, α, and *HH* which are ratio changes.

	Panel B: Mature Firms										**Fama-Macbeth Regression**	
Variable	1988 Coeff.	t-stat.	1989 Coeff.	t.stat.	1990 Coeff.	t-stat.	1991 Coeff.	t-stat.	1992 Coeff.	t-stat.	Coeff.	t-stat.
INT	-0.177	-0.292	-1.018	-1.675*	-0.824	-0.879	0.873	0.703	0.411	0.419	-0.091	-0.617
ET	-0.177	-1.827*	-0.164	-1.780*	-0.211	-2.036**	-0.449	-2.303**	-0.462	-2.766***	-0.293	-4.285
ΔA_{t+1}	-0.804	-2.350**	-0.385	-0.821	-1.236	-1.978**	1.918	1.541	-1.213	-1.689*	-0.344	-1.794
ΔA_{t-1}	-0.419	-1.119	0.322	0.744	-0.229	-0.509	-1.147	-1.124	0.323	0.303	-0.230	-0.682
ΔS_{t+1}	0.348	1.079	-0.274	-0.599	0.076	0.255	-0.893	-1.120	2.249	3.074***	0.301	1.331
ΔS_{t-1}	0.373	0.850	0.432	1.270	-0.303	-0.665	-0.080	-0.132	-0.480	-0.783	-0.098	0.216
P_t	-0.031	-1.091	-0.010	-0.389	0.012	0.413	-0.039	-0.631	-0.056	-0.861	-0.025	-1.024
PP_t	-0.023	-0.863	0.001	0.022	-0.030	-1.272	-0.069	-2.079**	-0.040	-1.052	-0.032	-1.122
ΔP_{t+1}	0.023	1.289	0.019	0.540	0.023	0.685	0.151	2.636***	0.123	2.525**	0.068	2.015
X_t	-2.908	-2.049**	-5.232	-3.353***	-6.815	-4.515***	-9.495	-3.815***	-9.090	-3.935***	-6.708	-7.066
ΔX_{t+1}	-9.207	-2.570**	0.413	0.119	-4.767	-1.064	4.649	0.834	-26.65	-4.609***	-7.112	-2.891
ΔX_{t-1}	4.036	1.223	-3.931	-1.121	4.563	1.601	-3.154	-0.430	13.09	2.564**	2.922	1.535
Y_t	-0.840	-0.229	2.880	0.764	3.966	0.677	-15.637	-1.183	5.181	0.459	-0.890	0.098
ΔY_{t+1}	-12.533	-0.269	28.990	1.898*	-15.480	-0.190	28.908	0.470	32.22	0.658	12.421	1.027
ΔY_{t-1}	41.725	0.985	1.678	0.044	44.741	0.959	184.29	1.669*	-13.47	-0.143	51.792	1.405
K_t	2.224	1.401	0.889	0.582	4.571	2.836***	4.126	1.449	5.568	1.981**	3.475	3.300
ΔK_{t+1}	0.794	0.390	0.984	0.357	8.290	3.270***	2.491	0.499	-2.487	-0.604	2.014	1.565
ΔK_{t-1}	-1.318	-0.501	1.312	0.518	-2.654	-0.884	5.894	1.221	-1.016	-0.267	0.444	0.035
α_t	-0.043	-0.376	0.122	1.123	-0.211	-1.717*	0.224	0.980	0.041	0.240	0.026	0.100
L_t	-0.001	-0.076	-0.001	-0.089	0.011	2.424**	0.004	0.388	0.003	0.465	0.003	1.245
ΔL_{t+1}	0.001	0.207	0.005	1.334	-0.004	-1.093	-0.009	-1.413	-0.004	-0.742	-0.001	-0.683

$\Delta I_{q,t-1}$	0.002	0.496	-0.004	-0.777	-0.007	-2.148**	0.009	1.270	0.005	0.716	0.001	-0.110
D_t	0.202	2.239**	0.149	1.728*	0.029	0.340	-0.101	-1.197	-0.196	-1.667*	0.016	0.577
ΔD_{t+1}	0.137	1.274	0.061	0.672	-0.207	-1.513	-0.235	-0.666	-0.192	-0.790	-0.163	-0.409
ΔD_{t-1}	-0.169	-1.114	-0.128	-0.898	0.200	1.453	0.224	0.913	0.043	0.132	0.034	0.195
CF_t	4.281	4.542***	7.078	7.471***	6.663	6.939***	6.943	4.155***	6.082	4.073***	6.210	10.872
ΔCF_{t+1}	0.808	0.817	0.727	0.781	3.412	3.393***	1.728	0.741	2.878	1.538	1.910	4.398
ΔCF_{t-1}	0.332	0.298	-3.660	-2.901***	-3.339	-2.737***	1.728	0.741	2.848	1.563*	-0.418	-1.214
HH_t	-0.000	-0.204	0.0001	1.690*	0.000	0.785	0.000	0.402	0.000	0.579	0.000	1.095
ΔHH_{t+1}	-0.001	-0.768	-0.001	-0.614	0.003	1.063	-0.006	-1.527	-0.001	-0.318	-0.001	-0.866
ΔHH_{t-1}	0.001	1.324	0.001	0.960	-0.004	-0.998	0.000	0.069	-0.003	-0.971	-0.001	-0.154
σ_t	-0.406	-1.558	0.114	0.519	-0.011	-0.062	0.767	2.279**	0.397	1.356	0.172	1.013
$\Delta\sigma_{t+1}$	-0.104	-0.675	0.074	0.402	-0.046	-0.301	0.782	2.460**	-0.181	-0.853	0.105	0.413
$\Delta\sigma_{t-1}$	0.167	0.721	-0.083	-0.401	0.148	0.960	0.444	1.523	-0.187	-0.627	0.098	0.733
Adj. R^2	0.424		0.573		0.573		0.580		0.605			
F-Stat.	3.2***		5.1***		5.1***		5.2***		5.7***			
											4.86***	

*** Significance at the 0.01 level in a two-tailed test.

** Significance at the 0.05 level in a two-tailed test.

* Significance at the 0.10 level in a two-tailed test.

Table 5.6: One-year Change Cross-sectional Regression Analysis with Current Patents, P_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. *INT* denotes intercept and *ET* is the natural logarithm of the number of years of life of a firm since establishment. All other variables are as defined in table 5.3. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (one-year) in R&D is expressed as: $\Delta X_{t+1} = (X_{t+1} - X_t)/A_t$. Past change (one-year) in R&D is expressed as: $\Delta X_{t-1} = (X_t - X_{t-1})/A_t$. Changes (expected values) in all other variables are computed similarly and scaled as defined in table 5.3, except for *L*, α, and *HH* which are ratio changes.

	Panel A: Emerging Firms										**Fama-Macbeth Regression**	
Variable	1988		1989		1990		1991		1992			
	Coeff.	t-stat.	Coeff.	t.stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
INT	-102.5	-0.995	-46.811	-1.435	5.021	0.056	89.955	2.032**	7.289	0.353	-9.417	0.004
ET	-1.078	-1.882**	-0.766	-1.154	-1.870	-1.207	-0.871	-1.381	-1.684	-2.405**	-1.254	-3.212
ΔA_{t+1}	0.238	0.119	5.064	3.086***	0.152	0.059	-3.705	-2.003**	-1.014	-0.728	0.147	0.213
ΔA_{t-1}	3.099	1.427	3.189	1.274	-11.99	-2.694***	1.336	0.671	1.283	0.521	-0.617	0.480
ΔS_{t+1}	-2.329	-1.406	1.753	1.071	-0.288	-0.127	2.562	2.129**	1.305	1.036	0.601	1.081
ΔS_{t-1}	0.792	0.392	-3.943	-1.812	10.292	2.627	0.723	0.529	-0.196	-0.094	1.534	0.657
PP_t	0.315	1.496	0.354	2.066**	0.993	2.385**	0.825	9.240***	0.281	3.203***	0.554	7.356
ΔP_{t+1}	0.384	4.128***	-0.043	-0.472	-0.266	-0.946	0.199	2.184**	0.196	1.802*	0.094	2.678
X_t	7.006	1.119	14.556	2.828***	16.661	1.826*	4.160	1.311	1.093	0.246	8.695	2.932
ΔX_{t-1}	-13.45	-1.155	-16.713	-1.598	28.469	1.371	-0.776	-0.116	32.758	3.203***	6.057	0.681
Y_t	327.3	0.930	361.7	1.891*	65.097	0.101	-735.7	-2.922***	-183.9	-0.725	-33.10	-0.290
ΔY_{t-1}	1277	0.832	1485	1.216	483.3	0.239	876.9	0.848	2765	1.561	1377	1.878
K_t	21.702	2.640***	-6.903	-0.855	-8.144	-0.438	2.675	0.357	-10.34	-1.296	-0.202	0.163
ΔK_{t-1}	-10.432	-1.008	-8.170	-0.724	23.389	1.171*	-1.569	-0.163	1.328	0.128	0.909	-0.238
α_t	0.536	3.224***	-0.556	-1.375	-0.041	-0.056	0.342	1.180	-0.091	-0.296	0.040	1.071
L_t	0.001	0.107	-0.018	-1.056	-0.009	-0.323	-0.007	-1.101	-0.004	-0.257	-0.007	-1.052
ΔL_{t-1}	0.000	0.017	0.013	0.741	0.002	0.058	0.020	2.398**	0.001	0.067	0.007	1.312
D_t	-0.414	-0.826	-0.302	-0.684	-0.316	-0.288	-0.046	-0.124	0.111	0.310	-0.193	-0.645
ΔD_{t-1}	-0.633	-1.002	0.895	1.520	-3.042	-1.620	0.034	0.037	-0.419	-0.519	-0.633	-0.634
CF_t	-4.131	-1.637	0.533	0.224	0.958	0.172	-4.452	-2.052**	-0.937	-0.277	-1.606	-1.428
ΔCF_{t-1}	-2.477	-0.721	2.424	0.913	-4.268	-0.787	6.206	3.675***	4.996	1.257	1.376	1.735
HH_t	0.046	1.063	0.012	1.118	-0.005	-0.167	-0.025	-1.534	0.002	0.408	0.006	0.355

ΔHH_{t+1}	0.152	1.218	-0.047	-1.285	-0.016	-0.095	-0.018	-0.948	-0.072	-1.729*	-0.008	-1.136
ΔHH_{t-1}	0.001	0.119	-0.047	-1.472	-0.106	-0.323	-0.034	-0.681	-0.028	-1.189	-0.043	-1.430
σ_t	0.159	0.134	-0.647	-0.574	-0.037	-0.015	-1.524	-1.844*	-1.046	-0.986	-0.619	-1.314
$\Delta\sigma_{t-1}$	0.298	0.297	0.351	0.397	-1.268	-0.566	2.350	2.931***	2.090	2.345**	0.764	2.162
Adj. R^2	0.542		0.486		0.311		0.781		0.382			
F-Stat.	6.0***		5.0***		2.9**		16.1***		3.6***		6.7***	

*** Significance at the 0.01 level in a two-tailed test.

** Significance at the 0.05 level in a two-tailed test.

* Significance at the 0.10 level in a two-tailed test.

Table 5.7: One-year Change Cross-sectional Regression Analysis with Current Patents, P_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year t across all firms. INT denotes intercept and ET is the natural logarithm of the number of years of life of a firm since establishment. All other variables are as defined in table 5.3. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (one-year) in R&D is expressed as: $\Delta X_{t+1} = (X_{t+1} - X_t)/A_t$. Past change (one-year) in R&D is expressed as: $\Delta X_{t-1} = (X_t - X_{t-1})/A_t$. Changes (expected values) in all other variables are computed similarly and scaled as defined in table 5.3, except for L, α, and HH which are ratio changes.

	Panel B: Mature Firms										**Fama-Macbeth Regression**	
Variable	1988		1989		1990		1991		1992			
	Coeff.	t-stat.	Coeff.	t.stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
INT	3,995	1,709*	-4,745	-1,768*	-2,874	-0,944	4,140	1,985**	-0,278	-0,150	0,048	0,333
ET	-0,174	-0,484	0,246	0,594	0,403	1,123	0,135	0,376	0,043	0,137	0,131	0,698
ΔA_{t+1}	-0,130	-0,113	-0,019	-0,017	1,432	0,786	0,868	0,630	1,056	0,932	0,641	0,887
ΔA_{t-1}	-1,728	-1,166	-1,669	-0,952	0,855	0,480	-1,120	-0,596	0,616	0,321	-0,609	-0,765
ΔS_{t+1}	-1,619	-1.679*	-1,293	-0,757	0,340	0,355	-0,796	-0,737	0,103	0,107	-0,653	-1,084
ΔS_{t-1}	1,849	1,078	3,015	2,063**	-1,820	-1,058	1,111	1,066	0,545	0,514	0,940	1,465
PP_t	-0,087	-0,837	0,211	1,711*	0,513	7,207***	0,115	1,969*	0,137	2.027**	0,178	4,831
ΔP_{t+1}	0,285	4,398***	0,905	8,543***	0,586	5,222***	0,375	4,304***	0,557	8,408**	0,542	12,35
X_t	0,126	0,023	28,126	4,536**	6,401	1,319	-3,113	-0,750	2,124	0.514	6,733	2,257
ΔX_{t-1}	6,656	0.569	-51,47	-3,970**	4,796	0,439	14,141	1,189	-26,67	-3,249***	-10,51	-2,009
Y_t	-40,324	-2,944***	14,998	0,891	28,062	1,402	-52,22	-2,885***	-6,376	-0,298	-11,17	-1,534
ΔY_{t-1}	22,271	0,234	138,9	0,937	-117,2	-0,963	267,7	1,418	92,569	0,608	80,86	0,894
K_t	10,707	1.730*	-5,705	-0,840	-6,292	-1,099	5,555	1,052	0,410	0,080	0,935	0,369
ΔK_{t-1}	-14,739	-1,595	-5,941	-0,523	3,240	0,301	-5,017	-0,694	10,43	1.508	-2,405	-0,401
α_t	-0,157	-0.452	0,024	0,067	-0,257	-0,707	-0,197	-0,721	0,221	0,952	-0,073	-0,344
L_t	-0,012	-0,871	-0,035	-1,823	0,021	1,673*	-0,012	-1,004	0,011	1,194	-0,006	-0,332
ΔL_{t-1}	0,010	0,640	0,042	2,003**	-0,017	-1,424	0,006	0,469	-0,016	-1,454	0,005	0,094
D_t	-0,231	-0,644	-0.472	-1,330	0,272	0,924	-0,144	-0,942	0,492	2,446**	-0,017	0,935
ΔD_{t-1}	0,006	0,011	-0,494	-0,848	-0,229	-0,417	0,147	0,360	-0,621	-1.008	-0,238	-0,761
CF_t	0,493	0,145	-1,959	-0,474	-4,644	-1,341	-0,882	-0,310	5,717	2,254**	-0,255	0,110
ΔCF_{t-1}	-0,225	-0,051	9,198	1,656*	4,140	0,874	0,314	0,115	-9,582	-3,157***	0,769	-0,225
HH_t	-0,000	-2,401**	0,001	1,651	0,000	0,702	-0,000	-2,887***	0,000	0,899	0,000	-0,814

ΔHH_{t+1}	-0.001	-0.130	-0.006	-0.702	-0.002	-0.232	-0.005	-0.804	-0.004	-1.033	-0.003	-1.160
ΔHH_{t-1}	0.002	1.298	0.006	0.725	0.007	0.444	0.003	0.621	0.004	0.834	0.004	1.569
σ_t	0.352	0.359	1.153	1.270	-1.057	-1.529	-0.068	-0.137	-0.710	-1.376	-0.066	-0.565
$\Delta\sigma_{t-1}$	-0.614	-0.713	-0.250	-0.283	0.615	1.154	0.204	0.374	1.022	2.027**	0.195	1.024
Adj. R^2	0.432		0.821		0.759		0.591		0.795			
F-Stat.	4.1***		19.4***		13.6***		6.8***		16.5**		12.1***	

*** Significance at the 0.01 level in a two-tailed test.
** Significance at the 0.05 level in a two-tailed test.
* Significance at the 0.10 level in a two-tailed test.

5.3 The Fama-French Methodology

I use a cross-sectional regression approach proposed by Fama and French (1997), following Fama and MacBeth (1973), in determining influencing variables on the valuation of growth opportunities of a firm to verify our findings. The Fama-MacBeth regressions have the following form:

$$G_{i,t} = \mu_0 + \sum_{j=1}^{H} \mu_{j,t}F_{i,j,t} + e_{i,t} \text{ for } i = 1, 2, \ldots.., N_t \tag{25}$$

where H is the number of explanatory variables, N is the number of firms, and $F_{i,j,t}$ is the realization of explanatory factor j for firm i in year t ($t = 1, 2, \ldots\ldots, T$). My sample period remains 1987-1993. I test the null hypothesis that the time-series average of year-by-year regression slopes is zero. That is,

$$\frac{\sum_{t=1}\mu_{j,t}}{T} = 0 \text{ for } j = 1,2,\ldots\ldots., T. \tag{26}$$

A t-test that assumes normality and identical independent distribution (i.i.d.) of the regression slopes is conducted. The time-series average slope coefficients are divided by their standard errors and multiplied by the square root of the number of observations.

Two sets of regressions are run for each panel, with excess firm value G, as dependent variable: (i) single variable regressions of their current, past and future changes without any control variable, whose results are given in tables 5.8 and 5.9, and

(ii) full variable regressions controlling for the influence of the rest of other variables, as presented in table 5.10. Only the two-year variable changes are included in the analysis.

I run single level regressions to first evaluate the effects of each variable on the dependent variable independent of influences from any control variable. Following Kothari and Shanken (1992) and Fama and French (1997), I include in each regression a two-year change in growth opportunities, $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$, to absorb any noise induced by their unexpected changes. When the dependent variable is G_t, the single-level cross-section regression for R&D, for example, is:

$$G_t = \mu_t + \beta_1 X_t + \beta_2 \Delta X_{t+2} + \beta_3 \Delta X_{t-2} + \beta_4 \Delta V_{t+2} \qquad (27)$$

where μ_t is the intercept term, and $\beta_1, \ldots\ldots, \beta_4$ are regressor coefficients.

I then conduct a full level regression analysis to determine if each of the variables would still retain its power in explaining changes in growth opportunities, after controlling for all other variables including the noise term. I examine if the coefficients are not zero and their t-values to confirm my earlier results. The full-level regression is expressed as follows:

$$\begin{aligned} G_t = {} & \mu_t + \beta_1 ET_t + \beta_2 \Delta A_{t+2} + \beta_3 \Delta A_{t-2} + \beta_4 \Delta S_{t+2} + \beta_5 \Delta S_{t-2} + \beta_6 P_t + \beta_7 \Delta P_{t+2} + \beta_8 PP_t \\ & + \beta_9 X_t + \beta_{10} \Delta X_{t+2} + \beta_{11} \Delta X_{t-2} + \beta_{12} Y_t + \beta_{13} \Delta Y_{t+2} + \beta_{14} \Delta Y_{t-2} + \beta_{15} K_t + \beta_{16} \Delta K_{t+2} + \beta_{17} \Delta K_{t-2} \\ & + \beta_{18} \alpha_t + \beta_{19} L_t + \beta_{20} \Delta L_{t+2} + \beta_{21} \Delta L_{t-2} + \beta_{22} D_t + \beta_{23} \Delta D_{t+2} + \beta_{24} D_{t-2} + \beta_{25} CF_t + \beta_{26} \Delta CF_{t+2} \\ & + \beta_{27} \Delta CF_{t-2} + \beta_{28} HH_t + \beta_{29} \Delta HH_{t+2} + \beta_{30} \Delta HH_{t-2} + \beta_{31} \sigma_t + \beta_{32} \Delta \sigma_{t+2} + \beta_{33} \Delta \sigma_{t-2} + \\ & \beta_{34} \Delta V_{t+2} \qquad (28) \end{aligned}$$

For emerging firms, the net investment components of internal capital (ΔA_{t+2} and ΔA_{t-2}) are positive and significantly different from zero, with t-values between 2.323 and 8.663 standard errors above zero in the single regressions in table 5.8. In the full regression in table 5.10, these variables still retain their power when subjected to control variables, with standard errors of 4.142 and 5.125 above zero. The past change in operating cash flows (ΔCF_{t-2}) is positive, with a t-value of 1.944 standard errors above zero in the single regression although in the full regression it loses its power. Current operating cash flow (CF_t) remains significantly negative with t-values of -5.837 and -4.170 standard errors above zero in the single and full regressions, respectively. The expected future change (ΔCF_{t-2}), however, has a weak and mixed influence. These results are very consistent with the findings in table 5.4. There is thus, strong evidence that internal capital significantly influences growth opportunities of emerging firms.

As for established companies, net investments are positive and significant in the single regressions in table 9. However, when controlled for other variables in the full regression, they become less influential and, in fact, show a change of sign (table 10). Overall, net investment explains changes in growth opportunities more in emerging firms than it does in mature firms. Operating cash flows are positive in both regressions (except past change), and current value is highly significant. This again confirms our results in tables 5.

Table 5.8 shows that R&D variables of emerging firms (X_t, ΔX_{t+2} and ΔX_{t-2}) significantly contributes to changes in growth opportunities. When controlled (table 5.10), they lose some power except current R&D (X_t) which remains significantly positive. These contrast with mature firms whose R&D variables in the single regression are positive, but not as significant, and the current R&D in the full regression is significantly negative.

Rival R&D has some effect on the dependent variable though not significant. There is evidence that past change in rival R&D (ΔY_{t-2}) has a positive influence but current level (Y_t) and future change (ΔY_{t+2}) have negative effects on growth opportunities of emerging firms (table 5.10). Independent of control variables, however, current rival R&D show a positive effect. For mature firms, rival R&D are not significant but they bear influence nevertheless. In the single regression, current and past rival R&D are positive but in the full regression, current rival R&D is negative while past and future changes are positive. We can conclude that for both mature and emerging firms, current rival R&D is beneficial. But when controlled for other variables, they show a negative relationship and only past change show a positive effect.

In the single regression, current patents (P_t) are positive, future change in patents (ΔP_{t-2}) is positive and significant, and stock of patents (PP_t) is negative for emerging firms. When controlled for other influences, current patents lose power and become negative, future change in patents lose power but remain positive, and stock of patents gain power and become positive. For mature firms, expected change in patents remains positive and significant whereas current and past change in patents are negative, with less influence in the control regression.

All current (K_t), past (ΔK_{t-2}) and future (ΔK_{t+2}) changes in capital expenditures for mature firms are positive. Current and future change variables show significance in the single regression but only past change in capital expenditure is significant after controlling for other influences. For emerging firms, only future change in capital expenditure show a positive relationship in the full regression. In terms of volatility in capital expenditures (α_t), the coefficient for emerging firms is negative in both single and full regressions. It is negative in the single regression but becomes positive in the full regression for mature firms. Nevertheless, it still lends support to the prediction of the model.

There is evidence that debt has a significantly negative relationship with changes in growth opportunities for emerging firms. This is not the same for mature firms which show that only future changes in debt (ΔD_{t+2}) is negative but current (D_t) and past debt (ΔD_{t-2}) levels are positive though not significant (table 10).

Another important factor to determine is the effect of volatility of the investment project (σ_t). The results indicate that volatility has a positive effect on growth opportunities for both subsamples. Future volatility ($\Delta\sigma_{t+2}$) has a particularly stronger effect for emerging firms whereas for mature firms it is past volatility ($\Delta\sigma_{t-2}$) which is significant. The prediction of the model that volatility of the project should contribute positively to the change in real growth option is thus supported.

Growth in sales (ΔS_{t-2} and ΔS_{t-2}) which are meant to proxy expected benefits of monopoly rents are positive and significant in the single regression for emerging firms as expected. However, they lose power drastically in the full regression, showing negative coefficients. The picture is similar for mature firms. The Herfindahl-Herschman index (*HH*) shows very little influence in both panels.

Following Fama and French (1997), I run regressions of only the change parameters on change value of growth opportunities, $\Delta G_t = [(V_t - A_t) - (V_{t-2} - A_{t-2})]/A_t$.

This is an alternative technique to the common event-study methodology and has the advantage of measuring valuation effects on a longer-term than the event studies do. The change-cross-section regressions are similarly expressed as in equation (27), for single-level, and in equation (28), for full-level, with the exception that only change variables are included. All current variables are omitted. The results, presented in tables 5.11, 5.12 and 5.13 are still very consistent with earlier analysis.

Table 5.8: Fama-French Cross-sectional Single Regressions with Excess Value, G_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year t across all firms. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in R&D is expressed as: $\Delta X_{t+2} = (X_{t+2} - X_t)/A_t$. Past change (two-year) in R&D is expressed as: $\Delta X_{t-2} = (X_t - X_{t-2})/A_t$. Changes (expected values) in all other variables are computed similarly and scaled as defined in table 5.3, except for L, α, and HH which are ratio changes. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$. All other variables are as defined in tables 5.3 and 5.6.

Panel A: Emerging Firms

	INT	ET_t			ΔV_{t+2}
Coeff.	2.639	-0.765			-0.147
t (Mean)	4.431	-3.487			-2.516
	INT		ΔA_{t+2}	ΔA_{t-2}	ΔV_{t+2}
Coeff.	0.405		1.762	0.745	-0.251
t (Mean)	3.647		8.663	2.323	-5.295
	INT		ΔS_{t+2}	ΔS_{t-2}	ΔV_{t+2}
Coeff.	0.357		1.310	0.271	-0.167
t (Mean)	2.995		8.523	1.068	-3.096
	INT	P_t	ΔP_{t+2}	PP_t	ΔV_{t+2}
Coeff.	0.331	0.023	0.068	-0.005	-0.202
t (Mean)	2.201	0.853	3.261	-0.359	-3.338
	INT	X_t	ΔX_{t+2}	ΔX_{t-2}	ΔV_{t+2}
Coeff.	-0.225	5.148	10.368	3.629	-0.229
t (Mean)	-1.632	6.614	7.610	2.840	-4.229
	INT	Y_t	ΔY_{t+2}	ΔY_{t-2}	ΔV_{t+2}
Coeff.	-0.227	12.695	34.876	-124.2	-0.156
t (Mean)	-0.317	0.797	-0.174	0.184	-2.541

	INT	K_t	ΔK_{t+2}	ΔK_{t-2}	α_t	ΔV_{t+2}
Coeff.	0.359	3.845	10.438	2.548	-0.172	-0.261
t (Mean)	1.916	1.128	4.277	1.000	-1.566	-4.045
	INT	L_t	ΔL_{t+2}	ΔL_{t-2}		ΔV_{t+2}
Coeff.	0.577	-0.009	0.012	-0.005		-0.107
t (Mean)	1.852	-2.108	4.335	-1.137		-1.820
	INT	D_t	ΔD_{t+2}	ΔD_{t-2}		ΔV_{t+2}
Coeff.	0.605	0.010	0.309	-0.213		-0.218
t (Mean)	3.433	0.114	3.576	-1.221		-3.312
	INT	CF_t	ΔCF_{t+2}	ΔCF_{t-2}		ΔV_{t+2}
Coeff.	0.879	-3.354	0.016	1.203		-0.170
t (Mean)	6.406	-5.837	-0.040	1.944		-2.788
	INT	HH_t	ΔHH_{t+2}	ΔHH_{t-2}		ΔV_{t+2}
Coeff.	1.433	-0.001	0.002	-0.002		-0.156
t (Mean)	0.482	-0.091	0.079	0.260		-2.561
	INT	σ_t	$\Delta\sigma_{t+2}$	$\Delta\sigma_{t-2}$		ΔV_{t+2}
Coeff.	0.086	0.640	0.444	0.021		-0.146
t (Mean)	0.087	1.765	1.320	-0.248		-2.426

Table 5.9: Fama-French Cross-sectional Single Regressions with Excess Value, G_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. All variables and their changes are as defined in tables 5.3, 5.6 and 5.8. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$.

Panel B: Mature Firms

	INT	ET_t			ΔV_{t+2}
Coeff.	1.297	-0.338			0.088
t (Mean)	3.544	-3.818			3.247
	INT		ΔA_{t+2}	ΔA_{t-2}	ΔV_{t+2}
Coeff.	-0.063		0.681	1.032	0.068
t (Mean)	-2.083		2.652	3.026	2.168
	INT		ΔS_{t+2}	ΔS_{t-2}	ΔV_{t+2}
Coeff.	-0.078		0.039	0.729	0.128
t (Mean)	-2.473		-0.880	4.048	4.089
	INT	P_t	ΔP_{t+2}	PP_t	ΔV_{t+2}
Coeff.	0.008	-0.029	0.054	-0.045	0.109
t (Mean)	-1.266	-0.439	1.760	-1.872	3.666
	INT	X_t	ΔX_{t+2}	ΔX_{t-2}	ΔV_{t+2}
Coeff.	-0.121	0.847	5.412	5.918	0.104
t (Mean)	-2.043	0.697	2.265	1.754	3.340
	INT	Y_t	ΔY_{t+2}	ΔY_{t-2}	ΔV_{t+2}
Coeff.	-0.238	3.713	-10.30	10.388	0.103
t (Mean)	-1.852	1.043	-0.157	0.296	3.586

	INT	K_t	ΔK_{t+2}	ΔK_{t-2}	α_t	ΔV_{t+2}
Coeff.	-0.315	5.117	8.809	1.752	-0.052	0.055
t (Mean)	-3.649	3.582	4.476	0.742	-0.540	2.266
	INT	L_t	ΔL_{t+2}	ΔL_{t-2}		ΔV_{t+2}
Coeff.	-0.327	0.011	-0.004	-0.005		0.119
t (Mean)	-2.736	3.067	-0.895	-1.856		4.445
	INT	D_t	ΔD_{t+2}	ΔD_{t-2}		ΔV_{t+2}
Coeff.	0.034	-0.070	0.006	0.067		0.111
t (Mean)	0.064	-1.152	-0.518	0.436		3.680
	INT	CF_t	ΔCF_{t+2}	ΔCF_{t-2}		ΔV_{t+2}
Coeff.	-0.679	4.565	1.192	0.495		0.059
t (Mean)	-8.494	8.382	1.415	1.147		2.028
	INT	HH_t	ΔHH_{t+2}	ΔHH_{t-2}		ΔV_{t+2}
Coeff.	-0.116	0.000	-0.001	0.000		0.109
t (Mean)	-2.113	1.463	-0.624	0.554		3.777
	INT	σ_t	$\Delta \sigma_{t+2}$	$\Delta \sigma_{t-2}$		ΔV_{t+2}
Coeff.	0.064	-0.170	-0.273	0.133		0.122
t (Mean)	0.238	-0.972	-2.001	0.162		4.131

Table 5.10: Fama-MacBeth Cross-sectional Full Regressions with Excess Value, G_t, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. All variables and their changes are as defined in tables 5.3, 5.6 and 5.8. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$. t-statistic in parenthesis.

Variable	Emerging Firms	Mature Firms
INT	9.124	-0.294
	(0.409)	(-1.114)
ET_t	-0.392	-0.221
	(-2.364)	(-1.998)
ΔA_{t+2}	1.457	0.709
	(4.142)	(0.981)
ΔA_{t-2}	2.580	-0.307
	(5.125)	(-0.154)
ΔS_{t+2}	-0.098	-0.503
	(0.377)	(-2.001)
ΔS_{t-2}	-0.596	-0.038
	(-1.928)	(-0.138)
P_t	-0.009	-0.037
	(-0.273)	(-1.448)
PP_t	0.063	-0.022
	(1.295)	(-0.927)
ΔP_{t+2}	0.010	0.072
	(0.627)	(2.923)
X_t	4.040	-5.711
	(3.438)	(-4.195)
ΔX_{t+2}	4.681	-0.559
	(2.083)	(-0.884)
ΔX_{t-2}	0.559	-2.335
	(0.384)	(-0.852)
Y_t	-45.734	-3.729
	(-0.435)	(-0.061)
ΔY_{t+2}	18.382	19.759
	(-1.209)	(0.810)
ΔY_{t-2}	18.504	60.109
	(0.628)	(0.860)
K_t	-3.053	1.873
	(-1.386)	(1.104)
ΔK_{t+2}	0.014	1.824
	(0.141)	(0.928)
ΔK_{t-2}	-0.794	4.030
	(-0.269)	(1.904)

Variable	Emerging Firms	Mature Firms
α_t	-0.024	0.144
	(-0.152)	(1.687)
L_t	0.002	0.003
	(0.512)	(0.702)
ΔL_{t+2}	-0.001	-0.004
	(-0.240)	(-0.852)
ΔL_{t-2}	-0.002	0.003
	(-0.175)	(0.618)
D_t	-0.026	0.065
	(-0.220)	(0.894)
ΔD_{t+2}	-0.071	-0.088
	(-0.488)	(-0.400)
ΔD_{t-2}	-0.643	0.037
	(-3.509)	(0.102)
CF_t	-3.049	5.914
	(-4.170)	(6.738)
ΔCF_{t+2}	-0.621	1.409
	(-1.467)	(1.487)
ΔCF_{t-2}	0.354	-0.984
	(0.313)	(-1.282)
HH_t	-0.004	0.000
	(-0.351)	(1.518)
ΔHH_{t+2}	-0.018	-0.002
	(-0.960)	(-1.324)
ΔHH_{t-2}	0.001	0.000
	(-0.138)	(0.571)
σ_t	0.180	0.271
	(0.649)	(1.141)
$\Delta\sigma_{t+2}$	0.507	0.358
	(2.217)	(2.014)
$\Delta\sigma_{t-2}$	0.301	0.231
	(1.299)	(1.456)
ΔV_{t+2}	-0.264	0.035
	(-4.583)	(1.168)

Table 5.11: Fama-French Cross-sectional Single Regressions with Change in Excess Value, $\Delta G_t = [(V_t - A_t) - (V_{t-2} - A_{t-2})]/A_t$, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$. All other variables are as defined in tables 5.3, 5.6 and 5.8.

Panel A: Emerging Firms

	INT	ET_t		ΔV_{t+2}	INT	ΔK_{t+2}	ΔK_{t-2}	α_t	ΔV_{t+2}
Coeff.	-0.430	0.224		-0.230	0.186	4.039	1.654	-0.159	-0.308
t (Mean)	-0.926	1.324		-4.804	1.485	2.500	0.852	-2.231	-6.045
	INT	ΔA_{t+2}	ΔA_{t-2}	ΔV_{t+2}	INT	ΔL_{t+2}	ΔL_{t-2}		ΔV_{t+2}
Coeff.	0.047	1.155	0.017	-0.348	0.332	0.003	-0.006		-0.222
t (Mean)	0.545	8.736	-0.501	-9.151	1.455	1.376	-2.609		-4.979
	INT	ΔS_{t+2}	ΔS_{t-2}	ΔV_{t+2}	INT	ΔD_{t+2}	ΔD_{t-2}		ΔV_{t+2}
Coeff.	0.088	0.503	-0.202	-0.230	0.191	-0.025	-0.273		-0.280
t (Mean)	0.810	4.960	-1.663	-5.527	1.461	0.800	-2.211		-5.665
	INT	ΔP_{t+2}	ΔP_{t-2}	ΔV_{t+2}	INT	ΔCF_{t+2}	ΔCF_{t-2}		ΔV_{t+2}
Coeff.	0.202	-0.002	-0.001	-0.279	0.173	0.017	0.029		-0.246
t (Mean)	1.576	-0.749	0.453	-5.976	1.345	-0.835	0.774		-4.702
	INT	ΔX_{t+2}	ΔX_{t-2}	ΔV_{t+2}	INT	ΔHH_{t+2}	ΔHH_{t-2}		ΔV_{t+2}
Coeff.	0.092	4.535	0.469	-0.259	0.251	0.001	0.001		-0.357
t (Mean)	0.902	4.576	0.179	-5.984	1.707	1.026	0.307		-5.300
	INT	ΔY_{t+2}	ΔY_{t-2}	ΔV_{t+2}	INT	$\Delta\sigma_{t+2}$	$\Delta\sigma_{t-2}$		ΔV_{t+2}
Coeff.	0.105	-3.766	7.696	-0.253	0.251	0.053	0.179		-0.246
t (Mean)	0.446	-0.070	0.723	-5.303	1.707	0.176	0.658		-4.702

Table 5.12: Fama-French Cross-sectional Single Regressions with Change in Excess Value, $\Delta G_t = [(V_t - A_t) - (V_{t-2} - A_{t-2})]/A_t$, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. All variables and their changes are as defined in tables 5.3, 5.6 and 5.8. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t-2} - V_t)/A_t$.

Panel B: Mature Firms

	INT	ET_t		ΔV_{t+2}
Coeff.	0.478	-0.125		0.048
t (Mean)	1.206	-1.439		2.183
	INT	ΔA_{t+2}	ΔA_{t-2}	ΔV_{t+2}
Coeff.	-0.055	0.424	0.321	0.022
t (Mean)	-2.401	2.781	1.609	0.869
	INT	ΔS_{t+2}	ΔS_{t-2}	ΔV_{t+2}
Coeff.	-0.056	0.008	0.560	0.049
t (Mean)	-2.621	0.080	2.653	2.080
	INT	ΔP_{t+2}	ΔP_{t-2}	ΔV_{t+2}
Coeff.	-0.010	0.026	-0.025	0.051
t (Mean)	-1.221	2.660	-2.997	2.201
	INT	ΔX_{t+2}	ΔX_{t-2}	ΔV_{t+2}
Coeff.	-0.035	4.106	0.526	0.043
t (Mean)	-1.959	2.823	0.390	1.734
	INT	ΔY_{t+2}	ΔY_{t-2}	ΔV_{t+2}
Coeff.	-0.013	-11.75	16.978	0.050
t (Mean)	-0.703	-1.264	1.440	2.125

INT	ΔK_{t+2}	ΔK_{t-2}	α_t	ΔV_{t+2}
-0.017	5.082	1.388	-0.072	0.019
-1.353	3.905	1.169	-1.294	0.867
INT	ΔL_{t+2}	ΔL_{t-2}		ΔV_{t+2}
-0.063	0.005	-0.006		0.047
-1.367	3.896	-3.704		2.220
INT	ΔD_{t+2}	ΔD_{t-2}		ΔV_{t+2}
-0.014	0.020	0.024		0.056
-1.523	-0.192	0.326		2.467
INT	ΔCF_{t+2}	ΔCF_{t-2}		ΔV_{t+2}
-0.024	0.677	2.766		0.016
-1.993	1.792	8.214		0.672
INT	ΔHH_{t+2}	ΔHH_{t-2}		ΔV_{t+2}
-0.003	0.000	0.000		0.055
-1.474	0.609	-0.931		2.431
INT	$\Delta \sigma_{t+2}$	$\Delta \sigma_{t-2}$		ΔV_{t+2}
-0.042	-0.259	-0.023		0.064
-1.641	-2.576	-0.729		2.778

Table 5.13: Fama-MacBeth Cross-sectional Full Regressions with Change in Excess Value, $\Delta G_t = [(V_t - A_t) - (V_{t-2} - A_{t-2})]/A_t$, as Dependent Variable

Mean coefficients and their t-statistics from simple regressions run for each year *t* across all firms. All variables and their changes are as defined in tables 5.3, 5.6 and 5.8. A firm must have data on all variables in the seven-year sample period, 1987-1993. Future change (two-year) in market value V_t is expressed as: $\Delta V_{t+2} = (V_{t+2} - V_t)/A_t$. t-statistic in parenthesis.

Variable	Emerging Firms	Mature Firms
INT	-0.485	0.084
	(-0.512)	(-0.174)
ET_t	0.204	-0.071
	(1.207)	(-0.611)
ΔA_{t+2}	1.250	0.419
	(4.933)	(0.457)
ΔA_{t-2}	0.680	-0.298
	(1.679)	(-1.420)
ΔS_{t+2}	0.090	-0.268
	(0.256)	(-1.660)
ΔS_{t-2}	-0.784	0.047
	(-2.590)	(-0.433)
ΔP_{t+2}	-0.009	0.035
	(-0.496)	(3.305)
ΔP_{t-2}	0.010	-0.024
	(1.191)	(-2.997)
ΔX_{t+2}	1.496	-1.051
	(1.178)	(-0.769)
ΔY_{t-2}	2.544	-3.515
	(1.881)	(-1.906)
ΔY_{t+2}	-30.805	2.334
	(-0.547)	(0.300)
ΔY_{t-2}	30.805	5.845
	(0.212)	(0.316)
ΔK_{t+2}	1.875	2.136
	(1.057)	(1.628)

Variable	Emerging Firms	Mature Firms
ΔK_{t-2}	-1.549	1.928
	(-0.830)	(1.312)
α_t	-0.160	-0.026
	(-2.481)	(-0.637)
ΔL_{t+2}	0.001	0.001
	(0.267)	(1.057)
ΔL_{t-2}	-0.002	-0.001
	(-1.252)	(-0.403)
ΔD_{t+2}	-0.082	-0.062
	(-0.619)	(-1.176)
ΔD_{t-2}	-0.129	0.029
	(-1.037)	(0.572)
ΔCF_{t+2}	-1.041	0.599
	(-1.573)	(1.075)
ΔCF_{t-2}	0.983	2.383
	(1.855)	(4.505)
ΔHH_{t+2}	0.002	0.000
	(0.337)	(-0.550)
ΔHH_{t-2}	- 0.001	0.000
	(-0.165)	(-0.682)
$\Delta \sigma_{t+2}$	-0.018	-0.083
	(-0.025)	(-0.526)
$\Delta \sigma_{t-2}$	0.331	0.245
	(1.775)	(1.972)
ΔV_{t+2}	-0.385	-0.001
	(-7.253)	(-0.180)

5.4 Concluding Remarks

This empirical study analyzes the theoretical model developed for valuing internal corporate growth opportunities. In the model we have shown that a firm acquires growth opportunities by making a successful risky competitive R&D investments. Growth opportunities which constitute the greater part of the market value of start-up and emerging firms are valued as a real compound option. The model and its underlying assumptions highlight important qualitative differences that exist between assets-in-place and real growth options. The objective of the empirical study is to examine the determinants of growth opportunities, particularly the relevant variables that spawn the real option, and their implications for both emerging and mature firms.

As predicted, the empirical results demonstrate that the magnitudes of growth opportunities of emerging and established firms are significantly different. On average, 38 percent of the market value of an emerging firm is accounted for by growth opportunities compared with only 5 percent for a mature firm. We recognize that all the firms in our sample are followed by Compustat, and may have already been qualified as "successful" with "tractable" performance of existing assets. It is therefore conceivable that the contribution of intangible growth options to the market value could be much higher than the reported 38 percent level for emerging firms.

Based on the theoretical model, we hypothesize that emerging firms tend to rely more on internal capital as opposed to mature companies that have greater access to external capital markets to finance investment opportunities. This is strongly supported by the empirical results. For emerging firms, R&D expenditures are significantly positive and internal capital markets are significant negative. These results are consistent with our model in the sense that internal cash flows are expected to be exhausted in financing innovation, with R&D being a valuable determinant of growth opportunities since it serves to speed up innovation and shorten the maturity date of the real call option.

However, mature firms show the opposite results: internal cash flows have a positive and significant influence on growth opportunities while R&D is negative and significant. A plausible explanation is that the market recognizes available investment opportunity sets for these firms but may prefer that they purchase ready technology through, for instance, synergistic mergers and acquisitions rather than engaging in risky R&D investments which have very uncertain payoffs.

If growth opportunities are a significant component of the market value of emerging firms, then we would expect acquisition of debt to have a negative impact due to the under-investment hypothesis of Myers (1977). We document that emerging firms have lower debt ratio than mature firms, but this difference is not significant. We also find that debt is negative for emerging firms but positive for mature firms. However, these influences are not significant, further indicating a weaker support for the hypothesis. As explained earlier, the emerging firms in our sample may not be "unknowns" in the market after all. Thus, they don't suffer from the capital markets constraints to the extent that a typical start-up firm would.

Patents are predicted by the model to be a good proxy for the time to maturity of the real option. Thus, we would expect patents to have a positive influence on growth opportunities. Our results show that they are valuable. However, they tend to lose power when controlled for other variables. Nevertheless, we find that past patents and R&D have significantly positive impact on the output of current patents.

We find that volatility in capital expenditures has a negative influence on emerging firms but a positive effect on mature firms, as predicted. However, their effects are not significant. The capital expenditure levels, except past changes, show a week and negative influence on growth opportunities for emerging firms but a strong positive correlation for mature firms. These results support the model prediction, and indicate that capital expenditures are a necessary price to pay to acquire the monopoly rents. However, the unexpected variation in the level of the strike price may lead to possibility of a firm leaving the real option unexercised, thereby foregoing the benefits of innovation. The positive effect for mature firms tends to suggest that they are well diversified and have adequate hedging possibilities.

The riskier the R&D investments, the more valuable the real growth option, strongly supporting the prediction of the model. However, this effect is weaker for mature firms, perhaps due to their ability to diversify, and the fact that their investments may be supported more by existing assets (collateral effect).

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

Most businesses are valued as going concerns with the assumption that management is expected to make continued future investments. The level of investment made at each stage of the life of the firm is determined by the net present value that is expected to accrue such that the return on investment exceeds the cost of capital. The set of such investments opportunities is generated by existing and continuously accumulated assets.

But what if the decision to invest is discretionary and not automatic? For instance, a firm may be faced with different future states of nature such that if conditions are not favorable it would decide not to make an investment. Furthermore, the investment opportunities available can only be valuable when it is acquired, and is not guaranteed by any asset in place. It turns out that under such circumstances, the firm has an option of whether to invest or not. Thus, part of the market value of the firm is accounted for by the present value of future growth opportunities, real options, that can only be acquired if management exercises the option to invest.

For many companies, the value of growth opportunities is greater than the value of assets-in-place. This is particularly true for start-up and emerging firms, although it may not be so important for well established firms. The possibility that current investments may influence future opportunities, either by creating growth opportunities or minimizing the value of an existing opportunity set, is widely accepted. However, despite known potentials, the scope of actual economic interactions of current options and future corporate growth opportunities have been far less understood. Popular valuation techniques, for instance the discounted cash flow models, tend to ignore the qualitative difference between real growth options and the assets-in-place. Thus, contractual growth relating to existing assets are erroneously lumped together with strategic growth opportunities arising from financing, investing and operating flexibilities.

Whereas this problem may have limited implications for mature firms, it is critical for start-up ventures where the bulk of market value is in the real options in intangible investment opportunities. The significance of the problem and the breadth of its implications has motivated this dissertation. The study aims at addressing this problem and has focused on the growth option component of the firm. The central point in this investigation is the recognition that firms are not endowed with real growth options. This implies that the issue of how real options are distributed among firms becomes nontrivial. Most models start with designing a form of distribution of real options across firms then proceed to value them. In my model, I begin one step earlier with the allocation of real growth options through competitive investments in basic R&D.

I have developed a model for valuing the growth opportunities of a firm that is internally generated. Growth opportunities are valued as compound real options. It starts with a firm having an original idea for making a breakthrough discovery and introducing a new product into the market. That idea must be financed, through R&D investments, and the discovery made sooner otherwise a successful competitor may overtake the firm and win. A firm that loses the competitive race to innovate gets zero value of growth opportunities.

Once a discovery is made, the successful firm must decide to make additional investments to manufacture the product. Thus, R&D is essentially a real call option: the underlying asset is the expected value of a completed investment project; maturity date is the time the discovery is made and the firm simultaneously decides whether to produce; the exercise price is the manufacturing expenditure which is considered uncertain as the R&D investments proceed; volatility of the underlying asset comes from the risk of the expected cash flows from a completed project as well as the uncertainty surrounding the capital investment.

Sometimes mass producing a breakthrough product may not be sufficient. Additional investments in advertising and marketing may be required to open up the market for the new product. The firm can only choose to incur advertising costs if the enhanced value it generates consequently is greater than the value it would have earned without making this additional expenditure. I therefore model advertising investment as a real exchange option where the original project value is the delivery asset and the enhanced value received is the option asset following Carr (1988). In sum, the value of internally generated growth opportunities is modeled as a combination of a real call option and an exchange option.

There are essentially three components of this investigation. First, the theoretical model is developed. Second, a scenario analysis is conducted to examine the impact of each of the variables reflected in the model on the value of growth opportunities. Third, real data on a sample of firms is analyzed to test the model and identify any deviations from the theoretical and scenario analysis results, and compare with earlier findings in existing finance literature.

6.2 Internal Capital Markets and Growth Opportunities

Because of information asymmetry surrounding basic R&D investments, access to internal sources of financing is a binding constraint on emerging firms. The theoretical model implies that internal cash flow should have a greater effect on growth opportunities for these firms. The study documents evidence that emerging firms tend to rely more on internal capital as opposed to mature companies that have greater access to the capital markets for external funding. This is consistent with Lamont (1997) who finds that decreases in cash flow decrease investments, and Myers and Majluf's information asymmetry model (1984) which implies that a decline in internal finance introduces under-investment problem. Fazzari, Hubbard, and Peterson (1988), and Hoshi, Kashyap, and Scharfstein (1991) also provide evidence that investment is related to the availability of internal funds.

6.3 Leverage and Growth Opportunities

I find that debt has a negative contribution to growth opportunities for emerging firms, consistent with the tradition of Myers (1977) suggesting that a firm's borrowing should be inversely related to the extent that its value depends on the value of future investment opportunities. These results are in contrast with Lang, Ofek, and Stulz (1996) who find that there is a negative relation between leverage and growth only for firms with low Tobin's-q. A liquidity argument to the debt over-hang hypothesis is that leverage should reduce growth more for firms with valuable growth opportunities, because such firms have greater informational asymmetries, making external funds more expensive to obtain. The agency costs of managerial discretion (Jensen 1986, Stulz 1990) also imply that the adverse impact on leverage on growth increases firm value by preventing managers from taking poor projects.

I establish contradictory results for mature firms. They exhibit a positive correlation of debt ratio with growth opportunities, although the effect is not significant. One could explain this behavior in the context of Schlingemann (1998) that, if management has exhausted all positive NPV projects, the likelihood of investing in negative NPV projects increases with greater levels of managerial discretion over investment funds. Thus, the choice of debt financing, which lowers managerial discretion, merely signals that the market recognizes ample positive NPV projects available for well established firms.

My results also show that emerging firms have lower debt ratio than mature firms, although this difference is not significant. They provide support to existing capital structure literature indicating that managers of firms with valuable growth opportunities should choose lower leverage because these companies might not be able to take advantage of their investment opportunities if they have to raise outside funds. Smith and Watts (1992), and Jung, Kim, and Stulz (1995) also provide supportive evidence that firms with valuable growth opportunities choose low leverage. Myers (1977) shows that the amount of debt supported by growth opportunities will be less, other things equal, than is supported by assets already in place. Mackie-Mason (1990) also finds that firms that have exhausted their tax shields (i.e., have little or no taxable income) are less likely to choose debt financing.

6.4 R&D and Rival R&D

The critical role of R&D expenditure of the firm and of its rival in the model is to speed up innovation and shorten the maturity date of the real call option. R&D (and to some extent past R&D) generally has a significant influence on innovation, and a strong positive correlation with growth opportunities of emerging firms, consistent with Bound et al (1984), Cockburn and Griliches (1988), Megna and Klock (1993), Chauvin and Hirschey (1993), and Szewczyck, Tsetsekos, and Zantout (1996). In contrast, I find that R&D of mature firms, when controlled for other variables, show a negative relation with growth opportunities. Here is a plausible explanation. Given that the market has recognized available growth opportunity sets for these firms, the agency cost of managerial discretion (Stulz 1990) and the over-investment problem of free cash flow of Jensen (1986) imply that investing in the more risky basic R&D, with uncertain payoff, is considered wasteful.

Rival R&D is beneficial to the extent that it lowers the expected time of successfully completing R&D project. Jaffe (1986) suggests that rival R&D spillovers constitute a positive externality. My model and results show that the benefit from rival R&D is overshadowed by its negative effect on the profits of the firm due to competition, in line with Ben-Zion (1984) and Jaffe (1986). Expected future values of rival R&D have especially negative impact on growth opportunities and reflects the confounding negative effect of competition.

6.5 Patents

The valuation of patents has often generated mixed results and controversies. Recently, with the emergence of biotechnology industry, the issue has renewed interest. Hamilton (1996) argues that calculations of quantity rather than quality are worthless, citing Japan's Takeda Chemical Industries Ltd. that was ranked first among biotech corporate patent holders in Europe, Japan and the U.S. but hasn't developed any gene-related drug. Other studies have shown that the usefulness of patents may be industry-related. Ben-Zion (1984) explains that not all patents result in the production of a new profitable product. However, a firm's patents are relevant for other firms in the industry in the sense that they contribute to increased technical knowledge or indicate a potential for new lines of research.

Griliches (1981) suggests that both R&D and patents are inputs of innovation. Cockburn and Griliches (1988) find that in the absence of R&D variables, past patents are significantly valuable. Austin (1993) shows that patents are useful as indicators of innovative output and may produce no value if they have been fully anticipated by the market. My results establish that patents are valuable, and have a significant influence on innovation. When controlled for other variables, however, only past stock of patents for emerging firms retain power whereas it is the expected future patents that are valuable for established firms. Subject to industry performance, a firm's patents can be a good proxy for the time to maturity of the real options.

6.6 Capital Expenditure

One key parameter of my model is the magnitude of the strike price, the capital investment, which is critical in determining the exercise decision of the firm. Because of the uncertainty underlying the process of innovation, the actual amount to be paid as the exercise price may be unknown at the time the discovery is made. If it turns out that the required capital investment is too high, the option is not exercised and the growth opportunities are lost.

I find that capital expenditure has a negative influence on growth opportunities for emerging firms but a positive effect for mature firms. Existing research, for instance, Pindyck (1993), Beranek, Cornwell, and Choi (1995), and Blose and Shieh (1997) have examined the effect of capital expenditure only on capital projects or mature firms. Although they document evidence similar to my findings for established firms, the distinction with relatively young companies is not considered. The emerging firms sample contrasts these existing results and strongly supports the prediction of my model.

I document that volatility in capital expenditures has a negative impact on emerging firms, implying that the high volatility may lead to an increased amount of required capital spending to the extent that the growth option is not worth exercising. This may be explained in part by Fazzari et al (1988) who provide evidence that when firms rely heavily on internal funds for financing investments, their expenditures on investments are more sensitive to fluctuations in cash flows than high-dividend-paying firms.

Consistent with my results for mature firms, McConnel and Muscarella (1985) also find that unanticipated increases in planned capital expenditures have a positive effect on the market value of the firm, and that unanticipated decreases have a negative effect. The implication is that for well established firms that have more access to the capital markets, the opportunity cost of passing up a valuable investment opportunity far exceeds the cost of hedging the uncertainty in capital investment.

6.7 Monopoly Rents and Underlying Risk

I have shown that the expected benefit to be derived from a successfully completed R&D investment is positively related to the real growth option, consistent with the prediction of option pricing theory. Emerging firms are found to be significantly riskier than well established firms, supporting Chung and Chareonwang (1991) who conclude that a firm that has large portion of its value accounted for by the present value of future growth opportunities, would exhibit a higher stock risk than the mature firm whose value is largely determined by the capitalized value of an earnings stream generated by existing assets. Furthermore, I find that the riskier the monopoly rents the more valuable the real growth option. This effect is strong for emerging firms but weak for mature firms, given the low volatility of the latter due to their very diversified nature.

6.8 Sample Selection Problem

As in many empirical investigations, this study has encountered lack of ample data set to test the model. This problem is particularly true for young and emerging firms which are the main focus of the dissertation.

For a firm to qualify for the sample it must be a U.S. publicly traded company, tracked by Compustat, have non-missing data for all relevant variables from 1987 to

1993, be covered by CASSIS CD-ROM (for patents) during the period 1969-1993, and belong to the Standard Industrial Classification code 3000 (manufacturing). These specifications effectively reduced the sample size considerably from a potential 1,000 to the final 208 firms. Furthermore, since companies followed by Compustat are reasonably successful, some young struggling firms may have been excluded, introducing a survivorship bias in the analysis.

Another problem concerns what may be considered "standard" or "more acceptable" definition and classification of "emerging firm" or "growth firm." So far I have no knowledge that there is any general consensus in the field of finance on the issue. My criterion was determined by dividend payments policy, based on evidence from signaling theory and capital markets constraints. I classified a firm as "emerging" if it has never issued any dividends since its incorporation, as in Pilotte (1992). Some researchers and practitioners have used price-earnings relationship, market-to-book ratio, and Tobin's q ratio. One may also argue that the growth phenomenon is cyclical citing, for instance, IBM which has been a mature company but has turned into a "growth firm" in the 1990s. And yet another might wonder if Microsoft (which has not paid common dividends) is still emerging.

6.9 Future Research

This dissertation project suggests several possible avenues for future research, including:

(a) an extension of the empirical work to cover more U.S. firms and industries.

(b) comparative analysis of determinants of growth opportunities and capital structure of firms in Japan, Western Europe and the U.S. (developed capital markets).

(c) analysis of determinants of growth opportunities and capital structure of firms in developing and emerging markets, examining the impact of the degree of capital markets development.

(d) valuation of IPOs and start-up firms (bank, venture capital, and market financing).

(e) valuation of advertising expenditure as a real exchange option, with reference to new product developments.

(f) valuation of biotech firms as well as new technology licensing agreements.

(g) mergers and acquisitions, and diversification strategies.

(h) privatization and restructuring.

(i) corporate control: why do firms remain private *vs* why do firms go public?

6.10 Concluding Remarks

I have presented a valuation model for pricing a firm that may have no existing assets as a compound option. Based on the scenario and empirical analyses, the model appears to fit emerging firms especially well. I find that any investment or financing policy that ignores the qualitative difference between real growth options and the assets-in-place is erroneous. In pursuit of innovative breakthroughs and new product developments, consideration of the volatility in capital investment is important, and could even be more so in less developed capital markets.

The model developed here could be further improved. Practitioners would find it to be a very valuable valuation model if the path to determining the parameter values can be smoothed.

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IMAGE EVALUATION
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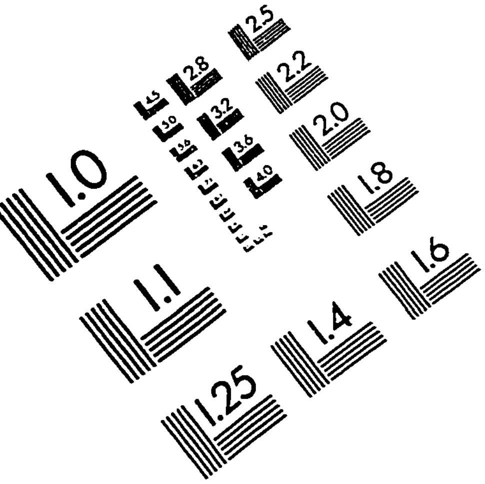

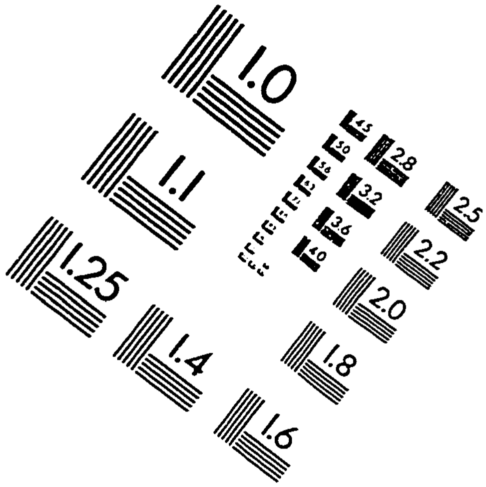

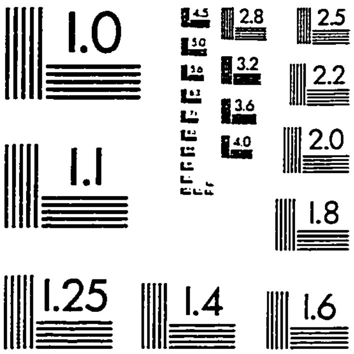

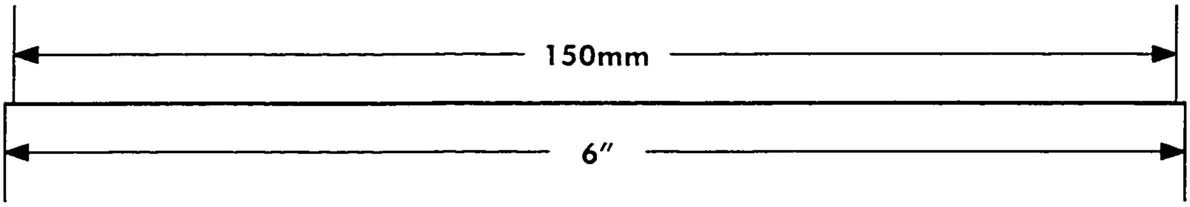

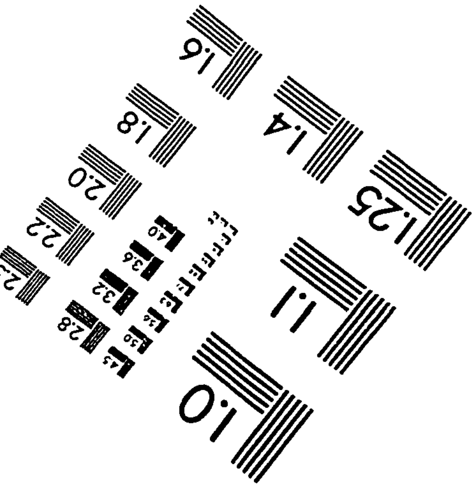

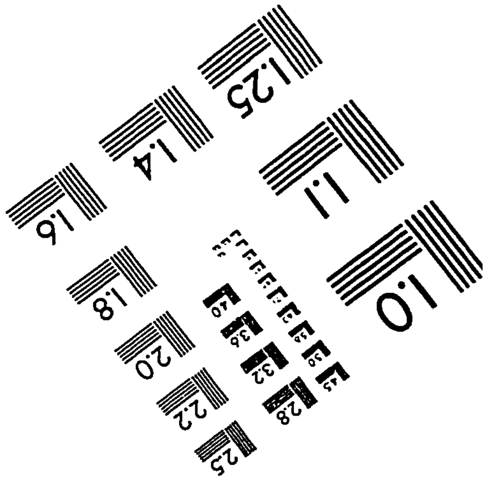

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