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Real Options for Evaluating Venture Capital and Strategic R&D Investments

Final Report

by

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- Rohini Gupta

Executive Summary

Research and Development (R&D) management inherently involves making investment decisions under extreme uncertainty where traditional financial analysis tools (such as NPV) present serious limitations. Facing similar high-risk investment decisions, the venture capital industry has emerged in recent years has an significant funding source for emerging technologies and entrepreneurial activity. In this study, we explore whether and how recent ideas in finance and management theory such as R*eal Options* are being used for evaluating venture capital and strategic R&D investments.

Our broad approach has been to survey published literature on real options and their applications, to interview experts such as academicians, consultants, authors, and finally, to interview practioners in the venture capital industry and corporate R&D managers. Among the venture capital industry, our study reveals that the Real Options approach is just beginning to garner interest. The corporate R&D community, however, has adopted real options analyses for objectives of risk management, R&D portfolio management, M&A planning – to varying degrees of sophistication. Further, based on the level of interest and activity on the subject (recent books, software tool-suites, consulting services, conferences and websites), we believe that Real Options have the potential for emerging as an important strategic and financial tool.

Introduction and Objective

Research and Development (R&D) management has historically been the *art* of creating value by managing an extraordinary degree of risk. Increasingly, however, companies are recognizing the need to closely integrate their R&D and technology strategy with their overall corporate and business strategy so as to optimally serve the near-, mid- and long-term goals of the company [1]. This drives the need to put a *value* on R&D investments, both financially and strategically.

R&D activities inherently involve making investment decisions under extreme uncertainty where traditional financial analysis tools present serious limitations. Metrics such as Net Present Value (NPV), Return-on-Investment (ROI) and other Discounted Cash Flow (DCF) approaches use discount rates to account for risk, which can be so high in emerging technology investments so as to make any investment in long-range R&D unattractive [1,2]. Yet, managers intuitively know that business growth *requires* making investment decisions under high uncertainty and, in fact, higher the uncertainty, higher the future potential payoff.

The importance that managers place on R&D investment for fuelling business growth can be inferred from the recent trends in the amount of dollars spent on R&D [see Figure 1]. In 2000, close to $250B was spent on R&D out of which about 75% was spent by US corporations. Another source of funds into emerging technologies and entrepreneurial activity has been the rapidly emerging venture capital industry [see Figure 2], which disbursed close to $100B in 2000. From a macroeconomic viewpoint, if innovation is the major source of economic and business growth, then it is useful to evaluate how investment decisions are made by R&D managers as well as by the venture capital community.

The objective of this project is to study the applicability of recent ideas in finance and management theory such as R*eal Options* for evaluating venture capital and strategic R&D investments. Since initial publications on Real Options (such as [1]) in the late 1980's, there has been a spurt of interest in the late 1990's on the subject as evident by dozens of books (search, for example, http://www.amazon.com), several websites[1], numerous publications and a few conferences dedicated to the subject of Real Options.

Background

The Nobel Prize-winning work of Fisher Black, Robert Merton and Myron Scholes on the pricing of financial option contracts is the foundation of the Real Options approach, which extends the option-pricing theory for managing real or non-financial investments.

Recently, the theory of real options has been applied in industries such as pharmaceutical, real estate, mining and oil exploration. Companies are using real options for far-reaching applications. General Motors and Ford, for instance, are using them for automobile applications using the global positioning system (GPS) satellite network in combination with

[1] http://www.realoptions.org, http://www.real-options.com, http://www.real-options.de

wireless (also known as telematics) technology[25]. In addition, the real-world applicability of real options has also drawn criticism stemming from assumptions of flexibility and organizational practices [24].

What are Real Options?

"An option is the right, but not the obligation, to take an action in the future." – this is the much-cited, classical definition of an *option.* Options are valuable when there is uncertainty. For instance, an *option* contract may give the buyer the opportunity to buy a stock at a specified price on a specified date and will be *exercised* only if the price on the stock on that date exceeds the specified price.

Many strategic investments create subsequent opportunities that *may* be taken in the future, which implies that the investment opportunity can be viewed as a stream of cash-flow plus a set of options (see Figure 5 for a set of common real options). Thus, in a narrow sense, Real Options are just an extension of financial option theory to options on real (nonfinancial) assets. (In fact, a one-to-one correspondence can be established between the variables used in financial option pricing and real options, as in Figure 4).

While financial options are detailed in the contract, real options embedded in strategic investments must be idenfitied and specified. Moving from financial options to real options, however, requires a way of thinking, one that brings the discipline of financial markets to strategic investment decisions[6]. By adding the important dimension of flexibility, real options allow for a better melding of strategic intuition and analytical rigor.

Why study Real Options?

Traditional valuation and strategy tools such as net present value (NPV) ignore the importance of flexibility. They assume a static decision-making ability because they are constrained to precommitting today to a "go" or "no go" decision based on information that is available today. Yet companies in all industries must allocate resources among competing opportunities and decide whether to invest in them now, take preliminary steps reserving the possibility of investment in the future, or do nothing. All of these choices create payoffs linked to further choices down the line, so they can all be regarded as *options.* The value of keeping them open is clearest in investment-intensive industries, such as oil extraction, in which licensing, exploration, appraisal, and development occur in stages, each pursued or abandoned according to the results of its predecessor.

Real-options strategies differ from their traditional counterparts above all in their response to *uncertainty*. In the traditional view, a higher level of uncertainty leads to a lower asset value. The "cone of uncertainty" (see Figure 3) contains a range of possible future outcomes and the firm's exposure to uncertainty remains large. Real options, on the other hand, assume a dynamic series of future decisions where management has the *flexibility* to adapt to changes in the business environment.

The shift in outlook from "fear uncertainty and minimize investment" to "seek gains from uncertainty and maximize learning" can open up a wide range of possible—and profitable—actions. In a real options approach, strategic

investments allows managers to reduce exposure to bad outcomes and enhance exposure to good outcomes (as the uncertainty resolves and embedded options in an investment are identified and managed), modifying the exposure to uncertainty and increasing the value of the investment.

This is the primary compelling reason why managers should grasp the insights behind real options. While option-pricing models are indeed a superior *valuation* tool – the purpose to which the theory is generally put – real options provide a systematic framework that serves as a powerful *strategic* tool.

Beyond Scenario Analysis

Practioners who are concerned with NPV's limitations in dealing with uncertainty tend to rely on techniques such as *scenario analysis* to capture the fact that the values used in NPV analyses must necessarily be *ranges* and not single numbers. Using high, low and medium scenarios helps to bound the uncertainty, but does not help to incorporate into the valuation the variance across the difference scenarios. Thus, scenario thinking recognizes that uncertainty exists but does not capture the *flexibility* value inherent in a situation and hence offers little managerial guidance. Real options, instead, specifically deal with the use of options theory to value management's *flexibility* to act in the future[8].

Our Approach

Towards our objective of understanding how Real Options are being used for R&D management and in venture capital investment decision-making, our approach has broadly been to: (1) Survey existing published literature on real options and their applications, (2) Interview experts (Professors, consultants, authors of books), (3) Develop hypotheses to analyze industry practitioners, and (4) Interview venture capitalists and corporate R&D managers.

Application of Real Options to the Venture Capital Industry

Hypothesis

In recent years, emerging technology firms have increasingly been supported by venture capital (VC) [see Figure 2]. Risky investments made under high degree of uncertainty in emerging technologies, such as those by venture capitalists, can be considered to be contracts on *growth* options. Typically, VC's use the terms of the contract (the *term-sheet*) to modify the risk-profile of the investment. Also, financing is provided in stages (sometimes, conditional on specific milestones being met) to ensure that the option value embedded in the investment is maximized.

The VC industry therefore presented a prime candidate for application of Real Options techniques [20]. Following the premise offered in several recent publications on the application of Real Options techniques to the venture capital industry [15,16,3,13], we sought to determine if real options are indeed being adopted by industry practitioners as a tool to evaluate and structure investments.

Summarized Findings

We interviewed Partners and Associates at several Venture Capital firms with investments in the biotech and information technology (IT) sectors. We also spoke with Professors at Wharton[2] who follow the VC industry trends closely to get their insights on the adoption of Real Options ideas by the VC industry. Our findings can be summarized as follows:

- Venture capitalists don't explicitly think about real options, but the real options theory has strong parallels with the way VCs think about valuation and investment. Venture capitalists ask questions that seek to *explore options embedded in their investment decisions*, play a mentoring role, and are incredibly close to the ventures they're interested in and they've invested in. This enables them to evaluate the projects (and their investments) closely. They think more in terms of *opportunity management* than *budget management*.

- Venture capitalists keep an eye out not for the incremental sure thing, but for the "next big thing". They nurture *portfolios of projects*, and they don't demand high probabilities of success from any one project. The average investment of a venture capitalist has probably about a 20% chance of success. Also, VCs *fund ventures in small, rapid stages and are ready to scale up investments* very quickly. This is in contrast with most investment decisions in large companies, which go through a financial screening process in which each project has to deliver value on its own merits. Also, the capital-budgeting process in most large companies (sometimes even within R&D) assumes that every investment is going to be largely incremental to existing businesses and that increments of investments will be fairly large. Most companies are not ready (organizationally and otherwise) to make a series of extremely rapid, small investments as you slowly accumulate learning and scale a project up.

We did not find that the real option theory and option-pricing models from corporate finance have attained acceptability in terms of valuing startups. Reasons for this primarily include a lack of awareness and already well-established traditional methods (sometimes, rules-of-thumb) of valuation.

However, venture capitalists who we spoke with expressed interest in exploring tools[3] for incorporating real options into their decision analyses. Also, our interviews with consultants[4] dealing with Real Options revealed that both start-ups and venture capitalists are starting to express interest in (and have sought consultation on) real options as a valuation technique.

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[2] Prof. Steve Sammut and Prof. Andrew Metrick, The Wharton School, Univ. of Pennsylvania.

[3] E.g. the Real Options Toolset from Decisioneering, Inc. (http://www.decisioneering.com) and the FlexAble™ Decision Management Suite from Real Options Software (http://www.realoptions-software.com).

[4] Dr. Peter Boer, Tiger Scientific and author of "The Real Options Solution", John Wiley & Sons, Inc., 2002, and Dr. Johnathan Mun, Decisioneering and formerly with KPMG Consulting, and author of "Real Options Analysis – Tools and Techniques for Valuing Strategic Investments and Decisions", John Wiley & Sons, 2002.

Application of Real Options to Management of Corporate R&D Investments

We interviewed R&D managers from a diverse set of industries, including Sprint (Telecom)[5], Schlumberger (Oil and Gas)[6], Timken (Manufacturing)[7] and Merck (Pharmaceutical)[8], as well as experts[9] on Real Options, who have recently published books on Real Options and have extensively used real options techniques in their consulting engagements and conduct seminars/courses on the subject.

Telecom Industry

Characteristic of the telecom industry are rapidly emerging new technologies that are highly capital intensive, especially in the early phases. Management is required to make critically important decisions regarding the implementation and adaptation of next-generation telecom technologies that can have significant impact on the value of the firm. It is important for a company like Sprint to have a structured decision-making process that has timely decision points and operational flexibility built-in that ensure that any new information about the technology, market-segment or application are incorporated into the decision, and resources are appropriately allocated, and redeployed, if needed. This is where Real Options have found an application at Sprint.

Real Options are used in the Technology and Product Strategy organization at Sprint[10] for *Project Portfolio Planning*, wherein the portfolio may consist of several interdependent projects and each project presents a high degree of uncertainty. The emphasis is not on valuation, but rather on "setting up the logic" to facilitate an understanding of the options available in R&D and on risk-mitigation.

Unlike the pharmaceutical industry where "natural" decision points, such as FDA reviews, define the life of a project, the telecom industry has no such explicit trigger points. Instead, decision points need to be actively defined by management and built into the Real Options (or any other structured decision-making) framework. At Sprint, product-development follows a NPV-based stage-gate process to which real-options based decision analyses have been added to assist the Strategy Organization in decision making and portfolio planning. Traditional techniques based on Economic Value Added (EVA) and Net Present Value (NPV) are used by the finance organizations at Sprint – Real Options based valuation techniques have not gained significant following outside of strategic planning in R&D.

Sprint uses its own internally developed software toolset for Real Options analysis and is also developed advances analyses capabilities in collaboration with John Charnes at University of Kansas' School of Business.

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[5] Technology and Product Strategy Manager, Sprint (http://www.sprint.com).
[6] Senior Research Engineer, Schlumberger (http://www.slb.com).
[7] Director of R&D Emerging Technology, The Timken Company (http://www.timken.com).
[8] Technology and M&A Strategy Manager and Pharmaceutical Economics Manager, Merck & Co., Inc. (http://www.merck.com).
[9] Dr. Peter Boer, Tiger Scientific and Dr. Johnathan Mun, Decisioneering.
[10] Real options practitioners at Sprint have earlier used them in the Aerospace and Pharmaceutical industries.

Oil and Gas Industry

Oil & gas companies make considerable investments of time, money and technology to develop an oil and/or gas field and increasingly have to make major capital decisions quickly against a backdrop of heightened uncertainty. Real options have a natural place in the oil industry, since they address the presence of uncertainty, limited information and existence of different development scenarios. The phases of oil and gas production – licensing, exploration and appraisal, development, production and abandonment – naturally fall into stages, each of which is pursued or abandoned according to the results of the previous stage. It follows therefore that the first stage, licensing and oil-block, represents the purchase of an option on subsequent stages.

In the Oil and Gas industry, BP and Shell have been the vanguards in terms of using real options for decision analysis [7]. For BP, for instance, the economics of prospective oil and gas fields in the North Sea were highly uncertain in terms of margins and volume. The company responded by embracing uncertainty and increased its exposure to volatile undeveloped prospects by accumulating licenses that exploit the flexibility to respond to new technology and operating practices in order to make currently uneconomic prospects profitable. The strategy transformed BP's view of the North Sea potential and is a classic example of real-options based thinking.

At Schlumberger, real options are used for *risk analysis* and *risk management* (today, in a somewhat adhoc manner) as well as for oil-production enhancement using market-expectations for oil price volatility and drift in the stochastic oil price model. Also, Schlumberger has found that real options based analysis can offer a significant leverage in negotiation situations in business development and marketing, since the thinking provides "reasonable limits" on the levers available to the negotiator.

Schlumberger's experience with real options has been that they are technically demanding, with a definite learning curve in the oil industry. While the potential for their application in the industry is undisputed, widespread adoption is still lacking. This raises important issues: (1) real options require careful problem framing and technical analysis, which requires suitably trained people; (2) beyond interpreting the results of a real options analysis, it is a challenge to have them acted upon, benchmarked, communicated and managed. It requires some early adopters/champions within the organization who both understand the power of real options and their limitations.

Manufacturing Industry

Timken is an international manufacturing company in the specialized steel, alloys, components industry, as well as related products and services, that is finding Real Options to be a part of their growth and profitability initiatives.

Traditionally, at Timken, corporate finance has been driven by NPV-based techniques, which are not well-suited for valuation under uncertainty and do not factor in the fact that management has flexibility in decision-making as new information becomes available and uncertainty is progressively resolved. Real Options, however, assume a dynamic series of future decisions where management can adapt to changes in the business environment. This idea goes against

established methods in financial theory, and therefore, has not received "sponsorship" from the corporate finance side at Timken.

R&D's adoption of Real Options ideas at Timken are being driven by: (1) R&D's need to become a profit center rather than a cost center, and (2) Working with increasingly scarce R&D resources. Real Options are being adopted from a product and corporate strategy perspective for Risk Management, Project Portfolio and M&A Planning, and a mindset of Project Timing in a way that can maximize the impact on growth. This has resulted in bringing a new perspective on risk and risk management before corporate leadership. Earlier, people acknowledged that there were risks, yet "did nothing about it". Using a stage-gate type approach, Timken is looking at *project portfolios and risk-mitigation,* rather than the earlier orientation to projects solely based on NPV and payback. With management teams trained in Real Options and sensitized to the importance of risk management (particularly for emerging technologies), portfolio planning and the need for better ROI on R&D, Timken is putting in place models and metrics for making real options based analysis an integral part of their strategic decision-making process.

Among the many challenges in adopting an approach such as real options at Timken have been (1) A lack of awareness and scepticism within the organization. Some of these have been addressed at Timken with help of an external expert[11] and via manager and executive training;(2) Showing a clear benefit from a real-options approach. This is particularly challenging since real options are typically valuable for projects that have a long-term horizon (which then leads to uncertainty) whereas "financially-driven" people are evaluating results on a quarter-by-quarter basis. Clear metrics are therefore critical; (3) Organizational inertia [13] cannot be underestimated. Adoption of a tool so radically different as real options requires a *sponsor* among the senior executives within the company. Even so, it is unclear at this point how extensively will Real Options be imbibed by the corporate culture at Timken.

Pharmaceutical Industry

In the pharmaceutical industry, on average, it takes 12 to 15 years and upwards of $500 million to bring a new medicine to the marketplace. Only five out of 5,000 compounds that enter preclinical testing make it to human testing, and only one out of these five that are tested in people is approved by the Food and Drug Administration (FDA). Furthermore, less than one-third of the drugs that make it to the marketplace recover their research & development costs. In 2000, U.S. research-based pharmaceutical companies invested more than $26 billion in 2000 to discover and develop new medicines.

Merck, a pharmaceutical industry leader, invests approximately $1 billion annually in research, which reflects upon the risky nature and high cost of pharmaceutical research. While scientists probe an idea for its merit, Merck has developed the discipline to define parameters that determine which scientific enquiry is or is not productive. Because success or failure in R&D at Merck is viewed to be as much determined by its investment prowess as by the quality of its

[11] By Dr. Johnathan Mun of Decioneering, Inc.

researchers.

Merck is well known as a long-time innovator in financial analysis and has been at the forefront in using option analysis to value its research investments as against traditional financial analysis. Merck believes that real options provide a more flexible approach that allow valuation of investments at successive stages of a project and better assess the value of the opportunity of delaying or ending projects. When an initial investment is made in a research project, the thought is that you are paying an entry fee for a right, but not the obligation, to continue that research at a later stage. By modeling a drug development project as a call option, a company can try to assess the value of the optionality embedded in the project, i.e. the opportunity to consider future events and information and then alter the course of the project. Real options incorporates the principle that there is value from the ability to decide whether to continue, defer, or stop a project in the future as the company gathers more info about the costs, potential revenue, and probabilities of success.

Merck's experience with R&D has given them a database of information that allows them to value the risk or the volatility of their research projects, a key piece of information in option analysis. Therefore, use of option theory to analyze R&D investment gives Merck a tool to examine uncertainty and to value it. An internally developed Research Planning Model [26] (based on Monte Carlo and Real Options analysis) is used within Merck which begins with an estimate of a project's scientific viability, then factors in the marketing and manufacturing variables as well as economic constraints, such as pricing, inflation, and selling costs. Extended over the long payoff period of pharmaceutical drugs, the model is used by senior managers for resource allocation and is an integral part of Merck's strategic decision-making process. This includes R&D investment, drug discovery and portfolio management, M&A, as well as strategic investments in biotech startups and university research.

Merck's usage of options-based thinking in finance and strategy is quite unique. Most commonly, corporate finance people are viewed as traffic cops that leads to a tension between finance organizations and operating units. At Merck, corporate finance earned acceptance as a partner in the business by capturing both the hard financials of a project and the strategic intent.

Key success factors that have enabled Merck to take advantage of cutting-edge finance and strategy theories such as Real Options have been: (1) A champion of the technique among the company's top executives. (CFO, Judy Lewent has been widely cited on the subject [19]); (2) A corporate culture of learning, technology, and acceptance of advanced quantitative approaches. Models are not viewed as a black box that completely ignores management's wisdom, but as tools with both potential and limitations.

Experts' Opinions[12]

With few exceptions, Real Options are in a phase today in the industry where most companies [that are using them] are

just beginning to understand their power, applicability and, to some extent, their limitations. It took over 20 years before corporate America widely accepted Net Present Value (NPV)[13] as the primary method of analysis for large corporate investments. The breakthrough in valuation of options was made in the early 1970's by Merton, Black and Scholes, whose Nobel prize winning work solved a tough problem that had been a challenge since the early 1900's. Early applications were exclusively in securities pricing where data was plentiful and where the market price of the underlying risky security was directly observable. Stochastic differential equations were the tool of choice, which however do not present a convenient environment for management applications of Real Options. As computing power becomes easily and cheaply available, it is now possible to use lattices and algebraic solutions (that are easy to understand and implement on a PC) to model realistic management problems including those that have embedded compound options and present multiple sources of uncertainty.

Real Options are a shift in paradigm and will take another 5-10 years to become a mainstream tool, as MBA programs start to incorporate courses in Real Options and as trained professionals develop the experience in applying the theory to real-world problems.

The main criteria that merit a real options based analysis are when uncertainty drives value, when there are a dynamic series of future decision points, where there exists flexibility to adapt to the changing business variables, and where management has a credible mandate to respond to them and reallocate resources, if needed. 50% of the value of Real Options is in "thinking about them" – the numbers come later. A common success factor at companies that have been successfully able to adopt the paradigm shift has been the willingness of a few champions/change agents to experiment with real options ideas.

Industries that are using Real Options range from oil and gas to pharmaceutical to electronic hardware manufacturers (see Figure 6), with applications ranging from oil exploration, drug discovery to valuing software licenses. Some companies have used real options to do a retroactive "post-mortem analysis" – for instance, on a prior acquisition – for which historic data is relatively easily available (as against proving-in real options on a project that might have a future life-time of several years).

It is important to remember that Real Options are not a solution to every problem and portraying them as such can be a major stumbling block since it creates unrealistic expectations and inappropriate applications. Another major stumbling is portraying them as a "black-box model", which only generates mistrust from managers and decision makers[14].

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[12] Summary findings from interviews with Prof. Bill Hamilton (Wharton), Prof. Graham Mitchell (Wharton), Prof. Ernest Gilmont (Wharton), Dr. Johnathan Mun (Decisioneering), Dr. Peter Boer (Tiger Scientific), Dr. William Bailey (Schlumberger).

[13] over Payback Period based techniques

[14] Closed-form solutions like the Black-Scholes model are elegant, quick and easy to implement. However, they are difficult to explain because are highly technical and also have limited modeling flexibility. Binomial lattices, in contrast, are easy to implement, highly flexible and easy to explain, but require significant computing power. It may be well-advised in practice to use closed-form solutions in conjunction with the binomial lattice approach when developing a complete real options solution.

Real Options are then[15]:

- Useful when we are faced with future uncertainties,
- Useful when we have the flexibility to respond in some way to this new information, conditions or event outcome, where these uncertainties bring with them valuable information and management can execute these contingencies or flexibilities when situations require it,
- Useful when a classical Discounted Cash Flow (DCF) analysis indicates marginal project viability,
- Essentially advanced DCF calculations that consider uncertainty, flexibility and new information
- Extensions of, but not fully beholden to, existing financial option theory (which form the basic conceptual foundations),
- Valuable as they confer the right, but not the obligation, to capture future benefits depending on prevailing conditions (e.g., values an additional exploration well to provide new information),
- Contingent decisions. Depending on the learning obtained from some future event, real options help us to decide whether to instigate, defer or curtail some action,
- Everywhere. From the decision to buy a new house to developing a new field, real options are prevalent. In many ways they are inescapable in an uncertain environment.

Real Options: What They Are Not

- *Not* the answer to all our valuation needs. They still require imprecise inputs, such as volatility and Weighted Average Cost of Capital (WACC) that are subject to uncertainty.
- *Not* suitable when project is highly lucrative or highly uneconomic (known as being *deep in-* or *deep out-of-the-money* respectively),
- *Not* just the blind application of a Black & Scholes type model taken from classical financial options theory. Such models are bound by a host of assumptions and caveats and are defined by unambiguous contracts. Real Options have less (or no) contractual structure *per se* but instead are loaded with opportunities and impactful decisions,
- *Not* applicable when there is no uncertainty or doubt as to future cash flows (an option model would then simply

[15] Adopted from [21]

emulate a deterministic DCF),

- *Not trivial* to perform and frame – sometimes.

Conclusion

Real options analysis is a significant step forward for thinking about flexibility, and especially, how to value it. The real options thinking radically changes traditional approaches to thinking about strategy. In an increasingly uncertain world real options have broad application as a management tool. They will change the way companies value opportunites. They will change the way companies create value – both *reactively* and *proactively*. And they will change the way companies think.

While Real Options are a powerful tool for valuation under uncertainty and managing risk inherent in strategic R&D investments, this study reveals there is along way to go before Real Options will be adopted as a mainstream tool for R&D management or venture capital investment. Much remains to be done to develop the theory and the tools for Real Options analyses, to build expertise in the techniques and the experience with real-world applications. And finally, Real Options present a paradigm shift that calls for organizational change – a challenge that cannot be underestimated.

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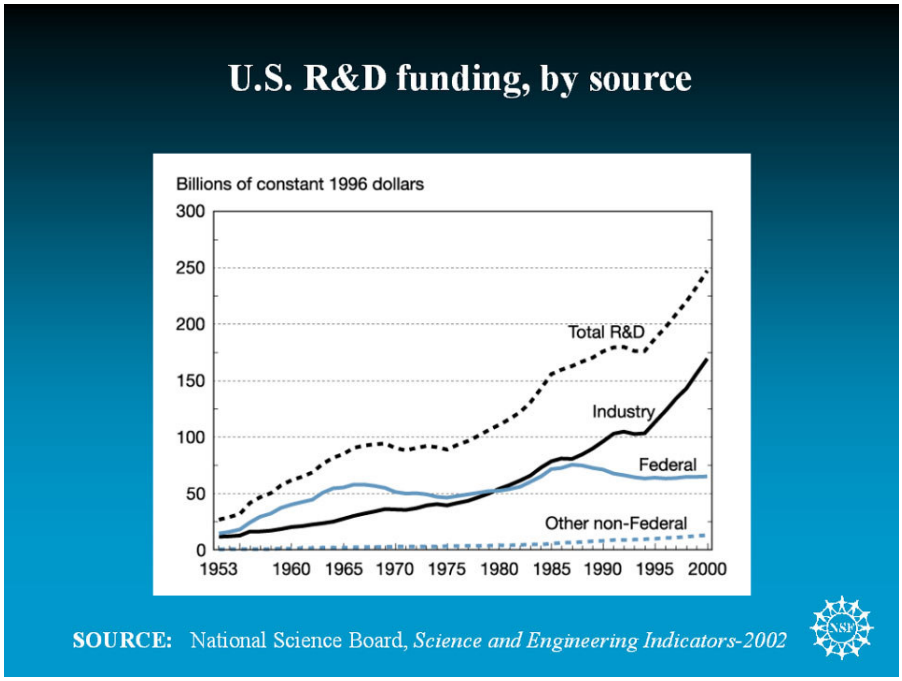
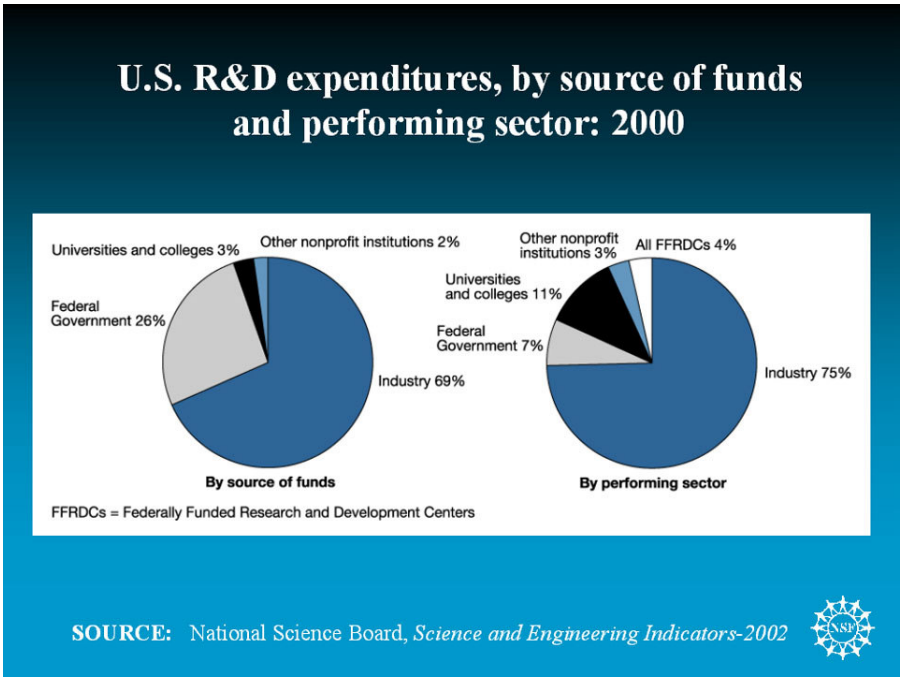
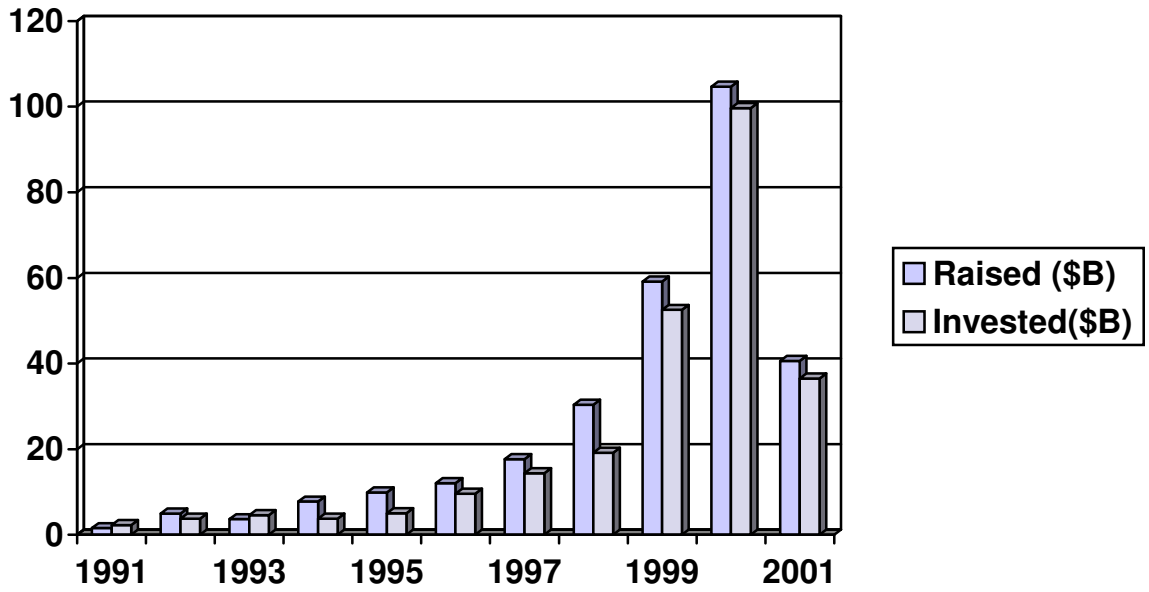
Figure 1: US R&D expenditures by source of funds and performing sector[16]





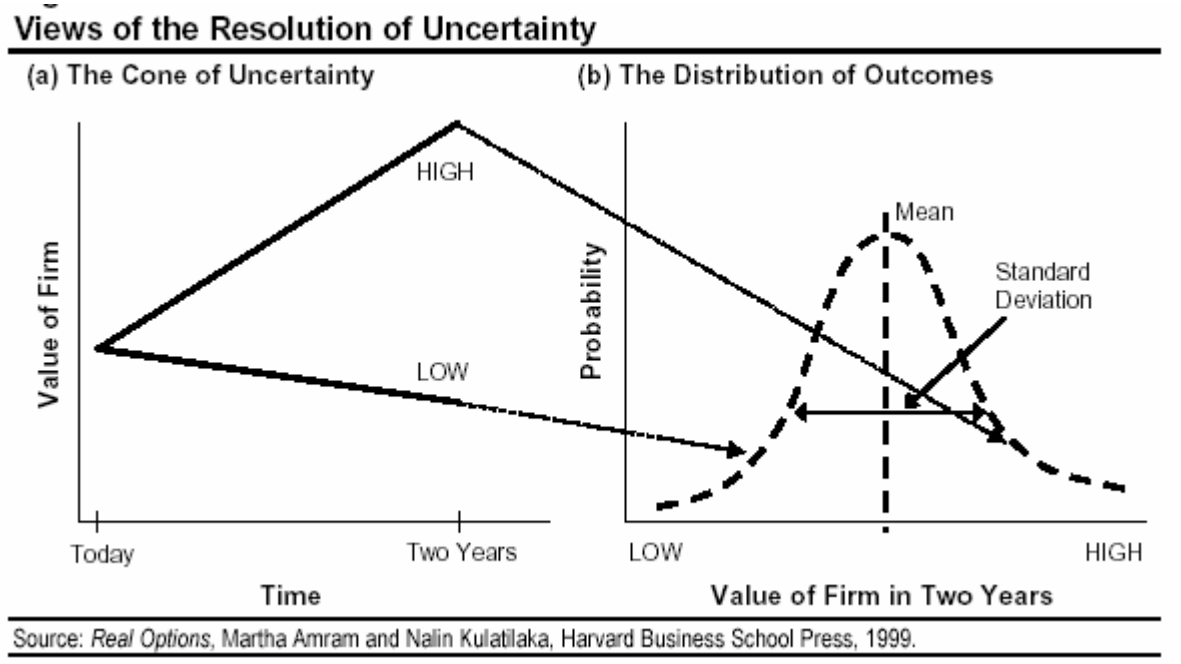
[16] Source: National Science Board publication, National Science Foundation, 2002.

Figure 2: US Venture Capital Raised/Invested (1991-2001)[17]



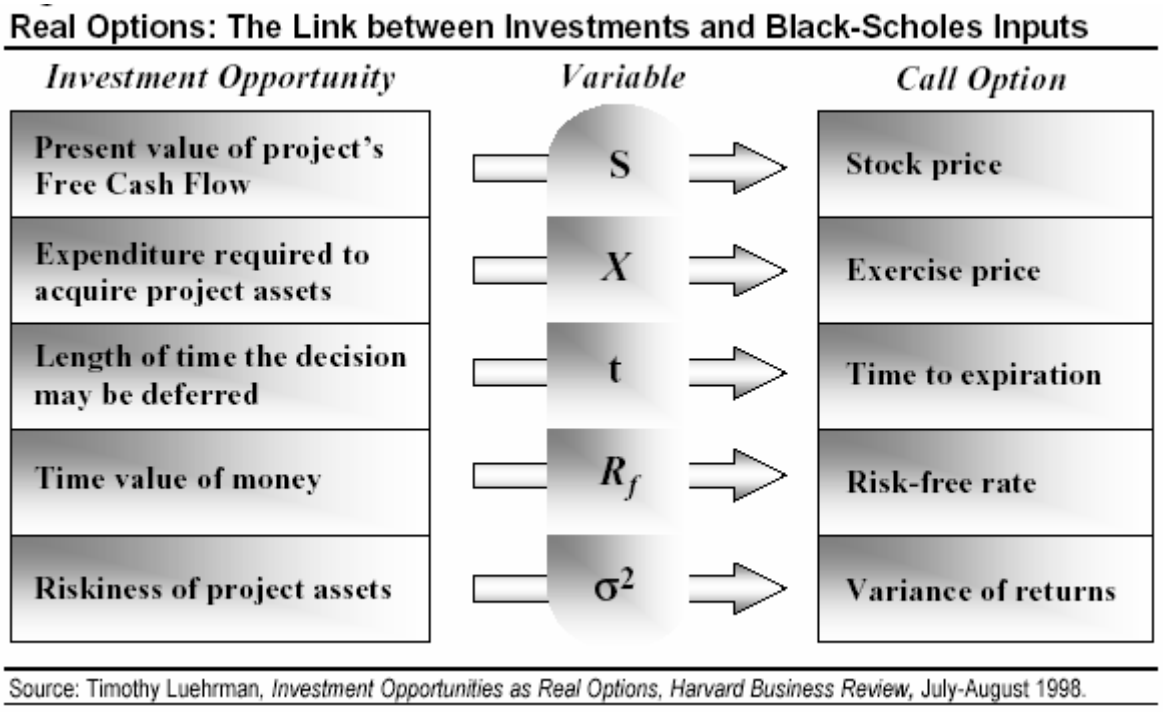
[17] Source: Class notes, Prof. Steve Sammut's course on Venture Capital Management, Fall 2002.

Figure 3: ***Resolution of Uncertainty***[18]



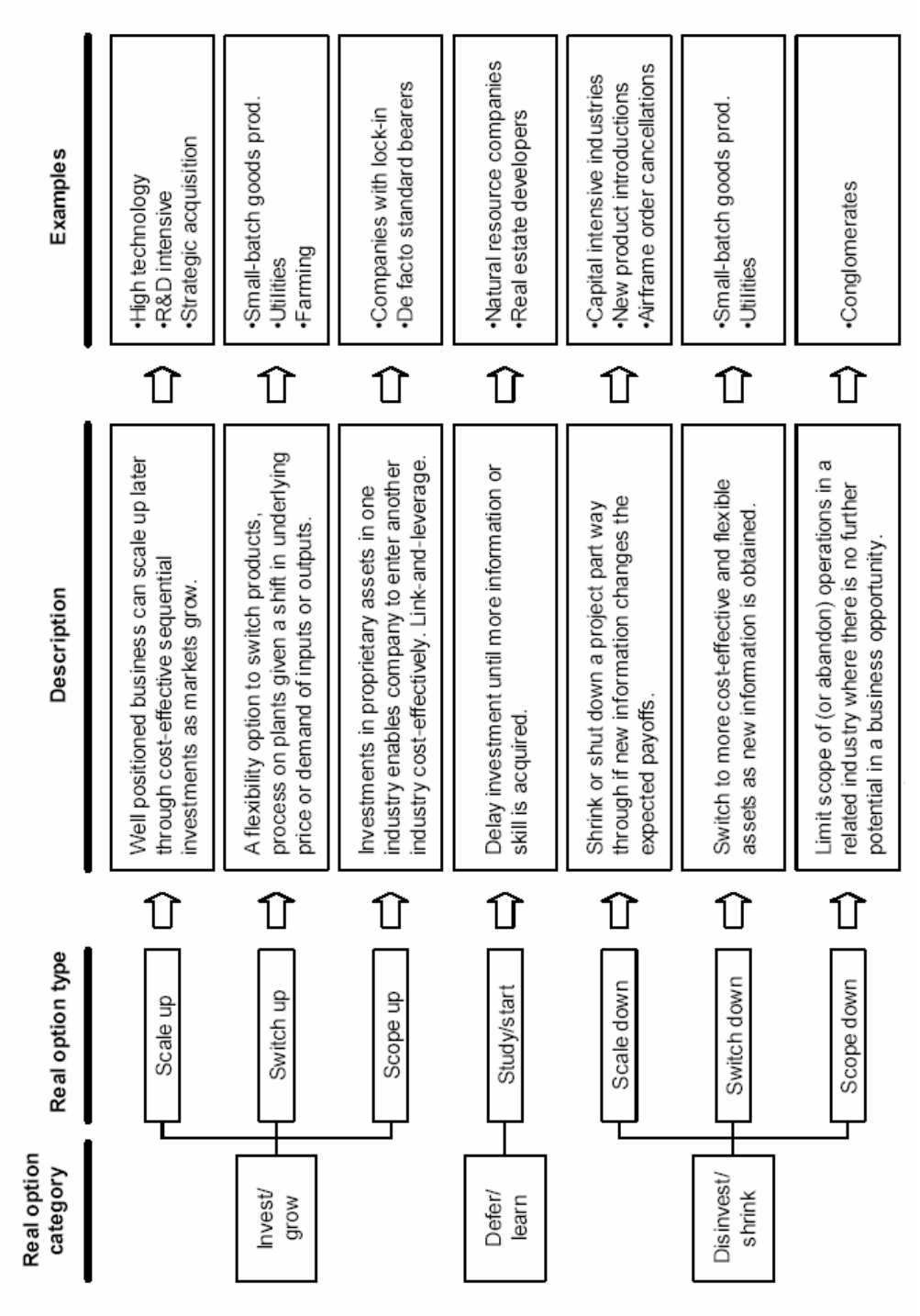
[18] Source: [3]

Figure 4:[19]



[19] Source: [16,22]

Figure 5: Common Real Options[20]



[20] Source: [22]

Figure 6: Few companies that have used Real Options[21]

Company	***When***	***Use***
Hewlett-Packard	Early 1990's	Production and distribution
Anadarko Petroleum	1990's	Bidding for oil reserves
Cadence Design Systems	1990's	Valuing software licenses
Tennessee Valley Authority	1994	Power purchase options
Mobil	1996	Development of natural gas field
Airbus Industrie	1996	Valuing delivery options
ICI	1997	New plant construction
Pratt & Whitney	1989	Cancelable operating leases
GM	1990's	Sourcing raw material from suppliers
Credit Suisse First Boston	Late 1990's	Valuing securities
Merck	Late 1980's and 1990's	Investment in biotech start-ups
Sprint	Late 1990's	R&D portfolio management; investment in fiber-option telecom infrastructure

[21] Some data adopted from [13]