

Financial Management of R&D 2002

The financial environment affecting R&D has been transformed dramatically since the mid-1980s. New patterns of funding have evolved, attitudes toward risk and value are more sophisticated, and analysts are armed with new tools for measuring intellectual capital.

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OVERVIEW: Financial thinking about R&D has evolved well beyond basic discounted cash flow models. Better tools have been developed to value intellectual capital, including the quantitative assessment of the value added by R&D. The dissection of the elements of risk, and the application of real options theory are new features of the R&D landscape. Financing vehicles have also changed with an enormous surge of venture capital and private equity funds. The analyst's toolbox has been enhanced by electronic spreadsheets, on-line databases, Monte Carlo software, the Internet, and the ubiquitous personal computer.

Industrial R&D is characteristically a high-risk investment with a deferred payoff. Its importance to industrial societies, and to individual firms within these economies, is paramount; Lau (1) has estimated that more than 50% of the wealth creation in developed countries originates from technology, which is typically a product of R&D. However, R&D comes at a cost, and it is as capable of destroying value as creating it. Knowing the difference is crucial; the penalties for underinvestment can be a deteriorating competitive position and lost opportunity; for overinvestment it will be a slow erosion of the firm's capital base.

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But measuring the difference between value creation and value destruction is not easy. One source of confusion is that accounting conventions treat R&D as an expense, not an investment (2). An even more fundamental issue is that past performance is not a reliable guide to future performance.

Faced by a measurement problem that is both difficult and important, the business, financial, and academic communities have continued improving their tools. As a result, R&D analysis and management has evolved dramatically in the past fifty years (3), and that evolution is far from over.

Background

In its first postwar phase, industrial R&D was viewed as a creative enterprise and its management was left to the R&D directors. Their main financial metric was an annual budget (a tool basically inadequate to evaluate an investment). The budget was in part determined by industry benchmarks, such as R&D expense as a percentage of revenues. Accordingly, the financial skills of R&D executives were largely focused on cost accounting and cost control (4). In many companies, top management (often lacking personal experience in R&D) didn't have a clue about the relationship of value to cost, and attempted to manage the function by a process that has been pithily described (5) as "managing the manager." In other words, poor R&D returns were viewed more as a product of poor management than a consequence of a firm's strategy. The solution was often to hire a "new boy."

The second phase, in the 1970s, was the introduction of increasingly powerful tools for evaluating investments under risk being adopted by financial analysts to R&D,

leading to a circumstance I would describe as “the apparent triumph of DCF (Discounted Cash Flow).” The use of DCF in evaluating investments *was* an important step forward in that it introduced the discipline of business plans, factored in the concept of risk, and helped bridge the communications gap between technical and non-technical executives. The DCF toolkit included net present value (NPV), internal rate of return (IRR), and risk-weighted cost of capital (6). DCF analysis replaced older measures such as “years to payback.” But as it was applied in practice, the use of excessive discount rates and overly conservative terminal values combined to condemn almost any long-term R&D project (7). This result contradicted industry’s common experience that many of the most profitable innovations had long gestation periods. Many R&D executives were profoundly uncomfortable with the DCF yardstick. But for a time at least, they had few tools to fight back besides putting their personal credibility on the line, or the even more perilous temptation to inflate their forecasts. It was toward the end of this era (1988), that Lynn Ellis published his comprehensive review article for this journal on “What we’ve learned about R&D finance (8)”.

The era of DCF dominance came to an end, and the third phase was initiated, in part because of a growing crisis in valuation. In effect, while the concept of basing value on cash flow was by itself intellectually impregnable, the marketplace was rejecting it. Sky-high valuations were accorded to companies with promising intellectual property but minuscule or negative short-term cash flow. At the same time, investments in “value” stocks, those in companies with steady and reliable cash flow, underperformed the market for a decade. The biotechnology boom in the early 1980s was a dress rehearsal, but it was the major run in technology stocks in the 1990s that underscored the valuation problem.

In addition, an unprecedented flood of money into venture capital investments suggested that a new paradigm was at work. There is certainly a school of thought that this phenomenon was merely a bubble driven by investor psychology (“irrational exuberance”). I think not. Vast wealth was created even if some of it was subsequently lost. Our thinking will not return to where it was in the 1980s.

Two tools emerged during this turbulent decade that improved our ability to analyze the phenomenon: I refer to them as the *intellectual capital solution* and the *real options solution* (9). Both illuminated R&D’s role in wealth creation. The intellectual capital solution identified important sources of value, but was inadequate to quantify them. The real options solution is especially attractive because it is a logical extension of ideas whose general validity is now well accepted in financial markets (that trade derivatives nominally valued at trillions of dollars) to the “real” battlegrounds of industry. This article proposes to trace the evolution of R&D finance from about the mid-1980s to the present. Because R&D finance is a part of corporate finance, many of the important trends are inseparable from developments in corporate finance itself.

The Concept of Value: From EVA to Total Shareholder Return

The word *value* has become a fixture of the business lexicon during the past two decades. Unfortunately, this omnipresent word is being used in two very different contexts: *economic value* and *market value*. The two forms of value are not at all the same. The distinction is profound for R&D, because innovation initially comes at a cost in economic value, but is equally often a driver for market value!

Economic Value

The term *Economic Value* is invoked in much current business jargon, explicitly in such concepts as Economic Value Added (EVA), and implicitly in discussions of “value chains,” and “value propositions.” The economic value of an enterprise is determined by the projected sum of its free cash flows (10), discounted by its cost of capital. It is synonymous with *Present Value*, as used in finance texts.

The EVA concept (11), although traceable to Albert P. Sloan, the legendary CEO of General Motors, was reintroduced to the corporate community by the firm Stern Stewart in the 1990s, with considerable impact. EVA is defined as net operating profit minus an appropriate charge for the opportunity cost of all capital invested in the enterprise. (The relationship between EVA and Economic Value is simple: Economic Value is just the sum of the EVA’s added by the enterprise in each successive year.) EVA is an estimate of true “economic profit,” or the amount by which earnings exceed or fall short of the required minimum rate of return that shareholders and lenders might earn by investing in alternative securities of comparable risk. The capital charge makes an enormous difference in a company's outlook: Under conventional accounting, most projects or companies appear profitable but many in fact are not.

Estimating the *cost of capital* is critical to measuring Economic Value, since to perform a valuation by the discounted cash flow method, the analyst first needs to establish a discount rate. This subject is amply discussed in financial textbooks (12). There is general agreement that the rate should be the current, weighted, after-tax cost of capital (WACC), and that WACC is dependent on the business in which one participates. In general, more volatile businesses are considered riskier, and therefore have higher

costs of capital. For example, the Capital Asset Pricing Model (CAPM), one of several models used by financial analysts, might attribute a WACC of less than 10% to a regulated utility, and perhaps more than 20% to a biotechnology company. It can make an enormous difference to the value of an investment what WACC is applicable.

Stern Stewart's approach to R&D was also a significant advance, in that it treated R&D projects as investments, much as a manufacturing plant is an investment. In their approach, R&D investment is amortized over the useful lifetime of the technology, say five years. The result is that current earnings are not charged for current R&D, but the depreciation of the total R&D investment is now a charge against earnings on the "EVA books." The EVA accounting method has the additional virtues of better matching R&D expenditures with the time frames in which cash flow will be realized (a sound accounting principle), and reducing the incentives for slashing R&D to shore up short-term reported earnings. Nevertheless, with this methodology, the value of the firm's R&D assets would be calculated from its historical cost, which would still not reflect the true value of the technology.

Market Value

For professional investors in securities, the bottom line is not economic return, it is total shareholder return (TSR), defined as the appreciation of the stock price plus dividend payments. This is "cash is king" reasoning, since liquid securities and cash dividends mean cash to an investor. To money managers, total return is also their report card. In such a world, the *Market Value* of a stock is the final metric, and Economic Value is but one component of it. Investors also gauge each firm's strategic position, plus other factors contributing to Market Value such as investor sentiment and

macroeconomic trends. Shareholder value has largely come to be synonymous with current market value - stock price - and executives or directors who ignore this reality do so at considerable peril.

The Crisis in Valuation; When Market Value Didn't Track

Economic Value

As the information sector of the U.S. economy grew to a size beyond even manufacturing in importance, it became obvious that the earnings power of many firms bore little relationship to the historical costs of their assets. It was no longer unusual to see the market value of a stock exceed its "book" value by a factor of ten or even twenty! If 90 to 95 percent of the value of a company is derived from what is not on the books, poring over financial statements and footnotes is obviously totally inadequate for purposes of valuation.

A part of the crisis in valuation arose from the growing differences between market value and the accountant's perspective of valuation based on historical cost. While this circumstance could, in principle, have resulted from smart management delivering superior cash flows, this explanation did not hold up when the actual cash flow projections of the companies were considered. An electronic publication by Ernst & Young (13), for example, estimated that only 25 percent of current market capitalization is based on cash flow anticipated in the next five years - the outer limit of the proverbial "short-term." Thus, more than 75 percent of the valuation of the total stock market must be related to something other than short-term economic value.

What accounted for this virtual capital? A clue came from the fact that most of that extra capital happened to be found in what has been called the “growth” sector of the stock market, in contrast to the “value” sector, where valuation is more closely tied to cash flow. But the word “growth” does not define the issue, but confuses it. There is a clear and established linkage between economic growth and economic value (14), which can be readily demonstrated using discounted cash flow techniques. This formula is intellectually consistent with value investing, as long as the sustainability of that growth is credible. The real issue, for the companies in question, was that the projected growth rates in cash flow required to support the market valuations were often implausible. Something else was afoot. Investors were focused on the additional, unforeseeable, opportunities that would come to successful pioneers.

In this scenario, as long as perceptions of opportunity grew faster than economic capital, the “growth” sector would outperform the “value” sector, and hence would attract more investment. This cascade effect would result in higher price-earnings ratios, since the price-to-earnings metric is tied to current economic performance. That is what occurred in the marketplace during the decade of the 1990s. Investors in effect equated investment in “value” stocks as investment in stocks with limited opportunities, and favored the “growth” sector. The trend continued until enough failures of emerging firms to execute their business plans made it evident that investors had, at least temporarily, overestimated the opportunities. In hindsight, this outcome was less than surprising, because the valuation metrics being used for new entrants to the technology sector were still very crude.

During this period two hypotheses were being developed to address the gap and provide improved metrics: one was based on the premise that the accounting numbers were missing *intellectual capital*, the second that they were missing *opportunity*. These two views correspond to the *intellectual capital solution* and the *real options solution* referred to above. A rejectionist view, currently tenable in light of the market setback of 2000-2001, is that the bursting bubble has only proven that the “value” investors were right after all.

The Intellectual Capital “Solution”

During the 1990s, as the valuation gap was growing, a host of articles began to extend the venerable concept of intellectual property to the concept of intellectual or knowledge capital, which added an important new dimension to intangible assets.

Some writers even choose to define intellectual capital as the difference between market value and the value of the tangible assets. This approach is exemplified by this quotation (15): “The greatest challenge facing any organization today is in understanding the huge differential between its balance sheet and market valuation. This gap represents the core value of the company – its Intellectual Capital.”

Consider, as a starting point, a 1988 accounting textbook that states (16), “Assets can provide future benefits without having physical form. Such assets are called *intangibles*. Examples are research costs, advertising costs, patents, trade secrets, know-how, trademarks and copyrights.” From this traditional base, the concept was now extended to include the knowledge of the organization and its employees, and its ability to learn. It thus went far beyond the more limited concepts of know-how and trade

secrets. Most importantly, there was recognition that intellectual and human capital could far outweigh tangible capital for valuation purposes.

This insight was important, but yet not very definitive. “But the idea of intellectual capital is a new one,” wrote P.H. Sullivan (17), “it brings to the foreground the brainpower assets of the organization, recognizing them as having a degree of importance comparable to the traditional land, labor, and tangible assets. If a survey were conducted, there would be agreement that many modern companies are filled with intellectual capital: law firms, consulting firms, software companies, computer companies to name but a few. But if the survey went on to ask people to define what intellectual capital is, there would be a wide range of answers. These answers would not converge onto one straightforward definition of intellectual capital, but rather on many. The range of views and the number of terms used to describe and define intellectual capital are broad, without a clear focus, and often confusing.... Once a firm understands that it has intellectual capital, how does it convert it into something of value? The answer is that it depends!”

Or, as two Ernst and Young commentators (18) put it: “So-called intangible assets such as brand equity, intellectual capital, corporate culture, employee skills, patents and trademarks — to name a few — were regarded as important, but lacking the pragmatic substance necessary to build them objectively into the valuation equation.”

But the tools continued to improve. Professor Baruch Lev and his associates (19) have pioneered in combining the concepts of economic value with intellectual and human capital. Lev defined intangible (knowledge) capital as the present value of the future stream of knowledge earnings. He did this by creating a model whereby the economic

performance of a company is based on separate contributions from its physical, financial, and knowledge assets. Important among the knowledge assets are past investments in R&D. He then applied a linear regression to corporate financial data to get a best fit to the overall operating profit, and thus measured the rate of return on each class of assets, including the intellectual ones. In a study of the chemical industry, for example, his work indicated a 16.5 percent after-tax return on R&D and a 9.8 percent after-tax return on physical assets. His work also showed some interesting correlations between the time at which an R&D investment was made and its effect on the bottom line (3-5 years for maximum effect).

These results suggests that the chemical industry cannot return its cost of capital (today, typically 10-12 percent) with investments in physical assets alone; instead, it needs the combination of R&D and physical capital to earn an economic return! In other words, state-of-the-art new plants are still commodities. Only those investments incorporating proprietary technology (or which have an otherwise “unfair” advantage) can earn a competitive edge. It seems those who make physical investments only destroy value. There also seems to be a scale effect: Lev's calculations also tell us that the larger chemical companies such as Dow, DuPont, 3M, and Bayer, which typically spend more on R&D, get a higher return from their investments than the smaller companies.

This work is reassuring to those of us concerned with making an economic profit through R&D. But the results are still tied to historical spending patterns and they are aggregated across the industry. As such, they provide cost-based rather than market-based valuations. They make no distinction between research that paid off big and research that failed utterly – although such things make all the difference to which

companies prosper and which diminish in time. In other words, they are inadequate to explain either the situational differences *between* companies or the ways in which relationships between the investments (say R&D programs and new production facilities) play off on one another. Investors are interested in the future and to get an edge they will look beyond economic performance (which is public record) in selecting their investment strategies. As we have seen, they will seek to move beyond economic value and anticipate *market value*. While some of the difference between book value and economic value can be accounted for by Lev's intangible/knowledge capital, in situations of great promise market value moves far beyond economic value. This fact still required a quantitative explanation.

Another fundamental concern about the intellectual capital "solution" is that a distinction needs to be made between intellectual capital that is currently contributing to cash flow and intellectual capital that has the *potential* to do so. For example, the formidable licensing revenues from Union Carbide's Unipol polyethylene technology (20) and patents contributed importantly and tangibly to the economic value of that company. However, a (hypothetical) new technology just emerging from its research pipeline might generate comparable value in the long-term, but because its support costs are making a negative contribution to current cash flow, it *decreases* economic value. Viewed purely as intellectual capital, the two situations seem to be direct analogs, separated only by time. Viewed financially, they are not at all the same. Options theory, discussed below, helps resolve that paradox.

Technology appraisal

A practical application of the economic value approach to intellectual property developed considerably during the 1990s. It has been termed *technology appraisal*. The approach is basically a DCF valuation of a *pro forma* business plan incorporating the technology being appraised (21). Technology appraisal has been used primarily for tax purposes: for example, the valuation of patents donated to universities by companies such as Dow Chemical (22) or the valuation of in-process R&D in mergers and acquisitions. DuPont (23) published a detailed description of typical technology appraisal methodology in connection with the completion of its acquisitions of Pioneer Hy-bred International and DuPont Merck. A number of consultants and accounting firms now offer technology appraisal services.

The Real Options Solution: Valuing Strategic Capital

Real Options

The term *real options* is used to distinguish those options that arise in ordinary business from financial options relating to securities or commodities. The phrase was originally coined by Stewart Myers in 1984 as a way to close the gap between strategy and finance (24). Real options analysis is certainly effective in this regard. More practically, Myers also recognized early that DCF techniques tended to understate the option value attached to growing businesses. Interest in the area developed slowly at first, but has surged since 1998, as reflected by a growing number of books (25), papers, and annual conferences. *Research•Technology Management* has itself published many articles on the subject (26). No wonder, because competition for capital is a reality in any company, and systematic undervaluation of R&D projects can distort decision-making in

ways that are unfavorable both to the corporation's future and to the careers of its R&D professionals.

Real options differ from financial options in that most complex financial derivatives can be "marked to market" and thus are tangible, whereas many real options are embedded in opportunities available to the corporation, and are blanketed by darkness and fog. There are important structural differences between real options and financial options, which make real options inherently more complex.

1. Real options are often situational and thus have very limited liquidity
2. Real options may not have a fixed strike price; indeed the cost of exercise may itself be subject to stochastic behavior
3. Real options do not expire on a date certain as financial options do
4. Exercise of a real option is not necessarily instantaneous
5. Transaction costs may take different forms than for financial options

Broadly speaking, there are three groups of firms making widespread use of real options, with many others starting to put a toe in the water. Pharmaceutical and biotech companies who have discussed using real options to guide R&D decisions include Merck (27), Eli Lilly, Baxter International, Amgen, Genentech, Genzyme, and Smith & Nephew. Petroleum companies that have entered the real options space, typically targeting investments in exploration and production, include Mobil, Chevron, Petrobras, Texaco, Conoco, and Anadarko Petroleum. Real options have been used extensively by energy firms such as Dynegy, Amerada Hess, Duke Energy, and Aquila Energy as a trading tool and for valuing electric power assets and companies. In addition to operating

companies, at least a half dozen consulting companies are now offering real option valuation services, among them PriceWaterhouseCoopers, Navigant, and KPMG.

The New Perspective on Risk

With options thinking comes the perspective that risk can be a source of advantage, and risk-taking can be financially rewarding. This mindset is affecting the R&D literature, which is increasingly focused on attitudes toward risk (28) and the development of tools to permit practitioners to estimate it (29).

Financial theory has expanded our perspective on risk by noting that there are two kinds of risk, and they can work in quite opposite directions. The first type of risk (30) is *unique* (sometimes called *private* risk). It is risk that is unique to a particular situation and is partially subject to your control, such as the risk of a household fire or a research project failure. Unique risks are diversifiable, for example, by pooling household risk using fire insurance or by holding a diversified portfolio of research projects. Investors, too, can pool the unique risks of individual companies by holding diversified portfolios. For this reason, it is axiomatic in finance that an efficient market pays no premium for unique risk. Unique risks can usually be expressed in terms of probabilities, such as “there is an 85% probability the FDA will approve this drug candidate.” Clearly, competitive advantage can be gained by better management of unique risk.

The second type of risk is *market* (or *systematic*) risk, which is exposure to volatility that one cannot control as long as one is exposed. Holding bond or stock portfolios, or foreign currencies, subjects one to market risk. Market risk is not diversifiable. Pooling one’s interest into a bond fund or a stock mutual fund with thousands of other investors will do little or nothing to eliminate exposure to an interest

rate hike or a market meltdown. A pharmaceutical company can do little to diversify the market risks inherent to being part of the health care sector. Exposure to market (undiversifiable) risk increases the cost of capital and thus reduces value, in accordance with CAPM. For options, it is the reverse: higher market risk increases value, and algorithms such as the Black-Scholes formula provide the quantitation.

The distinction between unique and market risk is critical, not only because they affect stock prices in entirely different ways than they affect option prices, but also for sound decision-making in real business. Indeed, it is impossible to apply real options analysis to business situations until the unique and market risks have been separated. Assets to which one is committed by ownership, like a power plant or a municipal bond, will be governed by one set of economic rules, while plans are option-like in their character and are affected by risk in a fundamentally different way.

Plans are Options

A plan is unlike the physical or financial asset it is intended to create because the owner of a plan retains freedom to modify or cancel the plan as circumstances change. This freedom has value, which can be analyzed quantitatively. For example, consider an automobile manufacturer's R&D plan to develop and produce fuel cells. The plan is subject to certain unique risks, such as technical failure. (Such risks are diversifiable by investing in alternate technical approaches or in other technologies such as electric, hybrid, and solar.) It is also subject to an important market risk, the volatility of demand for automobiles.

The fuel cell project inherently contains a valuable option to invest in production facilities in a favorable market, and to defer that investment in an unfavorable one, although the option is still subject to the probability of technical success. If no commitment has yet been made to invest, market risk contributes value, while technical risk remains a negative!

The "underlying security" for the option is the NPV of the business plan for fuel cells under *current* market conditions, the strike price is the investment required to get into production, and the value of the option can be determined quantitatively by the Black-Scholes formula using the volatility of the automobile stocks as a measure of market risk. The method is directly analogous to the valuation of a financial option; say a call option on General Motors stock at a strike price of \$50, when the underlying security (GM stock) is currently trading at \$45.

An important example of the misunderstanding of risk has been the use of risk-weighted hurdle rates for evaluating R&D plans (7); this practice is a holdover from the period of DCF ascendancy and incorrectly applies a concept applicable to market risk (volatility) to an unlike circumstance - the unique (and hence diversifiable) risk of an R&D project.

A need for more sophisticated ways to manage risk in an R&D portfolio is generally acknowledged, and new tools are being developed at the theoretical level, but for reasons of complexity, it remains far from clear that most R&D managers will soon adopt them (31). Evaluating complex combinations of options can be mathematically formidable. Effective implementation, too, requires an investment in education and training. This revolution in theory has yet to become a full revolution in practice.

Strategic Capital

We are now ready to turn to the alignment of strategic value with economic value via real options – the goal of Stewart Myers (24). With real options, the strategic link between R&D and corporate strategy can be measured, giving a quantitative solution to the problems discussed subjectively in *Third Generation R&D* (3). Strategy has long been recognized to be central to practitioners of industrial R&D, since much of their purpose is to create strategic value for their employers.

The key is to define *Strategic Capital* as the value of a firm's real options (32). The *total value* of the firm thus becomes the *sum* of its *economic capital* and its strategic capital. Strategic capital becomes the missing element described above in our discussion of the crisis in valuation, and in this view strategy becomes the framing of an attractive portfolio of real options (33). Not all strategic capital is R&D, but surely R&D that

creates new investment opportunities for the corporation will be an important contributor to strategic value.

The real options solution is powerful because it provides a universal valuation method – one that applies equally to the dullest old-economy company and to a wild new Internet startup. It also creates a framework for the special valuation issues that occur when brilliant innovations are being made within a traditional operating business. Consider two hypothetical automobile companies, A with a real option to make fuel cells and B without. A and B each have an economic value that an analyst can estimate based on the discounted sum of their future cash flows. But A has additional value, even though the decision to exercise this option is still ahead. If the funds are subsequently committed, A's economic value will then be increased by the NPV of the fuel cell project, and the strategic value will revert to zero.

Now, how would this formulation apply to a *technology startup*? This hypothetical company might be dedicated to the production of advanced fuel cells, have negative cash flow, an aggressive business plan, credible partners, is currently experiencing a high rate of revenue growth off a small base, and has a stock which is very volatile. The economic value of this company will be negative so long as cash flow is negative. But because both high growth rates and high volatility can greatly enhance the value of options (34), its strategic value, based on its business plan, which *is still an option*, may be surprisingly high. Its total value will be the strategic (option) value corrected for the (negative) economic value of its unfavorable cash flow. We would expect the stock price to be extraordinarily sensitive to good or bad news regarding its fuel cell business plan - certainly much more than the auto company.

Also, real options theory can go a long way in explaining the turbocharged valuations accorded to companies experiencing extraordinary growth and subject to high volatility, as occurred for Internet companies during 1998–1999. (The alternative seemed to be the invention of weird comparative valuation metrics such as "eyeballs" and "click-throughs.") Indeed, under circumstances where firms are experiencing negative earnings and cash flow, even though pursuing attractive opportunities, almost no other financially-anchored valuation method can be applied. But real options must be handled thoughtfully. Many Internet investors forgot, for example, that there are well-defined limits to the value of options, and also that options expire. For some startups, the effective expiration date of their real options was defined by their cash on hand divided by their “burn rate.”

Creativity as the Framing of Options

An option may, in principle, exist all along. However, it requires intelligence and information to identify it, creativity to frame it, analytical skills to value it, and executive skills and resources to realize its value. These steps are the prerequisite to an actionable real option: namely, (1) frame, (2) analyze, and (3) act.

Creativity, in a business context, thus appears to be congruent with skill at framing real options. It matters not whether the creative person is an R&D scientist, a chief executive officer (CEO), or a motion picture producer, or whether the payoff comes from a new-to-the-world product, a timely acquisition, or a blockbuster movie. To the degree that significant strategic capital hinges on creative skill, it makes business sense to reward the creators proportionately.

Celera Genomics, a company created by Craig Venter, exemplifies the principle. Venter had conceived what promised to be a faster and more efficient method of genome sequencing. Founding a company for this purpose *framed* the option. Its large appetite for scientific talent and instrumentation, and the need to match costs and capital to a revenue model required *analysis*. Making it work as an operating business (*act*) requires yet different skills and is still unproven.

The New Manager's Tool Kit

New tools inevitably affect the way managers think and behave with regard to R&D finance. I will focus on three, the spreadsheet, the electronic database, and the Internet.

With the assistance of several colleagues at Dow Chemical, I wrote my first business plan in 1977. It took several days to hand-crank the numbers, and at the end of the exercise, when the results were apparent, the business team would have liked to make several adjustments, but the deadline was upon us. Just a year later, Robert Frankston and Dan Bricklin created the first spreadsheet program, Visicalc, an electronic ledger book, which replaced the accountant's columnar pad, pencil, and calculator. While financial analysis software was then available on mainframes, Visicalc ran on an early personal computer (the Apple II), its results could be seen immediately, and the analyses could be done over and over again. It was ideal for financial modeling. User-friendly graphics capabilities soon added additional power to the spreadsheet program. Both spreadsheets and personal computers became increasingly feature-rich. Lotus 123, derived from Visicalc, was introduced by Mitch Kapor in 1983 and became the single leading software program for microcomputers. By 1984, my colleagues and I were using Lotus to build *pro forma* business models to evaluate the attractiveness of R&D projects using DCF methodology. In 1987, new spreadsheets such as Excel started to emerge, which took advantage of the graphical user interface (GUI) and improved graphics. Soon thereafter, spreadsheets were incorporated into "office suites," allowing fast integration of tables and charts into word processing documents and presentation software.

Two other enhancements of spreadsheet software are extremely useful for dealing with the uncertainties inherent in R&D modeling. One is the basic statistical/mathematical package incorporated in Excel and Lotus. It allows the easy manipulation of probability functions, such as the normal distribution and the Black-Scholes option formula. Even more powerful are Monte Carlo bolt-on programs, such as Crystal Ball (35), which allow the user to run many thousands of iterations of an Excel spreadsheet, in which sensitive variables are given predetermined probability distributions. The modern microprocessor's capabilities are such that a hundred thousand iterations of a detailed spreadsheet can be run while the analyst is making a cup of coffee.

The second major innovation during this period has been the growth of electronic databases. Databases may be private and confidential, available to the public for a fee, or within the public domain. Among the most useful private databases are the financial and technical histories of R&D projects, which enable companies to calculate probabilities of success and to project future costs and revenues (36). An abundance of data suitable for benchmarking has been compiled in the IRI/CIMS database (37).

One caveat for the R&D practitioner: a traditional approach to R&D risk management has been the view that R&D projects may fail for *either* technical reasons (unique risk) or for commercial reasons (which can combine unique and market risk). We have seen that probability is not the best tool for dealing with market risk, so the interpretation of historical data may need revision in terms of what we now understand about risk. For example, while I was at W.R. Grace, we had a portfolio of projects in the area of advanced environmental technology. Nearly all of the projects were to fail for "commercial reasons." However, failure occurred during a period when environmental

firms as a whole were having extreme difficulty earning the cost of capital. Hence, it may have been inappropriate to attribute the failed projects to unique (diversifiable) commercial risk, but rather to broader, undiversifiable, market risk. This observation is obviously applicable to other technical sectors subject to market forces: energy, health care, and telecommunications have all hit rough patches in recent memory.

The Internet is also an increasingly powerful resource for financial analysis related to R&D. Enormous financial databases are updated daily on free Internet sites such as Yahoo, BigCharts, and the Chicago Board Options Exchange (www.cboe.com), while Bloomberg and Reuters market proprietary data systems for financial professionals. The information is far more current, and in a more useful format, than the paper-based databases of twenty-years ago. Public financial documents from competitors, customers, and suppliers are also available on the Security and Exchange Commission's edgar-online website. Search engines such as Google facilitate on-line research and uncover new sources of information of which professionals may have been barely aware. Obviously, the development of cheap and powerful microprocessors and growing broadband capabilities have made information resources more affordable and often more productive than the specialized commercial databases on which professionals relied in the 1980's.

While none of these individual developments was enabling in its own right, the cumulative impact of the new toolkit has been a revolutionary increase in the quantity, quality, and productivity of financial analysis for R&D managers.

New Trends in R&D Finance

New trends in corporate finance, and a new toolkit, are naturally to be expected to cause structural changes in industrial R&D. In fact, the changes that have taken place in the past two decades have been remarkably far-reaching.

The Impact of Leveraged Buyouts (LBO's)

The 1980s marked the advent of the leveraged buyout era and its sibling, the high-yield or “junk” bond. The era culminated spectacularly in the RJR bidding war, depicted in the book and subsequent movie, *Barbarians at The Gate* (38), the book, *The Predator's Ball* (39), and the imprisonment of prominent participants for insider trading and securities violations. About \$400 billion of LBO's were financed in the decade of the 1980s. Excessive bids, such as for RJR, caused a broad collapse of the first junk bond market, but the technique is alive and well as a more sophisticated generation of LBO firms, backed by institutional funds, trawls the industrial marketplace for new buyout opportunities.

LBO's were generally financed with 10 percent or less equity put up by limited partners and 90 percent by bank loans and subordinated debt, typically in the form of high-yield bonds floated by Drexel Burnham Lambert and others. An LBO becomes a possibility when the share price of the target company has fallen to a level where the required debt to purchase the company can be paid down quickly by a combination of asset sales and cash flow from operations. Ideally, the company is purchased with its own assets, leaving the investors with a large profit after the debt burden is eliminated.

The LBO strategy is not one of maximizing value; it is one of maximizing cash flow. The target company may be substantially depleted of physical and intellectual

capital at the end of the game. Ironically, however, an LBO comes into play when management's efforts to enhance value have either failed, or are perceived by the marketplace to be failing.

There were lasting effects from this traumatic period, some beneficial and some less so. Managements rapidly became more disciplined about value creation when it became apparent that they were vulnerable to a raid, or were missing opportunities to enhance shareholder value. The notion was that if shareholders could benefit from streamlining, downsizing, etc., management would do it before the raiders arrived to do it for them. Corporations shed expensive frills, such as costly headquarters, unprofitable divisions, and pet projects, to focus on core operations, and to scrutinize new acquisitions and capital investments from an economic value viewpoint. The well-publicized reign of Jack Welch at General Electric symbolized many of the elements of this approach.

The effects on R&D finance were significant: long-term R&D, and R&D not targeted to existing businesses, was often curtailed to shore up short-term cash flow. This process took place not only within companies that were in LBO mode, but also in companies that considered themselves LBO *targets*. Many large central research centers were downsized or eliminated, and those that remained were tied directly to strategic business units (SBU's), which had now become the focus of value creation. In addition, a typical corporate reaction to external threats was to merge with others in the industry, and create value by eliminating duplicate headquarters, sales organizations, and R&D operations. The elimination of these costs clearly generated economic value; the issue would be how much of it came at a cost in strategic value.

The Growing Role of Venture Capital

Coincidentally, when many traditional industrial companies were cutting back on innovative research, a boom was about to take place in technology start-ups. In the 1980s, the venture capital industry began a great period of growth. The stimulus was in part the opportunities created by the revolution in biotechnology, and the success of firms such as Genentech and Amgen. In 1980, venture firms raised and invested less than \$600 million. That sum grew to nearly \$4 billion by 1987.

Venture capital then moved aggressively into the technology sector in the 1990s, and by 1995 the venture firms were raising \$10 billion. That number climbed to \$29 billion in 1998 and \$93 billion in 2000 (40) on Internet momentum. The gold rush was inevitable, since before the peak some venture capitalists were reporting returns north of 50 and even 100 percent – numbers irresistible to money managers – compared with the low 20 percent range more typical of the industry's history. Venture capital's successes became household words: Netscape, Yahoo, AOL, eBay, Amazon, etc. With the rush of money into venture funds, it is not surprising that the quality of opportunities at the margin would drop, and a correction would ensue ("the venture capital cycle"). Many venture-supported companies were badly wounded in 2001, and it seems unlikely that the venture investment peak will be reached again in the near future. But, given the successes, it is also unlikely that venture capital will return to the financing levels of the 1980s.

Was there a connection between the LBO boom and the venture capital boom? The case can certainly be made. At the level of human capital, the people who generate technical innovation and entrepreneurship, the brightest talent was attracted to the start-

ups and often deserted traditional industrial companies, taking their best ideas with them. At the level of financial cash flows, endowment, pension and other institutions seeking exceptional returns fueled the partnerships that financed both the LBO and venture capital booms.

While by no means all expenditure by technology start-ups is R&D (nor is the source of all start-up funds venture capital), the magnitude of venture capital spending is now significant when compared (1997 figures) to \$133.3 billion of R&D funded by U.S. industry and the shrinking \$62.7 billion funded by the Federal government (41).

Above all, the venture capital phenomenon has validated, in purely financial terms, the concept that R&D can be a highly profitable vehicle for investment, as contrasted to the view that it is merely a risky and unpredictable expense of doing business.

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