Financial Options Methodology
for
Analyzing Investments in New Technology

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ABSTRACT

The evaluation of investments in longer term research and development in emerging technologies, because of the nature of such subjects, must address inherent uncertainties. Most notably, future cash flow forecasts include substantial uncertainties. Conventional present value methodology, when applied to emerging technologies severely penalizes cash flow forecasts, and strategic investment opportunities are at risk of being neglected.

Use of options valuation methodology adapted from the financial arena has been introduced as having applicability in such technology evaluations. Indeed, characteristics of superconducting magnetic energy storage technology suggest that it is a candidate for the use of options methodology when investment decisions are being contemplated.

INTRODUCTION

Conventional financial analysis utilizing present value methodology (i.e., discounted payback period; net present value; internal rate of return, profitability index) is often applied to engineering problems in order to more optimally allocate resources. The use of such familiar techniques satisfies the requirement for a structured approach to perform such analyses as well as provides a common basis for communicating economic justification to financial managers. Present value methodology, however, may not be suitable for analysis of research and development investments — those which may not yield significant results until many years in the future, hence cash flow forecasts are uncertain — since the benefit stream from the investment is severely discounted.

Near term investments in research and development are typically modest in comparison to near-commercial project capital requirements. Research and development expenditures often times buy the investor early rights to later larger and preferential pre-commercial positions. In essence, the early research and development investments give the investor the right, but not the obligation, to purchase a more substantive position in the technology in the future. By definition, the investor is purchasing a call option contract — a call option gives the purchaser the right to purchase shares of an enterprise at an exercise price on a certain future date.

Options methodology and option pricing valuation are techniques well-established in the financial arena which can be borrowed to more appropriately value investments in research and

development. The recognition that research and development expenditures maintain the strategic option for the corporation can provide a perspective which may offset present institutional bias toward both short-term evaluation tools and short-term results.[1]

OPTIONS METHODOLOGY

The most well known and commonly used technique for valuing options is the Black-Scholes option pricing model (OPM).[2] This model's introduction roughly coincided with the opening of the Chicago Board of Trade in 1973 and has been accepted for valuing call options. The model consists of two elements to assess the value of a contemplated option purchase. The first element in the model accounts for the benefit stream anticipated from the exercise of the option. The second element accounts for the estimate of the striking price or exercise price at maturity of the option. The exercise of this option will be necessary to enable the benefits to be realized at some future date.

Stated in equation form:

$$V_0 = P_0[N(d_1)] - Ee^{-rt}[N(d_2)]$$

where

V_0 = the value of the option

P_0 = the current price of the investment

$[N(d_i)]$ = probability that a deviation less than d_i will occur in a standard normal distribution. The value of a cumulative normal density function.

E = the exercise price

e = exponential constant, 2.71828

r = risk-free interest rate

t = time until option is exercised

d_1 = $\dfrac{\ln(P/E) + [r + 0.5(\sigma^2)]t}{\sigma\sqrt{t}}$

d_2 = $d_1 - \sigma\sqrt{t}$

σ^2 = variance of the rate of return on the investment

Assumptions used in the Black-Scholes OPM are:

1. The call option can only be exercised on its maturity date (known as a European option).

2. No dividends, taxes, or transaction costs are associated with the option over the life of the option.

3. The short-term interest rate is known and constant during the life of the option.

4. No short sales restrictions exist.

5. The price moves randomly in continuous time.

A more detailed description of the model can be found in a number of financial textbooks. Its use rather than its derivation are important here.

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[1] Mitchell, G.R. and Hamilton, W.F. "Managing R&D as a Strategic Option." *Research and Technology Management* (May-June 198), 15-22.
[2] Black, F. and Scholes, M. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy,* 81 (May-June 1973), 637-654.

The factors in the OPM can be illustrated on a timeline as shown in Figure 1, below.
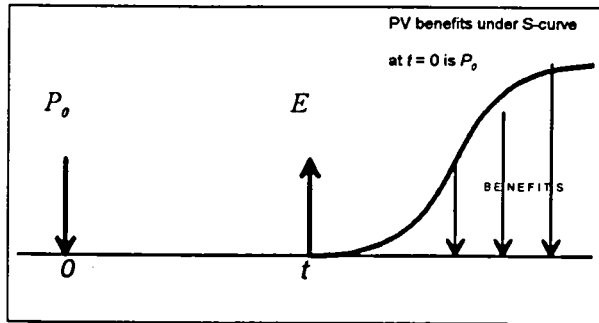

Figure 1

The interpretation of the Black-Scholes OPM equation is rather simple. The first element, $P_0[N(d_1)]$, represents the current value of the investment adjusted by a factor which represents the variability one expects in this value. Mathematically, the adjustment is the probability that a deviation less than d_1 will occur in the standard normal distribution. In normal stock options, the first element represents the present value of the stock. The second element, $Ee^{-rt}[N(d_2)]$, represents the value of the exercise price at time of maturity, t , discounted by the risk-free rate of return. The exercise price also is adjusted for the probability that it will actually occur as expected.

APPLICATION TO RESEARCH & DEVELOPMENT

Observation of investments in research and development suggest that the call option model can be applied to research and development or new technology investments in certain circumstances. OPM is not applicable to those projects which are near-term and involve capital investments to achieve final commerciality — traditional present value techniques may readily

and perhaps most appropriately be used to analyze such near-term investments. On the other hand, those projects which require an up-front investment (i.e., the option purchase price) to reserve future rights and whose benefit stream is conditioned on some future capitalization (i.e., the exercise price) indeed represent a typical call option situation which can be adopted from the financial arena. For situations such as this, Black-Scholes OPM can be used.

In dealing with stock options, the exercise price, E, is the additional capital the investor can chose to expend at the maturity of the option. In research and development, this exercise price is the additional start-up capital required for commercialization just prior to initial benefits being realized. This may appear to the investor as the cost for, for instance, pilot manufacturing facilities to achieve the first batch of benefits from the new technology. The exercise price is discounted by the riskless rate of return, r, continuously compounded over the duration of the option, t, and adjusted by $[N(d_2)]$ for the probability that the cost will actually occur as estimated.

Again dealing with stock options, the current investment price, P_0 , is the present value of the expected dividends to be returned from the investment. In research and development, P_0 is correspondingly the present value of the expected yield from the project. The adjustment to this element in the model, $[N(d_1)]$, accounts for the variance of the investment price, P_0 .

Most of the factors in the OPM model can be reasonably estimated for option investment analysis. The riskless rate of return, r, is usually taken as the current U.S. treasury bill or treasury note rate. Time, t, is the time before the investment of additional capital, E, is necessary.

The anticipated benefit stream can be reduced to a present value, P_0. Estimating the variance, however, can be problematic.

As a proxy for the variance associated with new drug development, the pharmaceutical company Merck uses the annual standard deviation of returns for typical biotechnology stocks in their application of OPM.[3] Conservatively, Merck uses between 40% to 60% for project volatility.

Pharmaceutical development is confined within the same industry and past performance may provide some prognosis for future results. However, typically, new technologies and research and development deal with issues without a historical pattern from which to draw.

The model appropriately is sensitive to the variance factor. Common sense would dictate that predictions of actual results are subjective and variance will be an important parameter in the analysis. Experienced judgment must, therefore, be utilized to generate a reasonable model input.

Two factors in the analysis deserve special attention: (1) the time to maturity and (2) the variance of the estimates. In contrast to present value techniques, OPM suggests *greater* value is associated with longer term projects. That is, with longer times to maturity of the exercisable option, the greater the opportunity for the value of the investment to rise. Consequently, OPM imputes greater value to long-term projects than perhaps traditional present value techniques which exponentially discount and penalize future benefit streams.

Using options methodology also ascribes greater value to projects whose outcome may be uncertain. The variance of longer term projects increases the probability of larger than expected yields, increasing the value of the option. The probability of *smaller* than expected results is not as detrimental. Downside loss is limited to be no greater than the option purchase cost. Longer term projects which have lengthy periods before they become commercial and which have uncertain yields do, in fact, *increase* the value of the option in stark contrast with how such projects would be viewed using present value methodology.

What the Black-Scholes OPM provides is a credible tool for the analysis of certain new technology investments which provide the investor meaningful insight into the value of, especially, projects with long term results.

POTENTIAL APPLICATION OF OPTIONS METHODOLOGY TO SMES

Superconducting Magnetic Energy Storage (SMES) has characteristics which suggest that OPM may be useful to analyze decisions regarding investment in research and development of the technology. The need for SMES technology exists today. Utility and customer requirements for energy storage range from small kilowatt-second storage devices for power quality up through the large, multi-megawatt-hour, bulk power devices for utility spinning reserve and/or load leveling. The smaller one megawatt-for-one-second SMES systems are commercially available. One would not find Black-Scholes OPM too useful in analyzing a commercial hardware purchase decision.[4] Conventional present value techniques would apply.

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[3]   Nichols, Nancy. "Scientific management at Merck: An Interview with CFO Judy Lewent." *Harvard Business Review* (Jan-Feb 1994) 88-99.

However, research and development investments in intermediate- and large-sized SMES systems *could* be analyzed using OPM. Such investments in research, development, and even demonstration are analogous to option purchases. The future commercial start-up investments necessary to take the technology to market are analogous to the option's exercise price.

Market analyses for utility and customer use of SMES devices includes uncertainties. If one were to use present value methods to analyze the early research and development investments, depending on the discounting applied to the analysis, such investments may not be justified. Despite potential extraordinarily huge benefits from the SMES technology and the relatively small investment in research and development, the technology may not get off the ground without proper analysis of early investments.

Since the early research and development costs are likened to the option purchase, the use of Black-Scholes OPM may yield sufficient incentive to pursue research and development.

IDENTIFIED NEED

To utilize Black-Scholes OPM, one must be able to estimate the various factors involved in the model. Further examination of the variability of estimates of (1) follow-up investment needs, and (2) benefit streams, from new technology research and development is necessary to better judge the appropriate statistical parameter, d_i. Unlike stock options which can be valued based on the stock's historical variability or like pharmaceutical research and development which has a database

of drug development statistics, new technologies often confound existing paradigms and, therefore, defy simple analysis.

CONCLUSION

Use of options methodology such as the Black-Scholes option pricing model has particular relevance to the analysis of early expenditures for research and development in emerging technologies. Financial managers should recognize that the usefulness of conventional present value methodology diminishes as the framework for the project departs from near-term commercial likelihood. OPM may provide a useful approach to the analysis of such longer term technologies as SMES, not only being a more appropriate analysis tool but one which financial managers will already have familiarity.

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[4] One might, however, find OPM useful if one were evaluating investment in a start-up company marketing such devices.