Valuation of technology: exploring a practical hybrid model

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Abstract

How much is this technology worth? This is a question of great interest and importance in a wide variety of circumstances. These vary from companies considering investing in R&D projects, to venture capitalists funding start-up companies. However, such valuation is notoriously difficult to get right, and the cost of failure can be very high.

Many techniques have been proposed to assist managers facing this issue, from traditional discounted cash flow analysis to more recent methods based on real options thinking. This paper discusses the practicality of the various methods available, and explores the application of a hybrid model, which aims to make these rather abstract ideas more accessible to practicing managers.

Introduction

Under the influence of ever increasing competitive pressures and shorter product life cycles, many companies are concerned to both diversify their technology portfolios and accelerate the introduction of new technologies to the market. These pressures have lead to an increase of technology development and trading within and between companies, with the associated need to value technology [1]. Additional reasons for valuing technology include support for finance applications and accounting for tax.

However the financial value of technology, usually in the form of technological projects or investments, is difficult to determine. This is largely due to the uncertainties that surround such activities. Often large sequential investments are required and rewards are not realised until the final investment is completed. Key information can sometimes only be obtained by making the early investments. Practically, many managers know that there is something inadequate about the traditional valuation method of Net Present Value (NPV) in these situations. Having the option to invest if appropriate is not something that is given a value by NPV methods. NPV methods tend to penalise uncertainty by using higher discount rates, even when there is flexibility in a project to profit from this uncertainty. There is sometimes value to be obtained through waiting for more complete information, and this value is also not incorporated in the NPV calculation [2].

Recognising that the true value is not captured by NPV calculations, many analysts have sought to justify their 'gut-feel' and industry experience by manipulating the valuation process and raising cash-flows to unlikely levels. The result is a decision-making process that lacks credibility [3]. Conversely, it is also argued [4] that by instead sticking to the correct use of traditional valuation tools, many US firms missed significant growth opportunities in their industry. The consequence is that valuing technology is still more of an art than a science, since the methods generally used have been adapted from those applied to value more tangible assets i.e. not such assets as "managerial flexibility". There is still major scope for research in this area [5].

Hence in recent years, new methodologies have been sought and options-based approaches have emerged. Options-based approaches value ways to control risk at a cost, limiting losses while magnifying upsides – "the most attractive feature of options" [6]. The adaptation of financial options theory to real assets such as technology is known as "real options" and may provide the basis for a more realistic valuation of risky technological projects. However there are a number of difficulties with the application of options-based techniques in real situations. Not least of these is the high level of the mathematical concepts involved [7].

The work described in this paper sets out to explore the *practical* use of options-based thinking for two major groups of people who invest in high-risk technological projects. The first group consists of technological venture capitalists who review the business plans of many promising start-up technological firms and make decisions on whether to invest in them or not. The second group consists of the management teams of large technology companies who need to make decisions on selecting and acquiring new technologies to incorporate in future products or services.

Overview of valuation methodologies

Before giving an overview of valuation techniques, it is useful to clarify their purpose. Valuation techniques are intended to generate understanding of the value of projects, enabling those involved to compare projects and to find ways of adapt them to increase their value. As such, there is a tradeoff between accuracy and simplicity. A very complicated technique might generate a more accurate value. However it may be unsuitable because it requires accurate input data that is hard to obtain, or because it does not enable its users to understand where the value is generated.

Fig. 1 shows the main approaches that have been adopted for technology valuation. Real options and hybrid models are discussed in more detail in the following section; the others are summarised below. Advantages and disadvantages of these techniques are discussed in (Smith and Parr 1994; Megantz 1996; Razgaitis 1999; Damodaran 2001).

Relative/market valuation. Technology is valued by comparing it to the known value of similar technologies. For example in a start-up firm, comparable technology companies can be used to obtain the market value to sales ratio. The projected sales of the start-up can then be multiplied by this ratio to get an estimate of market value.

Auctions. The technology characteristics are disclosed to potential customers and the licensor accepts sealed bids.

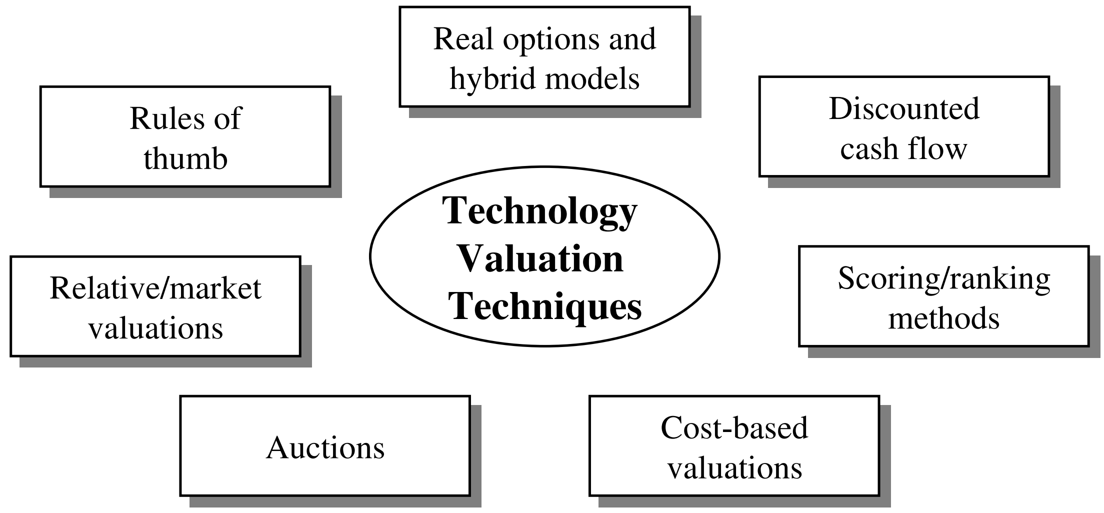

Figure 1: Popular technology valuation techniques

Cost-based approaches. This equates the cost of replacing the technology with identical or equivalent technology to its value. One common approach is to add up all the expenses associated with developing the technology and convert that to the current value. Another approach is to estimate the cost of recreating the technology.

Scoring and ranking methods. Attributes of a technology such as market size or market environment are used. These are weighted and scored, resulting in a combined score. With a comparable reference of value to a standard weighted score, the relative value of the technology can be determined.

Discounted cash flow (DCF). This concept is central to the valuation of any asset when any part of its return is captured in the future, and can be found in most finance textbooks. It is the basis of Net Present Value and Internal Rate of Return valuation methods. In technology companies the method is widely used when projected revenues can be calculated, but in venture capital where inputs are very uncertain, relative valuation is more commonly used.

There are limitations to each of the above techniques, however in particular circumstances they may provide useful insights to the value of technology. In order to address the value of uncertainty, techniques based on real options offer other advantages.

Real options and hybrid models

Options are “the right, but not the obligation”, to do something at a future date. In the financial world they are contractual agreements. An example would be the right to buy a share in a particular company at a particular price on a particular date in the future. If the market price on that future date turns out to be above the agreed price, then there is profit to be made by buying a share at the agreed price and selling at the market price. Clearly there are parallels to investing in a technology, that gives you the ability to do something in the future, but not the obligation.

In the literature on real options there seems to be three levels of real options thinking. The starting level is simply to realise that some investments are options, that what is being paid for is the “right to play”, and that there is not guaranteed pay-off. Mitchell and Hamilton [8] make this point in the context of R&D, dividing projects into three types: knowledge gathering, investments and strategic options. MacMillan and McGrath [9] further distinguish between options with high market uncertainty and ones with high technical uncertainty, and suggest an appropriate balance of options and guaranteed investments for an R&D portfolio.

At the second level is an attempt to quantify the value of the flexibility in projects by using decision trees and estimated probabilities. A typical example of this approach is [10]. Much previous work on decision trees does not carry the options label. There is some difficulty in estimating probabilities, since the events in a decision tree are typically one-off e.g. will our R&D team solve technical problem X, whereas intuitive notions of probability are based on long run frequencies in repeated trials. However there are useful insights generated at this level. One is that market risk can be a good thing, if there is flexibility in the project to avoid the downside and exploit the upside. There may be value in delaying investments until the market value becomes clearer. Conversely there may be value in performing research projects to generate the information necessary to accurately value an opportunity. Overall, level two approaches address the worst deficiencies of pure NPV approaches, and encourage a positive attitude to exploiting uncertainty rather than fearing it.

The third level of real options thinking attempts to transfer the mathematical modeling techniques that have proved successful in the financial markets, across into the world of real investments. It brings in the ideas of *replicating portfolios* and of *arbitrage pricing* i.e. what should the price of this option be so that no-one can make "excessive" guaranteed profits. (In the financial world, options are usually related to an underlying asset that is traded on the market. It is then possible to construct a portfolio of assets and options whose value is not affected by the outcome of events, since an increase in the value of the assets is compensated for by the decrease in value of the options and vice versa. This portfolio is termed risk-free and it is assumed should pay the same rate of return as any other risk free investment, such as money in the bank). This approach circumvents the problem of estimating probabilities, but in its place substitutes the problem of estimating how much the market prices are going to fluctuate i.e. the volatility of the prices.

There are problems at this third level, some of them outlined in [11]. If we consider the specific example of a project to develop technology for a new market application, then there is no underlying asset, unlike financial options. Even if there were, or if we could simulate one somehow, is it reasonable to assume its price moves as the exponential Brownian assumed in the Black-Scholes-Merton model? We could adopt a more sophisticated stochastic model, but the question of whether it is valid still remains. Arbitrage pricing arguments are not well founded if it is not possible for an arbitragist to form a risk free portfolio. The date on which the project/option will mature and its cost are not guaranteed as they are in the financial world. In fact, the project might fail and not provide an option at all, again unlike the guaranteed options contract in the financial world. If the project does complete successfully, then the payoff is typically the option to launch another project to commercially exploit the technology i.e. typically real options are compound options.

Clearly any accurate stochastic model of a real option must address these caveats. It is likely therefore to be considerably more complex than the Black-Scholes-Merton model. However, this is probably already at the limit of accessibility for the users under consideration: venture capitalists and management teams. Furthermore, validating any such stochastic models is likely to be difficult.

Concluding this overview of real options, it seems that useful tools for quantitative valuation of technology for managers are more likely to be built round level two idea of decision trees than level three ideas of stochastic differential equations. We propose a hybrid model that consists of a decision tree for the early stages of the project where specific risk is prevalent, and a binomial lattice for the later stages where market risk is the major consideration. A hybrid options model has been proposed in the area of product development [12], and a combination of stochastic differential equations and decision trees has been proposed for R&D project evaluation [13]. We illustrate the model with a simple example in the next section.

A hybrid valuation model

The following example is summarised from [14]. It is constructed from the information presented in the Vusion Inc business case, which was runner-up in the Moot Corp business plan competition [15]. It was chosen since the case was well written and most of the data publicly available. The aim was to construct a simple example and then test this with venture capitalists and technology managers to collect their opinion on whether they found such an analysis useful.

Vusion Inc is developing a chemical analyser and sensor cartridge based on Electronic Tongue technology. It fills a gap in the market for the real-time analysis of chemically complex products in the liquid processing industry. Skipping over the technical background and the marketing and licensing strategies, the essence of the venture capital funding for Vusion is presented in Fig. 2.

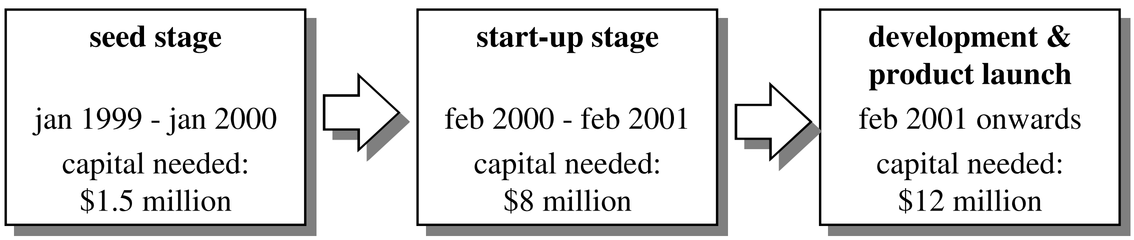

Figure 2: The first three years of Vusion Inc

We apply real options valuation to explore whether a venture capitalist should invest in the first round of seed funding. The first step in applying real options valuation is to identify the options available [3]. In this case there are two growth options accessed by the initial investment of $1.5M in 1999:

1. Option of further partial investment of amount I_2 at the start-up stage in 2000
2. Option of further partial investment of amount I_3 in the development and product launch stage from 2001

The second option can be delayed by up to two years. There is an important distinction between the types of risk involved at the various stages. In the two early stages the risks are largely specific to Vusion, particularly the risks due to technical problems. In the final stage, the technical problems have been solved and the risk is market risk i.e. whether the demand for the technology is better or worse than estimated.

The value of the initial investment will include some value due to the option to increase the investment at the second stage. Similarly the value of this first growth option includes the value of the future opportunity to invest further in the final stage. The value of the final investment is directly tied to the market revenues generated. Thus the decision is a compound option. If the venture capitalist does not invest in a stage, he or she cannot invest in the later stages. This is depicted in Fig. 3. Note the revenues received are different in the three different cases and that the launch can be delayed by two years.

The way to evaluate this compound option is to start from the second growth option and work back. Valuing this second option requires some simple model of the evolution of the value V of the Vusion investment. We assume, as is common, that V follows a continuous time exponential random walk. We approximate this process using a binomial lattice. This approximation is more intuitively understandable than handling the equations directly and provides an easy way to deal with the issue of delaying exercising the second option.

For the binomial lattice to approximate a continuous time random walk we make a set of standard choices [16, p184]: we specify that each year V will either rise to the value Vu or fall to the value Vd (see Fig. 4). We choose $u = 1/d$. To match the volatility of the random walk we choose $u = \exp(\sigma)$ where σ the volatility is the standard deviation of the annual proportional change in V.

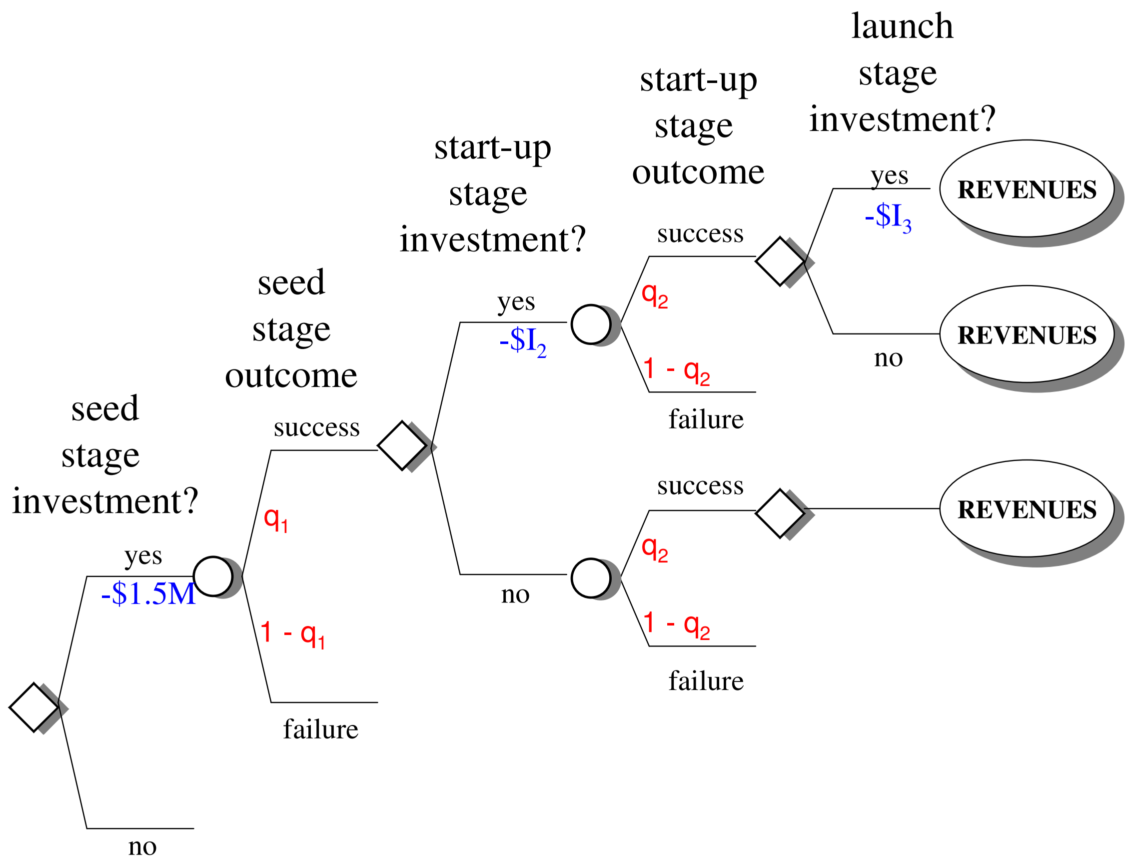

Figure 3: The tree of outcomes for the venture capitalist

We then put a risk neutral measure p on the tree [17]. This standard device enables us to calculate the value of the option, simply by calculating the expectation of the payoffs using this measure. If r is the risk-free interest rate then the appropriate measure is $p = (\exp(r) - d)/(u-d)$ for upward moves and 1-p for downward moves [16, p184]. The volatility σ can be estimated by examining the volatility of stocks of companies specialising in this area, but since the market is new we used a volatility of 30% suggested by Razgaitis [18] for a technology that needs further testing, but for which a clear market exists. V_1, the start value for V, was from the discounted projected cash flows from 2002 onwards, as estimated in the business plan.

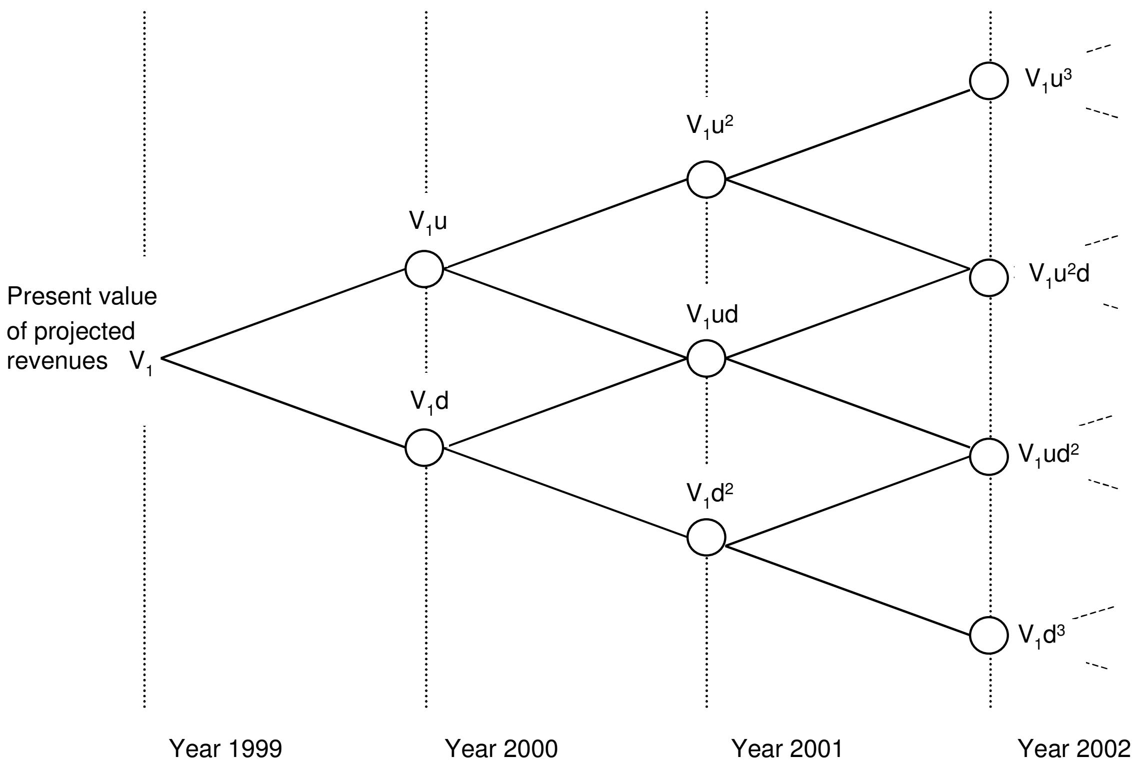

Figure 4: Binomial lattice approximating continuous-time fluctuations in

The values of the second option at the leaves A,B,C,D,E of the tree in Fig. 5 are max(V - I_3, 0) i.e. the venture capitalist only invests if the expected gain is positive. Thus node A has value max($V_1u^4 - I_3$, 0). We can then calculate the values back through the tree to the root using the risk neutral measure: the value at a node is the greater of the value we would receive if we invested now i.e V - I_3, and the discounted expectation of the future value of the option to invest i.e. exp(-r)(pVu + (1-p) Vd). This enables us to obtain three different values at I,J and K for the second option that arises in 2001, depending on how the market has evolved.

The value of the first option at nodes L and M is calculated using the value of the second option at I,J and K. If the venture capitalist invests I_2 at node L then he (or she) has probability q_2 of reaching 2001 with the possibility of profiting from the second option. If the venture capitalist does not invest, then he has a probability q_2 of receiving revenues (but does not have the option to invest further). He will naturally select the

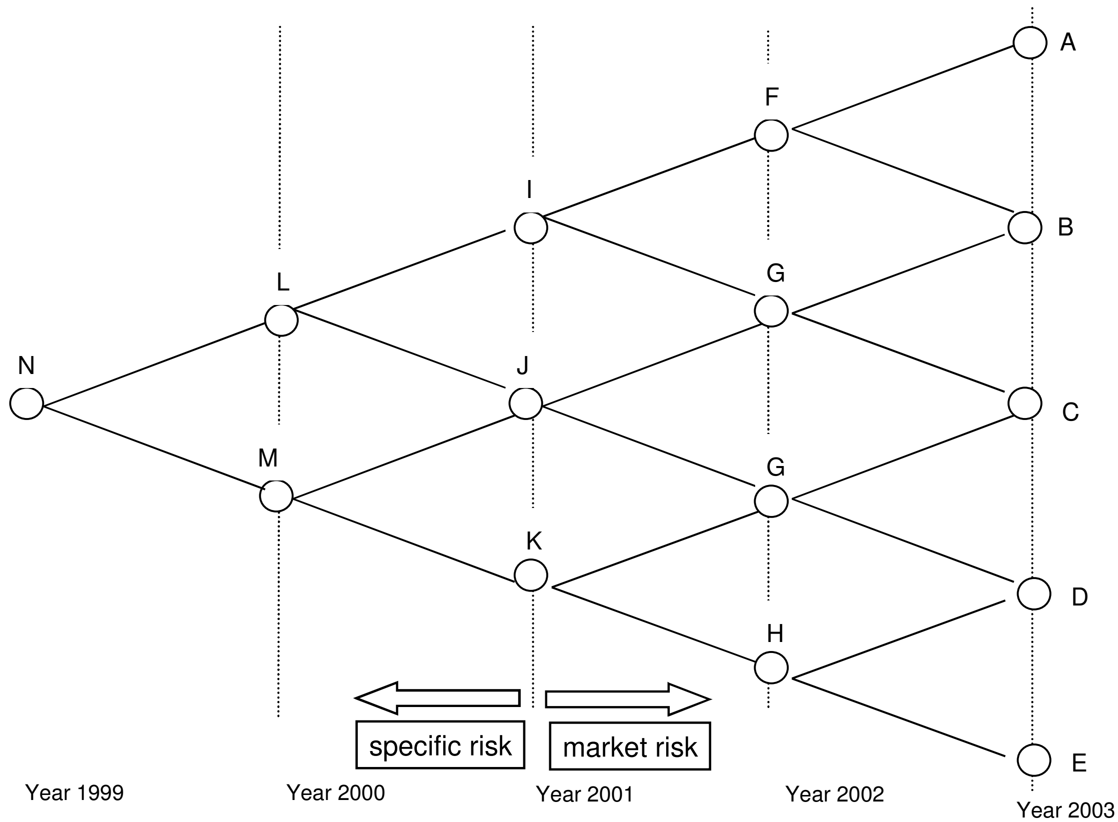

Figure 5: Tree for calculating the option values

larger of these two amounts. Discounting this by the rate r (we assume the risk can be diversified away, so use the risk-free rate) gives the value of the first growth option at nodes L and M. The probability q_2 needs to be estimated by an expert.

Similarly the original investment decision gives the venture capitalist a q_1 chance of accessing this first option. If q_1 times this option value, discounted at the rate r exceeds the original investment cost, then the investment has a positive payoff. It is possible then to do sensitivity analyses on variables such as the volatility, to investigate the robustness of the conclusion [14].

Testing the model: venture capitalist and technology manager feedback

A model similar to the above was programmed into a spreadsheet and presented to venture capitalists and technology managers in order to determine the utility of such real options methods. Both were generally enthusiastic.

Interestingly the VCs thought they would be likely to use the model to justify the investment to their own investors, rather than in negotiating with entrepreneurs. This implies that they see its main value as one of backing up decisions they have already made, rather than as a tool to explore value. They were skeptical of using the projected cashflows as the value of the project, and suggested that the liquidation value was of more interest to them. They were similarly wary of the assumption that specific risk could be diversified away, since often their investments are in similar areas. This is probably due to the fact that domain knowledge is needed to assess the viability of particular start-ups and it is not possible for the VCs to have domain knowledge in many diverse areas.

The technology managers thought the real option model proposed was a useful input into a decision making process. Like the VCs, they questioned the reality of diversifying away specific risk and queried the volatility Fig.. Usually they use ranking and scoring methods when assessing projects and so volatilities are rarely estimated.

Discussions and conclusions

The feedback on using real options models with VCs and technology managers was positive. However the key benefit is probably that of change of mindset, as suggested by Faulkner [10]. If there is flexibility to respond to it appropriately, uncertainty can be something to be welcomed rather than shunned.

The hybrid model presented above attempts to strike the right balance of being sufficiently simple as to be intuitively understood, but not so simple as to be unhelpfully misleading. Clearly NPV when applied to risky projects can fall into the unhelpfully misleading category. Unlike in the financial markets, there is also a trade-off between the time spent on the decision and the time spent on making the decision work. In the financial markets once an option is traded, the participants need to wait to see how the prices evolve – they do not have the power to influence them.

In terms of future research, there is little published evidence of how well particular stochastic models fit the data for real investments. Also there is scope for investigating how real options valuation is used within companies, since this takes in aspects of organisational dynamics as well. One key point is that if real options valuation is to be credible, then the difficult decisions of discontinuing projects that are no longer likely to succeed needs to be controlled – management flexibility is only valuable if used well.

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