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STRATEGIC INVESTMENT DECISION-MAKING: COMMUNICATING THE TRUE MEANING OF THE REAL OPTIONS FRAMEWORK TO THE BOARD

Once heralded as a revolution in capital budgeting and enthusiastically put forward as a major breakthrough to explore the real value of strategic investment projects, the real options approach seems to be losing momentum. For many senior managers and members of board of directors, 'real options' is nothing more than a theoretical-academic construct that is hard to apply in practice. Decision analysis, the multiperiod binomial model and the Black-Scholes and Margrabe formulae are well known but sometimes poorly applied and distrusted. Taking strategic investment opportunities as real options is widely accepted as the right approach, but the mathematical models to evaluate those options are often not understood. For that reason we believe that there still is a need to better communicate the true meaning of real options and of options thinking to senior management and board of directors. The setup of a gradually developing line of communication with the board is illustrated by means of simplified but real applications of the concepts.
Keywords: real options, Black-Scholes model, Margrabe formula, multiperiod binomial model, decision analysis

1. INTRODUCTION AND KEY CONCEPTS

Though it is widely accepted that over-reliance on conventional financial appraisal tools such as Net Present Value (NPV) or Internal Rate of Return may bias decision-makers against strategic investment projects (Myers 1977, Hayes and Garvin 1982, Block 2007), there is evidence that, with the exception of some industries, alternative analysis tools or extensions of the conventional NPV-method, such as real options, barely register in practice. The results of a number of surveys (Alkaraan and Northcott 2006, Abdel-Kader and Dugdale 1998, Pike 1996) seem to suggest that the same set of financial indicators is used for strategic and non-strategic investments. If

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additional ‘strategic’ evaluation elements are taken into consideration, this is often limited to a kind of non-quantitative ‘gut-feeling’. In the end however traditional financial criteria will have the greatest weight.

The situation is not improving: whereas in the past some have pleaded to give strategic projects the advantage of a kind of ‘strategic discount’ (a lower discount rate to make up for the strategic benefits) there is evidence that in practice strategic projects (typically with a long time span, a high level of risk and uncertainty, and slow payback) are consistently ‘punished’ with a higher discount rate (Alkaraan and Northcott 2006), not taking into account risk variation during the project (Accola 1994). Boyle and Guthrie (2006) find evidence that slow-payback projects face a higher hurdle rate than fast-payback projects. The widely used practice of a risk-adjusted discount rate can be very problematic for strategic projects.

Alternative strategic tools such as value chain analysis, benchmarking, technology road mapping, the balanced score card and equivalents, have all been suggested as potential tools of analysis to compensate for the apparent lack of strategic appeal of the conventional tools and to integrate financial and non-financial evaluation criteria. In the surveys, the active use of all of these tools, with the possible exception of benchmarking, is disappointing.

Even extensions of the conventional NPV-method, e.g. real options, decision tree analysis or Bayesian approaches are not widely used. It is striking that one of the theoretically most promising analysis tools for strategic investments, the ‘real options’ framework, has the smallest perceived importance score in a UK survey of capital investment decision-making of large manufacturing companies (Alkaraan and Northcott 2006). In that survey only 3.6% of the respondents indicated that the real options approach was important for their company, even worse, no one thought it to be very important, 56.6% believed it to be not important at all… The forecast of Copeland and Antikarov (2001) that real options would dominate the capital budgeting process within this decade seems to be completely unrealistic. Other surveys (Ryan and Ryan 2002, MacDougal and Pike 2003, Block 2007, Burns and Walker 2009) also find a very low use of real options. Block (2007) surveyed US Fortune 1000 companies: only 40 of the 279 respondents (14.3%) used real options, of which only 18 (6.5%) indicated a major utilization. This is in line with Ryan and Ryan (2002) who reported a utilization rate of 11.4% and confirms recent evidence that the valuation technique may be losing traction as earlier surveys reported higher usage figures. The often cited 1999 survey of Graham and Harvey (2001) reported that 27% of the 392 responding CFOs of Fortune 500 companies

(9% response, multiple CFOs per company) said they “always or almost always incorporate the ‘real options’ of a project when evaluating it”. Promoters of the real options framework argue that the low figures could be the result of differing interpretations of the term real options (Triantis 2005) and that the figures underestimate the extent to which managers take real options into account regardless of whether they use formal option pricing models (McDonald 2006). The low adoption rate is even more troubling because the usage of the real options framework seems to be concentrated in a limited number of high tech, innovation-intensive or utilities industries. Out of the 40 users in the Block-survey (2007), 34 came from the following industries: technology (13), energy (11), other utilities (6) and health care (4). Though the real options framework is particularly suited for new ventures with a high level of uncertainty and risk, it should not be limited to those situations. Every organization has to decide on strategic investment projects and can benefit from the use of the real options framework. So what is stopping them from doing so? Surely not a lack of models or successful cases. Since the term “real options” was introduced in 1977 (Myers 1977), it was first picked up by an enthusiastic but relatively small community of academics, but in the mid-1990’s it attracted a broad range of professionals which gave rise to an impressive multitude of models, methodologies and applications, first in the oil and gas industries, then extending to other industries (Borison 2005). The real options framework quickly found its way to the curriculum of management education, often as a special topic, perhaps too special. The topic received a lot of attention – in popular management publications – and can be considered as a mature, mainstream field of interest for both academics and professionals with a steady stream of journal papers, textbooks and large conferences. So the lack of adoption is due to other causes.

It has been suggested by Busby and Pitts (1997) that few practitioners understand the use of the real options approach. For many managers and board members, the real options framework lacks transparency and is overloaded with seemingly complex mathematics. The analogy between financial options and corporate investments that create future opportunities is appealing, but as Luehrman (1998, p. 51) states, “for many nonfinance managers the journey from insight to actions, from puts and calls of financial options to actual investment decisions, is difficult and deeply frustrating”. The financial crisis of 2008 and the traumatic valuation problems of financial derivatives have strengthened the scepticism of senior management and board members who have the feeling they have to decide on the basis of models they do not fully understand.

So the heart of the problem is that senior management and board members have to be persuaded that the real options approach is the right frame of analysis for strategic investment projects, without losing them in a technical discussion.

Once heralded as "the real options revolution in decision making" (P. Coy in a 1999 article in "Business Week") and backed up by a staggering number of research papers and methodologies, the real options approach still has to find its way to the boardroom of many companies. Financial options (in the financial markets) are widely accepted, but real options, built on the same foundations, are still considered to be "kind of weird".

Basically though, real options are a very simple and attractive concept. An option gives the holder the right to do something, without the obligation to do it. Usually, the option holder has to pay an amount of money to obtain the option: the option premium. An option framework of decision making is based on the opportunity to make a decision after one sees how events unfold. If things turn out to be unfavourable, the option right is not exercised and the option holder limits his loss to the amount of the premium.

Companies benefit by keeping their options open. For example, if a company wants to exploit a new technology with the aim to bring new products to the market within 3 years, it has to invest in research and development (do research, acquire patents) now. It is possible that the new technology does not live up to the expectations, or that after one year an emerging technology proves to be superior, or that after two years it becomes clear that there is no viable market for the new products. In those cases research will be stopped and the new products will not be introduced, and of course no further investment is needed in development, production or marketing facilities. In those cases the R&D efforts are useless for the company, although perhaps they can be sold to another company. So investing today in R&D yields the option (not the obligation) to bring new products to the market (requiring additional investments in development, manufacturing and marketing) and the option (not the obligation) to sell the R&D results. This strategic flexibility should be accounted for by the method of analysis, and real options are the easiest way to do this. Park and Herath (2000) state that "any corporate decision to invest or divest real assets is simply an option". Apart from the direct contribution a project makes to the firm's value (the conventional NPV), it also has a strategic value: e.g. the opportunity to grow or to adapt to changes in the environment. A conventional NPV-method inadequately captures the operating and strategic flexibility. It is very unlikely that a strategic project will ever be implemented on exactly the original scale and timing. For large projects it is only natural to expect all kinds of adjustments during the implementation, taking into account the best information available at that moment of time. Flexibility is a fact of life. Sometimes investment projects should be undertaken just to keep the option open to decide later on the eventual project. A static NPV-calculation that does not take into account this flexibility may be grossly misleading. Even a rather simple investment in a production facility often has the added value of a growth option: implementing this project makes it possible to expand it later. But even growth itself (without taking into account later expansion) can be a strategic aim of the company, and thus have a distinct value. Growth potential is not accounted for in the conventional NPV-calculation. Most investment projects contain options. The well-known McKinsey Copeland (2001) 7 S-framework illustrates the wealth of real options: grow (scale-up, switch-up, scope-up), defer (study), disinvest (scale-down, switch-down, scope-down).

As strategic investment projects have a direct impact upon shareholder value and the creation of sustainable competitive advantage, they are typically closely scrutinized by the board of directors, requiring management to present a clear business case on the basis of sound, transparent criteria. Opaque mathematical models are not convincing at all, while the existence of a multitude of specialized real option models is further adding to the uncertainty of board members. That is where educational and management concerns meet.

The purpose of this paper is not to develop a new real option model or to present the results of a survey of models actually used, but to help to demonstrate in a generic way the advantages of the real options framework. Real options can contribute in a substantial way to understand the strategic value of an investment project and to value and exploit inherent flexibility, if necessary taking into account competitive reactions. The purpose is to show in plain words that the real options approach has superior value to analyze strategic projects and that depending on the kind of situation the conversation with senior management and the board can be based on simple logic instead of complex mathematics. The real options approach explicitly incorporates the value of project flexibility, which is a basic attribute of the overwhelming majority of strategic projects, takes into account platform characteristics, where later projects are conditional on the success of previous projects (compound options) and can be used to restructure the investment project. So real options are not only useful to compute the value of flexibility (the calculation of the option premium) but at least as important is the fact that options thinking helps to reorganize investment projects in such a way that the best use is made of information that it is expected to be available later, and if needed, to reshuffle activities. Traditional capital budgeting is a static model (Dixit and Pindyck 1995). It assumes rather passive management, inflexibility and unavailability of new information in the course of the project. The NPV determines the initial decision to fund the project. If the situation changes before the project is actually implemented, the decision can be reversed, but during the project no changes are considered, managers do not react to new or better information. Uncertainty is handled by adjustments to the discount rate. More uncertainty leads to a higher discount rate, so the promoters of the project are inclined to mask or underestimate uncertainty. Thinking of investments as options helps to alter the investment decision in drastic ways. Options thinking may result in investment projects with a conventional negative NPV being approved and recognition of uncertainty as an opportunity to create value. Real options thinking requires a dynamic investment model where results are closely monitored and used to adapt the project. This matches the needs of senior management and the board for strategic investment projects: they will be better able to set up a conversation with operational management to steer the projects instead of taking one-time decisions with a high level of risk. The real options framework matches the requirements of an active board of directors and enhanced governance.

2. FOUR PROBLEMATIC INVESTMENT PROJECTS

To illustrate the importance of flexibility, consider the following four projects that will be rejected on the basis of a conventional NPV-calculation, but can, as will be shown in the latter part of this paper, be positively evaluated by means of the real options approach. The four situations are chosen in such a way that the amount of technicality of the real options model used is increasing. For the first illustration, simple logic is sufficient. This kind of a situation would be a very good introduction to the use of real options for a company whose board has never before used the concept. Management should be able to persuade the board that the line of reasoning is sound and should stress flexibility, active reshuffling of activities and close monitoring. Introducing real options this way takes away the fear that the board has to decide on the basis of esoteric mathematical models and should make clear that the main benefit of the use of real options is not an evaluation technique to account for flexibility but a concept to exploit flexibility (Kim and Sanders 2002; Fichman et al. 2005). It also yields the opportunity to have a critical look at the risk-adjusted required rate of return. It shows that the real options framework is not replacing but enhancing the conventional NPV-computation: it relies on the same financial drivers as the well-understood NPV-model and remains consistent with business judgment (Amram et al. 2006).

The second example requires the use of a binomial tree, which again can be explained rather easily without much technicality. It can be used to show that strategic investment projects of the type 'very small likelihood of a very big reward' do not mean that the company is turned into a casino. It also offers the opportunity to introduce the board to real option games, if they are ready for it.

The third example naturally resorts to the use of the Black-Scholes model. Again, the underlying logic is stressed and the message is that uncertainty can be a source of strategic advantage instead of a looming disaster.

The last example illustrates the use of a more tailored real options model, the Margrabe formula.

2.1. Example 1: R&D investment at the Clever Company

A technological research company Clever is doing independent research with the aim to sell the research results to other companies. It has plans for a project to develop a radical new technology. The cash outflow is budgeted to €2,000 now (year 0) and €22,000 for the next year (year 1). The cash inflow is budgeted to €40,000 during the second year, provided the project can be sold to an interested manufacturing company, or €2,000, if the project results have to be sold to a research broker. At the start of the project (now), the Clever management estimate of the subjective probability that an interested manufacturing company will show up is 40%. After the first phase of the research though (start of year 1), it is expected that the main technological hurdles will have been overcome or that it will have become clear whether the technology is infeasible. It is also expected that at the start of year 1, when the technological uncertainty is resolved, it will be clear whether a definitive contract with a manufacturing company can be signed. Assume the risk-adjusted required rate of return for this class of investment projects for this company to be 25%, while the risk-free rate of interest for this company is 10%.

A conventional $NPV_{25\%}$ computation for the project as a whole yields: $-€2{,}000 - €22{,}000/1.25 + (0.4 \cdot €40{,}000 + 0.6 \cdot €2{,}000)/1.25^2 = -€\,8{,}592$. So the project is rejected as only projects with a positive NPV will be accepted. The verdict seems to be very clear.

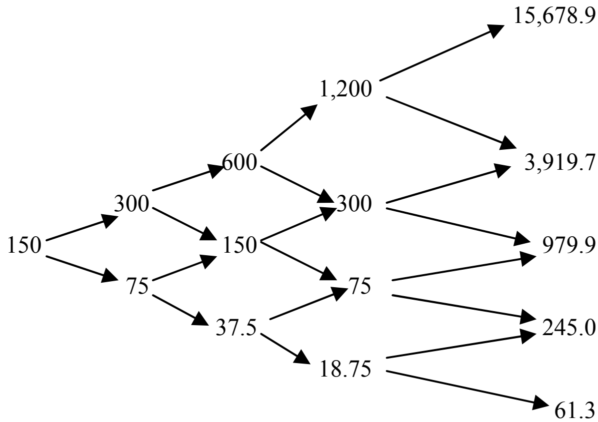
But the reader will have noticed that this calculation does not take into account some specific characteristics of this decision situation: at the start of year 1, the initial uncertainty about the ability to sell the results to a manufacturing company is expected to be resolved. If management flexibility is taken into account, a more favourable evaluation results, as will be shown later.

2.2. Example 2: a chain of strategic investments at the Bright Company

The Bright Company, a large industrial company, is considering substantial investments in new generation LED light technology. In the past, the Bright Company has already spent €50 million on research and development (R&D) for LED. If the Bright Company would have been able to bring the product to the market now, this would have had a hypothetical value of €150 million. Hypothetical, as the Bright Company does not yet possess the necessary manufacturing and marketing facilities. If the product is a success, the market is expected to grow rapidly (100% growth, for LED-1 to €300 million); in the other case it will decline with 50% (for LED-1 to €75 million). The subjective rate of success is estimated by management to be 1/3. Further assume the first generation will last for only one year, as the technology is expected to evolve rapidly, so you can ignore cash inflows of later years for that generation. The first generation will be succeeded by a second and third generation (each with a lifetime of one year) and a final fourth generation product (lifetime 3 years). The cash flows of the final generation will always show a 100% growth per year. The Bright Company's management estimates that it will take about €100 million to invest in manufacturing facilities and marketing for the first generation product and that this amount will be doubled for each generation. The Bright Company is mainly interested in the long range effect of the LED product. If it is decided to manufacture the first generation product, it will automatically imply that a further investment in R&D for the next LED-generation is approved. It is expected that the cash outflow for R&D for the next generation is twice the amount invested for the previous generation.

This first generation product is thus expected to yield a net cash inflow of €300 million during the first year (if the product is a success) or €75 million (if the product is a failure) and requires an investment of €200 million (€100 million for manufacturing and marketing facilities, €100 for R&D for the new LED-generation). The following figure contains all the cash flows for the project.

Binomial lattice budgeted cash inflows



Budgeted investment amounts (cash outflows)

	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4*
R&D	50	100	200	400	800	
mfg/mkt		100	200	400	800	
Total	50	200	400	800	1,600	

* Year 4 value = discounted value future cash inflows (explained below)

Figure 1. Binomial lattice for the Bright Company

Source: authors' own

To explain the year 4 value, let us have a look at the first situation (straight success). The cash inflow of year 3 will grow to €2,400 in year 4, €4,800 in year 5 and €9,600 in year 6. To compute the year 4 equivalent, these cash flows are discounted. Assume the risk-free interest rate is 5%, as risk is accounted for in an alternative way.

$$€2{,}400 + \frac{€4{,}800}{1.05} + \frac{€9{,}600}{(1.05)^2} = €15{,}678.9$$

For the second case, the year 4 present value is calculated as:

$$€600 + \frac{€1{,}200}{1.05} + \frac{€2{,}400}{(1.05)^2} = €3{,}919.7$$

For the other year 4 situations:

$$€150 + \frac{€300}{1.05} + \frac{€600}{(1.05)^2} = €979.9$$

$$€37.5 + \frac{€75}{1.05} + \frac{€150}{(1.05)^2} = €245.0$$

$$€9.375 + \frac{€18.75}{1.05} + \frac{€37.5}{(1.05)^2} = €61.2$$

Assume both decisions (R&D, manufacturing/marketing) are always linked. If the company decides to stop research, it will not introduce the current generation product and if the current generation is not introduced, research for future generations will be stopped. The decision to stop is irrevocable. Once the company has quit the market (or the research) no return is possible. Assume there is no alternative use of the research results or of the investments in marketing and manufacturing facilities. The risk-free rate of interest is 5%; the risk-adjusted rate of discount for this class of investments for the Bright Company is 25%.

Let us analyze the decision to be taken in year 0. As explained above the Bright Company has to invest in R&D for the next LED generation (twice the amount of the previous generation, so 2 times €50 million) plus in marketing and manufacturing facilities to bring the present generation product to the market (twice the amount spent on research, so twice €50 million). This total investment of €200 million is expected to yield a cash inflow in year 1 of €75 million if the product is a failure (half of the market value of the older generation product) or €300 million if the new generation is a success (twice the market value of the older generation product, success rate 1/3): $\left((1/3)\cdot €300 + (2/3)\cdot €75\right) = €150$. So, to summarize, Bright Company's management has to decide whether it is advisable to invest €200 million now in order to earn an inflow of €150 million in year 1 and the opportunity to participate in future LED developments. It is obvious that if the option value is ignored, the LED-1 decision is negative: why spend €200 million to earn €150 million? Taking into account the risk-adjusted rate of return of 25%, the NPV of the LED-1 decision is very disappointing: $NPV = ((1/3) \cdot €300/1.25 + (2/3) \cdot €75/1.25) - €200 = -€80$.

Now one could argue that this negative NPV is the price the Bright has to pay to stay involved in a potentially very attractive market. Looking at the figures for year 4, the management of the Bright Company is in a state of delirium: a cash inflow equivalent of a staggering €15,678.9 million is waiting to be collected. This is clearly much more than the sum of all the required investments (200+400+800+1,600). The probability of this opportunity is however rather small. Every successive generation has to be a market success, so the probability is: $(1/3)^4$ = 1.2346%. But anyhow, if this optimistic scenario materializes, the return is high, and the option to be active in that market must have a positive value.

The second situation (3 successes and one failure) is much less attractive, with a market value in year 4 of €3,919.7. The probability of this outcome is, taking into account the binomial distribution nature of the problem, $4p^3q$, with p = success rate and q = failure rate: $4 \cdot (1/3)^3 \cdot 2/3$ = 9.8765%. The three remaining situations yield a negative return. So this looks like a project with a very small probability of a huge success, a small probability of a marginal success and an overwhelming probability of a complete failure. Bright Company's management decides to have a closer look at the expected cash flows.

Further inspection of the cash flows indicates that the expected value of the net cash flow per year is always €150 million for any generation. This is due to the particular characteristics of this project: double if it is a success, half if it is a failure, with a 2/3 probability of failure.

To illustrate, in year 4, on the basis of the binomial lattice, the expected cash flow of that year alone can be computed as follows:

Cash flow	Probability		Cash flow · probability
2,400	p^4	0.012346	29.63
600	$4p^3q$	0.098765	59.26
150	$6p^2q^2$	0.296296	44.44
37.5	$4pq^3$	0.395062	14.81
9.375	q^4	0.197531	1.85
		1.000000	150

Figure 2. Cash flow computation for the Bright Company
Source: authors' own

This means that future generations are even more unattractive than the first generation, as the required investments are twice the previous generation investment, while the expected cash inflow is a constant. A NPV computation for each LED-generation yields :

LED-1: $NPV_{25\%}$ = €150 million/1.25 -€200 million = -€80 million.

LED-2: $NPV_{25\%}$ = €150 million/1.25^2 -€400 million/1.25 = -€224 million.

LED-3: $NPV_{25\%}$ = €150 million/1.25^3 -€800 million/1.25^2 = -€435.2 million.

LED-4: $NPV_{25\%}$ = €150 million/1.25^4 + €300 million/1.25^5 + €600 million/1.25^6 -€1.600 million/1.25^3 = -€502.2 million.

This looks really bad. Why invest in a project that does not show any positive NPV perspective at all? The investment in LED-1 (negative NPV) yields an option to participate in a next stage that is even more negative, and so on. So why bother to compute the value of this option?

Once more, a conventional NPV calculation based on the mathematical expectation is ignoring the inherent flexibility. Using the multiperiod binomial option model, it is easy to show that the option to stay involved in the LED-market has a positive value, as will be computed later.

2.3. Example 3: exploiting uncertainty at the Cutter Company

The Cutter Company has the opportunity to buy an option to exploit a large European forest area. It is assumed that the Cutter Company is allowed to cut a fixed volume of 10,000 m^3 first class timber per year. The option yields Cutter the right, starting one year from now, to cut the trees, for a period of one year. It is known to the management of the Cutter Company that the current exploitation by a competing company is a financial disaster. The current price of this timber is €1,325 per m^3; the variable exploitation cost €1,350 per m^3. Assume there are no fixed costs, except for the purchase of the exploitation right and that all costs are cash costs. The Cutter Company does not possess a unique management quality enabling the company to reduce the exploitation cost, nor can Cutter have any influence on the future sales price of the timber. So it is expected that the future exploitation cost and the future average timber price will be the same as the present ones. To simplify things, assume that the Cutter Company's management has to decide (and pay) now (time 0) to buy the exploitation right, and that the decision to exploit will be taken at the end of the first year when a definitive contract can be signed for delivery (and payment) of the timber at the end of the second year. Cutter's required minimum rate of return is 10%. How much can the Cutter Company afford to pay for the right to exploit the area?

At first sight, this seems to be a clear case: who would be willing to pay anything for the opportunity to surely lose money? No NPV calculation is needed as it will certainly result in a negative value.

But the Cutter Company's management decides to look into the matter a bit deeper. Cutter observes that the timber price is heavily influenced by the weather conditions in Asia. If storms of moderate power hit the major production areas, the supply of timber is high, and the price is low. This is the pessimistic outcome. If the storms are really heavy, the supply of good quality timber will be low (due to the destruction of the timber and the difficulties to exploit the area) and the price will be high. This is the optimistic outcome. The forest region that the Cutter Company is considering to exploit is located in a very calm region that is never hit by storms.

Cutter computes two different scenarios for the weather in Asia. The first scenario is for a situation of limited changes in weather conditions with a small number of storms (low frequency). The timber price per m^3 will be €1,300 (only a few moderate storms not destroying the quality) or €1,350 (only a few heavy destructive storms). The second scenario is for a situation with drastic changes in weather conditions with a high number of storms (high frequency). The timber price per m^3 will be €700 (many moderate storms not destroying the quality and a big supply of timber) or €1,950 (many heavy destructive storms and a small supply of timber).

	Scenario of limited change weather conditions with low frequency storms	Scenario of drastic change weather conditions with high frequency storms
Moderate power storms (pessimistic)	€1,300	€700
Heavy power storms (optimistic)	€1,350	€1,950

Figure 3. Scenarios for the Cutter Company

Source: authors' own

As it is impossible to predict the weather conditions one year from now, it is fair to assume that the probability of moderate storms (pessimistic outcome) is equal to the probability of heavy storms (optimistic outcome), and that the probability of the limited change scenario is equal to the probability of the drastic change scenario.

The mathematical expectation of the timber price is the same for both scenarios, and this is of course the same as the current price, matching our initial assumption. For the first scenario: 0.5·€1,300 + 0.5·€1,350 = €1,325 per m^3; for the second scenario 0.5·€700 + 0.5·€1,950 = €1,325 per m^3. If the variable exploitation cost amounts to €1,350 per m^3 this means an expected loss of €25 per m^3, so for 10.000 m^3 a loss of €250,000 plus the amount that has to be paid for the option. So in every case the same negative result. Again, it is not necessary to compute the NPV, as it surely is negative. The two scenarios are very different if risk is taken into account. The spread for the drastic change scenario is much bigger than for the limited change scenario, further adding to the perceived risk of this project. In general, projects with a smaller coefficient of variation are considered more attractive (less risky) then projects with a larger variation. To illustrate this, assume the price range (minimum-maximum) for each scenario coincides with -1 σ and +1 σ.

The coefficient of variation for the first scenario is:

$$\sigma^2 = \frac{1,300^2 + 1,350^2}{2} - (1,325)^2 = 625$$

$$\sigma = 25$$

$$\text{coefficient of variation } = \frac{\sigma}{\mu} = \frac{25}{1,325} = 1.89\%$$

For the second scenario:

$$\sigma^2 = \frac{700^2 + 1,950^2}{2} - (1,325)^2 = 390,625$$

$$\sigma = 625$$

$$\text{coefficient of variation} = \frac{\sigma}{\mu} = \frac{625}{1,325} = 47.17\%$$

Once more, the careful reader will have noticed that the calculations did not take into account the inherent flexibility in this decision situation. The exploitation contract will be signed (and the price is determined) at the end of the first year. If the exploitation decision can be postponed until that moment, the company will only decide to exploit if the price is high enough, in the other case the company will not exercise its exploitation right. In this situation it is clear that only in the heavy storms situation for the drastic change scenario the timber price exceeds the variable exploitation cost. So it is possible that this exploitation option has a positive value, as will be calculated later on. It is thus clear that the scenario with a small coefficient of variation is not interesting at all, while the second scenario may offer a real opportunity: risk is potentially positively related to value.

2.4. Example 4: multiple levels of uncertainty for gas storages at the ElecCo

Utility companies provide electricity and gas services to their industrial clients as well as to the households. Part of the electricity production is done through gas-technology, making the utility company also a natural consumer of gas. Typically, the consumption pattern is very seasonal with more demand for gas during the winter months and less during the summer months. This leads to a corresponding price pattern for gas.

In order to optimize this consumption service, a utility company can decide to buy or build a seasonal gas storage. This is typically a huge underground gas reservoir, connected to the gas grid. During the summer months, when the prices are low, gas is pumped inside the cavity and in the winter, when the demand is high, the gas is pumped out again and used for satisfying the consumption.

Such a gas storage is a real option and the valuation should be done taking into account this optionality. The valuation of gas storage is a highly complex mathematical problem that has received some attention in the literature. The biggest complexity lies in the daily operation of the gas storage. Typically the physical constraints of the gas storage are such that the filling of the gas reservoir can be done in less than 6 months. This allows further optimization of the storage in the sense that instead of using a steady flow to pump gas into the reservoir, one has further flexibility to fine-tune and select periods when gas prices are the lowest.

In the example we consider here, we will not focus on this higher level of complexity and rather consider the case where the valuation of the gas storage only depends on the price difference between the summer and the winter contracts.

The gas market is organized in such a way that forward prices for summer and winter volumes are available to buy and sell. Let us denote the forward price for the summer as F_{sum}, which is the price that has to be paid after the delivery of the gas in the summer. In practice, the payments are settled on a monthly basis, but for this example, we will assume they are settled at the end of the summer, or after the injection period. Similarly, the winter price is denoted as F_{win}.

Suppose the forward price for the summer is €15 per MWh and the forward price for the winter is €20 per MWh.

Assume the total volume in the reservoir is 1,000,000 MWh, which is filled during the summer at a constant rate and emptied during the winter, again at a constant rate. If the utility company would buy and sell forward the entire volumes of gas at the above prices, the price difference would be locked at €5 per MWh, leading to a valuation of €5 million for the storage. Suppose this result does not meet the conventional NPV-requirements of the company.

3. COMMUNICATING ABOUT THE REAL OPTIONS FRAMEWORK FOR THE FOUR INVESTMENT PROJECTS

Sometimes the real options framework can be explained by means of simple decision analysis (e.g. decision trees), in many cases though it will be more appropriate to use specific option value models to compute the value of the option, e.g. the multiperiod binomial model, the Black-Scholes formula, the Margrabe model. It may be interesting to start the communication with senior management and the board of directors with non-technical applications, purely based on a line of logical reasoning, and gradually building up the model expertise.

3.1. Level 1: decision analysis and the Clever Company

A simple decision analysis combined with options thinking, about how a project can be improved by taking into account the fact that later on more information will be available to take the right decision, can in many cases yield interesting results, without the need to use sophisticated models. To illustrate this, let us analyze the example of the Clever Company**.**

Taking into account flexibility, using a simple decision tree, the static analysis fallacy should be clear. The outlay expected for year 1 will occur only if an interested company is willing to sign a contract at the start of that year for €40,000; in the other case the project will be abandoned. It would indeed be nonsensical to spend €22,000 to earn €2,000.

Revised flexible NPV-calculation: $-€2{,}000 - 0.4 \cdot €22{,}000/1.25 + (0.4 \cdot €40{,}000)/1.25^2 = €1{,}200$, so the project can be approved. This calculation can be interpreted in an alternative way. The outlay of €2,000 in year 0 is a kind of an option premium: the outlay yields the opportunity to continue the project if an interested party is found, without the obligation to continue. When no interested party is found, the research company loses €2,000 (the premium). If the interested party is found, the project is continued. This yields an NPV of €8,000 (not taking into account the option premium), with a probability of 40% the mathematical expectation is €3,200, and so after subtracting the option premium, this is the revised NPV of €1,200. Breaking up the project examination into stages makes it clear that it makes sense to fund the first stage of the project (€2,000) and to postpone the decision for the second stage to the end of the first year. But this is only a partial view of the usefulness of real options.

The use of real options stimulates creative options thinking to reduce project risk and to optimize the result. On the one hand, one should try to minimize the amounts spent up front and postpone as much as possible to the later stages of the project as this will reduce the amount of the 'option premium'. On the other hand, one should try to implement the most risky activities up front, unless the technological evolution is such that a delay will reduce the risk (Kumar 2002). Sometimes it will be better to delay the whole project, or to delay a part of the project, until the uncertainty is resolved. Let us apply this to the Clever Company. Suppose the Clever Company could reshuffle some of its research efforts. Assume that the original first stage (spending €2,000) includes some research efforts (spending €500) that are necessary but do not contribute to resolving the uncertainty issue. These research efforts can be postponed to the second stage, thus reducing the amount of the premium that will be lost if the decision after one year is a no-go.

It should also be noted that the standard static NPV-calculation will be based on a risk-adjusted rate of discount (here 25%), whereas the flexible NPV-calculation should be based on a risk-free rate of discount (which is much lower, here assumed to be 10%) as the specific risk is accounted for by the opportunity to stop the project. This further improves the NPV of the project. The revised flexible NPV-calculation, with the lower cost of capital and the reorganized project: $-€1{,}500 - 0.4 \cdot €22{,}500/1.1 + (0.4 \cdot €40{,}000)/1.1^2 = € 3{,}541.32$ looks quite good.

Management should be able to persuade the board that the flexible calculation is sound and that the board will be able to monitor the investment. In this way, the board will get accustomed to the idea of real options thinking, the use of a lower required rate of return and dynamic investment monitoring.

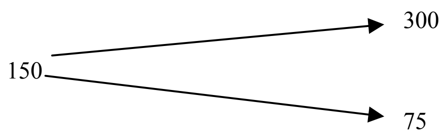
3.2. Level 2: the multiperiod binomial model and the Bright Company

Some decision situations for real options are easy to model using the binomial approach (Copeland and Tufano 2004). As explained earlier, the Bright Company's LED-project has the characteristics of a multi-period binomial distribution. The heart of the binomial valuation model is the computation of the risk-neutral probability *p**. The binomial option valuation formula has an interpretation as a discounted expected value, with the risk-neutral probability *p** used to compute the expected payoff and the risk-free interest rate used to discount the expected payoff. This is known as risk-neutral valuation. In this hypothetical risk-neutral world, where the return is expected to earn the risk-free interest rate, we can solve for the probability *p**:

Expected return = *p** · high return + (1- *p**) · low return
Expected return = initial return · (1+*r*)

Management needs to emphasize that at no point is it assuming that investors are risk-neutral. The valuation calculations are consistent with investors being risk-averse (see e.g. McDonald 2003 or Hull 2000).

Let us return to the example and compute the risk-neutral probability p*, using the risk-free interest rate of 5%. As the structure is identical in every node, this can be calculated at any arbitrary node, e.g.



$$150 \cdot (1+0.05) = p^* \cdot 300 + (1-p^*) \cdot 75$$
$$p^* = 0.366666666$$

Now we work backward through the tree to compute the value of the option. If in a particular node the expected cash flow value is insufficient to cover for the investment required to earn the cash flow, the value at that node is set to zero. This yields the following results (based on the market value in year 4 calculated above).

<u>Computations year 3:</u>

$$\frac{p^*\cdot(€15{,}678.9)+(1-p^*)\cdot(€3{,}919.7)}{1.05}+€1{,}200-€1{,}600=€7{,}439.5$$

$$\frac{p^*\cdot(€3{,}919.7)+(1-p^*)\cdot(€979.9)}{1.05}+€300-€1{,}600=€659.9$$

$$\frac{p^*\cdot(€979.9)+(1-p^*)\cdot(€245.0)}{1.05}+€75-€1{,}600<0 \quad \textit{yields} \quad 0$$

$$\frac{p^*\cdot(€245.0)+(1-p^*)\cdot(€61.2)}{1.05}+€18.75-€1{,}600<0 \quad \textit{yields} \quad 0$$

<u>Computations year 2:</u>

$$\frac{p^*\cdot(€7{,}439.5)+(1-p^*)\cdot(€659.9)}{1.05}+€600-€800=€2{,}795.9$$

$$\frac{p^*\cdot(€659.9)+(1-p^*)\cdot 0}{1.05}+€150-€800<0 \quad \textit{yields} \quad 0$$

$$\frac{p^*\cdot 0+(1-p^*)\cdot 0}{1.05}+€37.5-€800<0 \quad \textit{yields}\ 0$$

<u>Computations year 1:</u>

$$\frac{p^*\cdot(€2{,}795.9)+(1-p^*)\cdot 0}{1.05}+€300-€400=€876.4$$

$$\frac{p^*\cdot 0+(1-p^*)\cdot 0}{1.05}+€75-€400<0 \quad \textit{yields} \quad 0$$

So the value in year 0 yields:

$$\frac{p^*\cdot(€876.4)+(1-p^*)\cdot 0}{1.05}+€150-€200=€256.0$$

The Bright Company could thus afford to pay €256 million for the option to be in the fourth generation LED business. The negative NPV of stage 1 (-€80 million) is a small amount compared to the value of the option, so it can be stated that the strategic NPV for stage 1 is positive. The same is true for the other stages. So the project can be positively advised.

Though the probability of continuing success is only 1.2346%, this is not a casino-kind of a gambling project. Again, management should be able to communicate this message to a board that has learned to deal with flexibility and replacing a risk-adjusted rate of return by a more appropriate measure of performance and feels empowered to closely scrutinize the development of such projects.

As shown by Smit and Trigeorgis (2009) and Ferreira et al. (2009), the binomial tree model can easily be combined with game theory to incorporate competitive reactions. Unlike financial options, real options are indeed not exclusive for individual firms and the results depend on the possible actions of competitors. The 'option games' approach is particularly useful for large strategic investments in a highly competitive environment (Huisman et al. 2005).

3.3. Level 3: the Black-Scholes model and the Cutter Company

As already explained, the low volatility case was always yielding bad results while the high volatility case yielded a high return if the lumber price turned out to be high. Options thinking helps to overcome the 'risk fallacy'. Financiel people are trained to equate higher risk to a higher required return and associate higher risk with higher volatility. The more volatility, the higher the risk and thus the higher the hurdle rate. But this is not always the case. Often, uncertainty can be exploited, as clearly is the case with an options framework.

The value of a European call option on a stock (no dividends, no transaction costs) can be calculated by the well-known Black-Scholes formula (based on the seminal paper of Black and Scholes 1973).

The value of the option C is a function of five variables, where

S = the current price of the underlying stock,

X = exercise price of the option,

t = time until expiration date (in years),

σ = annual volatility of the underlying stock price (as measured by the standard deviation of logarithmic stock returns),

r = annual risk-free interest rate.

$N(.)$ = cumulative normal probability density function. $N(a)$ is the probability that a value is less than a. The constant e = 2,71828…

$$C = SN(d_1) - Xe^{-rt}N(d_2)$$

$$d_1 = \frac{\ln\frac{S}{X} + (r + \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{\ln\frac{S}{X} + (r - \frac{\sigma^2}{2})t}{\sigma\sqrt{t}}$$

d_2 can also be expressed as :

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

In the formula, e^{-rt} is the present value of €1 continuously discounted at the risk-free interest rate r for t years. The following is a verbal description of the formula: the call option value equals the price of the underlying stock minus the present value of the exercise price, adjusted for the probability that when the option expires, the stock price will exceed the exercise price.

Similar formulas are available for an American call option (can be exercised at any point in time for the life of the option) and for call options on stocks that pay dividends during the option period. For an American call option with dividends, it is clear that if the option is left unexercised at the dividend date, the dividend is forfeited and the value of the option is reduced. This model can be applied to real investment projects to evaluate the best timing: if an investment project is postponed, the lost benefits (foregone cash flow from delaying the investment) can be seen as a dividend that is forfeited (Campbell 2002, Perlitz et al. 1999).

Let us apply the Black-Scholes formula to the timber example for the high volatility case. The price of timber now is €1,325 per m^3. If heavy storms reduce the supply, the price will be €1,950. We can consider the exploitation right as a call option on a stock with price €1,325 and a strike price of €1,350 (the exploitation cost; as soon as the price exceeds the exploitation cost there is a positive contribution). The strike period is one year, suppose the risk-free interest rate is 4%. We assume that the standard deviation of the timber price is 47% (as suggested earlier). Using the Black-Scholes formula yields the value of the option €257.79 per m^3. Therefore the maximum price of the exploitation right of 10,000 m^3 is €2,577,900.

Ln (S/X)	-0.01869213
$(r+\sigma^2/2)\ t$	0.15045
d1	0.280335887
d2	-0.18966411
N(d1)	0.610390028
N(d2)	0.424786186
SN(d1)	808.7667874
$Xe^{-rt}N(d2)$	550.9756105
C	257.7911769

Figure 4. The intermediate results of Black-Scholes for the Cutter Company

Source: authors' own

As Black-Scholes is a widely used model for the valuation of financial options, it is easy to persuade board members to rely on it once they have accepted the idea of real options. The applicability of the Black-Scholes model to real investments has proven to be successful in quite a number of different situations, e.g. for IT-investments (Benaroch and Kauffman 1999). Though it will remain a black box for many people, it can be explained in plain words. It will be more important to indicate how management can manage the option and how the board can monitor this process.

3.4. Level 4: the Margrabe formula and the gas storages at the ElecCo

Extending the original Black-Scholes model to take into account two sources of uncertainty has been done independently by Margrabe (1978) and Fischer (1978). In fact this is known in the literature as an 'exchange option' and the formula that gives the valuation is known as the Margrabe formula. Applied to the problem of a storage, the Margrabe formula gives the value of an exchange option that gives the owner the right but not the obligation to exchange one unit of summer gas with one unit of winter gas.

The formula that gives the price of such an option (EO) resembles the classical Black-Scholes formula a lot, but the difference in timing for the cash flows needs to be taken into account. Besides the volatilities of both the summer and the winter prices, a new parameter comes into play, the correlation between those. Denote ρ as the correlation coefficient between the logarithmic price returns. The function $N(.)$ in the formula below, is again the cumulative normal distribution function. The relevant expiration is when the filling of the reservoir starts.

$$EO = e^{-rt}(F_{win}e^{-r/2}N(d_1) - F_{sum}N(d_2))$$

$$d_1 = \frac{\ln\frac{F_{win}}{F_{sum}} - \frac{r}{2} + \frac{\sigma^2}{2}t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{\ln\frac{F_{win}}{F_{sum}} - \frac{r}{2} - \frac{\sigma^2}{2}t}{\sigma\sqrt{t}}$$

$$\sigma = \sqrt{\sigma_{win}^2 + \sigma_{sum}^2 - 2\rho\sigma_{win}\sigma_{sum}}$$

Remember we supposed the forward price for the summer to be €15 per MWh and the forward price for the winter to be €20 per MWh. We assume that the standard deviation or volatility of the summer prices is 40% and the volatility of the winter prices is 45%. The correlation between both prices is assumed to be 80%. This leads to a volatility of the spread between winter and summer of 27.29%. For the risk-free interest rate in this example, we take a fixed constant of 1%. There is uncertainty until the summer price starts to go into delivery, which is right before the summer. Suppose this time, measured in years is t=0.85.

$\ln(F_{win}/F_{sum})$	0.28768
$r/2+ t\sigma^2/2$	0.036662
d1	1.2491
d2	0.99752
N(d1)	0.8942
N(d2)	0.84074
$F_{win}e^{-r/2}N(d1)$	17.795
$F_{sum}N(d2)$	12.611
e^{-rt}	0.99154
EO	5.1397

Figure 5. The intermediate results of the Margrabe formula for the ElecCo
Source: authors' own

Putting together the components in the Margrabe formula, we will find that the storage has a higher value. Taking into account the total volume in the reservoir, 1,000,000 MWh, we get a valuation of this seasonal storage at €5,139,722. Disregarding this higher value would be misleading.

4. CONCLUSION

The uptake of the real options framework for strategic investment projects appears to be poor. Though there is wide acceptance of the shortcomings of a conventional NPV-calculation ignoring the inherent value of flexibility in most strategic projects and often also ignoring the existence of platform characteristics, real options still are 'too academic'. The challenge remains to develop comprehensive but easily understandable methodologies to explore the value of flexibility and to communicate the results in a clear way. In this paper an evolving approach for communication with senior management and the board of directors was proposed, starting at a non-technical logical level and gradually including more technical material.

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