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Real Options for PlayStation®

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Abstract.

In 1973, Black, Scholes and Merton published two path-breaking papers on rational pricing of financial options, the right, but not the obligation, to buy or sell a stock in the future at a given price. This new approach to the evaluation of financial projects vividly inspired the academic community: over eleven thousands papers have been published on Real Options so far. Yet, thirty-five years after the publication of the first paper, Real Options have penetrated the decision-making processes of large corporations very slowly.

Although the general concept of real options is clear, their specific benefits for individual investment decisions are not. Options are still an obscure mathematical tool and the partial differential equation at the core of the option pricing model leaves management with a blank face. The complexity of the stochastic calculus is preventing practitioners from seeing the new "decision space" created by Real Options and from moving inside this space at ease.

This paper reviews the entire development of Real Options research, taking a completely new direction inspired by the unique goal of achieving relevance in management's eyes. The graphical representation of the Ito's lemma, the partial differential equation central to the Black and Scholes pricing model, would help practitioners to visually capture the essence of Real Option thinking.

How different would the development of real Options have been if it had originally been designed as a videogame?

1. Real Options: a breakthrough idea

In 1973, Black, Scholes and Merton published two path-breaking papers on rational pricing of financial options, the right, but not the obligation, to buy or sell a stock in the future at a given price. Their intuition was essentially a logical consequence of the efficient market hypothesis, a fundamental principle of finance asserting that all information available to anyone anywhere is instantly reflected in the current stock price, as market participants instantly profit from new information. Thus successive price changes of a stock ought to be considered to be uncorrelated random variables, since they depend on information still unravelled. Although the directions of the motions were unpredictable, the "space" containing all most likely swings was uniquely determined by five boundary conditions: the current stock price, the future expected price, the extension of historical price changes, the time left to make the decision and the risk free rate.
The possibility to univocally determine the value of a financial option, found an immediate application in the evaluation of investment decisions, where the underlying asset was represented by a future project rather than equity.
The so called "Real Options" marked the beginning of a new renaissance in capital investment theory, as they put management back in the centre of the value creation process. Opposite to the "now or never" deterministic approach underpinning Discounted Cash Flow, Real Options valued the management ability to make opportunistic investment decisions in the future, when new information become available. The option to delay, to abandon or to expand an investment in the future became an integral component of its actual value.
This new approach to the evaluation of financial projects vividly inspired the academic community: over eleven thousands papers have been published on Real Options so far. In 1997, Scholes and Merton received the Nobel Prize for their contribution to the development of the option pricing theory.
Yet, thirty-five years after the publication of the first paper, Real Options have only penetrated the decision making processes of large corporations very slowly.

2. Why are Real Options still unpopular among business practitioners?

Although the general concept of real options is clear, their specific benefits for individual investment decisions are not. Options are still an obscure mathematical tool and the partial differential equation at the core of the option pricing model leaves management with a blank face. The complexity of the stochastic calculus is preventing practitioners from seeing the new "decision space" created by Real Options and to move inside this space at ease.
The development of the classical Black and Scholes equation probably did not help executives to make Real Options real. Academicians felt that the early attempts to apply real options to the business world had been too simplistic to reflect the complexity of actual investment decisions. Theoretical research took the direction of searching for more "realistic" statistical models, increasing the

complexity of calculus instead of focusing on management relevance. A number of sophisticated models were rapidly introduced, raging from Binomial Lattices to Exotic Options. Fundamentally, over the years Real Options never left the territory of fancy mathematics to move to the desk of management practitioners. The quest for statistical precision reached its paradox in 2002, when J. Mun[1] observed that at their limit, results obtained with the use of fancy binomial lattices tended to approach those derived from the Black and Scholes model. To prove that, the Author performed a 10,000 simulation test, making approximately 5 x 10^9 nodal calculations! This daunting task was equivalent to 299 Excel spreadsheets or 4.6 Gbytes of computer memory.
Probably the real paradox was to try and help managers to understand the intricacy of a difficult mathematical model by using even more obscure levels of calculus. If the original Black and Scholes equation has not been used so far because it is difficult to understand, what are the chances that management will ever use a Quasi-Monte Carlo American Binomial Lattice or a Discrete Up & In Barrier Option model?
Is the sophisticated calculus even relevant to Real Options based decisions? What is actually relevant to management in making an investment decision? How can Real Options become a relevant evaluation tool in the hands of business executives?

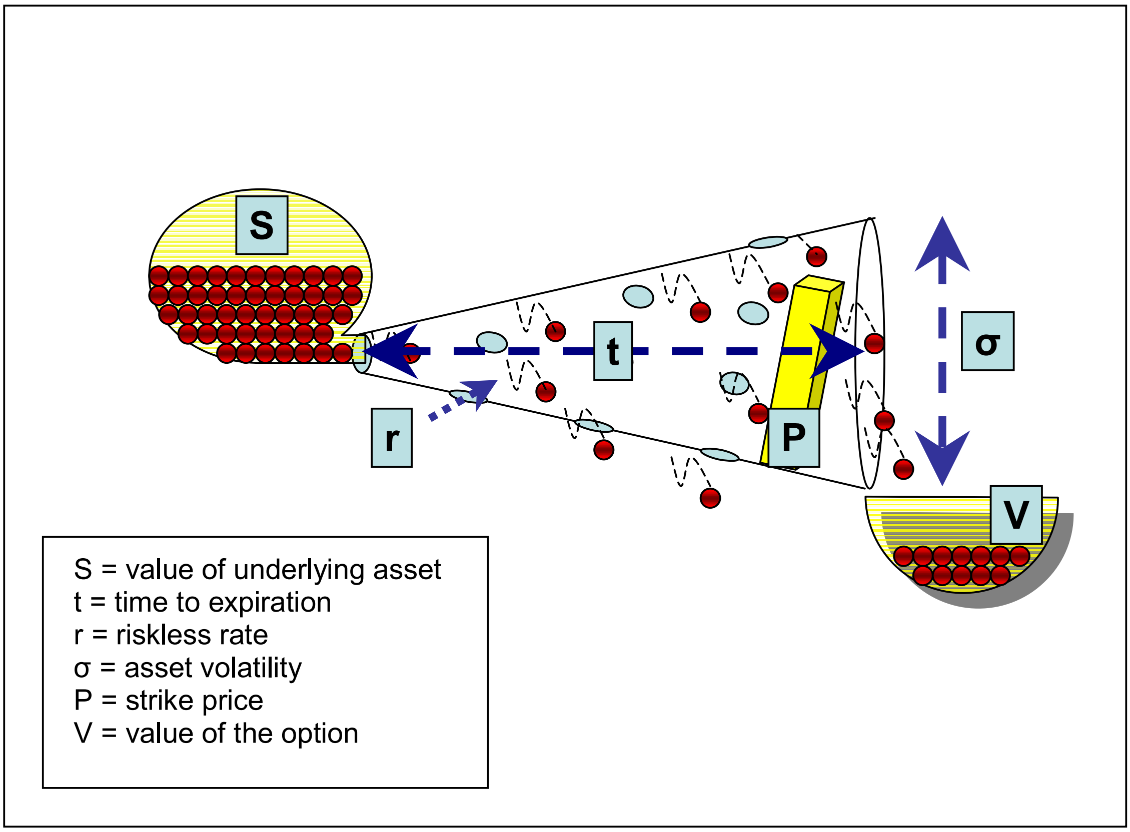
3. Thinking about Real Options as a videogame.

To answer these questions we should rethink the entire development of Real Options research, taking a completely new direction inspired by the unique goal of achieving relevance to the management's eyes.
Providing a graphical representation of the Ito's lemma, the partial differential equation central to the Black and Scholes pricing model, would possibly help practitioners to visually capture the essence of Real Option thinking.
What if Black and Scholes had invented a video game rather than a financial evaluation tool? The hypothesis is provocative but not without foundation. Actually at the beginning of the 70's, at the same time as Black, Scholes and Merton were applying the newly available computational capabilities to derivative pricing, software engineers were having some fun using basic programming language to create the first console games for television. The first tennis game, "Odyssey", was actually released in 1972, one year before the first Real Options publications.
How different would the development of real Options have been if it had originally been designed as a videogame?
First of all, Real Options would have been graphical.
The Authors imagined a simple dynamic visualization of the original Black and Scholes replicating portfolio, where the option value is arrived at as the result of a basic television game, not dissimilar from the first arcade games. The essence of Real Option thinking jumps out of the screen as an immediate visual experience,

[1] J.Mun, Real Options Analysis: Tools and Tecniques. Wiley, 2002.

maintaining intact the rigour of its logical and mathematical foundations. The actual graphical expression of Black and Scholes partial differential equation is protected by copyright and it will be a core component of the paper.

Figure 1: the Real Options videogame.



At first the basic videogame would have been received as an amazing innovation and a lot of fun by home games fanatics. For the first time this basic game would allow interaction with the television set, making the viewer an active player of the game, rather than a passive recipient of television programmes. This enthusiastic acceptance would have been no different from the original expectations originated by Real Option thinking. While cash flow discounting was substantially ignoring any active management influence on the value of an investment projection into the future, Real Options were valuing the possibility (option) to change direction at a later date. Rather than passively looking at the television, now management was able to be a player and to make its own game.
The original Black and Scholes game was simple, fairly intuitive and did not require specific skills: anybody who owned a television set could immediately play and have fun. But it never had the chance to become really popular. Keeping pace with the development of a new technology, the personal computer, it soon became boring and obsolete. The new generation of computer geeks

soon realized that the game was too simplistic to reflect reality: the new computational capability now available could run far more sophisticated “reality games”. A number of software releases were developed based on the original Black and Scholes simple game for video console: the new games were highly graphical, more exciting and with progressive levels of challenge. They also required complicated set up procedures, some level of programming skills and bigger and bigger computers. The new games were fascinating but difficult to play: every single computer key operated a different command and the set up was so exhausting it spoilt the fun of the amazing new graphics.
Videogames became the pass time of a restricted elite of computer nerds, who could spend the night figuring out the way to proceed to the next level of the game. Realism was obtained at the expense of simplicity: the average person did not even understand the gist of the new games and felt that they were simply too difficult to play and to have fun with.
The new level of complexity was not relevant to their entertainment needs.
Once again, the mechanistic development of Real Options pricing models did not differ at all from the development of computer games. Supported by increasingly larger computational capabilities, the academic community focused on high math to develop new generations of sophisticated Real Option pricing models. The attempt to capture the complexity of real investment decisions with mathematical calculus could be defined as the quest for the ultimate silver bullet. But instead of improving the quality of investment decisions, the high math trend of financial research probably scared management away. The new models are too complex to be fully understood by executives with a large diversity of cultural backgrounds: they do not have time to appreciate the nuances of sophisticated statistical scenarios. Common experience is that investment decisions spanning long time periods are influenced by many factors unknown at present, so managers are not overly concerned by false precision, but what they really need is a flexible valuation tool, easy to understand and which can be played with any time after the decision is made, when new information becomes available and the investment scenario consequently changes. Management did not have the possibility to fully understand and put into practice the initial Black and Scholes model: the chances that they will use more sophisticated models based on a concept which is still unclear are actually marginal. Real Options thinking should be developed with the aim of making its core concept accessible and relevant to everybody.

4. Real Options for PlayStation®: it’s awesome!

The same revolutionary direction illustrated by Sony in the development of videogames with the introduction of Playstation®: to transform computer games into home entertainment that everybody could enjoy. To achieve this breakthrough development of an existing technology, Sony redefined the concept of relevance in videogame programming, based on the perspective of the player. To really enjoy a game, players wanted amazing graphics, hassle free set up and simple commands enabling them to play and enjoy the game itself immediately.

To make this possible, Sony made the decision that all games for PlayStation® could be initially played using only four keys. All other commands and set up choices are grouped into pull-down menus, because they are not relevant to play the essential game, while they can still be useful in more advanced stages.
The success of PlayStation® was unprecedented: Sony sold over seventy million consoles to an incredibly diverse customer base, becoming a cult for players of all ages and the most diverse cultural and educational backgrounds.
The key to success was its redefined concept of relevance.
The Authors imagined what it would take to play the Black and Scholes videogame with the PlayStation®.
First of all, the PlayStation® version of the classic Black & Scholes game should be played using only the four main command keys. The Authors identified the four parameters most relevant to the determination of Real Option Value, among the possible choices: the selection of the most appropriate Real Option pricing model, the asset price, the strike price, market volatility, time to expiration and risk free rate. To choose the main four command keys, the authors needed to provide an answer to a series of questions:

- How much would the Option value change using a different pricing model?
- What is the Option Value sensitivity to each of the fundamental parameters common to all models?
- Are the chosen four main command keys sensitive enough to command the game?

To avoid selection biases, the Authors used a published investment decision business case, related to the pharmaceutical industry. A biotech company must decide whether to continue the development of a drug in late clinical stage of development. All the fundamental parameters for Real option evaluation are given. Which are the most relevant drivers of the development option?
Calculated with the classical Black and Scholes model, the resulting Option Value was $3.9 million. The key parameters were input into twelve different Real Option spreadsheets, including European, American, Lattices and Exotic models. The convergence of Option Values resulting from such a variety of calculus was surprising. The choice of the Real Option Model had a very limited impact on the Option Value. As the distribution of outcomes did not fundamentally violate normality, 95% of the time Option Values calculated with all thirteen models will fall into plus or minus two percent points from the mean value. The difference was statistically significant, but is it relevant from a management perspective?
To answer this fundamental question, the Authors proceeded to test the sensitivity to the main Real Option parameters in all thirteen models used to calculate the Option Value. The impact on Option Value of a one percent change in each main parameter calculated separately was compared to the Value calculated with the Black and Scholes model, considered a the base case.
All thirteen models behaved very consistently and the correlation between the paired outcomes of the sensitivity analysis for all models was significant. The outcomes grouped by each single pricing model were also normally distributed. The statistical robustness of the sensitivity analysis allowed comparison of the median impact of a one percent change in the main parameters on the resulting

Option Value. Changes in the expected asset value, strike price, market volatility and time to expiration determined a significantly greater impact on Option Value compared to the risk free rate and choice of the Real Option model.
Therefore, the four main command keys of the Real Option game for PlayStation® should be: Asset value, strike price, volatility and time to expiration. Both the choice of risk free rate and pricing model should go into a set up menu. The implications of the research outcomes for management will be discussed at length in the next session.
It is still important, though, to briefly point out the most relevant managerial take away of this entire research effort: the Option value is influenced by the case parameters much more than by the choice of the pricing model. The accuracy of an investment decision depends more on the quality of the fundamental inputs, such as the future expected value of the project, the cost of the option (strike price), the changes in the market (volatility) and the length of time available to postpone the decision (time to expiration) than on the complexity of calculus used to assess the project. Spending time on the evaluation of these four parameters is actually more important than choosing any sophisticated pricing tool. Continuously monitoring the evolution of the main parameters and their relative changes compared to the initial assumptions is the fundamental driver of Real Option value. In the final summary, the Real Option version for PlayStation® creates value by allowing the player to focus on investment fundamentals: always keeping their eyes on the ball and controlling the game.
The Authors also came up with a graphical representation of how to control the game using just the four main command keys, showing the action of each command on the basic game.
The last question left to answer was whether the four main controls were sensitive enough to command the actual speed of the game. In other words, how easy is to make a one percent error, the chosen threshold for the sensitivity analysis, in real life? The Authors chose the most critical variable, the future value of the project, to answer the question: was a one percent error in forecasting frequent and relevant in pharmaceuticals? On a real sample of forty two drugs, whose sales were projected to a three year outlook, the average forecasting error versus actual sales was 4.4% in the first year out, 9.1% in year two and almost 22% in year three. Looking at each individual estimate, eighty percent of times the single forecast error was larger than five percent. The selected four main commands were probably sensitive enough to command a real life investment game.
In conclusion, the newly released game for PlayStation® would possibly facilitate the adoption of Real Options by management executives, allowing any player to start playing immediately and to control the game using just the four main drivers of Value: it should be fun!

5. Testing the game: a biotech case.

Original research was conducted to demonstrate the relative impact of the choice of any Real Option continuous pricing model compared to the sensitivity to fundamental inputs on the Option value.
To avoid methodological bias, the Authors used a biotechnology business case published by Villiger & Bogdan in Nature Biotechnology, volume 23, number 4, April 2005. The case was related to a stop/go development decision on an experimental drug at the beginning of its clinical phase of development (Phase III).

Inputs to the model:

Expected probabilized DCF from marketed product	\$42.7M
Value of R&D Phase III investment	\$70.0M
Volatility of Phase III	30%
Expected length of Phase III	3 years
Risk free rate	5%
Dividends	0.0

Methodology.
The Authors input the above data in 13 different Real Option continuous pricing models. Models included European options, American Options and Exotic.

Results:
A set of 13 option values was obtained:

Option pricing models	Value of the call
European BS with no dividends	3.9357
European BS Monte Carlo (5,000 simulations)	3.9012
European BS quasi Monte Carlo (5,000 simulations)	3.8862
European binomial (100 steps)	3.9394
European trinomial (100 steps)	3.9412
Jump diffusion (50% vol. expl.): 1 jump	3.8896
Jump diffusion (50% vol. expl.): 2 jumps	3.9147
Jump diffusion (50% vol. expl.): 3 jumps	3.9233
American binomial	3.9390
American trinomial	3.9412
American finite difference	3.9409
Exotic Up&In (100 it.5,000 simulations): continuous	3.9726
Exotic Up&In (100 it.5,000 simulations): discrete	3.8247
Mean	3.9192
Standard deviation	0.037215

The price distribution did not fundamentally violate normality, although both skewness (-1.352) and kurtosis (2.618) values indicated a certain difference from central tendency. 95% of the times, option prices calculated with the 13 models

would fall in between 2 standard deviation points (0.37215) from the mean value (3.9192). In other words, the choice of the model had a +/- 2% impact on the option value.
The t test of the sample (379.712 – sig .000) confirmed that the sample prices difference from the mean is statistically significant.

Discussion.
A 2% difference may be statistically significant, but is it relevant from a management point of view? To answer this question, the Authors proceeded to verify the sensitivity of all 13 models to inputs, calculating option prices for inputs changing one at a time by an interval of 1% (from +5% to -5%). These values were then compared to the ones obtained from the base case, to measure the magnitude of difference. All 13 models behaved very consistently. The correlation between the sensitivity paired outcomes for all models was always very high, with the exception of the models based on Monte Carlo simulations, which showed a lower degree of correlation, but always significant at different levels, with just one exception. The correlation table showed additional evidence that all models move in synchrony, and their outcomes were concordant.
As it was demonstrated that all option pricing models outcomes by input change were correlated, the regression slope would define the sensitivity to each variable. The Authors selected the American binomial model as a base case, as it better reflected the decision tree often used in pharmaceutical R&D. The linear equations related to percent change of each single input were the following:

Value of the asset:	y=14.942x + 3.952	Rsq: ,999
Option price:	y=-11.043x + 3.951	Rsq: .998
Volatility:	y= 8.578x + 3.3937	Rsq :1.000
Time to exp.	y= 5.919x + 3.3938	Rsq:1.000
Risk free rate:	y= 1.605x + 3.940	Rsq:1.000

Therefore, a 1% change in inputs would have the following impact on the base case option price (42.7):

+1% value of the asset =	+ .14942	3.50%
+1% option price=	- .11403	-2.59%
+1%volatility=	+ .8578	2.01%
+1%time=	+ .5919	1.39%
+1%rate=	+ .1605	0.38%

The choice of the Real Option pricing model had an impact (+/-2%) lower than a 1% change in future value of the asset, option price and volatility, a 2% change in time to expiration and a 5,5% change in risk free rate.
How frequent would be a one percent error in real business life? The Authors analysed a database of 42 pharmaceutical products, whose sales were projected to a three year outlook. All products were already on the market when the forecast was prepared, which makes the case much easier than estimating the future value of a Phase III stop/go decision. Yet, the average error forecast error on all products compared to actual sales was +4.4% in year 1, -9.1% in year 2

and +21.9 in year 3. Looking at a sub group of 14 promoted products, which should have received more management attention, only 5 times the forecast error was lower than 5% (12% of cases).
The impact of a >5% error in the estimate of future value would have been equivalent to a > 20% error in option price. So 80% of the time, the error in just one input of the model could have been ten times more relevant than the choice of the real option pricing model.

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Giampiero Favato is an Academic Fellow and Subject Area Leader, Corporate Finance and Governance at Henley Management College. For the previous two decades Giampiero had international management responsibility in the healthcare sector. This was ultimately as a Director in one of the major research based pharmaceutical companies where he was leader of global teams dedicated to innovation and change. Giampiero conducted the development of the earliest disease management programmes with a remit to improve total patient care and quality of life. Giampiero was trained in marketing and was formally educated in economics and finance at the University of Chicago, where he gained an MBA. He was recently awarded a DBA from Brunel/Henley Management College and his research focused on Shareholder Value Creation and Real Options. More recently he has conducted intensive research into predicting the cost of late-stage pharmaceutical R&D projects and the use of Real Option Pricing Models to estimate their economic value.

Professor Roger Mills

Roger Mills works with executives in delivering practical and effective solutions to cost management, performance measurement and value related problems. He has worked with major banks and financial institutions, as well as companies and not - for - profit organisations, both in the UK and internationally. He has analysed and applied his state of the art ideas about internal controls, decision making, corporate governance and managerial accountability to a wide range of organisations including major banks and financial institutions. He is Professor of Finance and Accounting at Henley Management College and has been involved with major research projects, including the application and implementation of Activity Based Costing and he has published widely in books and journals.

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