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How Real Option Theory Has Gained Space in Research and Practice - An Overview of the Last Four Decades

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Abstract

In the last 40 years real options theory has been, with its empirical findings and qualitative reasoning a constant driver of strategy research, whether if it dealt with market entry timing, choice of organizational forms, foreign direct investments, or the cooperation vs. competition trade-off. Yet, the understanding and application of real options still comes with challenges not even in the strategy field, but also in its original discipline of investments. With this paper the author tried to build a strategic framework for the application of real options, with the aim of giving the theory a strategy based logic and trying to solve the chaos of the case-by-case type of application of research and practice. To confirm the stability of the framework, after showing the process of real option creation, valuation and management, a more than 1000 article based literature survey was conducted. This shows that the strategic direction is a must for practitioners and researchers also, and highlights future research areas like the portfolio based approach of real options, or a need for a general valuation model.

Keywords: Real options theory, discounted cash-flow, valuation, strategic management
JEL codes: G11, G12, G32

1. Introduction

Since its first application in the 1970s, the real options (RO) valuation method has been proposed as an analytic tool for all types of investment problems–from natural-resource investments and new products to start-ups, acquisitions, factories, information technology, patents and more. Not only investment opportunities but also the capital structure of a firm can be analysed by real options theory (Mauer – Triantis, 1994). Trigeorgis (1996) applied real options to analyse credit risks of financial institutes. Real options theory also applies to social life. Strange examples are the applications in assessing the waiting value in a marriage (Strobel, 2003) and estimating the probability of suicide risk in the old age population (Lo – Kwok, 2004).

Economists were quick to realise that options theory - created for analysing financial options - can offer notable added value for decisions about real investments (Black –Scholes, 1973; Merton, 1973). The field caught first moderate attention of academics in the 80s and 90s; widespread dissemination, however, was yet to come. In the mid 90s, real options provided the transition from restrained, specialised interest in options theory to the mainstream generally accepted by science and practice itself (Borison, 2005).

This study contributes to the current literature by providing a detailed and complex overview of the evolution of real options in valuation theory and practice, embracing a period of more than 40

years. The author combined the information given in literature to come up with a real option framework that enhances academic and real world application. Furthermore, the author extends the existing literature by first conducting an empirical investigation of the most cited real options literature from 1977 to 2017, identifying 987 articles, than narrowed down the scope of research to the most recent works, and analysed 951 studies available in Google Scholar, using text mining technique.

In the following chapters the basics of real option theory will be presented through a unique and specific strategic application lens: the process of identifying real options, the types of real options, the real option value drivers and finally the available valuation models. The aim of the study is to highlight the potential of the real option theory as a decision support tool, its advantages and disadvantages and give advise to future users how to incorporate real option theory into a strategic framework. The text mining research attempts to explore the existing real-life applications with the aim of identifying the most significant research directions of its first 40 years and pointing to those areas, where only limited progress has been made, but would require further focus due to their relevance.

2. Real option Theory

The expression real options was first used by Stewart Myers in 1977, when he investigated the possibilities of applying options pricing in the non-financial, primarily real estate investment valuation domain, by which he meant flexibility and as an added value, the phenomenon of deferred learning. A real option can be considered the option to defer and adjust investments and production decisions with the purpose of reducing and dispelling uncertainty (Triantis, 2000). A real option is the right, but not the obligation, to take an action (e.g., deferring, expanding, contracting or abandoning) at a predetermined cost called the exercise price, for a predetermined period of time - the life of the option. A real option is a certain kind of flexibility that is embedded in a real asset or company. Flexibilities can be identified along the lines of two dimensions: concentrating on timing, and along project size.

How to take embedded flexibilities into account varies across companies. Triantis and Borison (2001) offer a categorization. According to them there is the opportunity for companies to include real options into their decision making process as a way of thinking, as a qualitative tool; there are the identified real options which can be assessed quantitatively, in this case we consider real options as an analytical tool; and the third level of application is to consider real options as a strategic process, which identifies and effectively searches for new embedded flexibilities. As shown in Table 1 the strategic management application of real options starts with the identification of existing (shadow) options, which have emerged from previous strategic decisions of the company; after that comes the identification of attainable real options (through research and development, contracts etc.). This step, and the valuation of real options, is built basically on individual competencies. Based on the organizational and behavioural characteristics, the company starts to manage the portfolio of real options which leads to a, mostly intuition based, decision about the exercise of the option (Trigeorgis-Reuer, 2017).

Table 1: Strategic real options management

1. step Identification of ROs	**2. step RO valuation**	**3. step RO management**	**4. step RO Exercise**
Strategic analysis	**Strategy building and election**	**Application**	**Strategic decision**
Identification of shadow options	Identification of value determinants	Interactions between real options	Market entry, or exit
Identification of single options	Choosing the right valuation method		Staging
Identification of complex real options	Valuation		Switch of input and/or output parameters
Ranking of real options			Timing etc.
Individual competencies		**Organizational, behavioural characteristics**	**Intuitions**

Own construction based on (Hommel - Pritsch, 1999; Pritsch - Weber, 2003, Trigeorgis-Reuer, 2017)

2.1. Types of Real Options

One may distinguish a relatively narrower and a more diverse categorization of real option types depending on the degree of freedom project operators are given when managing the asset or project. Table 2 shows the basic stand-alone types of real options according to the dimensions of flexibility and strategic use (Copeland – Keenan, 1998), whether they are meant to open new opportunities (growth options); or learn through them about the market, the customers, etc. (learning options); or for risk management purposes (insurance options).

Table 2: Real option types according to flexibility and strategic aspects

	Timing flexibility	**Operational flexibility**
Growth options		(1) Growth options
Learning options	(2) Delay options (3) Abandonment options (4) Staging options	(5) Pilot options;
Insurance options	(6) Switch down/on options	(7) Option to contract/expand (change size) (8) Option to change input/output mix (9) Outsourcing options

Own construction based on (Trigeorgis, 1996; Amram – Kulatilaka, 1998; Benaroch, 2002; Copeland – Antikarov, 2003).

According to the real option for growth, a given investment may be the precursor or basis for starting a chain of interconnected projects, thereby opening up future growth prospects (for instance, the implementation of new projects, new processes; new market penetration; strengthening of base competencies) (Kester, 1984). Insurance options uncover the possibility to respond to unfavourable demand or price developments for management in the shape of shutting down, as well as and/or operative adaptation.

In contrast with growth options, insurance real options provide protection for a company against potential loss risks in a manner whereby they can avoid dips in their cash-flow (Copeland – Howe, 2002).

A real option to learn enables the investment decision to be postponed, abandoned reducing the risk of management, making irreversible decisions, based on incomplete information and thus suffering unfavourable consequences. The higher the uncertainty surrounding the decision, the more company executives prefer deferring project implementation, maintaining the option to implement the project at a future date (Myers, 1977). Since activities that determine the availability of production or later production cannot be postponed indefinitely, the deferral strategy frequently goes hand in hand with a next level of exercising management flexibility, i.e. splitting the decision into consecutive stages (staging real option) (Trigeorgis, 1996).

2.2. Real Options and Valuation

The use of option theory for valuing investments is based on the shortcomings of the traditional discounted cash-flow (DCF) based approaches. The classic DCF models are applied for several different valuation problems, such as company valuation (Copeland et al 2000, Damodaran 2002, Fernandez 2002, Takacs 2007a, 2015b), examination of stock pricing problems (Takacs 2007b, 2014), and even for valuing specific objects, like brands (Fernandez 2005, Takacs 2011, 2015a). These traditional models all assume a passive management approach (Kogut – Kulatilaka, 1994); they make the implicit assumption whereby a project will begin immediately and operate continuously until the end of anticipated useful life even if the future is uncertain. As a consequence, discounted cash-flow procedures disregard the added value that can be incorporated in a project by means of the management's flexible adaptation and innovation, i.e. they systematically underestimate the value of investment projects (Dixit – Pindyck, 1994; Trigeorgis, 1993; Kemna, 1993; Kumar, 1995; Van Putten – MacMillan, 2004). The undervaluation of investment alternatives may lead to underinvestment, and

to losing competitive position (Dean, 1951; Hayes – Abernathy, 1980). An efficient project valuation procedure takes both uncertainty and active decision-making – essential to the success of a strategy – into account (Luehrman, 1998b).

A real option resembles a financial option in many ways. The investment opportunity in a project can often be seen as a call option on the present value of the expected cash flows from the investment. Similarly, an option to abandon a project is analogous to a put option on the project's value. The exercise price is the salvage value of the equipment. However, real options are more complex than financial options. Table 3 shows the real option value drivers connected to the, in Table 2 introduced types of real options. The author collected the interactions between value drivers and basic types of financial vs. real options. *(For instance the increase of upside volatility (σ) ceteris paribus increases the value of the option, while this increase results in higher capital costs with a consequence of lower current value (S) of the underlying project).*

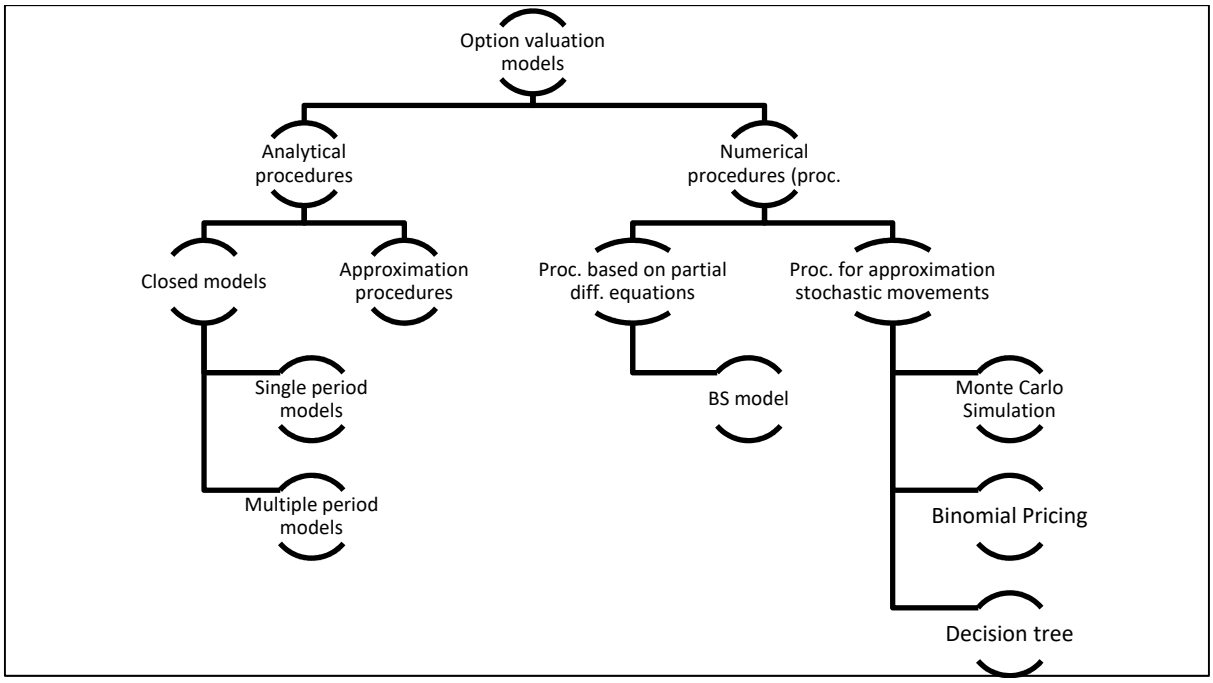
Table 3: Real option value drivers and the interaction between value drivers; where (1)-(2)-…etc. is the number of real option type from Table 2

Value drivers; [drivers that determine their value]	**CALL OPTION TYPE OF REAL OPTIONS [(1)-(2)-(4)-(5)-(6b)-(7b)-(8)]**	**PUT OPTION TYPE OF REAL OPTIONS [(3)-(6a)-(7a)-(8)-(9)]**
Time (t); [d]	+	+
Strike price (X); [d; σ]	-	+
Current value (S); [d;t; σ;r]	+	-
Risk free interest rate (r);	+	-
Uncertainty, volatility (σ)	+	+
Dividend (d); [S]	-	+

The next difference between financial and real option is that the underlying assets of real options are not tradable. Non-tradable real assets may earn a return below the equilibrium rate of return expected in the financial market. The rate of return shortfall necessitates a dividend-like adjustment. In option pricing, we mostly apply a risk-neutral valuation, by using the certainty-equivalent or risk-adjusted growth rate, which is equal to the actual growth rate minus an appropriate risk premium.

Figure 1 shows the systemic sorting of real option valuation methods. These valuation procedures may have unique pros and cons in the given decision situation. This is why it is important to contemplate which method is best suited for providing decision support to the given project. The most important requirements of valuation procedures include transparency, accuracy of valuation, the versatility of the valuation process, lowest possible complexity, along with the least possible preliminary skill requirements on behalf of those who will apply them. Amram & Kulatilaka (2000) distinguished market risks and private risks in relation with real option value. Market risks are risks captured in the price fluctuations of traded securities and private risks are risks that can not be captured with these price fluctuations. The value of real options can be influenced by market risks, by private risks or by a combination of them both. When market risk can be separated from private risk, option-pricing models can be used to value the part of real options that are influenced by market risk. However, it is not always possible to separate market risk from private risk. Dixit and Pindyck (1994) advise the practitioners to use decision analysis to value real options influenced by private risks, but decision analysis can be very complex and time-consuming. Copeland and Antikarov (2001) came up with the Market Asset Disclaimer, the MAD assumption. The MAD assumption assumes that the present value of the underlying asset is equal to the value of the project without flexibility. This assumption is often followed by the assumption that the value of the underlying asset behaves as a Geometric Brownian motion through time. The method based on the MAD assumptions makes it possible to calculate the value of real options influenced by all risk types.

Figure 1: Classification of option valuation models



The most commonly used methods from Figure 1 are the binomial pricing, the risk adjusted decision tree analysis and the Black-Scholes (BS) model. The binomial option pricing model, which is a discrete model for valuing European and American options, was created by Cox, Ross, and Rubinstein in 1979. A binomial tree can be seen as a special case of dynamic programming, in which the decisions are binary. The state variable can either go up or go down by a specific multiplicative factor in the next step of the tree. Afterwards the value of the option can be determined by working backwards from maturity. This model is mathematically simple compared to the Black-Scholes model (Cox et al, 1979). The major drawback of the binomial model is its quite slow process, especially when calculating many prices in a short period of time as well as the large number of required inputs, which are the expected future prices at each node (Damoradan, 2005).

The risk-adjusted decision tree allows for multiple decisions and uncertainties over time. The basic principle is that objective probabilities are used instead of risk-neutral probabilities. Therefore, the model can also incorporate private risks that cannot be diversified (Borison, 2003). Decision analysis tells us to assign subjective probabilities to the risks based on subjective judgment. Applied in a risk-adjusted decision tree, objective probabilities (i.e. probabilities withdrawn from the market) are assigned to market risks.

The Black-Scholes formula is a result of contingent claim analysis under strict assumptions. The six items in the first column of Table 3 are exactly the drivers of the option value in the Black-Scholes formula. These parameters are difficult or, in some cases, impossible to estimate accurately (Majd and Pindyck, 1987).

Theory and practice has split into two in answering the question about which – Cox, Ross and Rubinstein's (1979) binomial pricing or Fisher – Black and Myron – Scholes' model published in 1973 – proves more useful. Practitioners tend to favour the BS model for the most part (Courtney et al., 2001), while the majority of academic publications apply and recommend the binomial procedure. Without a doubt, the BS model surpasses the binomial procedure regarding the requirement of simple applicability (Amram – Kulatilaka, 1999); at the same time it is important to note that the complex modelling of real options relies on programming languages and, consequently, assumes a relatively high level of methodological know-how (Dorner, 2003). This is the very complexity that makes adapting the BS formula's rigid structure and assumptions impossible as it were in the case of tangibles

(Copeland–Antikarov, 2003), i.e. the binomial procedure proves dominant in the field of model transparency. Although the binomial procedure often loses out to the BS model in terms of precision, its results qualify as sufficiently accurate for value-driven corporate governance and easy to illustrate, and this option of graphical representation improves model transparency and accessibility.

2.3. Pros and Cons of Real Options Valuation

Using the option framework to evaluate strategic real options requires much effort, as not all of the required information is easy available. The problem lies in the imprecise nature of the analogy between financial and real options. Given the non-standard and non-financial aspect of real options, coupled with market incompleteness, the pricing of real options is more complicated. Even if we believe in the exact analogy between financial and real option by ignoring the limitations, the estimation of the option value drivers is not an easy task. Real options techniques are regarded by practitioners, as "black boxes", due to the sophisticated mathematics and the consequent lack of transparency and simplicity (Teach, 2003). But thanks to the increasing power of computers, commercial software vendors offer many user-friendly applications of complex real options and enforce application in complex situations also.

3. Empirical Research

To analyse the key areas of research and practice, the author identified 1101 studies through a Google Scholar search, with a filter of the keyword "real options" and a time frame of 2011-2016. From these studies 951 were English language studies, and therefore the objects of a conducted keyword and abstract based literature survey. The aim of the research was to identify the relevant fields of application, the potential research gaps, and through highlighting the industry and discipline focus giving researchers and practitioners a guide of potential application. The first step was to determine the focus of research. In the previous chapters the author built a strategic framework of application (qualitative, quantitative, strategic real options application), this was the first dimension of the conducted research, the second dimension introduced an industry and an identifiable discipline focus.

Based on the first dimension of the research we can state that the studies focus mostly (61.2%) on the quantitative application and use real option theory to value embedded flexibilities, while 33% of them use options logic as a qualitative assessment of opportunities to hedge against downside risk or to take advantage of upside potentials (See Table 4). Only 5.8% of the research objects look at real options as a tool of strategy. If we analyse the findings through the lens of the strategic real options management framework introduced in Table 1, future research directions show up. We can state that the studies are rarely concentrating on shadow options, options that can be derived from previous strategic decisions, a few of the studies aim to help practitioners understand how real options can be obtained or created, and the low percentage rate of strategic real option analysis highlight the need for a more complex, portfolio aspect of flexibilities with an organizational and behavioural focus.

Table 4: Real options (RO) literature survey results according to decision categories and field of application

		RO THINKING	RO AS AN ANALYTICAL TOOL	RO IN STRATEGY
100.0%		**Qualitative analysis 33.0%**	**Quantitative analysis 61.2%**	**Strategic RO analysis 5.8%**
General application	**42.3%**	38.0%	39.2%	100.0%
Power generation sector	**14.9%**	7.7%	**20.1%**	0.0%
Operations management	**8.0%**	**9.8%**	7.8%	0.0%
Natural resources	**7.9%**	3.7%	**10.9%**	0.0%
Environment and climate change	**6.3%**	**9.1%**	5.4%	0.0%
Info-communication technology	**4.8%**	6.1%	4.5%	0.0%
Agriculture	**2.6%**	2.7%	2.7%	0.0%
Research and Development	**2.1%**	3.0%	1.8%	0.0%
Real estate investments	**2.0%**	2.4%	2.0%	0.0%
Entrepreneurship and venture capital	**1.9%**	5.1%	0.4%	0.0%
Infrastructure development	**1.6%**	1.7%	1.6%	0.0%
Engineering	**1.2%**	2.7%	0.5%	0.0%
Pharmaceutical industry	**1.0%**	1.7%	0.7%	0.0%
Innovation	**1.1%**	2.7%	0.4%	0.0%
M&A transactions	**0.4%**	0.0%	0.7%	0.0%
Other	**1.9%**	3.7%	1.1%	0.0%

The second focus of the research was to determine the field of application, whether it is an industry or a discipline in which the theory is applied. As Table 4 indicates, the number of the application areas exceeds 16, despite summing every field, which occurred in less than 5 articles in the "other" category. Table 4 sorted the fields according to relevance from high to low. 42.3% of the studies use real options theory for valuation and modelling purposes in a general decision making process. 39.2% of these use actually a valuation model, while 38.00% of them take flexibility qualitatively into account. The strategic application of real options appear only in 5.8% of the research objects as it was mentioned before, and all of them examine real option theory's role in strategy only in general, without taking industry specific circumstances into account. The next few application fields in line are basically the industries and disciplines which can be characterized with project irreversibility, opportunity of granting exclusivity by rights, patents, uncertainty and project embedded flexibility, like the power generation sector, operations management, natural resource projects, environment and climate change related investments, ICT investments etc. An interesting finding that in case of operations management and among them the most commonly appearing supply chain related studies and the environment and climate change related, on corporate social responsibility concentrating works use dominantly the qualitative real options logic, while most of the quantitative applications can be connected to power generation projects and natural resource investment decisions. As Table 4 indicates in case of analytical application the results concentrate around the most dynamic industries, with a large amount of money at stake during the execution of a flexibility embedded investment; while the qualitative applications are highly fragmented.

4. Summary and Concluding Remarks

After the introduction of real options by Myers (1977) numerous studies proved the viability of the real options logic. While the majority of them used the option valuation method to value project embedded flexibility, we can find studies that concentrate on the improvement of the theory from a methodological, a strategic, an organizational or behavioural aspect, but there isn't any finding available that would show researchers or practitioners a map of application. The research results clearly confirm the critique of practitioner against the theory. There isn't a general, universally accepted real option framework or model that could be applied with adjustments to industry or discipline specific circumstances. The application, especially the qualitative applications stick to the case-by-case method.

Although we must state from the results that digging deeper into the general results, which total up to 42.3% of the analysed studies, 7% of them deal with the critique of real options application, and 93.00% of them work on optimization and model perfection responding to the practitioner needs. As a conclusion of the research, based on the number of application fields and involved disciplines, whether it was a business discipline, or for example engineering, we suggest that researchers and practitioners consider real options analysis and the real option framework as an operational, viable and efficient tool of decision support. According to the central premise of the real option theory, the focus of managerial decisions is to recognize, create and reduce (not to enforce) the options that increase flexibility, and reduce uncertainty. If we are able to recognize, create and apply real options with this dual endeavor, not only will we improve our resilience to risks, but also increase shareholder value in the long run.

Real options are potentially a more effective way for managers to allocate their company's capital and maximize shareholder wealth by dealing with uncertainty and reducing risk. Although real options theory has not become a generally accepted paradigm for investment theory, it is vital for the decision-makers of high-profile, strategic issues to take project embedded flexibility into account. The present study attempted to synthesize the first 40 years of real option research and practice, with the aim to show the diversity of existing applications, to serve the understanding of practitioners, and to identify research gaps. In order to provide empirical support for the conclusions drawn during the presentation of the structured strategic framework, the author conducted a text mining based literature survey, which resulted in clearer view of future research tasks and practical implications. We can expect from the next decade the spread of strategic and portfolio based applications and a research focus around a general valuation method.

Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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