

DEVELOPMENT OF REAL OPTION THEORY IN THE LAST 20 YEARS

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Abstract:

The main goal of this study is to offer an overview on the real option theory in the past two decades. The beginnings of real option researches go back to the 1980s, with their first applications deployed in the natural resource extraction industries. A further important milestone of development came in 1996, when upon Lenos Trigeorgis' initiative a series of annual real option conferences was launched. This year witnesses the staging of the 20th conference, and therefore it can be taken as a worthy occasion for having an overview on the main literary guidelines of the theory with emphasis on the key outcomes. The first part of my study details the most important results of real option financial valuation. The second part sheds light on the potential relationship of strategic management and real options in the light of literary researches. The third section focuses on the real option results of strategic decision-making. The interpretation of the real option procedure as an organizational process gives way to linking the results of strategic management to those of financial management by creating an integrated organizational decision-making model. This statement will be backed by the results pertaining to the real option organizational models.

Keywords: real option, investment valuation, strategic decision-making, organisational development

JEL classification: G31, L21

1. Introduction and research question

In recent decades, the business environment has undergone considerable transformation, and consequently the traditional models of investment valuation and the theoretical approaches to corporate strategy-making have also been altered. In investment valuation theory, the real option approach and valuation emerged after the financial option analogy. This approach has become especially important in relation to staged projects that are hard or even impossible to evaluate with conventional methods of discounted cash flow, still carry strategic benefits. Value-adding strategic investments are also closely associated with the most recent theories of corporate strategy. This line of thinking is represented by the theory of dynamic capabilities, as well as knowledge-based approaches of strategic and corporate theory, which regards the valuation of strategic investments and the management of in-process changes as a source of corporate knowledge and organizational potentials. Consequently, for integrated corporate management, the challenge of the day is how managerial decision-making procedures embracing financial, production and strategic processes can be made even more efficient with the application of the real options methodology.

It was Stewart Myers to first conceive the option-based idea of assessing future opportunities that are inherent in projects. In 1977, he was studying the potentials of using option-pricing in the field of real-estate property investments, where he

understood extra value added by flexibility as deferred learning (Csapi, 2013a). In 1984, Myers also pointed out that conventional valuation methods based on discounted cash flow are not able to handle projects encompassing both production and strategic options, and therefore proposed option pricing is to be used for valuation purposes. This basic principle formed the foundations of real option researches and their corporate applications. The theoretical and practical scientific results of the first decade were summed up in a dedicated handbook by Trigeorgis (1996). A further important milestone of development came in 1996, when upon Lenos Trigeorgis' initiative a series of annual real option conferences was launched. This year witnesses the staging of the 20th conference, and therefore it can be taken as a worthy occasion for having an overview on the main literary guidelines of the theory with emphasis on the key outcomes.

The first important financial consequence of the emergence of real option thinking and methodology was the introduction of the strategic NPV rule and the identification of the types of real options. The strategic NPV expresses two value components: the conventional net present value of direct cash flows and flexibility in production, as well as the option value of strategic interrelations (Trigeorgis, 1996). Initially, it seemed that strategic NPV model would create grounds for the consideration of the value of interrelations among projects and production flexibility, and additionally strategic effects. However, the study of long-term strategic criteria and the outcomes of the scientific development of strategic management made it obvious that the option component of strategic NPV was not sufficient and adequate for the examination of the strategic components of value-adding investments. This recognition directed scientific attention to integrated strategic decision-making.

The above statement is also confirmed by the surveys of Triantis and Borison (2001) with large company managers from 7 industries. According to scholars, the real options techniques and processes applied in practice can be categorized in three groups (Csapi, 2013a):

- real options thinking (qualitative analysis of decision-making problems, interpretation of alternatives),
- real option analytic tools (application of option pricing models in project valuation),
- real option organizational process (management tool for the identification and exploitation of strategic options belonging to the field of real options).

The significance of real option organizational processes are underlined by research and development (R&D), pharmaceutical and advanced manufacturing technology projects that feature sequential structures and special option characteristics. In these cases, the real options logic is applied as an analytic and communication tool encompassing the entire organization. The results of the line of thinking emphasizing the real option organizational valuation processes additionally led to the modernization of the strategic net present value. It was Smit and Trigeorgis (2004) to first propose the use of the expanded strategic NPV. The point of this model improvement was that to the earlier strategic NPV formula the authors added strategic option values that also integrated certain results from game theory.

In the meantime, the real option approach gained broader interpretation as such a form of investment into physical assets, human resources and organizational capabilities that improved the ability to respond to future events (Kogut and

Kulatilaka, 2001). The potential correlations of capabilities, real options and resource allocation processes were studied by Maritan and Alessandri (2007), while a compilation of studies by Tong and Reuer (2007) focused on the general, multicriteria applicability of real options in strategic management.

In view of Driouchi and Bennett's findings (2012, p 43), the relationship between strategic management and real options can be summed up as follows: „Resources and strategic investments can be viewed as real options, while governance modes and strategic positioning decisions contain real option chains. The advantage of management view is that it pays more attention to learning, managerial competences and endogenous uncertainty. Strategic option decisions are generally applied in the fields of various forms of market entrance, managerial styles and innovative investments. Therefore, corporate performance is a function of the structure and sequential design of these types of decisions.” The broader interpretation of real options and the most recent results of strategic management researches further confirm the development of the real option approach in connection with integrated, organizational processes. Driouchi and Bennett's analysis (2012) looking at more than 200 professional publications assessed and systematized the directions of real option decision-making, applications in strategic and international production processes, as well as empirical assessments (Table 1).

Table 1. Main directions in real option studies

Real option decision-making	Strategy and international production	Empirical applications
- Real option valuation	- Shared or proprietary options	- Real option characteristics of investments
- Real options logic	- Strategic growth options	- Effects of real options on performance
- Real options as capabilities	- Production (flexibility) options	- Real option corporate practices

Source: Driouchi-Bennett (2012), p 56.

In the further parts of the study, I have summed up the most important results of real option financial valuation, analyzed the potential correlations between strategic management and real options in the light of literary researches, and finally evaluated the real option results of strategic decision-making.

2. Development of financial investment valuation using real option approach

Starting out from Myers' thought, the theoretical and corporate experts were aspiring to reveal various types of real options, and identify the most usable option models for the evaluation of the individual real option cases. At the present, the associated literature knows a broad range of real option types (Trigeorgis, 1996; Amram and Kulatilaka, 1999; Smit and Trigeorgis, 2004; Rózsa, 2008; Bélyácz, 2011; Csapi, 2013b). The most common categorizations are:

- naturally occurring real options (deferment option, option to abandon, growth, staged and compound options) and real options that can be incorporated with extra costs (modification and flexibility options),
- product options, timing options and execution options (Kylaheiko et al., 2002),

- learning options (Yeo and Qiu, 2003),
- real options along the temporal dimension (deferment, abandonment) and size-related dimension (growth, change, expansion, compound, as well as exploration, outsourcing and rainbow options) (Csapi, 2014),
- flexibility (simple, usually timing options connected with specific projects, without strategic values) and strategic (generally growth and compound options belonging to multiple projects, carrying considerable strategic values and leading to new value-creating projects (Van Aarle, 2013).

Table 2 shows the most general real options categories, as well as the associated industries and most important publications.

Table 2. Summary of the types of real options

Option category	Contents	Fields of application	Publications
<i>Option to defer</i>	<p>There is an option to acquire a valuable land or resource. The company monitors the market events, obtains additional information by resolving uncertainties that it integrates into decision-making.</p>	<p>Natural resource extraction industries, real estate developments, agricultural industries, paper products</p>	<p>Tourinho (1979); Tiltman (1985); McDonald and Siegel (1986); Paddock et al. (1988); Ingersoll and Ross (1992); Anderson (2000)</p>
<i>Option to abandon</i>	<p>When market conditions take an unfavourable turn, the company can terminate its operations, sell the project, and realize the residual value.</p>	<p>Capital intensive industries, financial services, new product introductions in uncertain markets</p>	<p>Myers and Majd (1990); Berger et al. (1996); McGrath (1999); McGrath and Nerkar (2004)</p>
<i>Time-to-build option, staged investment sequential option</i>	<p>There is an option to abandon the project while it is in progress in case the new information is deemed as unfavourable. The commencement of the individual phases is conditioned on the success of the previous phase. It can be interpreted as a serious of successive options.</p>	<p>All the R&D intensive sectors, especially the pharmaceutical industry; capital-intensive projects calling for long-term development (e.g. large-volume construction works, power plants); startup of risky enterprises</p>	<p>Majd and Pindyck (1987); Carr (1988); Trigeorgis (1993); Kemna (1993); Perlitz et al. (1999); Loch and Bode-Greuel (2001); Lint and Pennings (2001); MacDougall and Pike (2003)</p>
<i>Growth options</i>	<p>An earlier investment is regarded as the precondition of another project. The success of the initial investment can open up new, future investment options for the company.</p>	<p>Infrastructure-based or strategic industries: especially high-tech, R&D, where there are complex product generations; strategic acquisitions; multinational activities; organizational capabilities</p>	<p>Myers (1977); Kester (1984); Trigeorgis (1988); Pindyck (1988); Brealey and Myers (1991); Kester (1993); Borissiouk and Pelli (2001); Tong and Reuer (2006); Broutthers and Dikova (2010)</p>
<i>Option to alter</i>	<p>Under favourable market conditions, the company can extend the lifecycle of the project, increase the size of series production or accelerate resource utilization. On the other hand, in unfavourable situations, the company may cut back production, or even suspend production temporarily in justified cases.</p>	<p>Natural resource extraction industries (e.g. mining); design of equipment and construction in cyclic industries; fashion products; consumer goods; commercial properties</p>	<p>McDonald and Siegel (1985); Brennan and Schwartz (1985); Trigeorgis and Mason (1987); Pindyck (1988); De Neufville (2003); Chung et al (2010)</p>

<p><i>Flexibility option, option to switch, , input and output</i></p>	<p>Under conditions of production flexibility, in case there are changes in the prices or demand, the management of the company can change the output structure, product structure (production flexibility) or make the same products with the use of different types of inputs (process flexibility).</p>	<p><i>Output changes:</i> In the case of products that are sold in small volumes, or attract fluctuating demand (electronics; toys; automobile parts) <i>Input changes:</i> electric power; agricultural crops; chemicals; raw materials requiring mechanical processing, pending opportunities</p>	<p>Margrabe (1978); Kensinger (1987); Kulatilaka (1988); Kulatilaka and Trigeorgis (1994); Lieblein and Miller (2003); Mol et al (2005)</p>
<p><i>Compound option</i></p>	<p>Options or option chains associated with other options. Because of the mutual dependencies, the values of multiple options are different from the amounts of the individual values of the same options.</p>	<p>Most of the real projects in the above-mentioned industries.</p>	<p>Brennan and Schwartz (1985); Trigeorgis (1993); Kulatilaka (1994); Schwartz and Trigeorgis (2001); Triantis and Borison (2001); Jiang et al (2009)</p>

Source: ed. by me based on Trigeorgis (1996), pp 2–3., as well as Driouchi and Bennett (2012).

According to Trigeorgis (1996) four closed-form solutions can be used in real option analysis: Black and Scholes (1973), Margrabe (1978), Geske (1979) and Carr (1988). It was in 1973 when Black and Scholes (B-S) worked out the first closed-form solution for the valuation of financial options and warrants. Most of the option pricing techniques used nowadays are some variation of the B-S solution and procedure. The Black-Scholes solution is used in the valuation of deferral, abandonment and growth options. The option to replace a risk-carrying asset that did not pay dividends for another asset was evaluated by Margrabe in 1978. The only difference between the B-S and Margrabe solutions is the handling of the exercise price. In the former model, the exercise price is deterministic (it is defined in advance), whereas in Margrabe's solution it is handled as a stochastic variable. The Margrabe solution is similarly used in the valuation of deferral, abandonment and growth options. Beyond the deterministic exercise price, Geske's name is associated with the solution connected with the valuation of compound options. Geske's model is applied in sequential (staged) investment decisions. Investments of this kind are often found in the case of R&D and technological decisions (Perlitz et al., 1999). In 1988, Carr defined his solution for compound options with the application of stochastic exercise prices. Carr's solution can be detected in applications that are similar to the ones in the Geske model. Haahtela (2012) summarizes the various real option valuation approaches. As an alternative of closed-form solutions, he analyzes simulation-based methods (Copeland and Antikarov, 2001). Another alternative is presented by the lattice and tree-based methods. Haahtela (2010) demonstrated one example of an enhanced lattice approach for real option valuation recombining trinomial lattice with changing volatility. Finally, he emphasized the applicability of the most novel fuzzy pay-off methods (Collan et al., 2009 in Haahtela, 2012).

3. Development of strategic management and potential real option relations

In corporate strategy and the study of organizational decisions, the real option paradigm offers an especially remarkable framework for decision-making under uncertainties (Sanchez, 2003, Driouchi and Bennett, 2012). According to Kogut and Kulatilaka (2001), real options as investments into capabilities promote organizational learning, create values, and sustain the competitive edge. Barnett (2008) claimed that real option decision-making is the ability of managers to recognize, maintain, support and exploit real option opportunities in their own specific business environments.

When companies enter a new development lifecycle, knowledge becomes a fundamental competence, whereas learning serves as the source of advantage in competition (Miller, 2002). According to Bräutigam et al. (2003), the real option theory is suitable for reconciling development phases with inherent endogenous and exogenous uncertainty factors. McGrath et al. (2004) regards real options as the driving force behind choice and heterogeneity, and argues that real option reasoning is a valuable contribution to the existing learning, decision-making and organizational theories.

Smit and Trigeorgis (2004) summarize the key results concerning external and internal views of the firm and approaches to strategy (Table 3).

Table 3. Most important views of the firm and corporate strategy

Types/Scientific area	Publications	Main concern
External		
competitive advantage	Porter (1980)	structural conditions and competitor positioning
strategic conflict	Shapiro (1989) Brandenburger and Nalebuff (1995)	strategic interactions
Internal		
resource-based view	Rumelt (1984), Wernerfelt (1984), Teece (1980, 1982)	asset accumulation
dynamic capabilities	Prahalad and Hamel (1990) Hayes and Wheelwright (1984) Teece, Pisano, Shuen (1997)	asset accumulation, replicability
Linkage		
real options and games	Smit and Ankum (1993) Kulatilaka and Perotti (1998) Bowman and Hurry (1993), McGrath (1997)	adjusting decisions in dynamic and competitive environment

Source: Smit and Trigeorgis (2004), pp 39.

In view of the important strategic implications, it can be assumed that in spite of its numerous advantages strategic NPV is not suitable for the coordination of strategic and financial principles, which aims at the creation of strategic flexibility (Rózsa, 2008). In the strategic NPV model, the above-detailed long-term strategic criteria cannot be integrated. On the other hand, it has been evidenced that they are just as essential parts of strategic investment decision-making as the mathematically more manageable future cash flows, estimable discount rates, as well as simple and compound options that can be assessed with the use of financial option models. This set of issues has also directed the attention of scholars to strategic decision-making.

4. Analysis of strategic decision-making concerning real options

Several models have been proposed to tackle the problem. These models place emphasis on the completion of strategic decision-making with the real options theory.

Amram and Kulatilaka's (1999) model considers the identification of the sources of uncertainties and decision-making alternatives as a principal organizational responsibility where efficient implementation necessitates strategic and financial real option communication. It is followed by the selection of valuation parameters, and then the execution of the option valuation models. Based on the results and the obtained critical strategic values, a strategic decision-making space can be drawn up that enables continuous control and the redesigning of processes.

Similarly, Smit and Trigeorgis (2004) recognized the demand for complexity – the necessity to forge relations between financial and strategic planning – and first they tried to improve the decision-making process by expanding the strategic NPV. The essence of their proposal is expressed in the following equation.

expanded strategic NPV = passive NPV + option premium + strategic option value

The point of the theoretic model improvement was that to the earlier form of financial valuation the authors added strategic option values that also integrated certain results from game theory. The complex model they recommended is

demonstrated in Table 4.

Table 4. Effect of strategic planning on the market value of the company

Market value (Expanded NPV)	Value controls	Strategic planning	Valuation methodology
STRATEGIC VALUE	Strategic POSITION	Competition strategy	Game theory
FLEXIBILITY VALUE	Adaptive capabilities	Strategic planning	Real option valuation
NET PRESENT VALUE	Competitive advantages	Project planning	Discounted cash flow

Source: Smit and Trigeorgis (2004), pp 4–5.

In my opinion, the Smit and Trigeorgis model, while it gives very detailed description of strategic issues, fails to abandon the fundamental assumption concerning the priority of financial decisions.

The situation is similar to those researches and results focusing on real option organizational processes that relate to the formation of real option valuation processes. From among them, the most notable results have been published by Amram and Kulatilaka (1999), as well as Copeland and Antikarov (2001). The primary objectives of the both models are to facilitate the analysis of practical cases, as well as simplify the performance and application of real option calculations.

My earlier studies (Rózsa, 2008, 2015) call this view a reverse approach, and suggested that it should not be the option approach regarded as the primary aspect in which we try to embed strategic factors, but on the other way round: we are rather to consider the recognition, valuation of options, the application of the option approach itself as a corporate capability, factor serving as the foundation of knowledge. To this end, I have developed the so-called strategic real option model (Table 5).

Table 5. The suggested strategic real model

STRATEGY	REAL OPTION	VALUATION	FEEDBACK
competitive advantage	real option types	model selection	organizational tasks
knowledge and innovation	uncertainty	option evaluation	operating problems
continuous development	matrix-based approach	strategic decision-making space	changing environment
dynamic capabilities	options for exercise	conditions of exercise	new information

Source: Rózsa (2015)

On the basis of my model development in Rózsa (2008, 2015) I stated that: “In the process of decision-making and implementation, strategic, real option, valuation and feedback analyses have to be performed in all the phases of decision-making. I have defined the fundamental questions relating to the four elements of the extended model as follows:

- What a role does the project under review have in acquiring competitive advantage, or by what strategic characteristics does it support the sustenance of competitive advantage?
- What sources of uncertainties are anticipated to occur? What real option types is it worth concentrating on? Which are the most important ones?
- What is the value of the real options that are also financially assessable? What should be the next decision?
- What organizational tasks have to be executed in the given phases of the

project, what responses can be given to the operating problems occurring, what environmental and information changes need to be taken into consideration, and how do they affect the commencement of the next phase? “

The opportunities for creating strategic framework systems have also been analyzed by Csapi (2013), and by referencing German sources she has proposed the following strategic approach (Table 6).

Table 6. Flowchart for strategic real option management

STRATEGIC ANALYSIS	FORMATION AND SELECTION OF THE STRATEGY	APPLICATION OF THE STRATEGY
Identification of real options	Valuation of real options	Real option management
Capturing real options	Selection of valuation methods	Governance of real options
Examination of the option analogy	Determination of the valuation parameters	Adjustment of structures and systems
Prioritization of real options	Implementation of valuation	Provision of information, training, motivation to employees

Source: Csapi (2013)a, p 84.

It can be claimed that this latter two models are in close correlation with the most recent researches. Driouchi and Bennett (2012) give a detailed analysis on the role of real options in strategic decision-making, and summarize the results of the most recent studies in the light of the real option debate.

Table 7. Practical application of real options

Real option trends	Strategic decision-making	
	Case studies	Managerial assessments
OPTIMIST	Lint and Pennings (1998) Lint and Pennings (2001) Borissiouk and Peli (2001) Miller and Park (2004) Raynor and Leroux (2004)	Triantis and Borison (2001)
REALIST	Kemna (1993) De Neufville (2003) MacDougall and Pike (2003) Alessandri et al. (2004) Krychowski et al. (2010)	Busby and Pitts (1997) Howell and Jagle (1997) Graham and Harvey (2001) Miller and Shapira (2004) Verbeeten (2006)
PESSIMIST	Philippe (2005)	Ryan and Ryan (2002)

Source: Driouchi and Bennett (2012), p 55.

5. Conclusions

The main conclusion of the theoretical development of real options theory in the past 20 years is that by today the system of real option tools has become an indispensable element of corporate strategic decision-making. The strategic NPV method and its expanded version are broadly known, and successful practical applications also exist, especially in pharmaceutical, R&D, advanced

manufacturing technologies and electronic field of investments. At the same time, coordination of strategic, production and financial aspects calls for integrated model development. There have been attempts in the associated literature to satisfy this theoretical demand, but a further direction of research is embodied in its practical testing. The potential effects of the real option approach on organizational processes are subject to further research.

As opposed to the mainstream trend of studies, my suggestion is that preference should be given to the reverse approach, i.e. that it should not be the option approach regarded as the primary aspect in which we try to embed strategic factors, but on the other way round: we are rather to consider the recognition, valuation of options, the application of the option approach itself as a corporate capability, factor serving as the foundation of knowledge.

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