ZESZYTY NAUKOWE UNIWERSYTETU SZCZECIŃSKIEGO
NR 690 FINANSE, RYNKI FINANSOWE, UBEZPIECZENIA NR 51 2012

WŁODZIMIERZ RUDNY

FLEXIBILITY AND RISK MANAGEMENT IN TRANSPORTATION PROJECTS USING REAL OPTIONS

Introduction

Among the key issues in project evaluation one can find those of valuation and risk management. This is particularly true for complex, capital intensive, multi-stage projects. Such projects, especially in the context of a hyper competitive business environment, require new methods of evaluation and risk mitigation. One of them is the real option method.

The value of flexibility in project management

One of the key concepts for a new competitive environment is one of flexibility. Flexibility can be defined as "the ability to change or react with little penalty in time, effort, cost or performance" (Upton, 1994).

Rapid changes in technology and the ever increasing pace at which new products and processes are introduced, requires that firms remain flexible, both with regards to strategy and organization. A comprehensive analysis of the importance of strategic flexibility is provided by Sanchez (1995). Strategic flexibility – further subdivided into resources flexibility and coordinated flexibility – which denotes the firm's ability to respond to various demands from a dynamic and competitive environment.

Considering the subject of flexibility, Kaluza (1993) distinguishes between goals and means flexibility. Goal flexibility refers to flexibility that eliminates existing goals or incorporates new goals into the corporation's goal system. Means flexibility denotes the flexibility in choosing the means to obtain the aforementioned goals. One can further distinguish between *built-in flexibility* and *action* flexibility. The first category of risk management is related to defensive risk management, which helps reduce the impact of unfavorable changes in the business environment. Action flexibility refers to the company's offensive capacity of reaction to take advantage of chances.

Management of flexibility can be understood as *reactive* or *proactive*. In the first sense, flexibility management refers to the management of a company's ability to react in response to changes in the relevant environment. In the second sense, it denotes the company's capability to proactively use existing flexibility in order to strengthen its competitive position, e.g. by creating new products, employing new technologies or serving new customer groups.

Flexibility potential is of value. Its value is especially high in cases where all the components of an investment project's variability (market payoff variability, schedule variability, performance variability, market requirement variability) are considerable and decisions have to be made well in advance. Flexibility should be managed at both project and corporate levels.

The rapid changes of a competitive environment pose an important question as to how to evaluate major capital expenditures (e.g. new-technology development projects, new plants, new businesses) characterized by a very high degree of uncertainty. In such circumstances classic discount-based techniques become inadequate. One alternative that is gradually gaining in popularity is to treat investments with above mentioned characteristics as taking options on future cash flows generated as a consequence of current capital expenditures. Hence, conceptual framework as well as valuation techniques transferred from finance, called *Real Option Analysis* (ROA), have attracted the attention of a number academics as well as practitioners.

Financial versus real options

The three main characteristics of financial options are:

- flexibility
- uncertainty
- irreversibility

Flexibility refers to a key characteristic of this instrument, namely, that the option holder has the right but not the obligation to exercise the option. Options also contain an element of *uncertainty* because the economic attractiveness of the option primarily depends on the development of the underlying asset. *Irreversibility* is related to the fact that an option holder's rights cease to exist once the option is exercised.

Financial options limit the downside potential of the underlying asset while at the same time offering an upside potential. As a consequence financial options have an inherent value, the option premium. In general, the option value is influenced by six factors: price of the underlying asset, uncertainty of the underlying asset's price movement, time to expiry, exercise price, dividend payments and risk-free rate.

The term "**real options**" was introduced by Stewart Myers (1977). It refers to the application of option pricing theory to the valuation of non-financial or "real" investments with learning and flexibility. In finance theory, option pricing is a widely acknowledged instrument to assess uncertainty and flexibility. Since the mid-1990's there has been a growing interest in real options perceived as a potentially important tool for the valuation of uncertain investment projects with embedded flexibility. There has also been growing interest in using real options for business strategy formulations.

A real option is a right, but not an obligation, to acquire the present value of expected cash flows generated by the project by making an irreversible investment on or before the date the opportunity ceases to be available.

Real options are similar to financial options (Miller and Park, 2002). They contain the same three elements that were used to characterize financial options. For most of investment projects there will be some form of flexibility (e.g. when to start the project, whether to stop it, to abandon, to change then scale, to switch inputs or outputs) Most real options have to be purchased by a company through the payment of an implicit option premium (e.g. conducting an investment).

Any financial or real option can be seen as an initial investment offering an exclusive opportunity to keep open a specified follow-on (dis)investment trajectory at limited predetermined costs.

The value of a real option is influenced by the following six factors (corresponding to factors influencing the value of financial options): present value of expected cash flows from the project, uncertainty of the expected cash flows, time period until investment opportunity disappears, present value of fixed costs of investment, value lost over duration of option, risk-free rate.

Table 1 presents comparison of input variables for a call option on a stock and a call option for an investment project.

Due to the stated analogies it appears legitimate to apply the principles and pricing models for financial options also to real options.

Table 1

Comparison of a call option on a stock and a call option on an investment project

	Call option on a stock	Call option on an investment project
Underlying	Current value of stock	Present value of expected cash flows
Exercise price	A fixed stock price	Present value of investment cost
Time to expiration	Fixed date	Time until opportunity disappears
Risk	Stock value uncertainty	Project value uncertainty
Dividend payments	Payments to the stock holder	Payments lost through waiting to invest
Interest rate	Riskless interest rate	Riskless interest rate

Source: L. Trigeorgis: *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, Cambridge, MA, MIT Press 2007, p. 125.

The basic idea of the real option approach is to transfer the sophisticated option pricing models from finance to the valuation of risky investment projects. The rationale behind this analogy is that if the option is exercised, projects – like financial options - may lead to substantial financial returns. If, however, an option is not exercised, because of detrimental changes in the business environment, the losses are avoided. Thus, the treatment of the project as an option creates the potential for future profits, while at the same time limiting downside risk.

The concept of real options acknowledges that downside risk is limited and upward potential is maximized if management can alter the sequence of actions and investment. However, real options generally require control over the underlying asset whereas financial options do not.

Projects with in-built flexibility give the decision maker an opportunity to react to new information, “arriving” in the future, in different ways. Depending on this information, a project may be delayed, continued, stopped or halted to wait for additional information. The scope of the project may be limited or enhanced. The categorization and rigid quantitative treatment of these different possibilities of reacting are of central concern in real option research.

The real option approach is especially tailored to deal with **uncertainty** and **flexibility**.

One can distinguish between several major kinds of real options, namely:

1. Option to **defer.** This option quantifies a trade-off between the increased revenues from immediate investment and losses avoided by waiting to resolve uncertainty about future outcomes. The option to defer is especially valuable if there is high economic uncertainty about the future cash flows of the project, and if the entrance of competitors is not very likely.
2. Option to **expand** or **contract**. These types of options incorporate the possibility of altering the existing scale of the project according to the changes in market conditions.
3. Option to **abandon**. This option quantifies the value of the possibility to stop a project, sell it for a price equal to certain salvage value, and save its follow-up expenditures. The project that can be liquidated is worth more than the same project without such management flexibility.
4. Option to **switch**. This option quantifies the opportunity to reorient the operating mode of the project, to change the technology used, change the input required or the output turn out.
5. Option to **grow**. This type of real option implies the possibility of investing in the follow-on opportunity of the initial project. Growth options allow managers to justify the decision to invest in projects with negative NPV projects because of the possibility of undertaking follow-on investments with much more favorable future cash flows. In this way the strategic value of the initial project can be captured.
6. **Compound** option. The compound option is an option that gives access to another option. This option reflects the value of multi-staged, sequential investments, where the completion of an earlier stage is a prerequisite for investments at later stages.

Real options analysis and DCF analysis

In finance, the discounted cash flow (DCF) model has become the basic framework for most analyses. In investment analysis, it is generally accepted that the net present value of the project is the measure of the value that it will add to the firm accepting this project. In valuation, value of the firm is the present value of the expected cash flows derived from the assets of the firm. In recent years this framework has been criticized for failing to consider the options embedded in projects that are being valued.

The NPV approach may fail to channel company's resources toward the right project because it does not properly value a management's ability to react to future changes in the business environment. It does not consider the value of options to wait and revise an initial operating strategy if future events differ from what was originally predicted.

A number of deficiencies of discounted cash-flow methods (DCF) have been highlighted in the related literature. Laughton (1998) identifies the following problems relating to using DCF-based methods:

1. DCF methods can induce significant and systematic biases into the financial analyses that are part of the evaluation process. They may hamper long-term or strategic decision-making by discounting the future excessively, and by undervaluing the ability of project managers to respond to future contingencies.
2. DCF analysis depends critically on the choice of a project discount or hurdle rate.
3. DCF methods lead managers to consider risk in ad hoc ways through some combination of their choice of a discount rate and their opinion of the spread in valuation results across "sensitivity" scenarios.
4. DCF methods do not value flexibility that are inherent in big projects which are usually developed through a number of stages.

Miller and Park (2002) identify three main limitations to traditional DCF-based techniques:

- selecting the appropriate discount rate poses problems,
- DCF techniques ignore flexibility,
- investment decisions are typically viewed as now or never types of decisions.

Mitchell and Hamilton (1988) suggest that companies may fail to position themselves on important markets because they reject long-term risky projects that embed downstream options. The authors have distinguished three categories of investments and proposed distinct valuation tools for them. The first type is "knowledge-building investments", which are an inevitable part of the company's activity and can be treated as cost of doing business, and do not need any formal evaluation. The second category are short-term "business investments". They should be valued using discounted cash flow (DCF) methods because their parameter estimations are characterized by low uncertainty. The third category is long term, risky investments, which are called by Mitchell and Hamilton (1988) "strategic positioning investments". This type of expenditure is not a mere business investment but rather an option creation that requires an option evaluation approach.

The value of the investment project is affected by both economic and technical uncertainties. In traditional (i.e. DCF-based) analysis, investment decisions are usually treated as "now or never" opportunities operated in a planned manner until the end of their expected life. DCF and NPV analysis makes an implicit assumption concerning the expected scenarios of cash flows and assumes management's commitment to a certain strategy. In a real world, with uncertainty and competition, the realized cash flows will differ substantially from the expected ones. A rational manager makes decisions based on currently available information. As the new information arrives and uncertainty gets resolved, management can make decisions that may depart from the original strategy.

A "real options" approach to project evaluation has been suggested in a number of publications as an alternative method that avoids some of the limitations of the DCF method. This approach to project evaluation focuses on the effects of future flexibility in project management. Flexibility in the timing of decisions about the firm's capabilities and opportunities, gives managers "real options". The value of real options stems from the way they deal with uncertainty and flexibility. Real options can be used to valuate flexibility and the strategic character of the investment decisions under scrutiny. They are embedded in projects with irreversible investments, asymmetric payoff structures, uncertainty and the flexibility to act. Flexibility appears to be the crucial factor in establishing the added value of real options, as it enables management to react to changes in the environment and opens up the possibility to directly influence an option's value.

The usage of real options technique is appropriate only if there is:
- uncertainty regarding the outcome which can be limited by,
- managerial flexibility to take action during,
- totally or partially irreversible investment involving,
- asymmetric payoffs.

The value of a real option comes from both the uncertainty of the investment decision and from the decision-maker's ability to take action to make the most of the opportunities created by this uncertainty. Real options analysis aims at quantifying risk and uncertainty of investment projects and "discovering" the additional value stemming from project in-built flexibility as well as managerial opportunities to react to new information which changes the perceived risk and uncertainty. The goal of this type of analysis is to increase shareholder value through accepting projects which might be rejected based on traditional DCF-based techniques.

Real options in transportation projects

During the last decade real options method has grown in popularity in the analysis of transportation projects. Smit (2003) analyzes the decision to expand a European airport combining real options theory and games theory. Bow and Lee (2004) use real options valuation methodology to evaluate a high-speed rail project. Tibben-Lambke and Rogers (2006) propose a framework for enabling managers to extend the use of options to the future use of logistic resources. Tsai (2008) analyzes the procurement for transportation services based on real options theory. Sodal and Koekebakker (2008) derive a real options model of flexibility and applies it to shipping, valuing the option to switch between the dry bulk market and wet bulk market for a combination carrier, a type of ship that is capable of operating in both markets. Evans and Zhang (2009) apply real options analysis to evaluate an investment in a flexible manufacturing system in the automotive industry; the investment project analyzed has two phases, with the expansion investment viewed as a real extension option. The usage of real options in the automotive industry is also presented by Ford and Sobek (2005). The authors adapt real options concepts for product development management, to partially explain the so called Toyota paradox, i.e. the fact that Toyota Motor Corporation achieves the fastest development times in its industry by intentionally delaying alternative selection, a strategy termed "set-based development". Galera and Soliño (2010) use real options to value highway concessions. Hult *et al.* (2010) theorize how options are related to perceived value under the conditions of high supply chain **risk uncertainty**. Overall, their investigation builds knowledge by extending real options theory to the supply chain context and by providing evidence suggesting that some options operate differently in supply chains than they do in firms. Supply chain coordination and performance management with real options is analyzed by Johnson (2010). Negotiated, bilateral, contingent performance commitments - effectively contracts with multiple embedded real options - are shown to be necessary to convey information, incentives, and allocation of risk required to identify and execute appropriate strategies across the supply chain. Schafer and Sorensen (2010) provide a general valuation model for the optimal design of the product development process, exemplified by automobile development. Using a novel real options model the authors demonstrate that it is possible to have an optimal number of design alternatives developing in parallel. Under certain circumstances, developing multiple design alternatives in parallel is shown to generate significant value, fully justifying the increase in costs of doing so. Chow and Regan (2011) present a model to address managerial flexibility in transportation planning. According to the authors, the model can be applied to any network design problem under uncertainty. Jain and Cox (2011) examine the uncertainty of acquiring a lowest possible airfare when contemplating the purchase of a ticket. A real option model is applied to value insurance contracts that could be offered to passengers to cope with price risk. Tsai *et al.* (2011) applies concepts from the theory of real options to hedge uncertainty in transportation capacity and cost using derivative contracts, called truckload options.

Real options in revenue risk management in public-private partnerships in infrastructure projects

Prior to the economic troubles that began in 2008, the interest in public-private partnerships (PPPs) for infrastructure, and particularly highways, was substantial (Garvin and Bosso, 2008). A driver for this interest was the potential of additional private financing to address public sector budgeting shortfalls.

The success of PPP projects largely depends on effectively managing a variety of risks (li *et al.*, 2005; Ng and Loosemore, 2007). A common principle is that risks should be allocated to the party who is best able to manage them (Loosemore *et al.*, 2006). For example, the government uses its authority and jurisdiction to acquire rights of way, while the concessionaire takes the responsibility of completing the project on time and within budget. In the context of revenue risks allocated between government and concessionaire, a variety of approaches have been implemented. *Real toll projects* charge user fees to fund a project that concessionaires collect. *Shadow toll projects* allow travelers to use the facility free at the point of entry, while a concessionaire is later compensated by the government with a fixed fee per vehicle. In *availability payment* projects, the government reimburses a concessionaire with periodic payments subject to service quality. In all three types of projects, concessionaires bear some form of revenue risk, i.e. a chance of not receiving payment.

In availability payment projects, this risk is essentially budgetary appropriation risk – whether or not the government will allocate the funds necessary for payment for the contract period. In shadow toll projects, the concessionaire assumes appropriation risk and does not bear demand/traffic risk since its fees are tied to traffic volume. In real toll projects, concessionaires typically bear the full brunt of revenue risks. Within a real toll funding method, revenue risks are managed by specific concession agreement terms and financial guarantees. Every PPP real toll project has different characteristics. As a result, no single revenue risk technique applies universally.

Real toll projects with a fixed concession duration

One common approach to dealing with revenue risks in a real toll fixed-duration project, is that the concessionaire assumes the entire risk and the government does not provide any subsidy when collected revenue is not sufficient to cover upfront construction costs as well as operating and maintenance expenses. Since the concessionaire takes the full responsibility for reimbursing its expenses from project revenues and carries great credit risks, lenders may require clauses that grant them step-in rights in case of default on payments. In addition, since toll rates and demand are the major determinants of operating revenue, the concessionaire may require a non-competition clause to safeguard project revenues.

Another approach is that the government grants subsidies when the project is not expected to generate the needed level of revenue. Such subsidies are essential for certain projects to boost their financial viability. Some countries such as Chile, Korea and Spain, grant minimum revenue guarantees in exchange for sharing upside revenue. Some developed countries, for example Australia, the US and the UK use either similar guarantees or direct operating revenue subsidies. Academics have made attempts to value revenue guarantees, however up to now such a valuation is not the norm and if conducted are usually made in an unsophisticated manner.

Real toll projects with a variable concession duration

In a variable concession duration, the contract ends when certain financial targets are met. The least present value of revenue (LPVR) grants the concessionaire the right to collect tolls until the present value of the total revenue reaches an agreed level (Engel *et al.*, 2001). Alternatively, the least present value of net revenue (LPVNR) takes the duration-dependent operation and maintenance costs as the threshold parameter instead (Nombela and de Rus, 2003). In both models the uncertain duration can complicate financial planning and discount rate selection.

Options as a new revenue guarantee technique

Revenue guarantee put option

A *revenue guarantee put option* is principally another risk management technique. Revenue guarantee options have been studied as a way to enhance a project's financial viability (e.g. Ho and Liu, 2002; Garvin, 2005); Huang, Chou, 2006; Chiara *et al.*, 2007; Brandao and Saravia, 2008).

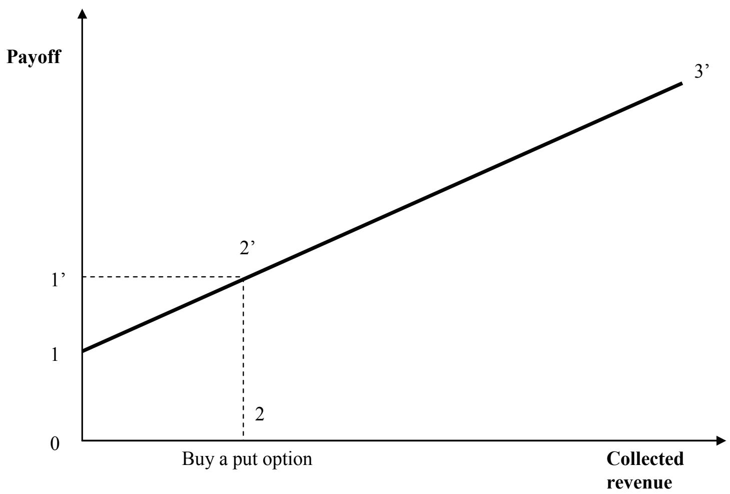

Figure 1. Concessionaire's payoff with a put option

Source: L. Shan, M. Garvin, R. Kumar: *Collar options to manage revenue risks in real toll public-private partnerships transportation projects*, "Construction Management and Economics" 2010, Vol. 28, Issue 10, p. 1059.

If implemented within a project, a revenue guarantee put option would grant a concessionaire the right, but not the obligation to claim a revenue subsidy from an option writer. The concessionaire and the underwriter choose the underlying asset, such as traffic volume or toll revenue, and negotiate the guaranteed value of the underlying asset (strike price), for example at level 2–2’ in Figure 1. In the event that the actual value of the underlying asset falls below 2–2’, the concessionaire has the right to exercise the option and claim the subsidy for the loss paid by the underwriter. If the actual value exceeds the guaranteed value, the option is out-of-the-money and expires without being exercised. Line 1–2’–3’ represents the collected toll revenue, while line 1’–2’–3’ represents the concessionaire’s actual payoff.

Revenue collar: a new type of revenue guarantee option

The major constraint of revenue guarantee options is that if it were to be priced and sold, then the concessionaire would need to pay a substantial premium to the underwriter. A concessionaire is typically unwilling to make additional payments, so the option purchase becomes an extra burden. The revenue collar option demands less or no upfront payments and, hence, becomes a potentially attractive alternative to the revenue guarantee option (Shang *et al*., 2010).

A **collar,** another type of guarantee option, is a more complex arrangement than a put option. A collar is a combination of a call and a put option. In a revenue collar, a concessionaire buys a floor (a put option) form the underwriter to receive protection against revenue below the floor, and simultaneously sells a cap (a call option) to the underwriter to defray the cost of the floor. In Figure 2 line 1–2’–3’ still represents the collected revenue, but part

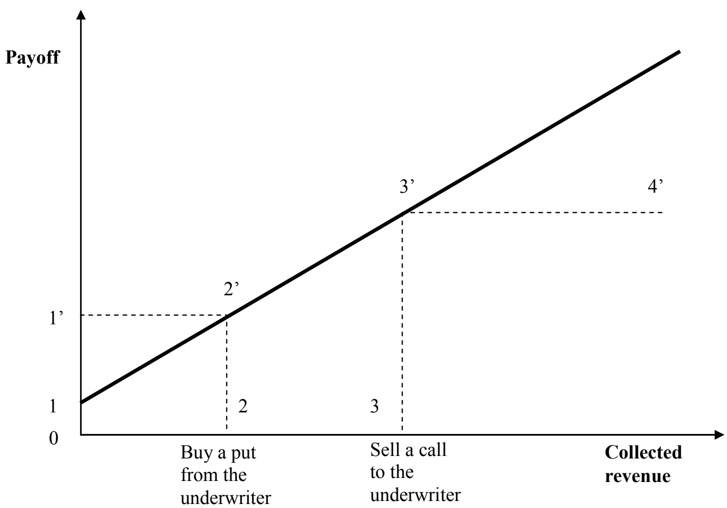

Figure 2. Concessionaire’s payoff with a zero-cost collar

Source: L. Shan, M. Garvin, R. Kumar: *op.cit.*, p. 1060.

of the concessionaire's payoff line 1'–2'–3'–4' differs from the case in Figure 1. The put option the concessionaire 'buys' secures its minimum revenue at level 2–2'. The call option it 'sells' forfeits its right to retain the excess revenue beyond level 3–3'; this excess revenue is then captured by the underwriter.

If the collar is structured in a way that the premium received from the sale of the call option, V_{call}, completely offsets the purchase price of the put option, V_{put}, the collar has zero value, and the concessionaire pays no upfront cost. This type of collar is called *a zero-cost collar.*

An *income-producing collar*, on the other hand, sets a narrower band: the call strike price is closer to the put strike price (Figure 3). The lower strike price increases the value of the call option in excess of that required to defray the put option's cost, thus generating cash equal to $V_{call} – V_{put}$. Compared to the zero-cost collar, the income-producing collar is a more conservative approach to managing the risk. Although the concessionaire gives away more potential for larger profit, it is able to harvest immediate cash rather than less predictable gains in the future. If the concessionaire is confident in the project's future profitability, the zero-cost collar is a better strategy.

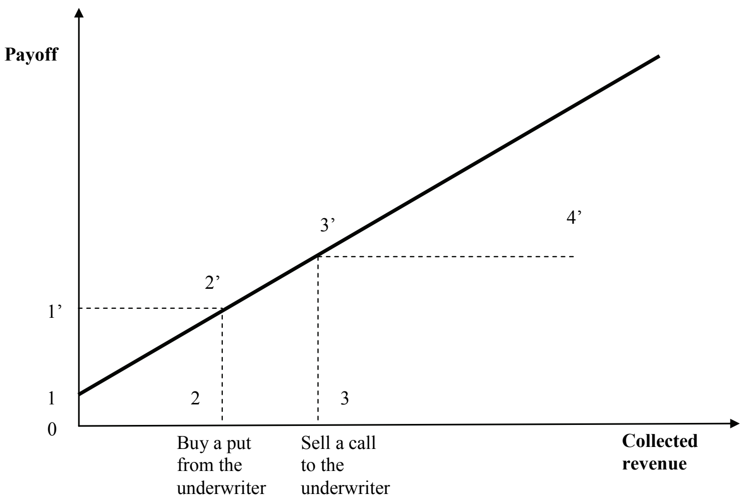

Figure 3. Concessionaire's payoff with an income-producing collar

Source: L. Shan, M. Garvin, R. Kumar: *op.cit.*, p. 1060.

A concessionaire and an underwriter maintain their interests through arranging collar option terms in a flexible manner. For example, the probability that the concessionaire will need the underwriter's coverage to fulfill debt repayment obligations is higher in a transportation project's ramp-up phase. Similarly the underwriter will expect the option duration to be long enough so that after the ramp-up phase, when traffic and revenue have stabilized, a project's cash flow is more likely to exceed the call option's threshold. Consequently, the underwriter can harvest the excess revenue to compensate it for the coverage paid earlier.

Therefore the two parties need to exercise due diligence to examine project conditions and external factors to decide whether or not to enter into the deal and subsequently determine mutually acceptable collar option terms. Factors worth consideration include: traffic projection, toll rate structure, capital expenditure plan, road capacity, demographic conditions and transportation network.

Studying these factors is necessary for assessing a collar contract's value from the concessionaire's perspective and demonstrating profits from the underwriter's perspective. The two strike prices in a collar allow for significant flexibility. By changing the values associated with the strike price band, the concessionaire can adjust the future and current cash flow to accommodate its financial needs. The different levels of the strike prices can also serve the concessionaire's risk appetite.

A major constraint of revenue guarantee put option as a means of managing revenue risks in real toll PPP transportation projects, is that it requires the concessionaire to pay the risk premium. A revenue collar can overcome this barrier. The opposite position in a put and a call option produces a collar with zero value. In addition to the removal of upfront payment, the collar is worthy of consideration for other reasons such as embedded incentives, easy early termination, flexibility and favorable tax treatment.

Real options – promises and drawbacks

Real option valuation is based upon transferring models developed for financial markets to actual investment decisions. Assessment of the value embedded in real options requires a detailed analysis of the inputs. However, the inputs required for applying option pricing techniques are quite often difficult to get or even estimate.

One of the distinguishable features of the option pricing techniques is that the future values of the underlying asset are unpredictable. Future values are assumed to follow certain defined processes and numerical techniques that try to approximate this process. A key assumption is perfect knowledge of the asset price that determines exercise policy and option value. In capital budgeting projects it is sometimes very difficult, if not impossible to identify the correct stochastic process that the underlying asset follows. However, if there are difficulties in determining the initial value of the underlying asset or difficulties in determining the parameters for the assumed diffusion process governing the behavior of the underlying asset, than the usage of an option-based model is limited.

The underlying asset

With regards to the **underlying asset**, two issues are of primary importance: the movement of the underlying through time and whether the asset is traded or not.

For movement through time, one can distinguish between discrete time and continuous time contemplation of asset price movement. If the continuous time approach is used the following processes are most frequently used to model price evolution over time:

- diffusion process (e.g. geometric Brownian motion, GBM),
- jump process (e.g. Poisson process),
- mean reverting process

or a combination of these.

One of the key issues concerning the underlying is its tradability. Financial option pricing model assumes buying and selling the underlying asset in an efficient market. Tradability makes possible the construction of a duplication portfolio. However, most real assets are not traded. Hence, certain simplifying assumptions must be made. It is then advisable to find a so called "twin security" that is perfectly or at least highly correlated with the real asset value.

Discount rate

In financial option pricing models, because of the existence of a replicating portfolio that is used to hedge all risk of the option's value, risk-free rate is used for discounting. Adoption of the same approach for real options valuation raises concerns because of non-tradability of the underlying asset. Therefore, alternative proposals concerning the discount rate are formulated in the literature.

For instance, Hull (2000) states that the following relationship must be satisfied in selecting the discount rate: $m - \lambda s = r - q$, where m is the mean return of the underlying asset, s is the standard deviation of the underlying asset, λ is the market price of risk, and q is the continuous constant dividend yield.

Other authors, while analyzing risk related to real options, highlight that these risks may be divided into private (unique to the firm) and market (tied to the economy) risks. They state that private risk will reduce the projected value, while the higher market risk will increase the projected value. The firm can hedge the market risks but cannot hedge the private risks.

Risk

Risk of the underlying is characterized by its **volatility**. Volatility of the underlying is the key parameter driving the option's value. For financial options, it can be calculated either from historical data or calculated as implied volatility from traded options. For real assets, information about historical returns usually does not exist. Hence, volatility must be estimated using a different approach. One alternative is to derive the volatility of the underlying from an analysis of the volatility of the duplicated portfolio created through spanning, provided an appropriate twin security can be identified.

Real option has a different view of uncertainty than the traditional tools of project evaluation. It identifies situations when uncertainty represents a potential for future gains rather than a risk of losses. Traditional tools "punish" the project's uncertainty through heavier discounting, whereas real option methodology views uncertainty as a source of value creation. The reason is that a maximum loss is limited to the investments in previous stages and an unlimited gain can be received as a result of follow-up investments undertaken in case the market situation improves.

Exercise price

The **exercise price** in investment projects (i.e. the present value of investment costs) may be known in advance (i.e. deterministic) or not known (i.e. stochastic). In the second case it has to be replicated by a stochastic variable in an option valuation model. The issue of stochastic exercise prices has been addressed by the closed-form equations.

Additionally, the exercise price of financial options is assumed to be one lump sum amount, whereas a real asset's exercise price can occur as a series of payments.

Exercise date

Exercise date can be known in advance or unknown. For investment projects analyzed as real options, the time to maturity is often unknown. It may for instance, depend upon the market risk resolution or upon the exercise of another real option. It is also usually much longer in duration, compared to financial options. Additionally, often real options are not exercised immediately, because it takes time to build a plant, install equipment, etc.

In the investment model, the value of the project is discounted as a consequence of the time value of money. DCF methodology sees a long time span between investment expenditures and the return on them as a major source of value decrease. Option approach views the same time span as a source of value creation. During the period for which the whole project or part of it can be deferred, new information may arrive that will provide for better investment decisions.

Dividends

With regards **to dividends** the important issues are the amount and frequency. Option pricing models in finance also differentiate between continuous and discrete dividend payments. The amount of dividend can by deterministic or stochastic. In real options valuation models, dividends (understood e.g. as cash payouts, insurance fees, licensing royalties, income lost to competition through waiting to invest) are considered a leakage of value.

The concept of real options has grown in popularity in recent years. Despite numerous theoretical publications the number of business applications of the real options concept is not impressive. The reasons for slow adoption of real options can be summed up as follows:

- the types of valuation models currently used are not well known or understood by corporate managers and practitioners,
- many of the required modeling assumptions are often and consistently violated in practical real option application,

– the necessary additional assumptions required for mathematical tractability limit the scope of applicability.

Another shortcoming for most real option models is that they do not take into account the effects of competition.

Literature

Bowe M., Lee D.: *Project evaluation in the presence of multiple embedded real options: evidence from the Taiwan High-Speed Rail Project*, "Journal of Asian Economics". 2004, Vol. 15, Issue 1: 71–98.

Cow J., Regan A.: *Real option pricing of network design investments*, "Transportation Science" 2011, Vol. 45, Issue 1: 50–63.

Evans J, Zhang D.: *Real options evaluation of financial investment in flexible manufacturing systems in the automotive industry*, "International Journal of Automotive Technology and Management" 2009, Vol. 9, Issue 3: 275–289.

Ford D., Sobek D.: *Adapting Real Options to New Product Development by Modeling the Second Toyota Paradox*, "IEEE Transactions on Engineering Management" 2005, Vol. 52, Issue 2: 175–185.

Galera A., Soliño, A.: *A Real Options Approach for the Valuation of Highway Concessions*, "Transportation Science" 2010, Vol. 44, Issue 3: 416–427.

Hult G., Craighead T., Ketchen D.: *Risk uncertainty and supply chain decisions*, "Decision Sciences" 2010, Vol. 41, Issue 3: 435–458.

Jain A., Cox R.: *Airfare price insurance: a real option model*, "Journal of Financial risk" 2011, Vol. 12, Issue 1: 5–14.

Johnson B.: *Supply chain coordination and performance management with real options*, "Multinational Finance Journal" 2010, Vol. 14, Issue 1: 29–64.

Lander D., Pinches G.: *Challenges to the practical implementation of modeling and valuing real options*, "The Quarterly Review of Economics and Finance" 1998, Vol. 38, Special Issue: 537–567.

Laughton D.: *The potential use for modern asset pricing methods for upstream petroleum project evaluation: Introductory remarks*, "Energy Journal" 1998, Vol. 1, Issue 1: 1–9.

Kaluza B., Blecker T., Bischof C.: *Strategic Management in Converging Industries*, Discussion Paper No. 9803, University of Klagenfurt, Klagenfurt 1993.

Miller L., Park C.: *Decision making under uncertainty – Real Options to the rescue?*, "The Engineering Economist" 2002, Vol. 47, Issue 2: 105–145.

Mitchell G., Hamilton W.: *Managing R&D as a strategic option*, "Research and Technology Management" 1988, Vol. 31, Issue 3: 15–22.

Shan L., Garvin M., Kumar R.: *Collar options to manage revenue risks in real toll public-private partnerships transportation projects*, "Construction Management and Economics" 2010, Vol. 28, Issue 10: 1057–1069.

Schafer S., Sorensen D.: *Creating options while designing prototypes: value management in the automobile industry*, "Journal of Manufacturing Technology Development" 2010, Vol. 21, Issue 6: 721–742.

Smit H.: *Infrastructure Investment as a real options game: The case of European airport expansion*, "Financial Management" 2003, Vol. 32, Issue 4: 27–57.

Sodal S., Koekebakker S.: *Market switching in shipping – A real option model applied to the valuation of combination carriers*, "Review of Financial Economics" 2008, Vol. 17, Issue 3: 183–203.

Tibben-Lambke R., Rogers D.: *Real options: application to logistics and transportation*, "International Journal of Physical Distribution and Logistics Management" 2006, Vol. 36, Issue 4: 252–270.

Trigeorgis L.: *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, Cambridge, MA, MIT Press 2007.

Tsai M.: *Real option-based procurement for transportation services*, Ph.D. Thesis, UCLA, California 2008: 1–128.

Tsai M., Saphores J., Regan A.: *Valuation of freight transportation contracts under uncertainty*, "Transportation Research" 2011, Part E, Vol. 47, Issue 6: 920–932.

Upton D.: *The management of manufacturing flexibility*, "California Management Review" 1994, Vol. 36, Issue 2: 72–89.

dr hab. Włodzimierz Rudny
Uniwersytet Ekonomiczny w Katowicach

Summary

Real options have become an increasingly popular tool for valuation and risk management in investment project analysis. They give an ability to value managerial flexibility and help in project risk mitigation either through highlighting the desired sequencing of the project or through the generation of compensating cash flows. Real options are considered an alternative or a supplement to traditional methods of project evaluation based on discounting expected cash flows.

Numerous publications recommend the application of real options in transportation projects. This includes PPP highway projects where option-based tools are used to hedge against the risk of low revenue. The collar option appears to be an attractive alternative to the earlier recommended revenue guarantee put options.

Despite numerous theoretical works, the actual usage of real options in business practice is still limited. This is due to some factors, like the mathematical complexity of real option models and problems with the precise determination of variables which serve as valuation model inputs.

ELASTYCZNOŚĆ MENEDŻERSKA I ZARZĄDZANIE RYZYKIEM W PROJEKTACH INWESTYCYJNYCH W TRANSPORCIE WYKORZYSTANIEM OPCJI REALNYCH

Streszczenie

Opcje realne stopniowo zyskują na popularności jako narzędzie wyceny i narzędzie redukcji ryzyka projektów inwestycyjnych. Pozwalają na wycenę elastyczności menedżerskiej oraz wycenę ryzyka uwzględniającą sekwencyjność dużych przedsięwzięć. Metoda opcji rzeczowych traktowana jest jako alternatywa dla, lub uzupełnienie, metod oceny efektywności opartych na dyskontowaniu oczekiwanych przepływów pieniężnych.

Rośnie liczba publikacji poświęconych możliwości aplikacji opcji realnych w inwestycjach w branży transportu i komunikacji. Jedną z dobrze udokumentowanych aplikacji jest zastosowanie opcji gwarancji dochodu w projektach budowy autostrad w ramach partnerstwa publiczno-prywatnego.

Rozwój teorii opcji realnych nie idzie w parze ze wzrostem aplikacji tej koncepcji praktyce. Wśród przyczyn takiego rzeczy wymienia się m. in. złożoność modeli matematycznych wykorzystywanych do wyceny opcji oraz brak pełnej kompatybilności między zmiennymi wykorzystywanymi w modelach wyceny opcji finansowych, a ich odpowiednikami w modelach wyceny opcji realnych.