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REAL OPTIONS METHODOLOGY IN PUBLIC-PRIVATE PARTNERSHIP PROJECTS VALUATION***

ABSTRACT: *PPP offers numerous benefits to both public and private partners in delivery of infrastructure projects. However this partnership also involves great risks which have to be adequately managed and mitigated. Private partners are especially sensitive to revenue risk, since they are mostly interested in the financial viability of the project. Thus they often expect public partners to provide some kind of risk-sharing mechanism in the form of Minimum Revenue Guarantees or abandonment options. The objective of this paper is to investigate whether the real option of abandoning the project increases its value. Therefore the binominal option pricing model and risk-neutral probability approach have been implemented to price the European and American abandonment options for the Build-Operate-Transfer (BOT) toll road investment. The obtained results suggest that the project value with the American abandonment option is greater than with the European abandonment option, hence implying that American options offer greater flexibility and are more valuable for private partners.*

KEY WORDS: *public-private partnership projects, real options, abandonment option*

JEL CLASSIFICATION: G31, H44, H54

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1. INTRODUCTION

During the last few decades researchers and practitioners have paid a lot of attention to the concept of public-private partnership (PPP). It is usually defined as the "cooperation between public and private participants of a permanent nature, in which participants develop mutual products and/or services with shared risk, expenses and profit" (Rakic and Radjenovic, 2011, p. 209). The main reason for the great interest in this kind of cooperation is that many governments obtain the necessary funds for financing fundamental infrastructure projects by resorting to partnerships with the private sector. The number of PPP projects and countries using this form of cooperation has been growing rapidly since the beginning of the 21st century. The current public debt crisis has put additional emphasis on partnership with the private sector as it provides public budget relief and meets public needs. Therefore developing and emerging countries see in PPPs the potential for developing infrastructure and augmenting economic growth.

PPP can offer numerous benefits to public-private partners and the whole community in the delivery of public services and realisation of public projects, compared to traditional public procurement. When choosing to realise public projects through PPP, public partners seek to determine whether this will enhance the efficiency of the public sector and whether these projects offer better value for tax payers' money as compared to traditional state investment; i.e., the public partners are oriented toward achieving socio-economic and political benefits. Clearly, they want to ensure that the project with the private partner provides cost-efficient, reliable, and on-time services at the agreed price and in accordance with the arranged quality standards, as defined by the contract (Grimsey and Lewis, 2005). This effectively means that the PPP project has to be cost-efficient, and this is what the public sector is mostly interested in. On the other hand, the private sector is mainly interested in the long-term financial benefits that come from the partnership.

Although driven by different objectives, they can jointly reach these objectives via the mutual aim of delivering a successful project. The realisation of the objectives through PPP projects implies huge risks that have to be properly allocated and managed by both of the involved parties. Adequate allocation of risk in PPP projects is a crucial factor in their success and it is widely accepted that risk should be allocated to the party best able to manage that risk. That is, “the goal is not to maximize, but optimize risk transfer” (Carbonara et al., 2011, p. 1).

A possible way to manage and alleviate risk is through incorporating flexibility into PPP contracts by adding special clauses that can diminish risk by, for instance, modifying the order and time of activities. The Real Option approach can be used to model this contractual flexibility. It can be applied both to mitigating risk and to evaluating managerial flexibility, which increases the value of the project by enabling project managers to change their decisions depending on the project’s future performance.

In addition to real option methodology other valuation methodologies can also be applied to PPP projects, such as expert systems and statistical analysis, game theory, and artificial neural networks; but in this paper we will focus only on Real Option Analysis (ROA) and previous research concerning its application in the valuation of PPP projects.[1] Additionally, we will present a numerical example of a toll road investment with the option to abandon.

2. REAL OPTION THEORY

The simple reasoning for real options is presented in Brealey and Myers (2003, p. 268) as follows: “When you use discounted cash flow (DCF) to value a project, you implicitly assume that all assets are held passively. But managers are not paid to be dummies. After they have invested in a new project, they do not simply sit back and watch the future unfold. If things go well, the project may be expanded, if they go badly, the project may be cut back or abandoned altogether. Projects that can easily be modified in these ways are more valuable than those that do not provide such flexibility… Options to modify projects are known as real options”.

Real option theory is an extension of financial option theory to real assets and projects. Myers (1977) initially proposed the term ‘real option’ for the employment of option pricing theory and methods from finance for valuation of

[1] For details of the mentioned valuation methodologies see Apanavičienė and Rudžianskaitė Kvaraciejienė (2010).

investment in non-financial assets. Since the mid-1990s academics and practitioners have paid a lot of attention to this technique as an important tool for investment valuation and strategy (Borison, 2005). This is especially due to the fact that the traditional Net Present Value (NPV) approach to valuing investment projects has demonstrated numerous drawbacks.[2]

Similar to financial options - which give the holder the right, but not the obligation, to buy or sell a security at a predetermined price on a specific date - a real option gives the holder the right to take decisions concerning an asset or a project at a predetermined price or pre-specified time over the life of the option (Lawrence and Thomas, 2008, p. 3). ROA enables project managers to increase project value by detecting and exploiting opportunities for minimising losses and maximising gains in a dynamic market environment. Further, ROA deduces terminology from financial options, meaning that real option value is a function of the variables presented in Table 1.

Table 1. Comparison of real and financial options

Variable	Financial option	Real option
S	Value of the underlying risky asset	Expected cash flows from the project – value of the project
X	Exercise price	Investment costs
T	Time to maturity	Time to maturity
σ	Volatility of the underlying risky asset	Volatility in the expected cash flows from the project
r	Risk-free interest rate	Risk-free interest rate

Source: Authors' presentation based on Lee (2011, p. 6) and Lawrence and Thomas (2008, p. 3)

The option value is linked to project uncertainty. Unlike DCF analysis, in which the investment value depreciates with the volatility increase, ROA attempts to find and value the managerial flexibility in the project; i.e., the embedded option (Lee, 2011). Real options must be identified before they can be valued. Copeland and Antikarov (2003) designed a four-step model which is widely used by

[2] For details about problems with the NPV approach see Radjenovic (2008, pp. 83-84).

researchers and practitioners in identifying and valuing real options in projects. The four steps are:

- calculation of the NPV of the project without flexibility;
- usage of an event tree to model uncertainties;
- usage of a decision tree to identify and integrate possible managerial flexibility;
- calculation of the new value of the project with and without managerial flexibility; that is, the total project value and the option value.

There are two types of options, call options and put options. A call option gives the holder the right to buy the real asset if its price is above the predetermined level (exercise price) at a pre-specified date in the future (expiration date). A put option gives the right to sell the asset if the price falls below the exercise price in the future. An option becomes more valuable when it is closer to its exercise price. The value of the call option *C* is given in Equation 1, while the value of the put option *P* is presented in Equation 2 (Mun, 2002). European options can be exercised only at maturity, while American options can be exercised at any time before maturity.

$$C = MAX[S - X, 0] \tag{1}$$

$$P = MAX[X - S, 0] \tag{2}$$

There are numerous option types: expansion options, abandonment options, deferral options, options to contract, options to switch, compound options, etc. (Hull, 2006; Kulatilaka and Trigeorgis, 2001; Trigeorgis, 1996; Trigeorgis and Mason, 2001). All these option types take into account managerial flexibility to alter the project or asset in order to respond to changing market conditions. In the case of an abandonment option, management can decide to dispose of an asset for salvage value once market conditions turn unfavourable. Basically, the option to abandon is a put option that enables hedging against an economic downturn (Brach, 2003, p. 80). On the other hand, the option to expand is a call option that enables managers to take advantage of favourable market conditions; for instance, by expanding the capacity of the asset to meet the increasing demand.

ROT may be applied to a wide range of projects such as infrastructure projects, projects orientated toward exploitation of natural resources, research and development projects, developing and testing new drugs and technologies, expanding existing projects, entering into new marketplaces, etc.

In the context of infrastructure investment, for instance, a toll road investment, when revenues are lower or higher than expected, real options can offer the flexibility to avoid possible losses or exploit extra profit. The PPP contract can have a clause that enables private partners to exercise an abandonment option and sell the project to public partners for salvage value when revenue streams are lower than anticipated, thus increasing the market value of the project. Contrary, the PPP contract can have a clause that enables public partners to have the same managerial flexibility when revenue streams are higher than expected, i.e., they can exercise the option and redeem the project to their ownership from the private partners.

Before proceeding to the quantitative valuation of real options, we will discuss the findings of previous research.

3. LITERATURE REVIEW

There are numerous theoretical and empirical studies that deal with ROA in PPP projects, concerning both risk mitigation strategies and managerial flexibility vis-a-vis investment decisions. When considering risk mitigation strategies the studies are mostly orientated toward revenue risk.

Revenue risk is common to almost every PPP project because of the long contract duration – usually 20 to 30 years. Revenue risk is the risk that the project will result in insufficient cash flows to cover the project costs, service debt obligations, and provide the expected return on investment. A widely used strategy to mitigate revenue risk is a government Minimum Revenue Guarantee (MRG) where "government guarantees that project revenue will not fall below a specified limit during the contract" (Ali et al., 2012, p. 1600). This strategy is of special interest to the private investors, as their involvement depends on the project's financial viability (Chiara, 2006).

According to Ali et al. (2012), a PPP contract between a government and private investors that has a MRG clause should be flexible enough to encourage development of the infrastructure project in multiple stages. Development of a PPP project in multiple stages considerably reduces the value of the guarantee clause in a MRG contract, thus decreasing the risk retained by the government.

Chiara (2006) proposed a new valuation framework for mitigating revenue risk in the operational phase of a Build-Operate-Transfer (BOT) project. In his study three risk-mitigation BOT contracts are endorsed and implemented as multiple-exercise real options valued by Multi-Least Squares Monte Carlo method (MLSM) and Multi-Exercise Boundary method (MEB), which represent the combination of dynamic programming techniques and Monte Carlo simulation. The results highlight the importance of these methods in the assessment and allocation of risk in BOT projects.

Ho and Liu (2002) developed the BOT option valuation model in order to evaluate the impact of government guarantees and negotiation options on the financial viability of privatized infrastructure projects, and concluded that their model is a good foundation in the financial evaluation of PPP projects.

Lee (2011) investigated project value by using the DCF method and the ROA approach and compared project values when MRG and abandonment options were considered. His findings suggest that the project value is enhanced by government guarantees, since the project is safer and thus more favourable to the concessionaire. Additionally, if the government raises the MRG or coverage ratio of the abandonment option, the value of the project will be increased. Furthermore, volatility is proven to be quite valuable, since highly uncertain projects with government guarantees are more valuable than less uncertain projects.

Similarly, Huang and Chou (2006) applied ROA to value the MRG and the option to abandon in BOT projects. The obtained results suggest that both MRG and the abandonment option can create value, but when they are combined they counteract each other and their values are reduced.

Vajdić and Damnjanović (2011) developed a valuation method for pricing the buyback option as a risk mitigation strategy. This option enables public partners to buyback the project from the private partners when revenues are higher than anticipated. The proposed model employs the expected value of the project as the underlying asset in the option pricing (European call). However, their model has limitations, as it includes neither future operational and maintenance costs for the public sector nor remaining project debt.

Kashani (2012) proposed a market-based risk-neutral option valuation model in order to adequately capture the traffic demand uncertainty and determine the fair value of MRG and Traffic Revenue Cap[3] (TRC) options in BOT projects. His findings confirm that an increase in traffic volatility increases the uncertainty of future project revenues, thus leading to project underperformance and, in turn, to a negative value of the concessionaire investment. Additionally, as the BOT project progresses, the risk of underestimation of future traffic demand increases. The study also confirms that MRG is valuable in situations where private sector investment in infrastructure projects is reduced due to the high levels of traffic demand uncertainty. Furthermore, the study demonstrates that TRC "can be an effective mechanism for sharing the 'upside' potential between the concessionaires and the government by splitting the surplus revenue resulting from excessive growth of the traffic demand beyond the anticipated levels" (Kashani, 2012, p. 154). Therefore the suggested model can be a helpful tool for private and public partners to better analyse and understand the financial risk of BOT projects under traffic demand uncertainty.

These findings are in line with Ashuri et al. (2010), who investigated the significance of traffic revenue volatility in BOT projects and concluded that MRG and TRC can serve as viable risk-revenue-sharing mechanisms in these projects. The proposed model is proven valuable to both public and private partners, since private partners can decide whether to invest in the project based on the risk level, offered guarantees, and anticipated costs, while public partners can identify the optimal level of MRG and TRC thresholds in order to avoid underinvestment or overinvestment in BOT projects.

[3] Traffic Revenue Cap is a mechanism between public and private partners to share the surplus revenue when traffic demand significantly exceeds projected levels

In order to enhance traditional project evaluation, Garvin and Cheah (2004) proposed the application of an option pricing model for capturing the strategic value hidden in the flexibility to defer infrastructure projects. After applying the proposed valuation model to value a deferral option for the Dulles Greenway project, they concluded that ignoring its value would grossly underestimate the potential value of the project, since the option value was huge.

Ford et al. (2002) suggested that a real options approach should be used in order to exploit strategic flexibility by identifying and capturing project values hidden in dynamic uncertainties. The obtained results, based on the toll road project, demonstrated that using the structured real options approach in construction management can increase returns through improved project planning and management.

Van der Velde (2010) presented the project feasibility analysis model, developed to identify relations concerning the financial or strategic aims of the public and private partners and their commitment to the organisation of the project. His results propose that ROA can be used for PPP projects, but their strategic use is far more valuable than their functional use. His findings indicate that, given that the ROA process consists of the identification, manageability, and value of uncertainty, the first two parts of the ROA can be used for PPP projects, while the value is difficult to determine. Nevertheless, he suggests the strategic use of real options and concludes that the value of every PPP project increases when ROA is used.

As we can see from the above discussion, the number of studies concerning ROA applicability in PPP projects is vast, and while some only propose and develop theoretical models, others are focused on practical examples, mostly in BOT projects. Thus, before presenting a numerical example of toll road investment, we will explain the methodology applied.

4. OPTION VALUATION METHODOLOGY

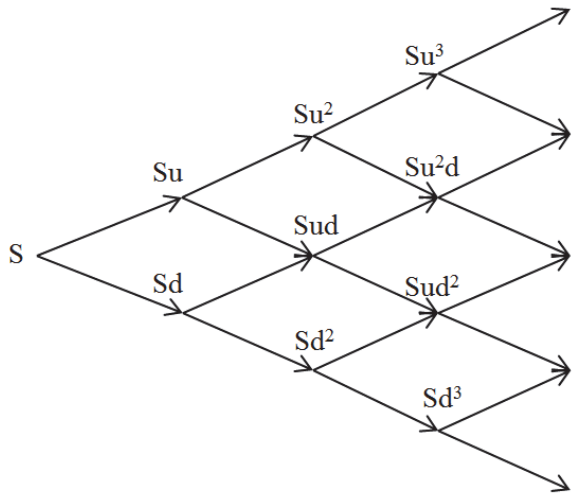
According to Mun (2002), numerous option pricing methodologies can be applied to the valuation of real options, such as the Black-Scholes model, Monte Carlo path-dependent simulation methods, lattices (binominal, trinomial, multinomial), variance reduction, and other numerical techniques. All these approaches have the same goal: to determine every possible value for the underlying at maturity, then calculate the option payoff at maturity by applying the probabilities of these possible future values, and finally to determine the actual option value by computing the present value of this probability weighted option payoffs (De Maeseneire, 2006). However, certain methods are not sufficiently flexible to reflect all features of complex real-world projects. The binomial valuation method is one of the more flexible option pricing models and is probably the most suitable model for valuing investment with high uncertainty (Radjenovic, 2008). This model offers significant benefits over other option pricing methodologies because it is easy to implement and explain, although it requires significant computing power.

The binomial option pricing model is a discrete model, which was first developed by Cox, Ross and Rubinstein in 1979. This model offers almost the same results as the continuous Black-Scholes Model, but it is simpler to derive and understand. The binominal option pricing model is based on scenario analysis and a binominal tree for valuing options. The result can be obtained in two ways: by applying the replicating portfolio approach or the risk-neutral probabilities approach.

The main assumptions of the replicating portfolio approach are no arbitrage opportunities, and the existence of a number of market-traded assets that can be acquired to replicate the existing asset's payoff profile (Liu, 2006). However, according to Mun (2002), these assumptions are hard to accept in a real options world where specific projects are valued. Contrary, the risk-neutral probability approach uses risk-adjusted probabilities of specific cash flows and discounts them at a risk-free rate. The results obtained by these two approaches are identical, but the advantage of the risk-neutral probability approach over the replicating portfolio approach is that the values of risk-neutral probabilities do not change as we move from node to node, which is not the case with units of underlying (N) and bonds (B) in the replicating portfolio method (Copeland and Antikarov, 2003). Thus, in this study the risk-neutral probability approach will be applied.

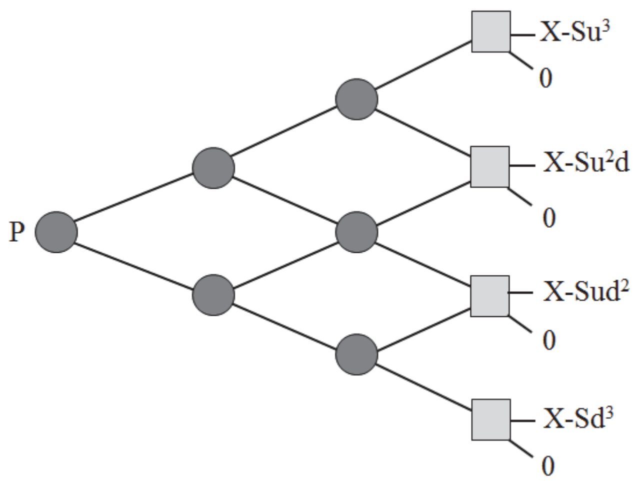
The binomial option pricing model is based on a simple formulation for the underlying asset value process, in which the underlying asset can move to only one of two possible values in any time period: up (u) or down (d) (Song, 2006). This model has two lattices: the underlying asset value lattice (Figure 1) and the option value lattice (Figure 2 and Figure 3).

Figure 1. Binominal Lattice for the Underlying Asset Value



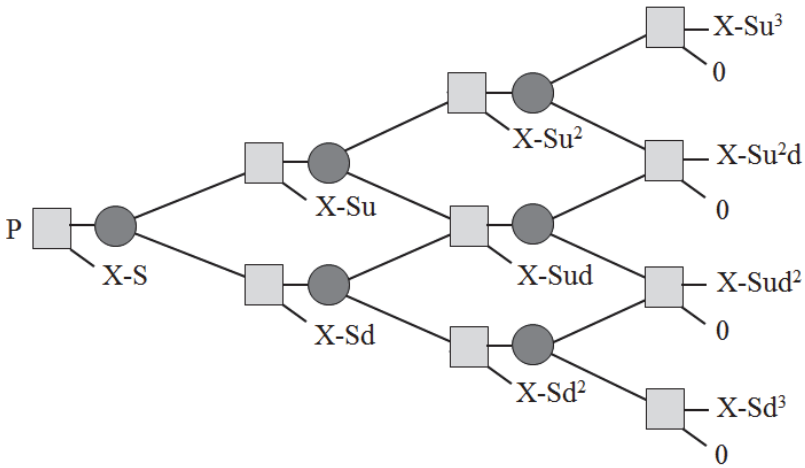
Source: Authors' presentation based on Mun (2002, p. 145)

Figure 2. Binominal Lattice for the European Put Option



Source: Authors' presentation based on Song (2006, p. 35)

Figure 3. Binominal Lattice for the American Put Option



Source: Authors' presentation based on Song (2006, p. 35)

The binominal approach requires two steps: estimation of the risk-neutral probability and determination of the option value. In order to calculate the option value the variables presented in Table 1 are required. These variables are used to determine risk-neutral probability *p*. In order to calculate the upside and downside movement, risk-neutral probability, and, finally, option value, it is important to know the volatility of the value of the underlying asset (σ) and time steps between nodes (*h*), since (Hull, 2006):

$$u = e^{\sigma h} \tag{3}$$

$$d = \frac{1}{u} \tag{4}$$

$$p = \frac{e^{rh} - d}{u - d} \tag{5}$$

$$V = \frac{pV^{+} + (1 - p)V^{-}}{e^{rh}} \tag{6}$$

The starting point in the binominal lattice is the present value of the future cash flows. The upside and downside movements are return values that the underlying can have at maturity. The upside potential is an increase of the present value of the underlying, while the downside potential is a possible loss of the value of the underlying. Hence, this up and down uncertainty creates the value in an option. If volatility increases, these up and down factors are higher, as well as the option value.

$$eNPV = NPV + Options\ Value \qquad (7)$$

Finally, the expanded net present value (eNPV) shown in equation (7) is "the sum of the deterministic base case net present value and the strategic options value" (Mun, 2002, p. 168). This eNPV takes into account both the NPV of the project and the added value of flexibility to execute the strategic option embedded in the project.

5. THE OPTION TO ABANDON A TOLL ROAD INVESTMENT

Toll road investments are usually realised through BOT projects. BOT is a form of PPP model in which private partners are responsible for the financing, construction, and operation of a facility for the contract period, during which they collect revenues in the form of user charges (Rakić, 2011). Since these projects usually last 25 to 40 years they are exposed to various risks. The successful delivery of BOT investment projects implies the efficient mitigation of those risks. Private partners are especially sensitive to revenue risk, so they often expect the public partner to offer some kind of risk-sharing mechanism.

In order to alleviate project risks the public partner may offer the private partner the possibility of abandoning the project and transferring it back to the public sector for a specific predetermined price (exercise price), or selling it to a third party in the market. Consequently, the BOT project becomes safer and more favourable from the private partner's perspective. The private partner will liquidate the project when "the exercise price is greater than the present value of cash flow in case private partner hold the project" (Lee, 2011, p. 15), meaning that this embedded option increases project value.

Specifically, the private partner can have either a European abandonment option or an American abandonment option. While the European option can be exercised only at a specific date, the American option can be exercised at any date during a specified period. Since the American abandonment option offers greater managerial flexibility it is assumed that it creates greater value for the project. Therefore the following hypotheses will be tested:

H_0: The value of the project with a European abandonment option is smaller than the value of the project with an American abandonment option.
H_1: The value of the project with a European abandonment option is greater than the value of the project with an American abandonment option.

To test these hypotheses we employ the binomial option pricing model to evaluate European and American abandonment options. In order to determine the value of these put options we present an illustrative example of a toll road investment.

Suppose that the present value of future cash flows from the toll road investment is €100 million. The volatility is ±30% per annum. The risk-free rate is 5%. The public partner offers the private partner the possibility of abandoning the project in the first 5 years of the project life only, for the salvage value of €80 million. Based on these parameters we can calculate the upward and downward movements, as well as the risk-neutral probability, by applying equations 3, 4, and 5:

$$u = e^{\sigma h} = e^{0.30*1} = 1.35$$

$$d = \frac{1}{u} = \frac{1}{1.35} = 0.74$$

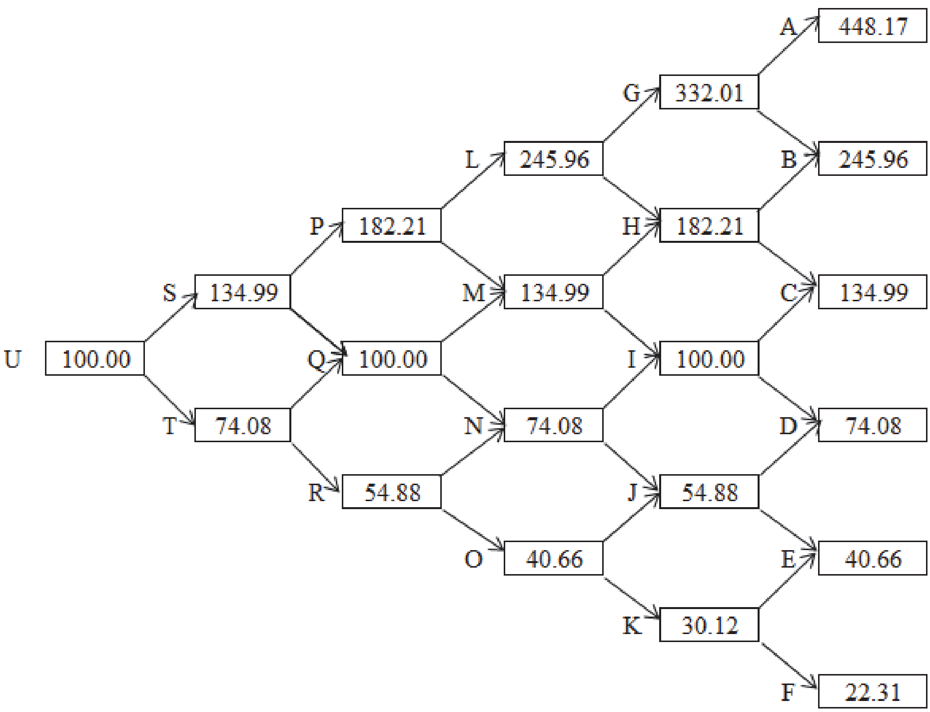
$$p = \frac{e^{rh} - d}{u - d} = \frac{e^{0.05*1} - 0.74}{1.35 - 0.74} = 0.51$$

The binominal lattice for the underlying project value (Figure 4) is calculated based on the formulas presented in Figure 1, but extended to incorporate a 5-period project value. All calculations are done using Microsoft Excel spreadsheets.

After calculating the value of the underlying asset, we proceed with the calculation for the European put option, which can only be exercised in the fifth year (Figure 5). The end payoffs of the project with flexibility to abandon at each six terminal nodes A, B, C, D, E, and F, are:

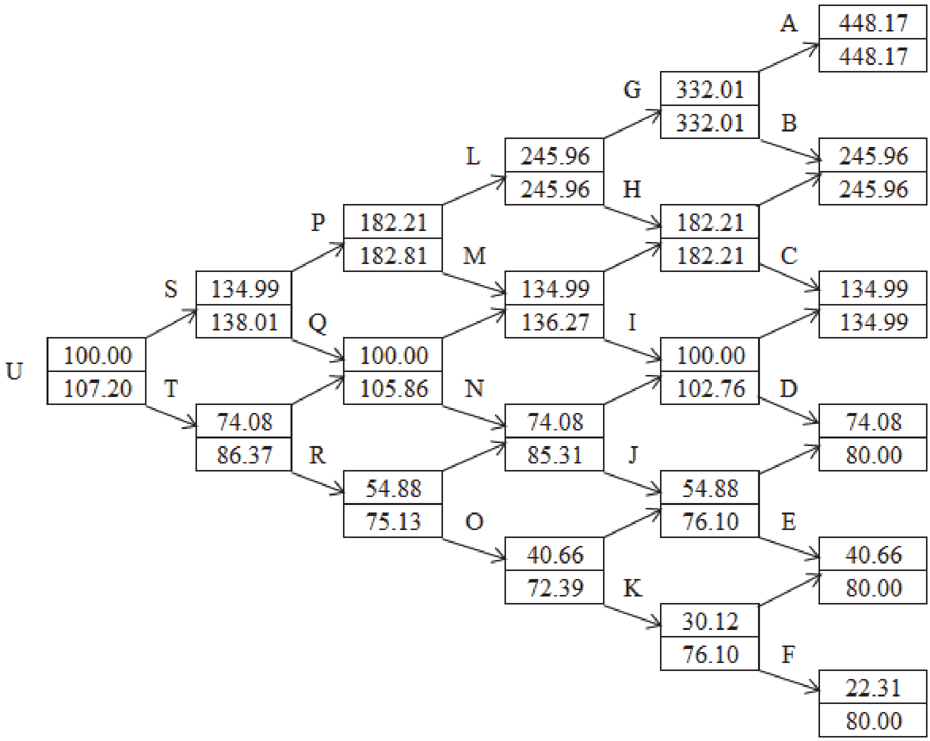
A: *MAX* [X, V] = *MAX* [80, 448.17] = 448.17
B: *MAX* [X, V] = *MAX* [80, 245.96] = 245.96
C: *MAX* [X, V] = *MAX* [80, 134.99] = 134.99
D: *MAX* [X, V] = *MAX* [80, 74.08] = 80
E: *MAX* [X, V] = *MAX* [80, 40.06] = 80
F: *MAX* [X, V] = *MAX* [80, 22.31] = 80

Figure 4. Value of the underlying project



Source: Authors’ calculation

Figure 5. Value of the project with European abandonment option



Source: Authors' calculation

Values of other nodes are calculated by employing formula 6 all the way back to node U, in the following mode:

$$\text{G:}\ \frac{pA+(1-p)B}{e^{rh}}=\frac{0.51*448.17+0.49*245.96}{e^{0.05*1}}=332.01$$

$$\text{H:}\ \frac{pB+(1-p)C}{e^{rh}}=\frac{0.51*245.96+0.49*134.99}{e^{0.05*1}}=182.21$$

$$\text{I:}\ \frac{pC+(1-p)D}{e^{rh}}=\frac{0.51*134.99+0.49*80}{e^{0.05*1}}=102.76$$

$$\text{J:}\ \frac{pD+(1-p)E}{e^{rh}}=\frac{0.51*80+0.49*80}{e^{0.05*1}}=76.10$$

K: $\frac{pE+(1-p)F}{e^{rh}}=\frac{0.51*80+0.49*80}{e^{0.05*1}}=76.10$

U: $\frac{pS+(1-p)T}{e^{rh}}=\frac{0.51*138.01+0.49*86.37}{e^{0.05*1}}=107.20$

Thus, the value of the European abandonment option represents the value of the project with flexibility minus the value of the project without flexibility, that is:

European abandonment option = 107.20 – 100 = €7.20 million.

In order to test our hypothesis we calculate the value of the American abandonment option as well (Figure 6). This option can be exercised in the fifth year or at any time before that. Hence, the end payoffs (nodes A, B, C, D, E, and F) in the fifth year are the same as for the European put and are calculated in the same way.

The values of the intermediate nodes are calculated all the way back to node U in the following mode:

G: MAX [X; $\frac{pA+(1-p)B}{e^{rh}}$] = MAX [80; $\frac{0.51*448.17+0.49*245.96}{e^{0.05*1}}$] = 332.01

H: MAX [X; $\frac{pB+(1-p)C}{e^{rh}}$] = MAX [80; $\frac{0.51*245.96+0.49*134.99}{e^{0.05*1}}$] = 182.21

I: MAX [X; $\frac{pC+(1-p)D}{e^{rh}}$] = MAX [80; $\frac{0.51*134.99+0.49*80}{e^{0.05*1}}$] = 102.76

J: MAX [X; $\frac{pD+(1-p)E}{e^{rh}}$] = MAX [80; $\frac{0.51*80+0.49*80}{e^{0.05*1}}$] = 80

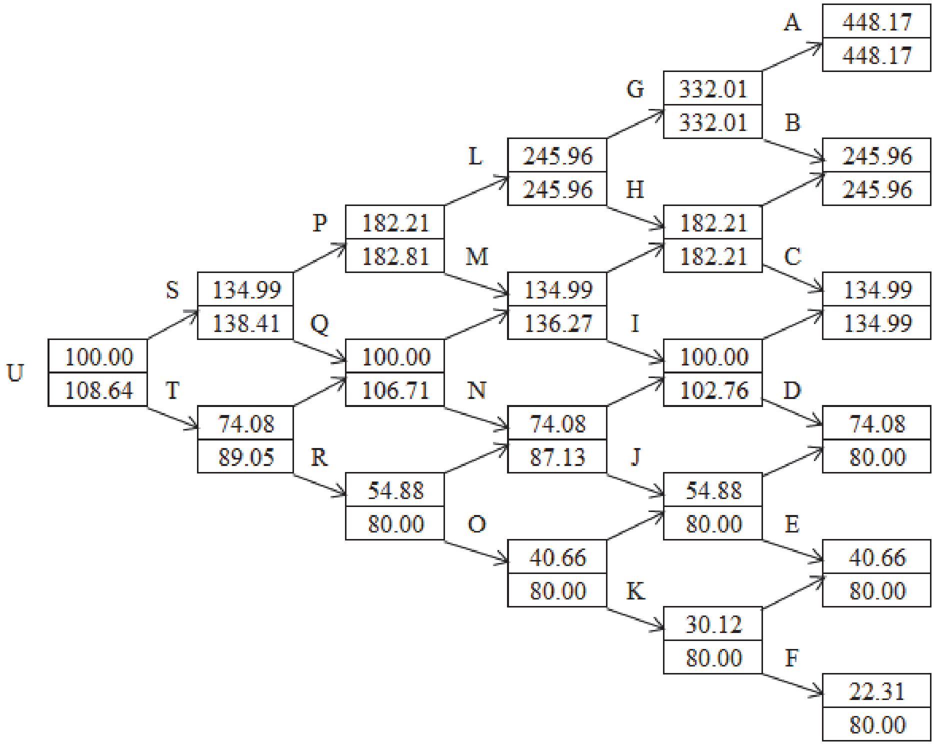
K: MAX [X; $\frac{pE+(1-p)F}{e^{rh}}$] = MAX [80; $\frac{0.51*80+0.49*80}{e^{0.05*1}}$] = 80

U: MAX [X; $\frac{pS+(1-p)T}{e^{rh}}$] = MAX [80; $\frac{0.51*138.41+0.49*89.05}{e^{0.05*1}}$] = 108.64

The logic behind these calculations in each node is that the private partner is willing to abandon the project, i.e., sell the project, at the predetermined value of

€80 million in those nodes where this value is above the value of continuing with the project. In node D (Figure 6) the value of abandoning the project is €80 million as compared to €74.08 million: hence in this node the decision of the private partner is to abandon the project, and the profit-maximizing value of node D becomes the abandonment value of €80 million.

Figure 6. Value of the project with American abandonment option



Source: Authors' calculation

Hence, the value of the American put option is:

American abandonment option = 108.64 – 100 = €8.64 million.

Based on the obtained results we can accept the null hypothesis that the value of the project with the European abandonment option is smaller than the value of the project with the American abandonment option; i.e., 107.20 < 108.64. The possibility of exercising the put option within the 5-year period is €1.44 million more valuable than the possibility of exercising the option in the fifth year only. Hence, those contracts which offer greater flexibility are more valuable for private partners.

In the previous example we have used only five time steps, each one-year long, although we could apply twenty or thirty just by reducing their length. The accuracy of the results is increased by increasing the number of time steps. Thus the obtained results can be viewed only as an approximation of the option value and should be taken with caution.

Furthermore, one of the most important inputs for the option valuation is the volatility, which we assumed to be constant over the project life. But volatility is used to measure the uncertainty of the investment value over time, and when transportation infrastructure projects are in question the volatility is difficult to estimate due to the project uniqueness and the nonexistence of historical data regarding the market price of transportation projects. Additionally, the volatility may not be constant during the life of the option, thus making the option valuation even more difficult.

6. CONCLUSION

PPP has become widely used to deliver vital infrastructure projects for which there are insufficient funds in public sector budgets. But this cooperation implies huge risks, which have to be adequately managed and mitigated. Because private partners are mostly concerned with the financial feasibility of the project they are especially sensitive to revenue risk. In order to alleviate this risk, public partners offer private partners numerous risk mitigation strategies such as MRG, TRC, and abandonment options, thus providing them flexibility to decide upon their investments during the project life. The ROA approach was introduced because traditional approaches to valuing investment opportunities do not consider managerial flexibility to revise decisions in the future.

ROA enables project managers to increase project value by detecting and exploiting loss minimizing and profit maximising opportunities in a dynamic market environment. In the context of a toll road investment, for example, the PPP contract may have a clause by which private partners may exercise the abandonment option if revenues are lower than expected and sell the project to public partners for salvage value.

The objective of this paper has been to apply ROA to the valuation of the option to abandon a toll road investment. Of the numerous option pricing methodologies for real options valuation we decided to employ the binominal valuation method, due to its flexibility and suitability for valuing highly uncertain investments. The result can be obtained either by applying the replicating portfolio approach or the risk-neutral probabilities approach: we chose the second option because risk-neutral probabilities are unchangeable when moving from node to node.

A hypothetical example of a BOT toll road investment was used to determine the value of the European option to abandon the project in the fifth year, and the value of the American option to abandon the project at any time within the first five years of the project life. After calculating the value of the project with European and American abandonment options the null hypothesis was confirmed, suggesting that the value of the project with the European abandonment option is smaller than the value of the project with the American abandonment option. The possibility of exercising the option within the 5-years period is €1.44 million more valuable than the possibility of exercising the option in the fifth year only. Hence, those contracts which incorporate American options offer greater flexibility and are more valuable for private partners.

Nevertheless, the presented results should be taken with caution due to the fact that a small number of time steps has been applied (five time steps, each lasting one year) and the assumed volatility does not change during the project life.

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