NEW ASPECTS REGARDING THE EVALUATION OF INVESTMENTS IN CRITICAL INFRASTRUCTURE

Prelipcean Gabriela
"Stefan cel Mare" University of Suceava, Faculty of Economic and Public Administration, 13 Universitatii Street, 720229 - Suceava, Romania, E-mail: gprelipcean@yahoo.com, tel. 0744-311292
Boscoianu Mircea
Military Technical Academy of Bucharest, 81-83 George Cosbuc, Bucharest, Romania, E-mail: mircea_boscoianu@yahoo.co.uk, tel. 0740-050465
Lupan Mariana
"Stefan cel Mare" University of Suceava, Faculty of Economic and Public Administration 13 Universitatii Street, 720229 - Suceava, Romania, marianal@seap.usv.ro , tel. 0745-776233

The additional risks associated to the actual global and contagious crisis put a severe pressure on the investments in critical infrastructure and there is a real need for new valuations especially those regarding the synergic financing strategies in critical infrastructure.The main problem of investments in critical infrastructure is related to the fact that there are some serious differences from other types of real investments (long term, long building time, no productivity during a delayed period between the investment decision and the completion of the construction). Moreover the circumstances may significantly change and this uncertainty is difficult to be explained by using traditional instruments. A robust decision support should be based on the main characteristics (large irreversible initial investment, long economic life, long term) of this kind of investments.
We mention that the traditional theory of investment does not consider the aspects of irreversibility and uncertainty. In this case is not included any managerial flexibility ingredient (the value of waiting, the possibility to postpone irreversible investments) and the standard profitability measures give inappropriate indicators for investment/ entry decisions (Barham, Chavas, Klemme, 1994). Pindyck (1991) demonstrated that an irreversible investment opportunity is much like a financial call option. Valuing real investments with option valuation models (Black-Scholes and binomial option pricing) use the assumptions that models may not be fully compatible with real investments. Pindik proposed an efficient method to include the option value of waiting in the traditional profitability analysis. In this case, the positive potential of the investment is taken into consideration by using real option valuation (ROV). In a new generation of models, ROV is mixed with soft computing techniques like fuzzy logic (Zmeskal, 2001, Collan, Carlsson, Majlender, 2003) or with DSS tools (Alcaraz, Heikkila, 2003).
Efficient synergic strategies should also respond to the main problems of the markets related to the global crisis: the private loan failure, the global nature of liquidity crunch, the destructive power of the feedback loop, in which weakening economic and financial conditions become mutually reinforcing. In this case, a new framework based on the mixing of ROV with other techniques like fuzzy logic (FL) or game theory (GT) is needed. Based on the critical review of the traditional investment valuation methods it is demonstrated that this type of frameworks offers a better performance of valuation and provide a robust decision support for the selection of financial instruments for investments in critical infrastructure.

Key words: synergic investments, critical infrastructure, real options valuation (ROV)

JEL Clasification: G11

1. Introduction

There are three stages of the lifecycle of long term investments: planning, building and operation. Planning stage, the time before the investment decision, is view as an option; both, investment cost and value are uncertain. Building stage resembles a commodity forward contract, where the price is fixed, but market price is uncertain. After the construction, the operation stage resembles a bond contract that is commonly valued with NPV. Estimation inaccuracy of the variables is present in all stages of the lifecycle

Investments in critical infrastructure require a huge initial investment, take a long time to build and have long economic consequences. Because of the cyclicity, the timing of the investments is important, since wrong timing will cause the perceived investment to face falling prices for the output product, which may cause losses. The main characteristics (large irreversible initial investment, long life and a long time to build) add high uncertainty regarding the future cash flows and are difficult to assess the profitability of this type of investments. The irreversibility of investments in critical infrastructure is mixed with the high uncertainty and the analysis of profitability should be changed (Dixit, 1994). Long building time adds another problem regarding the possibility of changing the circumstances surrounding the investment and should be modeled. The uncertainty of cash flow estimates together with the complexity of investments cause a credibility problem (Zadeh's principle of incompatibility). A new valuation method, more realistic is welcome to support decision-making.

2. A critical analysis of the valuation methods in critical infrastructure

Project finance is a way to finance large investments where the revenues generated are used to repay the loans and the assets as the collateral, based on a set of management strategies that offers the possibility to spread the risk. The type of financing may have an effect on the profitability of a project. The leverage may change during the lifecycle of the investment with effects on the discount rate and the risk.

The classical profitability analyses are based on Fisher's theory of investment which does not consider irreversibility or uncertainty, and could not consider any managerial flexibility ingredient. Traditional methods based on discounted cash flow (DCF) are focused on a single stream of income and expenses are inadequate for long term investments. The main assumption of net present value (NPV) is that initiation of the investment is based on a complete cash flow specification. NPV/ DCF are in error because they use only a single averaged cash flow and can not capture the asymmetry of the returns (losses can be limited but gains can be unlimited). Running multiple analyses for different cash flows, with an average procedure according the estimated probabilities could not overcome this difficulty. In a multi stage option based decision tree (starting, development) the manager can choose to continue with the second stage or to drop the project. Therefore, the cash flows are biased upwards with the low ones truncated, and the overall expected value of the investment will be superior to that of a traditionally valued project.

"An irreversible investment opportunity is like a financial call option" (Pindik, 1991) is the famous observation of the real option valuation (ROV) paradigm. The assumption in Black-Scholes option pricing formula and CRR binomial option pricing are not fully compatible with real investments and in the new literature are proposed different hybrid solutions (HROV), for example the integration of ROV with fuzzy logic (FROV) or other soft computing techniques (SCROV). Other initiatives try to enhance investment decision support by making real option valuation more practical with DSS tools.

Call option value is positive but the profitability of irreversible investment made under uncertainty can be negative. The uncertainty regarding the building period, when the investment is not productive and the circumstances may dramatically change, is not explicitly captured by ROV. In FROV is captured the uncertainty of future cash flow estimates and the randomly simulated cash flow distributions is replaced by possibility distributions (fuzzy numbers) inspired from the perception of uncertainty. These fuzzy sets do not follow bi-value logic but they are based on a separate fuzzy arithmetic.

3. A new framework for critical infrastructure valuation

The basis for building the model has been the observation that decision support offered to huge investments by the standard profitability analysis methods is not optimal. Based on their characteristics the model should be built to take in consideration also the potential value of

waiting which is important to irreversible investments, to include the uncertainty brought by time to build the investment, and to accept and model the perceived uncertainty of estimate accuracy.
The possibility to wait may be valuable to an investment, if waiting increases the value of the investment. This possible value increase by waiting is often called potential; however, it is possible that the value of an investment decreases during waiting. Potential from waiting is commonly modeled by real options valuation. Option valuation models, however, assume that the value of an option is always zero, or larger than zero, and hence do not take into consideration the possibility of a decrease in the investment value (negative potential). It is the intention of the FROV model to show both, the potential and the negative potential to the decision maker, to avoid showing only the positive and thus to avoid (showing) bias.
The potential and the negative potential are important, when there is time to wait and during the time the investment is being built. The potential and the negative potential are not symmetrical due to the fact that they are constructed differently; this resembles the separate (often different) upward and downward probabilities that are used in the CRR binomial option pricing model (commonly accepted to capture potential). FROV framework considers the total potential (potential and negative potential) for initial costs and for the revenue stream generated by the investment separately. This is achieved for initial costs by multiplying the possibilistic standard deviation (of costs) with the possibilistic mean value and with the time to wait. For revenues the calculation is similar, but the time to build is added to the time to wait. The two potentials are added to the fuzzy present values of the initial costs and the revenues by using a heuristic context dependent operator that allows the potential to be distributed realistically. Total potential for the investment is captured by adding the fuzzy present values of initial costs/ revenues, combined with their respective potentials.
The model separates between discount rates for the initial costs (IC) and for the free cash flows (FCF) and between standard deviation of the IC and the FCF. Using separate discount rates for costs and revenues reflects the different risks for the different types of cash flows. Assessing different discount rates for each cash flow is supported by evidence from the literature, because the capital structure of the investment and financial market conditions changes with time. The use of separate standard deviations for cost and revenue cash flows is due to the fact that they may follow different markets and different volatilities.
FROV relies on fuzzy sets for the modeling of forecasting uncertainty. Possibilistic standard deviation for the costs and revenue is computed from the aggregate fuzzy cash flow estimates making the volatility an internally determinable variable. A fuzzy variable is included to handle possible costs/ rewards arising from strategic interactions. The expected value of the variable is zero.
FROV model could be expressed by:

$$FROV = R\eta E(R) * \sigma_R * (t + t_C) - C\eta E(C) * \sigma_C * t + \lambda_i$$

where

$$R = \sum_{i=0}^{L} \frac{1}{(1 + r_{Ri})^i} * R_i$$

$$C = \sum_{i=o}^{L} \frac{1}{(1 + r_{Ci})^i} * C_i$$

r_{Ri} = discount rate specific to the free cash flows from the project;

r_{Ci} = discount rate specific to the initial cost cash flows;

(r_{Ri} and r_{Ci} are single numbers that can be specific for each type of cash flow);

t = time to wait

t_C = time to build the asset
λ_t = the external value created during waiting.
Possibilistic standard deviation of the fuzzy revenues is:

$$\sigma_C = \frac{\sqrt{var_F(C_i)}}{E(C_i)}$$

$$\sigma_R = \frac{\sqrt{var_F(R_i)}}{E(R_i)}$$

where cash flow estimates R_i and C_i are fuzzy sets.
The heuristic operator is introduced to treat the effects of wait and the time to build.

$$\eta = \begin{cases} - \text{ when } A(V) < E(A) \\ + \text{ when } A(V) \geq E(A) \end{cases}$$

FROV has the capability to capture the aggregate uncertainty related to the period of waiting and during the time to build. In the particular case when there is no time to wait and no building time, FROV is resuming to FNPV added with λ_t. Furthermore, if there is no uncertainty it result the simple NPV model.

4. Hibrid methods for high risk investments in critical infrastructure

Hybrid methods (HROV) combine option approach for the market risks, and decision analysis for the project risks. HROV permits the choice of discount rate for the valuation because: the project risks can be diversified; the market risks are transformed by the options analysis so that no further compensation for risk is required in the discount rate. Once investment outcomes have been transformed by the options analysis, both the project and the market risks can be properly analyzed through standard decision or expected value analysis using a consistent discount rate.
HROV divides the valuation process into a *technical* and a *financial* part, associated with the project and market risks, and can be treated separately. After data collection and the information processing, the analysis is split into financial/ technological tasks, concerning market versus project risks.
The *financial side* identifies comparable assets that can be used to benchmark the flexibility represented by the options and then assembles data on these assets and computes their volatility; option ingredient is used to develop the risk neutral probabilities of the prospective cash flows. The *technological side* assembles estimates of the project risks from comparable developments based on a *Hull* decision analysis to obtain the value of the proposed investment.
HROV is based on three steps. *Set up Phase* identifies managerial decision points and the opportunities to select the valuable options associated with the project. *Data Collection and Analysis* specifies the costs, benefits, and uncertainties associated with the decision opportunities, and combine them in the relevant option or decision analysis framework. *Financial analysis* is focused on the *market risks* and it identifies the underlying assets associated with the volatility of the project. The analysts compute the statistics of the underlying assets and apply standard risk-neutral valuation procedures to adjust the potential future outcomes (Hull, 1989). These transform the market risks into risk-neutral quantities that can be estimated using the risk-free rate of return. The result is input into the decision analysis that also incorporates the project risks. *Technological analysis* is focused on the *project risks* associated with a specified investment and it is analyzed the likelihood of success, the possibility of cost overruns and the influence on markets. *Decision analysis* can then estimate the mixed effect of the project risks, costs and benefits by using a standard risk-free discount rate without extra compensation for risk; decision analysis will also include the market outcomes that have been converted to risk-neutral equivalents by the options analysis. HROV combine option and decision analysis in an overall assessment of the value of flexibility (the option value) that offers the advantage to include the

favorable opportunities. In *Sensitivity analysis* are examined the sensitivity of the valuation to the estimates of the benefits, probability of success, the cost of implementation, market uncertainty and volatility.

5. Conclusions and future work

Because of the complexity of the institutions hit by the global crisis, the timing of long term investments in critical infrastructure is even more important, since wrong timing will cause the perceived investment to face falling prices for the output product, which may cause losses. If the investment is postponed cash flows will be lost from the beginning of the investment.

FROV offer a good capability to deal with the uncertainty caused by waiting and by the time to build, relevant for investments in critical infrastructure where timing is essential. Due to the fact that the cash flows are given as fuzzy numbers the model responds also at the possible negative scenarios. FROV integrates different capabilities (profitability, uncertainty, potentiality) of modeling in a framework in which the possible loss could be taken into consideration.

The dynamism of FROV is given by the possibility to escape from the Fisher's traditional paradigm of investment decision support. The dynamic nature of the model is apparent in the use of fuzzy cash flow estimates and in the way the standard deviation is internally generated from future cash flow estimates, and hence new information about the cash flows has a direct effect on the final result. The heuristic context dependent operator used in the model makes the model escape some problems that using the standard possibilistic operators would yield, however, the heuristic operator is also a simplification of the reality, for it assumes the possibilistic mean value to divide the distribution of the potential. This may in some cases be inaccurate. The term describing the value created during waiting and building is a simplistic one term aggregate representation of the net value created during waiting and building as a whole. This means that to be able to give a reasonable value for the variable demands a separate game theoretic consideration of the investment.

Using the possibilistic standard deviation for estimation of potential from the time to wait and from the time to build may bias the value of the potential, because it is calculated from the aggregate values of IC and FCF. The actual uncertainty may be higher or lower than the modeled uncertainty. This effect may be significant for giga-investments, because of their long economic lives. It may be beneficial to investigate, case-by- case, how the standard deviation should be calculated for the time to wait and for the time to build. However, when considering competing investments it is important that the method used is uniform, the selection of the possibilistic standard deviation has been based on usability and robustness of the method. When considering competing investments valued with FRIV, the result (fuzzy number) makes it necessary to use some descriptive numbers, or defuzzification, for ranking the investment alternatives. This adds a step to using the FRIV, which crisp number NPV does not have.

The increased value due to HROV is greatest for investment in critical infrastructure because the value of flexibility is greatest when the risk is largest. Flexibility also has more value when the size of downstream costs is relatively large because the exercise of the option has more leverage. This tool is efficient in exploiting flexibility and avoiding poor outcomes. HROV valuation is a practical and effective way to evaluate investments in critical infrastructure and it permits a consistent choice of the risk-free discount rate for the valuation, because the project risks can be diversified and the market risks are accounted for by the options analysis.

The main contribution is to offer a comparative analysis of the instruments for valuation long term investments in critical infrastructure and a robust decision support. Future research directions include testing the FROV with investment cases, to provide decision support for investments in critical infrastructure in the aftermath of the global crisis, and finding out managerial reactions to different types of decision support.

We should also improve the decision support for the selection of dedicated and flexible instruments that incorporates the main characteristics of an emerging financial sector in the aftermaths of the global crisis.

Bibliography

1. Alcaraz, F., Heikkilä, M. (2003): *Improving Investment Decision making by Expanding Key Knowledge with Real Option Tools, Journal of Decision Systems*, Vol. 12, No. 3-4, pp. 345-368.
2. Barham, B., Chavas, J.P., Klemme, R. (1994): *Low capital dairy strategies in Wisconsin: lessons from a new approach to measuring profitability*, University of Wisconsin-Madison Department of Agricultural Economics Staff Paper Series, Staff Paper No. 381.
3. Collan, M., Carlsson, C., Majlender, P. (2003): *Fuzzy Black and Scholes Real Options Pricing, Journal of Decision Systems*, Vol. 12, No. 3-4, pp. 391-416.
Dixit, A., Pindyck, R. (1994): *Investment under uncertainty*, Princeton University Press, Princeton, NJ.
4. Pindyck, R. (1991): *Irreversibility, Uncertainty, and Investment, Journal of Economic Literature*, Vol. XXIX, pp. 1110-1148.
5. Prelipcean G., Boşcoianu M. (2008): *An innovative decision support system for strategic investments in power sector, WSEAS TRANSACTIONS on POWER SYSTEMS*, Issue 6, volume 3, June 2008, pp. 426-435.
6. Prelipcean G., Boşcoianu M. (2008): *Computational framework for assessing decisions in energy investments based on a mix between real options analysis and artificial neural networks, The 9th WSEAS International Conference on Mathematics & Computers in Business and Economics (MCBE'08)*, Bucharest, June 4-6, pp.179-184.
7. Prelipcean G, Boscoianu M. (2008): *Some aspects regarding the dynamic correlations between different types of strategic investments in Romania after integration, WSEAS Mathematics and Computers in Business and Economics MCBE08*, Bucharest, Romania, June 24-26, 2008, pp. 162-166.
8. Tarrazo, M. and Gutierrez, L. (2000): *Economic expectations, fuzzy sets and financial planning, European Journal of Operational Research*, 126(1): 89-105.
9. Zmeskal, Z. (2001): *Application of the fuzzy-stochastic methodology to appraising the firm value as an European call option, European Journal of Operational Research,* 135.