Angelou, G.N. & Economides, A.A.: **Managerial flexibility quantification under competition threat in ICT investments**. *International Journal of Revenue Management (IJRM),* Forthcoming.

Managerial flexibility quantification under competition threat in ICT investments

Georgios N. Angelou* & Anastasios A. Economides**

UNIVERSITY OF MACEDONIA
Information Systems Department
Egnatia 156
Thessaloniki 54006, GREECE

** Corresponding author
Tel: +30-2310-891799
Fax: +30-2310-891750
email: economid@uom.gr
http://conta.uom.gr
*email: gangelou@tee.gr

Abstract

In this paper, we estimate the value of an Information Communication Technology (ICT) investment opportunity, modeled as a Real Option (RO), when there is competition threat that can influence negatively its value or even more eliminate it. We put our analysis in the revenue management concept, which is a very real concern for ICT service providers across the globe especially after the increase of competition as a result of markets' liberalization. The target is to maximize revenue level and minimize risk that influence business profitability. Finally, we apply our model to a real life e-learning case study showing how it can be formulated and solved.

Key words: Information-Communication Technology (ICT), Investment evaluation, Real options, Competition modeling, Revenue management, Competition threat.

1. Introduction

Information and Communication Technologies (ICT) lie at the convergence of Information Technology, Telecommunications and Data Networking Technologies. The valuation of ICT investments is a challenging task because it is characterized by high-level of uncertainty and rapidly changing business conditions. Traditional finance theory suggests that firms should use a Discounted Cash Flow (DCF) methodology to analyze capital allocation requests. However, this approach does not properly account the flexibility inherent in most ICT investment decisions. Real Options (ROs) analysis presents an alternative method since it takes into account the managerial flexibility of responding to a change or new situation in business conditions (Trigeorgis, 1996). An option gives its holder the right, but not the obligation, to buy (call option) or sell (put option) an underlying asset in the future. Financial options are options on financial assets (e.g. an option to buy 100 shares of Nokia at 90€ per share on January 2007). RO is the extension of the options concept to real assets. For example, an ICT investment can be viewed as an option to exchange the cost of the specific investment for the benefits resulting from this investment. By adopting the philosophy of managerial flexibility (also called active management) we decrease the possibility of experiencing losses while increase the possibility of gaining. This is achieved by waiting and learning about the changing business conditions and generally resolving over time part of the overall investment's uncertainty (Benaroch, 2002). The business conditions may refer either to market conditions or firm conditions, depending on where the investment is focusing on.

For a general overview of real options, Trigeorgis (1996) provides an in-depth review and examples on different real options. For more practical issues the reader is referred to Mun (2002). Also, Angelou and Economides (2006A) apply ROs to a real life ICT case study. Finally, Angelou and Economides (2005) provide a literature review of the ROs applications in real life ICT investments analysis.

In general, there are three dimensions in competition modeling, market structure, subject of investigation and nature of competitive actions (Vollert, 2003; Trigeorgis, 1996). Analytically, depending on the number of competitors, the market structure can be either a monopoly, an oligopoly or perfect competition if many market participants are present. In addition, a decision maker can be interested either in the optimal decision of the single firm or in the outcome of the decisions of all market participants. In this work we focus on the former while the later results on the microeconomic equilibrium theory. Finally, competition is modeled as an exogenous event if the firm has no means to influence other competitors' actions. This is more realistic to perfectly competitive markets with many market participants. In oligopolistic markets, actions taken by the firm may likely result in strategic answers by its competitors. In this case competition should me modeled as endogenous and requires the combination of ROs and game theory (Zhu, 1999).

After the liberalization of the telecommunications markets their structure has changed from monopoly to oligopoly or even more to perfect competition. Hence, the real life ICT business activities do not belong exclusively to only one firm but may also be shared by other competitors. Viewing ICT projects as ROs, this paper develops a methodology for evaluating ICT investments decisions in the joint presence of uncertainty and competition. We adopt financial option theory and enhance it with competition modeling theory to guide decision-making regarding the management and evaluation of ICT investments. Our target is to develop a RO model closely related to the ICT industry characteristics to support ICT evaluation under competition conditions. As the number of players is increasing the exogenous competition modeling should take place since market conditions converge to perfect competition. In this case, a competitor's entry into the market will only cause a degradation of the overall ICT investment opportunity "pie", while the rest of the competitors will not react to this entry by changing their business strategy.

Previous research has applied exogenous competition modeling to the shared investment opportunities where the anticipated competitive loss can be viewed as the impact of dividends on a call option (Ghemawat and Del Sol, 1978; Kester, 1984; Kumar, 1999; Trigeorgis, 1996). Examples include the opportunity to introduce a new product, which is influenced by the introduction of close substitutes or to penetrate a new geographic market without barriers to competitive entry.

In case of exogenous competition modeling the firm has to weight the value of waiting against the possible erosion of value of competitor's actions, which it cannot influence. The firm has to determine what information has available about competition. If for example the firm knows in advance the strategies of its competitors and their impact on the firm's value function, the situation is completely deterministic. However, this case is quite unrealistic. In reality, competitors are entering randomly the market and exercise their ROs. The firm might have a rough idea about the intensity of competition and its impact without having full information about when and how other firms act. Trigeorgis (1991, 1996) and Kumar (1999) model competition exogenously assuming that the competitors are entering into the market following Poisson distribution. They assume that the underlying asset (investment revenue V) under random competitive arrivals can be modeled as a mixed diffusion-jump process.

We also consider that the competitors are entering the market randomly according to an exogenous Poisson distribution. We relax existing literature assumptions by considering that: i) the impacts of each competitor's arrival, during waiting and operation periods are following a joint diffusion process with V, and ii) the expected arrivals rates of competitors during waiting and operation periods are also following a joint diffusion process with V.

So far in the ROs literature, the aforementioned competition parameters have been assumed constant. We relax this assumption assuming that these parameters are stochastic. In addition, we consider that the investor under investigation, for whom the analysis is performed, has partial capability to preempt its competitors after investing (exercising its RO) and examine the optimum strategy to enter the market. In our analysis we take into account the uncertainty control or managerial flexibility provided by the RO analysis and the competition threat experienced by the investor to the modern ICT business environment. Figure 1 presents a classification of exogenous competition modeling along multiple dimensions.

-------------------------------- Figure 1 ------------------------------------

Here, we focus on the Incumbent Operators (IO) site, which is facing a threat from other competitors. We model this threat and try to estimate its impact to the value of an investment that can be treated as a RO to invest, in the near future, if the business conditions become favorable.

A good example of many players in an ICT market, which is dominated by a strong player, is the Greek telecommunication market, which is dominated by the incumbent fixed telephony operator OTE (Hellenic Telecommunications Organization) (ITI, 2005; Kantor Capital, 2005). After liberalization of the Greek market in 2001, an increasing number of new players has entered the market and started competing with the incumbent OTE in the value-added services. However, none of them pose a significant threat to OTE. Actually, there are about 12 more players who possess low market shares compared to OTE. However, each of them may subtract some value from the overall business value of any new investment opportunity from OTE if the latter remains "inactive". For any new value added service, there is a market "pie" concerning its business activity that is usually growing over time. Some parts, of the whole "pie" will be subtracted by the competitors as they are entering in the market. So, the IO here faces a tradeoff between the value of flexibility to wait and the value of the possible competitive erosion during waiting period. The OTE's management has to determine whether it should exercise the option and implement the investment opportunity early or whether it should follow "wait-and-see" (WaS) strategy despite a competitive damage caused by the competitors' entry in the market.

We put our analysis is the concept of revenue management since our target is to optimally implemented investment opportunity for maximizing “revenue assurance” and minimizing “revenue leakage”. Revenue management is a very real concern for ICT service providers across the globe especially after the increase of competition as a result markets liberalization.

For the ICT industry, revenue management generally means maximizing revenues level and minimizing risk that influence business profitability. Revenue Management process may contain two activities; forecasting, and strategy planning and implementation. Market forecasting is an essential element of revenue management in order to predict overall market conditions, such as customers demand for a new product and competition intensity. The better the forecast for the IO will result to the better the business decisions and therefore the better profits. Strategy planning and implementation based upon a range of scenarios and options, so that a firm can maximize revenue. Forecasting and strategy planning activities may produce information for investment opportunity and treat this as ROs. However, revenue from these opportunities may “suffer” from competition threat that it can subtract or even more eliminate them. Hence, there are two opposite effects; managerial flexibility provided by the ROs analysis and competition threat coming from market competition.

Similarly, to our analysis Yeoman and Watson (1999) provide a model of revenue management activity based on three activities of management; forecasting, people and strategy. In their model the third activity, people, concern firm’s management that takes the decision and is accountable for those decisions.

Chiang et al. (2006) provide a comprehensive review of the recent development of revenue management in different industries including the ICT field. In a more general concept, form revenue management field, Rautio et. al. (2006) present a conceptual model to propose optimum pricing strategy for information goods and especially for mobile TV services. Finally, in competition field, Harris (2006) provides an analysis of how an incumbent airline operator has deterred a low-cost regional competitor. He argues that low cost competitor chose the right strategy but for the wrong entry game and proposes that the best reply responses of incumbents should be determined by customer sorting in response to stockouts. The implemented real-time inventory management optimization tools in incumbent are proved to be crucial to incumbent's success of deterrence.

The rest of the paper is organized as follows. In Section 2, we provide a ROs model under exogenous competition modeling. In Section 3, we specify our analysis in the ICT market mapping its characteristics to the competition parameters of our model. We also put our analysis in the context of a specific illustration. In Section 4 we apply our model to a real life E-learning case study. Finally, in Section 5, we conclude and suggest possible future research.

2. A RO Model Under Competition Threat

We define T as the maximum deferral or "Wait-and-See" (WaS) period of the real option. During this period the option is shared among competitors. We assume that after this period no option exists at all for any competitor. The maximum deferral period is separated in two sub-periods, as seen in Figure 2. In the first sub-period, the IO is not investing and is waiting for resolving some of the uncertainties associated with this investment opportunity. The second sub-period starts when the IO exercises its option. For simplicity, we assume that the investment period (construction period for the specific project) is zero. The WaS period starts at t_s (assume t_s=0) when the option is available to the IO. Also, t_e is the real exercise time of the option (implementation of the investment opportunity). Finally, the part of the operation period where the IO can still face Competition Threat (CT) is T-t_e. All the notations used in our model are given in Table 1 in Appendix B. In addition, we define two terms for modeling the competition conditions: i) *Preemption Threat from Competitors* (PTC) and ii) *Preemption Capability of Incumbent* (PCI). PTC indicates the threat, which is experienced by the IO during the WaS period of the option that other competitors may enter into the market and decrease or even more eliminate the option value. PCI indicates the capability of the incumbent to preempt the subsequent competitors after its entry time at t= t_e into the market.

-------------------------------- Figure 2 ------------------------------------

During the WaS period, competitors may enter the market causing degradation of the investment opportunity for the IO. We want to estimate the option value when there is a PTC against the IO. We model the PTC assuming that the competitors' arrival follows a Poisson distribution with an expected arrival rate λ_w and an expected competitive erosion c_w. The competitive erosion indicates the decrease of the investment revenues that are available to the IO, caused by each competitor's entry into the market.

The business target of the IO is to minimize the threat from competition that can significantly decrease or even more eliminate available to it revenues and hence degrade the option value. IO's target is to exercise its option at the optimum time compensating PTC and uncertainty control.

After the implementation of the investment (option exercise) the IO may also experience PTC up to time T that can further decrease its expected value of the operation's revenues. The target of the IO is to preempt the subsequent competitors, after this time. However, in case of hard competition, as it is in the ICT field where many competitors are sharing the same option, this is not realistic. Alternatively, the IO wants to minimize the effect of competitors' arrivals during the operation phase. Hence, an important characteristic for each business opportunity is to provide a strong capability for the IO to preempt subsequent competitors' entry after its entry in the market. At exercise time t_e, let I_{cwte} be the total competitive erosion of competitors who have already enter into the market. Let also V be the overall market investment revenues when no competition exists at all. Then, the revenues of the investment opportunity which are available to the incumbent are V - I_{cwte}. This value is fully available to the IO when there is full PCI to the following competitors, so no any other competitor's arrival is expected during the operation phase. However, as mentioned before, it seems more realistic to consider that a number of subsequent competitors can also enter the market after IO's entry into the market.

We model a partial PIC by considering that during operation phase and up to t=T, competitors may also arrive with an expected competitors' arrival rate λ_o. The smaller the arrival rate λ_o is the higher the PCI is. Each of the arrivals during this period will cause a percentage decrease of the investment revenues defined as c_o. Hence, the final investment value that will be available to the incumbent is given by

$$V_f = V - I_{cwte} - I_{co} \tag{1}$$

where I_{co} is the total competitive erosion during the operation phase. Here, for simplicity we assume that competitive erosion during the WaS period is the same for any competitor's entry. The same applies for the operation period. We could easily extent our analysis to consider different competition effect for each competitor's entry into the market. However, the multi-diffusion analysis would become very complicated. Alternatively, we might consider that competition effects may follow the same diffusion process having different amplitudes.

The competitive erosion of the investment value, for the incumbent, during the waiting period is given by:

$$I_{cwt_e} = V - g_w^{n_w} V \tag{2}$$

for n_w=0,1,2,... competitors entry during the waiting period

and the competitive erosion during the operation period is given by:

$$I_{co} = g_w^{n_w} V - g_o^{n_o} g_w^{n_w} V \tag{3}$$

for n_o=0,1,2,.. competitors entry during the operation period.

where $g_w = 1-c_w$ and $g_o = 1-c_o$.

Hence, assuming n_w competitors' arrivals during the waiting phase and n_o competitors' arrivals during the operation phase, the overall option value when it is exercised at $t=t_e$ is given by:

$$OV_{cte} = \max\left(V_f - X, 0\right) = \\ = \max\left[V\left[\sum_{n_w=0}^{\infty} P_{nw}\left(1-c_w\right)^{n_w}\right]\left[\sum_{n_o=0}^{\infty} P_{no}\left(1-c_o\right)^{n_o}\right] - X, 0\right] \tag{4}$$

where

$$P_{n_w} = P_{(c=n_w)} = \frac{e^{-\lambda_w(t_e - t_s)}\left(\lambda_w\left(t_e - t_s\right)\right)^{n_w}}{n_w!} \tag{5}$$

$$P_{no} = P_{(c=n_o)} = \frac{e^{-\lambda_o(t_s + T - t_e)}\left(\lambda_0\left(t_s + T - t_e\right)\right)^{n_o}}{n_o!} \tag{6}$$

are the probabilities of having specific number of competitors' arrivals, during the WaS and operation periods. In particular, P_{nw} indicates the probability that n_w competitors are arriving during the WaS period, while P_{no} indicates the probability that n_o competitors are arriving during the operation phase. As seen, the value of shared ROs with random competitive arrivals is a weighted sum or an expected value over a Poisson distribution. We do not consider any competitive "divided payout" as Trigeorgis (1996) (pp. 287). Instead we consider the overall competition threat, which we treat as "competition cost" denoted as I_c. The magnitude of I_c depends on the competition intensity parameters, λ_w, λ_o, and the market structure parameters c_w and c_o.

PCI cases

<u>No any PCI -</u> We assume that I_{cwT}-I_{cwte}= $I_{co.}$ So, the IO has not any preemption capability. This results to wait up to t=T. It is more preferable to wait up to time T, since V_f will be the same independently of the option exercise strategy. Hence, it is the same as a proprietary option with revenues V_f and waiting period T. There is no reason, for the IO, to exercise this option earlier since longer waiting period indicates more efficient control of the uncertainties and higher option value (Trigeorgis, 1999). In this case, we want to estimate the impact of the PTC, during the WaS period, to the option value of the IO.

Full PCI -We assume that I_{cwT}-I_{cwte}=I_{co}=0 for t_e<T. So, the IO has full preemption capability and exercises its options at t=t_e. In this case, we want to estimate, for the IO, the optimum time to invest (exercise its option). There are two effects negatively correlated between each other: i) the uncertainty control assured by both the ROs analysis and the managerial flexibility to deploy investment in a longer deferral period, and ii) the PTC that may fully eliminate the option value for the IO.

Partial PCI - It seems more realistic in real life business conditions that the IO may have a partial preemption capability. Actually, by investing earlier a level of preemption capability can be achieved. It might be optimal for the IO to invest earlier in order to ensure the highest possible level of the investment's revenues. Of course, it is still a matter of compensation between managerial flexibility and competition threat as before.

Finally, incentive of investing earlier can also be applied when WaS strategy results to significant revenues losses from the operation phase that overcome the value of the uncertainty control provided by the ROs approach. A divided yield parameter may indicate these revenues losses (Trigeorgis, 1996). Here, we assume that this divided yield is zero.

3. Analysis Process

Assumptions

We assume that the IO as well as the rest of the competitors posse a shared RO that can be exercised up to t=T. In a previous work of ours (Angelou and Economides, 2006B) we examine the option value for the first two cases, no PCI and full PCI. We here extent that work, assuming that IO has partial PCI, while the other competitors have no preemption capability at all. We initially consider a joint diffusion process for the c_w, c_o, λ_o and V (Figure 4 in the Appendix A), while we assume that the expected competitors arrival rate λ_w during WaS period and investment cost X to exercise the option are constant. Afterwards, in a real life case study we relax these assumptions. The results of our analysis show that sometimes the IO may be better to adopt longer WaS period despite of the PTC that may eliminate the option value. We adopt an extended log transformed binomial model (ELTBM) with 4-parameters that follow joint diffusion process (Gamba and Trigeorgis, 2001). For small number of steps or volatilities values of the stochastic parameters with respect to r, the Binomial Model becomes unstable since the up and down probabilities of asset parameters can be negative. ELTBM does not present this disadvantage being so fully stable and efficient. We provide a brief description of this model in Appendix A.

So far in the literature the competitive erosion has been considered as constant. However, in the ICT markets, especially after the telecommunication's market deregulation, competition intensity has been increased dramatically. Hence, random competitive erosion seems more realistic. Geske (1978) examines the impact of stochastic divided yield focusing on the financial traded options field. He does not mention anything about competitive erosion in the ROs analysis but focuses on a stochastic divided pay out on yearly basis. He shows that option value increases or decreases depending on the correlation between divided yield and the investment revenues V. Actually, if the correlation is negative then the option value increases. We extend this work to the ICT field. Similarly to divided-yield pay out, we consider the competitive erosion effect to be stochastic analysing deeper its impact on the option's value of the future investment opportunity. When the competitive erosion is stochastic the option value is given again by the equation 4. We consider c_w, c_o, λ_o as cost parameters, which either can be "added" to the overall investment cost or to the decrease of V due to competition. In this sense competitive erosion can be considered as asset (a part of cost) of the future investment opportunity (real option).

Correlation between V and competition parameters

In the following we examine the correlation value between V and competition parameters. One of our research interests is to examine the mapping of these parameters into real life ICT business activities.

c_{w}, c_o are positively correlated with V - If business conditions are bad, market demand is low, business opportunity seems to be not favourable and the possible competitor's entry can only capture a small part of the overall business opportunity. Someone may assume that the bad business conditions compared to the favourable ones experience no network externalities effects. The opposite may be assumed in case of favourable business conditions. Also, the bad business conditions indicate no achievement of the critical mass for the customers demand indicating so a relatively small subtraction of the overall investment opportunity that is available to the IO.

c_{w}, c_o are negatively correlated with V - Such cases may occur when while the market value appears appealing, the competitors cannot extract significant option value (e.g. not adequate ICT infrastructure to support high customers demand, cost disadvantage of other competitors compared to incumbents case, other idiosyncratic issues). Particularly, when competitors do not have the adequate ICT infrastructure to fully utilize their own investment's opportunity benefits, an increase of the overall market value V might finally decrease the part of the market share that a specific competitor can subtract from the IO. Finally, there might be cases where competitive erosion c_w, c_o are uncorrelated with V.

Correlation between c_w and c_o -It is reasonable to consider that competitive erosion parameters are negative correlated between each other. In particular, the higher the value of c_w is the smaller the value of the c_o will be since during operation period the competitors may experience weakness to gain a significant amount of the overall market value.

Correlation between V and λ_{w}, λ_{o} - In general, it seems more realistic to consider that λ_{w}, λ_{o} are positively correlated with V. However, there might be cases where λ_{w}, λ_{o} are not fully correlated with V. Such examples can be when there is information asymmetry for the overall market level between IO and the rest of competitors. Also, when there is cost asymmetry between IO and other competitors, meaning that investment cost seems very high for the latter compared to the IO cost structure. A cost advantage may be indicated by the availability of an initial ICT infrastructure for some players, we here assume for the IO, which enhances their investment capability. This specific ICT infrastructure may be able to support future investment opportunities in a more efficient way. Finally, another example can be when the market value increases more for the IO than for the rest of the competitors. However, this means that the real option to invest is not fully shared between IO and the other competitors.

Correlation between λ_w and c_w -It is reasonable to consider that λ_w is positively correlated to c_w since the higher the competitive erosion is the higher the competitors' incentive to invest will be too.

Correlation between λ_o and c_o -It is reasonable to consider that λ_o is positively correlated to c_o since the higher the competitive erosion is the higher the competitors' incentive to invest will be too.

Correlation between λ_w and λ_o -It is also reasonable to consider that expected arrival rates of competitors during WaS and operation periods are negative correlated between each other. In particular, the higher the value of λ_w is the smaller the value of the λ_o will be since during operation period the competitors, which would have not entered into market may experience weakness to gain a significant amount of the overall market value.

This field requires further analysis and the mapping of these parameters to real market situation is a very challenging task that can be considered, as mentioned before, as a further work itself. In our work we discuss the issue of correlation between model parameters, which can be negative, positive or zero[1].

Presentation of Analysis

In the following, we present a numerical example. We assume partial PCI during operation phase of the investment. For the estimation of the optimum deployment strategy of the investment we follow the rule suggested by Benaroch and Kaufman (2000) and applied by Iatropoulos et. al. (2004):

Decision Rule: Where the maximum deferral time is T, make the investment (exercise the option) at time te, $0<t_e<T$, for which the option, OV_{cte}, is positive and takes on its maximum value.

$$OVct_{\mathrm{e}} = \max_{(t=0\ldots T)} OVct \qquad (7)$$

Next, we present the results of our analysis for three exercise times, t_e=1, 2, 3, Figure 4. We estimate the OV_{cte} for various values of the uncertainty of the expected arrivals rates of competitors during operation period, $\sigma_{\lambda o}$. We model partial PCI considering that c_o is smaller than c_w. Finally, we examine only one case of correlation between V, $c_{w,}$ c_o and λ_o, which is zero correlation.

-------------------------------- Figure 4 ------------------------------------

The longer WaS period may indicate higher option values, for the specific values of competition parameters taken here, despite PTC to eliminate part of the investment value.

In general as mentioned before, it is a matter of compensation between, uncertainty control assured by ROs thinking and competition threat caused by the incoming competitors during WaS and operation period for the IO. In our example, we consider that the maximum length of WaS period is 3 years.

When IO decides to enter the market at the latest point, t_e=3, IO experiences only PTC since all

[1] In case of negative correlation between competition parameters and revenue, waiting is even more preferable while in case of positive correlation waiting is less preferable. Finally, a zero correlation is in the middle Angelou and Economides (2006B). We focus on the last case considering that we do not lose the generosity, while the last two cases can be examined in a future work. Finally, in Angelou and Economides (2006B, 2006C) we examine negative correlation between competition parameters and revenues.

the competitors who decide to enter the market will do it earlier or simultaneously with IO.

The optimum time for the IO to enter the market depends on the competition parameters λ_w, λ_o, c_w, c_o the investment revenues V as well as the existing uncertainties levels for all these.

As it can be seen, at t_e=3 it is the higher option value for high level of uncertainty for σ_{cw}, σ_c (i.e. 40%), while for low level of uncertainty, σ_{cw}, σ_c (i.e. 10%, 30%), the option value is giving the smaller value. Since, at t_e=3 no competitors are expecting after this point, the impact of the competitors' arrival rate uncertainty $\sigma_{\lambda o}$ does not influence to the option value at all. The option values for exercise times at t_e=1,2 are between the aforementioned cases.

The conclusion is that the higher amount of uncertainty for competition parameters for both WaS and operation period, indicates higher option values for the IO indicating longer WaS period. This is the core idea of the ROs analysis. The higher amount of uncertainty existence during Was period indicates higher option value since more uncertainty will be resolved.

The key issue for deciding the optimum entry time under the framework of the analysis is the uncertainty clearness and correlation level between investment revenues and competition parameters (characteristics). If by waiting the IO can learn more about business conditions, which could transform the business opportunity to non-favourable, it is better to adopt WaS strategy despite competition threat. In the opposite case, if business opportunity looks very promising (high NPV value) and the IO will not learn significantly more about business conditions by adopting WaS strategy, its is better to proceed and implement investment immediately. In addition, if competition parameters are following positive correlation with investment revenues the ROs analysis enhances less the overall business performance compared to lower correlation values (i.e. zero or even better negative correlation).

4. A specific real life case study

So far we have focused on IO analysis however, our analysis can be applied to any other ICT investments opportunity, such as the e-learning business field. Recently the e-learning market is expanding very rapidly experiencing high level of uncertainties, (Newman & Couturier, 2002). Managerial flexibility to implement such businesses may enhance their value and ROs analysis contributes to this enhancement. We next apply our model on a real life e-learning business activity presented by Oslington (2004). He examines, for a particular online investment: University of British Columbia (UBC) Master of Educational Technology program, the managerial flexibility to defer the investment for a year and estimates its contribution to the overall investment value. We extent this work by modeling competition threat that could eliminate the option value, which is available to the UBC. We assume that other organizations, universities, can also provide similar, courses causing a degradation of the available to the UBC investment opportunity value.

The project starts with one-time cost outlay of k$43 at year 1, while an amount of k$18.25 for year 2 to 7 is assumed as a fixed cost. Finally, the expected Revenues minus the operational expenses for the optimistic and pessimistic scenario are k$24 and k$18 respectively for year 2 to 7 too. In particular, in the analysis provided, a high demand and a low demand scenario are assumed, with equal probabilities of occurrence. The present value of expected revenues is V= k$93, while in order to apply the ROs model in the one time cost we add the present value of the fixed costs for years 2 to 7, since these costs are not dependent on the customer (students) demand. Hence the present value (at t=0) of the overall costs to exercise the option is X= k$125. The discount factor r is 6%, while the revenues uncertainty is σ=40,5% as estimated by the range of high and low demand values.

The specific investment opportunity with Net Present Value (NPV) analysis is non profitable since it gives a value of –32k$ (we come to a different value than Oslington 2004 who gives a value of 0.820 k$ correcting a calculation mistake). Furthermore, Oslington (2004) adopts the

ROs model in its very conceptual form without considering the risk neutral probabilities for the estimation of the value of the RO. Instead, he assumes equal probabilities for the high and low demand scenario. He considers that the decision makers have sufficient knowledge to be able to formulate good and bad scenarios and attach probabilities to them. However, this is not realistic in the complicated real life business cases.

During the adopted 1-year WaS period UBC may clarify customers (students) demand uncertainty. However, during this period we consider an expected arrival rate of the competitors, λ_w. Each competitor causes a competitive erosion c_w. We consider that competition parameters during WaS period are following stochastic processes. In this case we consider that λ_o=0 or/and c_o=0.

In addition, we model uncertainty for the one-time cost at expiration date assuming that it is stochastic too. Waiting can give a decision maker more information about costs. Costs can change through the introduction of new technologies, changes in the regulatory environment, new partnership possibilities, or the availability of grants to offset some of the development costs. However, sometimes, though, it is not waiting but investing that reveals information about costs.

Tables 2 and 3 present the Option Value under competition threat. We assume that during WaS period the UBC is experiencing an expected arrival rate of competitors λ_w=2 and each competitor causes a degradation in the e-learning investment revenues with and expected value c_w=0.1.

The option value under no any competition threat, monopoly conditions, is 3 k$ indicating a marginal profitability of the investment. However, taking into account competition threat the option value since the project is “deep-out-of the money” is zero. However, taking into account uncertainty for competition parameters the option value is becoming marginally positive, (i.e. 0.5 k$). The investment opportunity is becoming really promising when investment cost uncertainty is quantified and actually the higher uncertainty in the cost is the higher the option value it is.

--------------------Table 2----------------------

In addition, in Table 3 the effect of correlation between V and investment and competition cost parameters is presented. For negative correlation between V and cost parameters the option value is increasing, while for negative value it is decreasing. Especially, a negative correlation value between V and X could represent, for instance, that the inability to control the costs of the development project are associated with lower benefits after the project is completed.

--------------------Table 3----------------------

In general, we can comment that if there is uncertainty regarding competition parameters (λ_w, c_w), and investment cost X in parallel to investment revenues, the effect of uncertainty in option value is situation-specific and depends on the uncertainty level and correlation between these factors.

5. Conclusion and Future Research

After the liberalization of the telecommunications markets their structure has changed from monopoly to oligopoly or even more to perfect competition. The subject of investigation and nature of competition define the necessary type of competition threat modeling, adopting exogenous competition modeling for high number of players that each of them gains a small part of the overall market value and game theory analysis for interactive competition modeling in case of limited number of players. Adopting the former, this paper investigates the impact of Preemption Threat from Competitors (PTC) to the value of ICT investment opportunities, modeled as ROs. We relax existing literature assumptions considering uncertainties for the aforementioned competition modeling parameters.

By waiting uncertainties such us customers demand forecasting and competition impact (competitive erosion impact) are resolved. Off course preemption threat should be compensated with the aforementioned uncertainties control. The results of our model prove that sometimes it is more preferable to adopt longer WaS period for an investment opportunity despite competition threat that can subtract part of it. However, real-world use and empirical assessment is needed to determine the true benefits and drawbacks of the approach presented. A critical issue is the estimation of the variability of investment payoffs and competition parameters. In can be done either by market analysis and historical data evaluation from similar business attempts or by subjective estimation of managerial decision analysis process. In any case, an extended sensitivity analysis should take place.

A limitation of our model can be in the way we estimate the up and down coefficients in the multi-diffusion process for the competition parameters. We adopt the risk neutral probabilities for competition parameters in a similar way as the overall market value V. These assumptions may be an issue of criticism that requires further discussion for their validation. However, our intention is to show how the uncertainty in competition parameters influences the value of a future investment opportunity being treated as RO.

In our analysis we consider one time step multi-diffusion process. Of course, multiple time steps result to increased granularity and so to increased accuracy in the results. Though the complexity of the model is increasing dramatically we capture more efficiently the additional dimension of competition entry. However, the always-increasing computing power can handle this complexity efficiently. In practice, the single-step analysis is appropriate for investments where management has limited opportunity to influence the outcome of the investment and reviews investment status per half or year. On the opposite, in case of large enterprise projects where there is a significant opportunity during the life of the project for management to influence the expected value of the project cash flows, a more realistic solution would use a multiple steps analysis. In this case, management reviews quarterly and even weekly, and risk events will impact the project with a random periodicity. In conclusion, the frequency of management review for the investment status, such as customers demand, indicates the number of steps should be considered.

In addition, someone could adopt endogenous competition modeling assuming that each one of the competitors in the market experiences a different level of the competition parameters λ_w, λ_o, c_w and c_o. Actually, the smaller values these parameters for a player in the market are, the stronger its market position for the specific investment opportunity is. In this case endogenous competition modeling requires the integration of ROs with Game Theory.

Finally, the mapping of these parameters to real market situation is a very challenging task that can be considered as a further work itself.

Appendix A

-------------------------------- Figure 3 ------------------------------------

The option values at expiration time (investment implementation) for the various values of c_w, c_o, λ_o and V are given by:

$$
\begin{aligned}
OV^{dddu} &= \max\left(V^{d} - I_c^{ddu} - X, 0\right)\\
OV^{dduu} &= \max\left(V^{d} - I_c^{duu} - X, 0\right)\\
OV^{dudu} &= \max\left(V^{d} - I_c^{udu} - X, 0\right)\\
OV^{duuu} &= \max\left(V^{d} - I_c^{uuu} - X, 0\right)\\
OV^{dddd} &= \max\left(V^{d} - I_c^{ddd} - X, 0\right)\\
OV^{ddud} &= \max\left(V^{d} - I_c^{dud} - X, 0\right)\\
OV^{dudd} &= \max\left(V^{d} - I_c^{udd} - X, 0\right)\\
OV^{duud} &= \max\left(V^{d} - I_c^{uud} - X, 0\right)
\end{aligned}
\qquad \text{(A-1)}
$$

$$
\begin{aligned}
OV^{uddu} &= \max\left(V^{u} - I_c^{ddu} - X, 0\right)\\
OV^{uduu} &= \max\left(V^{u} - I_c^{duu} - X, 0\right)\\
OV^{uudu} &= \max\left(V^{u} - I_c^{udu} - X, 0\right)\\
OV^{uuuu} &= \max\left(V^{u} - I_c^{uuu} - X, 0\right)\\
OV^{uddd} &= \max\left(V^{u} - I_c^{ddd} - X, 0\right)\\
OV^{udud} &= \max\left(V^{u} - I_c^{dud} - X, 0\right)\\
OV^{uudd} &= \max\left(V^{u} - I_c^{udd} - X, 0\right)\\
OV^{uuud} &= \max\left(V^{u} - I_c^{uud} - X, 0\right)
\end{aligned}
\qquad \text{(A-2)}
$$

$$
OV_{t=t_s} = e^{-rt_e}\begin{pmatrix}
P_{uuuu}OV^{uuuu} + P_{uudu}OV^{uudu} + P_{uduu}OV^{uduu} + P_{uddu}OV^{uddu} + \\
P_{duuu}OV^{duuu} + P_{dudu}OV^{dudu} + P_{dduu}OV^{dduu} + P_{dddu}OV^{dddu} + \\
P_{uuud}OV^{uuud} + P_{uudd}OV^{uudd} + P_{udud}OV^{udud} + P_{uddd}OV^{uddd} + \\
P_{duud}OV^{duud} + P_{dudd}OV^{dudd} + P_{ddud}OV^{ddud} + P_{dddd}OV^{dddd}
\end{pmatrix}
\qquad \text{(A-3)}
$$

The indexes (e.g. uuuu) indicate the up and down movement of the competition parameters and V. The respective probabilities, as well as the expressions used in the ELTBM, are given below in a generalized form for an N-dimensional states variables analysis, while the interest reader is referred to Gamba and Trigeorgis (2001). For the numerical example the first term of index (e.g. udud) indicates the change of V, the second the chance of c_o, the third the change of λ_o and the fourth the change of c_w.

For the e-learning case study, we consider c_w, λ_w, V and X multi-diffusion process. In this case, for example I_c^{uud} indicates the case where c_w and λ_w are increasing and X is decreasing respectively through time.

In the following, we briefly introduce the ELTBM. The ELTBM values real options whose payoffs depend on several state variables (i.e. cost and benefits).

The probabilities for the ELTBM in the N-dimensional case are:

$$p(s)=\frac{1}{S}\left[1+\sum_{1\le i\le j\le N}\delta_{i,j}(s)\left(R_{ij}\rho_{ij}+\mathrm{M}_i\mathrm{M}_j\right)+\sum_{i=1}^{N}\delta_i(s)M_i\right] \qquad \text{(A-4)}$$

s=1,…,S, where $S=2^N$.

$$\delta_i(s)=\begin{cases}1\text{ if state variable i jumps up}\\ -1\text{ if state variable i jumps down}\end{cases} \qquad \text{(A-5)}$$

where i=1,…,N

$$R_{ij}=k_ik_j/h_ih_j$$

$$R_{ij}=\sqrt{k_i^{\,2}+(k_i\mu_I)^2}$$

$$M_i=k_i^{\,2}\mu_j/h_i \qquad \text{(A-6)}$$

$$k_i=\sigma_i\sqrt{\Delta t}$$

$$\mu_i=\alpha_i/\sigma_i^{\,2}-1/2$$

Finally, ρ_{ij} is the correlation between state variables i and j.

Hence, the state variable L (in our work state variable are V, X, λ_w, λ_o, c_w, c_o) at time t is given by:

$$L_i(t)=L_i(t-1)e^{h_iU_i(t)} \qquad \text{(A-7)}$$

In our example we consider t=1, while $\{U_1(t),\ldots,U_N(t)\}$ is a N-variate binomial process (an N-dimensional extension of the following bi-variate binomial random variable $\{U_1(t), U_2(t)\}$:

$$(U_1, U_2) = \begin{cases} (1,1) \text{ with probability } p_1 \\ (1,-1) \text{ w.p. } p_2 \\ (-1,1) \text{ w.p. } p_3 \\ (-1,-1) \text{ w.p. } p_4 \end{cases} \quad \text{(A-8)}$$

and $\sum_{i=1}^{4} p_i = 1$

The term e^{hi} indicates the rise and fall parameters, which are $u_i = e^{hi}$, $d_i = 1/ u_i$. Hence, $L_i(t)=u_iL_i(t-1)=L^u$ and $L_i(t)=d_iL_i(t-1)=L^d$

Appendix B

-------------------------Table 1----------------------

References

[1] Angelou, G. and Economides, A. (2006A) "A real life ICAT investment analysis with Real Options", *WSEAS Transactions on Business and Economics.* 4(3), pp. 253-260.

[2] Angelou, G. and Economides, A. (2006B) "ICT investments under competition threat", *18th Hellenic Conference on Operations Research – Planning, Information Retrieval and Knowledge Management*, pp. 983-992.

[3] Angelou G., and A. Economides, 2006, "ICT growth options analysis under Exogenous competition modelling", in *1st International Conference in Accounting and Finance*, Thessaloniki, Greece.

[4] Angelou, G. and Economides, A. (2005) "Flexible ICT investments analysis using Real Options", *International Journal of Technology, Policy and Management*. 5(2), pp.146-166.

[5] Benaroch, M. (2002) "Managing information technology investment risk: A real options Perspective", *Journal of Management Information Systems*, 19(2), pp. 43-84.

[6] Benaroch, M. and Kauffman, R. (2000) "Justifying Electronic Banking Network Expansion Using Real Options Analysis", *MIS Quarterly* 24(2), pp.197-225.

[7] Chiang, W.C J., Chen, C.H. and Xu, X. (2006) "An overview of research on revenue management: current issues and future research", *Int. J. of Revenue Management*, Vol. 1, pp.97–128.

[8] Gamba, A. and Trigeorgis, L. (2001) "A Log-transformed Binomial Lattice Extension for Multi-Dimensional Option Problems," presented at the 5th Annual Conference on Real Options, Anderson School of Management, UCLA, Los-Angeles.

[9] Geske, R.M. (1978) "The pricing of options with stochastic dividend yield", *Journal of Finance*, 33, pp. 617-625.

[10] Ghemawat, P. and Del Sol, P. (1998) "Commitment versus Flexibility?" *California Management Review*, 40(4), pp. 26-41.

[11] Harris, F.H.deB. (2006) 'Large scale entry deterrence of a low-cost competitor: an early success of airline revenue management', *Int. J. of Revenue Management*, Vol. 1, pp.5–27.

[12] Iatropoulos, A., Economides, A. and Angelou, G. (2004) "Broadband investments analysis using real options methodology: A case study for Egnatia Odos S.A.", *Communications and Strategies*, 55, 3rd quarter, pp. 45-76.

[13] International Telecoms Intelligence (ITI) Company (2005) "Available reports: Market Intelligence Report", http://www.espicom.com/web3.nsf/structure/tel_bksmgreece?OpenDocument

[14] Kantor Capital (2005) "Overview of status of the telecommunication market in Greece", http://www.kantor.gr/files/surveys/ExecSummary_Telecoms12_9_05.pdf

[15] Kester, W.C. (1984) "Today's Options for Tomorrow's Growth", *Harvard Business Review,* (March-April), pp. 153-160.

[16] Kumar, R. (1999) "Understanding DSS Value: An Options Perspective", *Omega*, *The International Journal of Management Science*, 27, pp. 295-304.

[17] Mun, J. (2002) "Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions", Wiley Finance.

[18] Newman, F. and Couturier, L. (2002) Trading Public Good in the Higher Education Market. Futures Project: Policy for Higher Education in a Changing World. January.

[19] Oslington, P. (2004) “*The impact of Uncertainty and irreversibility on Investments in Online Learning*”. Distance Education, vol 25, No. 2.

[20] Rautio, T., Anttila, M. and Tuominen, M. (2006) ‘Bundling of information goods: a value driver for new mobile TV services’, *Int. J. of Revenue Management*, Vol. 1, pp.45 –64.

[21] Trigeorgis, L. (1999) “Real options: a primer”, in Alleman, J. and Noam, E. (Eds.): *The New Investment Theory of Real Options and its Implication for Telecommunications Economics*, Kluwer Academic Publishers, Boston, pp.3–33.

[22] Trigeorgis, L. (1996) “*Real Options: Managerial Flexibility and Strategy in Resource Allocation*” The MIT Press.

[23] Trigeorgis, L. (1991) “Anticipated Competitive Entry and Early Preemptive Investment in Deferrable Projects”, *Journal of Economics and Business*, 43, pp.143-156.

[24] Vollert, A. (2003) “*A Stochastic Control Framework for Real Options in Strategic Valuation*” Birkhauser Boston.

[25] Yeoman, I. and S. Watson S. (1997) “Yield management: A human activity system”, *International Journal of Contemporary Hospitality Management* 2/3 pp.80-83.

[26] Zhu, K. (1999) “*Strategic investment in information technologies: A real-options and game-theoretic approach*” Doctoral Dissertation, Stanford University, CA.

Tables

Table 1

Notations used in the Proposed Mathematical Model

Parameter	Description
t_s	Time where the option is possessed for the first time by the IO and the rest of competitors.
T	Maximum deferral period in years for the option to be exercised at t_s+T. We assume that T is the same for all the competitors in the market.
t_e	Time where the option is finally exercised by the IO and the investment is implemented. Final waiting period is t_e-t_s.
λ_w	Expected arrival rate of competitors per unit time during waiting phase.
λ_o	Expected arrival rate of competitors per unit time during operation phase.
n_w	The number of competitors' entry that will take place during deferral waiting period.
n_o	The number of competitors' entry that will take place during operation phase where the option is still possessed by the competitors in the market.
c_w	The expected competitive erosion that each competitor's entry in the market will cause to the IO's investment revenues value during waiting period, $c_w=(V_{\text{before entry}} - V_{\text{after entry}})/V_{\text{before entry}}$. ($g_w=1-c_w$)
c_o	The expected competitive erosion that each competitor's entry in the market will cause to the incumbent's investment revenues value during operation period, $c_o=(V_{\text{before entry}} - V_{\text{after entry}})/V_{\text{before entry}}$. ($g_o=1-c_o$)
V	The overall market revenues value for the investment opportunity.
OV_{cte}	Option value under exogenous competition modeling when it is exercised at $t=t_s+t_e$.
I_{cwT}	Total competitive erosion during waiting period up to t_s+T
I_{cwte}	Total competitive erosion during waiting period up to t_e, where $t_s<t_e<t_s+T$
I_{co}	Total competitive erosion during operation period after option exercise at $t=t_e$. If $I_{cwT}-I_{cwte}=I_{co}$ the incumbent has no preemption capability, while if $I_{cwT}-I_{cwte}<I_{co}$ has preemption capability. If $I_{co}=0$ there is full preemption capability for the incumbent (PCI)
I_c	$I_{cwte}+I_{co}$, total competitive erosion cost.
V_f	V-I_c. Final investment revenues for the incumbent.
r	The risk free interest rate
X	Investment One-time cost
σ_v	Investment revenues uncertainty V
$\sigma_{\lambda w}$	Expected arrival rate λ_w uncertainty (volatility)
$\sigma_{\lambda o}$	Expected arrival rate λ_o uncertainty (volatility)
σ_{cw}	Competition effect c_w uncertainty (volatility)
σ_{co}	Competition effect c_o uncertainty (volatility)

Table 2. The effect of uncertainty of the X,λ_w, c_w
to the Option Value of the e-learning investment opportunity

Correlation between V and X is –0,5, while
correlation between the rest of parameters is 0
(values is k$)

σ_X	σ_{cw}=80%	σ_{cw}=80%
	$\sigma_{\lambda w}$=0%	$\sigma_{\lambda w}$=50%
	OV_{cte} (t_e=1)	
0%	0,11	0,5
10%	2,75	3,14
30%	10,08	9,95
60%	21,21	21,13
90%	33,09	33,34

Table 3. The effect of correlation between V and X, λ_w, c_w
to the Option Value of the e-learning investment opportunity

For the rest of the relationships we consider zero correlation between parameters.
σ_x=40%, σ_v=40,5%, $\sigma_{\lambda w}$=50%, σ_{cw}=80%

Correlation between V,X,λ_w,c_w			**Option Value OV_{cte}**
V&X	**V&λ_w**	**V&c_w**	
0	0	0	9,56
-0,5	0	0	13,77
0,5	0	0	5,34
0	-0,5	0	10,53
0	0,5	0	8,58
0	0	-0,5	11,03
0	0	0,5	8,08

Figure captions

Figure 1. Classifying exogenous competition modeling along multiple dimensions

········ Trigeorgis 91, 96, · — · — Geske 78

— — — Kumar 99 ━━━ Extensions of this work

Figure 2. Waiting and operation period for a single real option (t_s=0)

Figure 3. Overall expected market revenues V, one time cost X, competitive erosion c_w, c_o and expected competitors arrival rates λ_o, λ_w joint diffusion process, one time step

Figure 4. The effect of the expected competitors arrival rate λ_o, competitive erosion c_w, c_o uncertainty ($\sigma_{\lambda o}$, σ_{cw}, σ_{co}) on option value under partial PCI (zero correlation, ρ, between competition parameters and overall investment revenues V, r=5%, λ_w=1, λ_o=1, σ_v=40%, V=100, X=100, t_e=1,2,3)

Figures

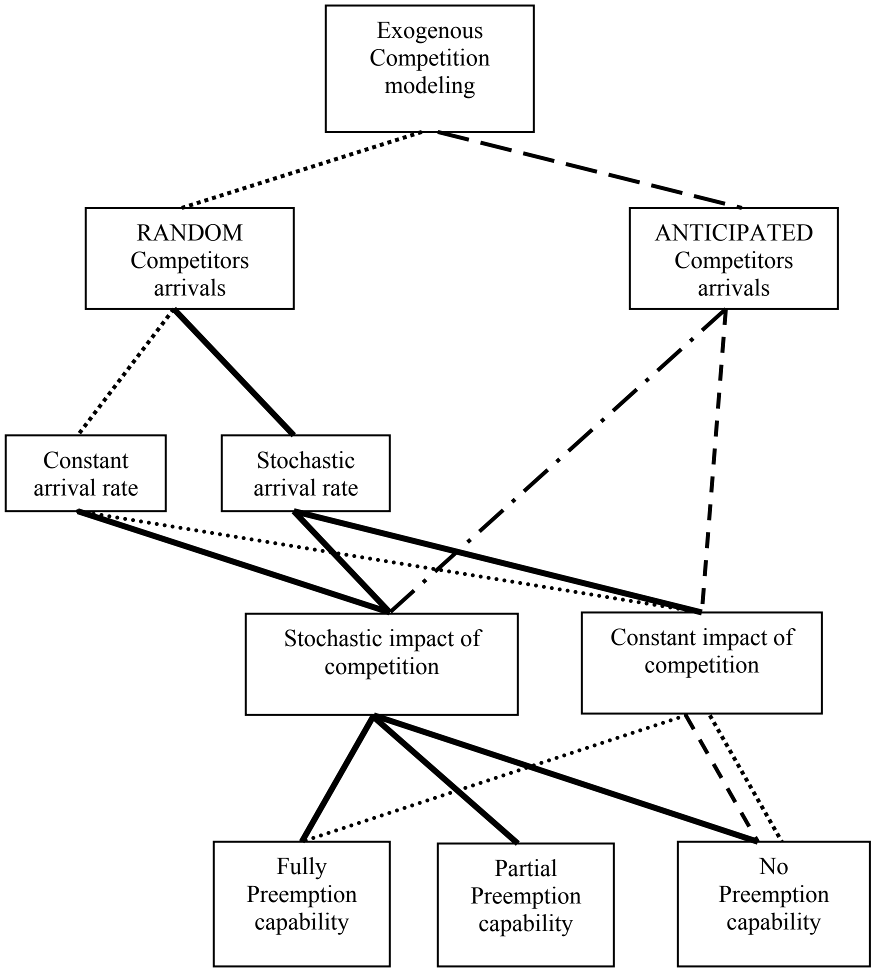


Figure 1

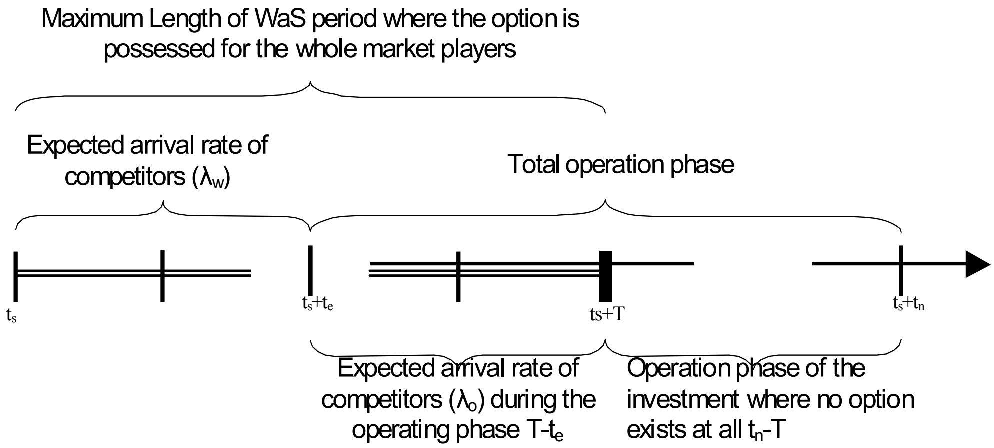


Figure 2

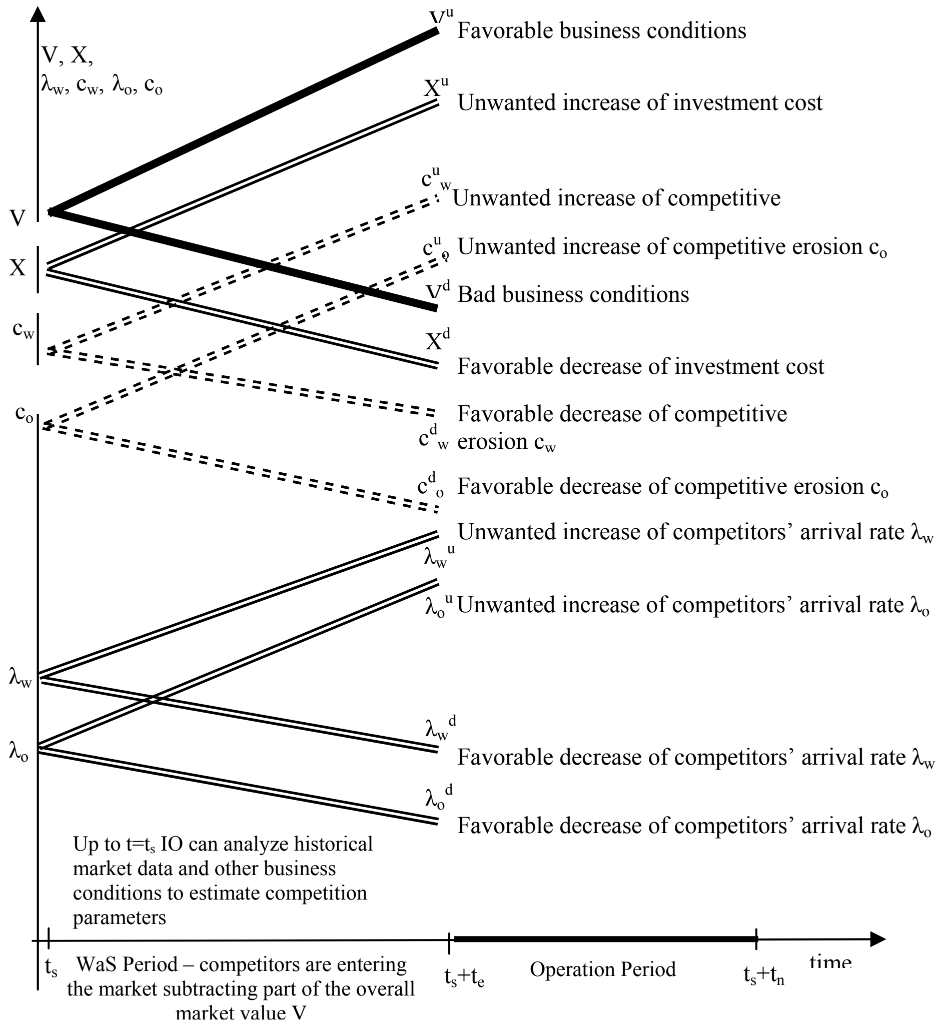
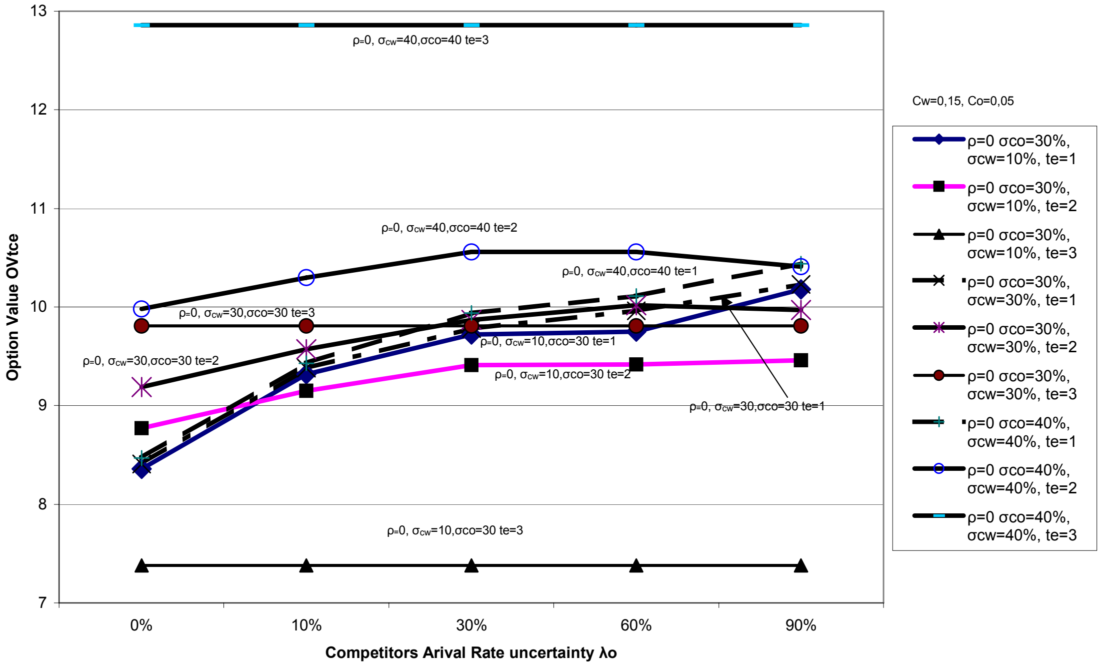

V, X,
λw, cw, λo, co
Vu Favorable business conditions
Xu Unwanted increase of investment cost
cuw Unwanted increase of competitive
cuo Unwanted increase of competitive erosion co
Vd Bad business conditions
Xd Favorable decrease of investment cost
Favorable decrease of competitive
cdw erosion cw
cdo Favorable decrease of competitive erosion co
Unwanted increase of competitors' arrival rate λw
λwu
λou Unwanted increase of competitors' arrival rate λo
λwd
Favorable decrease of competitors' arrival rate λw
λod
Favorable decrease of competitors' arrival rate λo
V
X
cw
co
λw
λo
Up to t=ts IO can analyze historical market data and other business conditions to estimate competition parameters
ts
WaS Period – competitors are entering the market subtracting part of the overall market value V
ts+te
Operation Period
ts+tn
time

Figure 3



Option Value OVtce
Competitors Arival Rate uncertainty λo
13
12
11
10
9
8
7
0%
10%
30%
60%
90%
Cw=0,15, Co=0,05
ρ=0 σco=30%, σcw=10%, te=1
ρ=0 σco=30%, σcw=10%, te=2
ρ=0 σco=30%, σcw=10%, te=3
ρ=0 σco=30%, σcw=30%, te=1
ρ=0 σco=30%, σcw=30%, te=2
ρ=0 σco=30%, σcw=30%, te=3
ρ=0 σco=40%, σcw=40%, te=1
ρ=0 σco=40%, σcw=40%, te=2
ρ=0 σco=40%, σcw=40%, te=3
ρ=0, σcw=40,σco=40 te=3
ρ=0, σcw=40,σco=40 te=2
ρ=0, σcw=40,σco=40 te=1
ρ=0, σcw=30,σco=30 te=3
ρ=0, σcw=30,σco=30 te=2
ρ=0, σcw=10,σco=30 te=1
ρ=0, σcw=10,σco=30 te=2
ρ=0, σcw=30,σco=30 te=1
ρ=0, σcw=10,σco=30 te=3

Figure 4