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PRICE COMPETITION ANALYSIS IN ICT BUSINESS

Georgios N. Angelou, University of Macedonia, Thessaloniki, Greece, gangelou@tee.gr,

Anastasios A. Economides, University of Macedonia, Thessaloniki, Greece, economid@uom.gr

Abstract

The information and communication technology (ICT) industry is one of the most capital intensive among the high-technology industries. ICT business analysis, especially after the industry deregulation, has become a difficult task. This study integrates Real Options and Game Theory perspectives and examines multi-period price competition in order to find the optimal ICT business strategy in terms of the time entry in the market and the service price. The analysis focuses on e-learning business activities showing how it can be formulated in the specific field.

Keywords: Information and Communication Technologies, Price competition, Decision-making, E-learning, Real options, Game theory.

1 INTRODUCTION

The valuation of Information and Communication Technologies (ICT) investments is a challenging task since it is characterized by rapidly changing business and technology conditions. Especially, after the liberalization of the ICT markets, the related business activities are not owned exclusively by a single firm but rather are shared by many competitors. Examples of ICT markets with a limited number of players are operating systems developers (eg. Microsoft, Apple, Sun, and Linux), CPUs (eg. Intel, Sun) and mobile phones manufactures (e.g. Nokia, Siemens, Motorola and Ericsson). Furthermore, most countries issued a limited number of licenses for Mobile Telecommunication Operators. So in every country, there are only a few mobile telecommunication operators. The main challenge for a potential provider (investor) is to roll out its business activity at the right time and the right attributes. The entry time depends on ICT services penetration, network infrastructure cost, area characteristics, applications offered, expected tariff evolution, customers' willingness to pay, demand forecasts, evolution of expected market shares and investor's technical skills. 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 for the flexibility inherent in most ICT investment decisions. For example, an ICT infrastructure project may have a negative Net Present Value (NPV) when evaluated on a stand-alone basis, but may also provide the option to launch future value-added services if business conditions are favorable. Real Options (ROs) analysis presents an alternative method since it considers the managerial flexibility of responding to a change or new situation in business conditions (Trigeorgis 1996).

This study focuses on the e-learning services business field. However, it can be easily extended to other ICT fields. E-learning is the delivery and management of learning by electronic means. Various devices (workstations, portable computers, handheld devices, smart phones, etc.), networks (wireline, wireless, satellite, etc.) can be used to support e-learning (Wentling et al. 2000). E-learning may incorporate synchronous or asynchronous communication, multiple senders and receivers (one-to-one, one-to-many, many –to many, etc.), multiple media and format independently of space and time. Recently the e-learning markets have been expanding very rapidly (Newman & Couturier 2002) and the potential investors face the dilemma of selecting the time to enter the market, the characteristics as well as the price of the offered service. This study treats these opportunities using option thinking and applies game theory to model the competition. It adopts price competition for modeling the competitive conditions. The interest investor

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faces one dilemma: “should he wait for understanding even better the overall business and control some of its uncertainties, such as customers demand and business experience, or he should act rapidly and enter immediately the market? Furthermore, what is the optimum price to offer his services?”

Previous research on e-learning cost analysis and investment evaluation has not considered the managerial flexibility of acting according to changing business conditions (Whalen and Wright 1999, Downes 1998, Morgan 2000). Few exceptions of e-learning investment analysis using ROs include Angelou and Economides (2007) and Oslignton (2004) works. In addition, price competition modelling in a general perspective of the information technology field was considered by Zhu (1999) and Zhu and Wyeant (2003). The present study extends these works by applying multi-period price competition under a ROs perspective. In addition, it applies the proposed analysis to e-learning services provision focusing on specific market characteristics. Previous research on investment evaluation has applied ROs to ICT, pharmaceuticals and petroleum fields (Angelou and Economides 2009, 2008a, 2008b, Iatropoulos et al., 2004, Mun 2002, Mun 2003). For a survey of options theory applications in the ICT field, the interest reader is referred to Angelou and Economides (2005).

The paper is organized as follows. Section 2 discusses arguments for price and quantity competition modeling, which motivate our analysis. Section 3 describes the model and the proposed analysis. Section 4 discusses a case study. Section 5 discusses the proposed analysis and suggests future work. Finally, section 6 concludes the paper.

2 ICT Price or Quantity Competition Modelling

The industrial organization literature has investigated various circumstances under which each type of competition is more likely to occur. In the airlines’ industry, where fixed costs are all paid before sales take place and the firms have capacity to fill many more orders than they may get, price competition is likely to occur. In other cases, where the production process takes a long time, firms may commit themselves to some level of output, and then sell it for what they can get. In these cases, competition is in quantities. Such case might be the dark fiber infrastructure installation in broadband technology field or infrastructure installation for e-learning services provision, while the quantity might be the geographical coverage or the number of customers’ connections fiber to the home (FTTH). One firm's temptation to undercut its rival's price and capture all the market, which underlies Bertrand's model, is present only when that firm has the capacity to serve the whole market. To see this, assume that two firms are in a Cournot equilibrium. Now also assume that both firms' plants are operating at full capacity (i.e. they cannot produce any larger output). Under these circumstances, there is no reason to cut price, since output cannot be increased beyond its present level by either firm. The firms will have the ultimate equilibrium in mind when planning how much capacity to install in the first place. Having built their plants, they then compete with each other to sell their outputs. When the firms decide on their own best capacity, they know whether the subsequent competition will be in prices (Bertrand) or quantities (Cournot). Under these circumstances, profit-maximizing firms (telecommunications investors) should build networks just big enough to supply the output that could occur in Cournot equilibrium. Then, whether they subsequently compete by deciding on quantities (as in Cournot's theory) or on prices (as in Bertrand's theory) they end up in Cournot's equilibrium. They cover their total costs and make profits that are less than the profits in a monopoly but more than in a perfectly competitive industry. When they do reach the Cournot equilibrium, they are not tempted to cut prices because they are already producing at full capacity. The intuitive reason for this result is as follows. Firms often recognize the self-destructive nature of the price competition that was analyzed by Bertrand. Having recognized it, they take steps to avoid it. They do this by limiting their capacity to produce. This argument leads us to expect Cournot's results when demand is such that firms can just use their capacity, and Bertrand's results when firms unexpectedly (or, as in the case of aircrafts’ airlines, unavoidably) find themselves with large quantities of unused capacity. Thus, for example, when demand falls to unexpectedly low levels during a recession, firms will have excess capacity and will be tempted to engage in price competition that may drive price below average total cost. But when demand is at its expected level, the firms will not find themselves with the excess capacity that tempts them to undercut their competitors, driving price below Cournot's equilibrium level. This is no accident; firms could have planned it that way.

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3 THE PROPOSED MODEL

As mentioned before this study focuses on e-learning service considering price competition. Particularly, firms choose products and services with specific attributes and quality to offer to the customers. The firms choose prices and offer services to the consumers who choose whether or not to buy services based on these prices; consumption takes place and profits are realized. Hence, the firms choose the quality and the price of the products/services offered and the customers choose the quantities. Particularly, the following game is to be analyzed. Two identical firms (players) may enter the e-learning business field. The target is to find the overall business equilibrium for the two players considering price competition modelling. It is assumed that both players are rational and have access to the same amount of business related information.

In appendix the analysis focuses on one-period game, estimating the equilibrium strategies of the firms. However, ICT business opportunities usually last more than a single period. This study assumes that the investment remains valid for two periods. All the notations used in the analysis are given in Table A-1 of Appendix. The possible decisions, for the duopoly case, for each player are the following: invest for high quality (IN_{iHQL}), invest for low quality (IN_{iLQL}), defer investment (DF_{iLQL}) for low quality, (DF_{iHQL}) for high quality, and abandon (A). We consider a binomial process for customer demand (D), where u_p and d_n are the changes up to u_pD or down to d_nD according to a binomial process, Figure 1. Especially, u_p and d_n are the multiplicative binomial parameters ($u_p>1$, $d_n<1$).

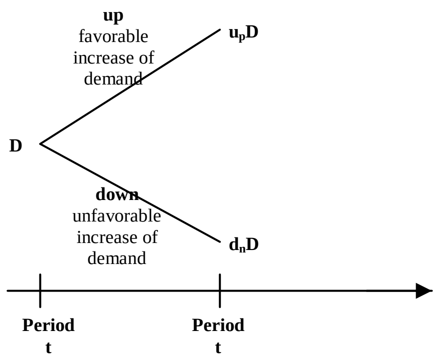

Figure 1. Uncertain demand as binomial process

We use the backwards induction process to determine the sub-game perfect equilibrium and then use the dynamic programming technique to bring back the values from period t (here t=2) to period t-1. Finally, when having these values for each period, both firms choose the equilibrium strategies. The same rule applies repeatedly for more than two periods. Concerning a multi-period perspective, dynamic programming and backward induction techniques solve the multiple period game. Particularly, the value of the business can be represented by the "Bellman" equation:

$$V(x) = \max\left\{E[\pi_t] - I, \frac{1}{1+r} E\left[V\left(x'\right)\middle|x\right]\right\}$$

where V(x) is the value of the business, x is the state variable (here market demand D). I is the investment cost, π is the expected revenues under the condition that the investment has been implemented and r is the discount factor. Finally, V(x') is the continuation value of the business conditional on the current state variable (demand D). Analytically, the first term represents the value of the exercised RO, while the second term represents the value of continuation (i.e., holding the RO). In each period, each firm (player) compares these two terms, taking also into account the action of its competitor. Concerning the two-period case, the ROs to enter the specific business field remain available for two periods. We use the backwards induction method to find the game equilibrium. Assuming that the game has only one period left, then the single period results are valid. If the game has two periods left, then each firm (competitors) has to compare the payoffs from each of the possible decision combinations. Particularly, the second period game has to start from one of the following decision combinations: (IN_{AHQL}, IN_{BHQL}), (IN_{AHQL},

IN_{BLQL}), (IN_{ALQL}, IN_{BLQL}), (IN_{ALQL}, IN_{BHQL}), (IN_{AHQL}, DF_B), (IN_{ALQL}, DF_B), (DF_A, IN_{BHQL}), (DF_A, IN_{BLQL}) and (DF_A, DF_B). Taking into account the one period analysis, given in Appendix, (IN, DF) and (DF, IN) are mixed strategies in the demand region 2 (see Figure A-1). When (IN, IN) set of decisions takes places the game is over and the decisions have been taken place. Hence, we only need to analyze the decision combinations (DF,DF). Analytically, if the game reaches to the decision combination (DF,DF) in the second period, we can use the one-period analysis as the restarting point adopting the ROs perspective. If the investment decision is to invest immediately at t=0 the overall business value is given by the Net Present Value (NPV) without any Real Options Value (ROV). On the other hand, if the decision is to defer up to t=T the overall value is given by the Expanded NPV, which actually contains the ROV (Trigeorgis 1996). All the decision alternatives for a two-period business game, for a duopoly case, are presented in Table 1.

B **A**	**IN_{BHQL} (invest high quality at t=0)**	**IN_{BLQL} (invest low quality at t=0)**	**DF_{BHQL} (defer up to t=T low quality)**	**DF_{BLQL} (defer up to t=T low quality)**	**A_B (abandon)**
IN_{AHQL} (invest high quality at t=0)	No ROV (NPV) No ROV (NPV)	No ROV (NPV) No ROV (NPV)	ROV (ENPV) No ROV (NPV)	ROV (ENPV) No ROV	Monopoly (No ROV)
IN_{ALQL} \ (invest low quality at t=0)	No ROV (NPV) No ROV (NPV)	No ROV (NPV) No ROV (NPV)	ROV (ENPV) No ROV (NPV)	ROV (ENPV) No ROV (NPV)	
DF_{AHQL} (defer up to t=T low quality)	No ROV (NPV) ROV (ENPV)	No ROV (NPV) ROV (ENPV)	ROV (ENPV) ROV (ENPV)	ROV (NPV) ROV (NPV)	Monopoly (ROV)
DF_{ALQL} (defer up to t=T low quality)	No ROV (NPV) ROV (ENPV)	No ROV (NPV) ROV (ENPV	ROV (ENPV) ROV (ENPV)	ROV (ENPV) ROV (ENPV)	
A_A (abandon)	M_{B0} (no OV)		M_{BT} (no OV)		No business at all

Table 1. Game choices and investment payoff matrix for a duopoly case

The expected Expanded Net Present Value (ENPV) for the (DF,DF) strategies that contains the ROV to wait for high and low quality firm are given by equation 1 and 2 respectively:

$$ENPV_{DFDF} = ROV_{HQL} = \frac{1}{1+k}\left\{q\max\left[\pi^u - I\ ,0\right] + (1-q)\max\left[\pi^d - I,0\right]\right\}$$
$$= \frac{1}{1+r}\left\{q\max\left[\frac{uN^2h^4\omega^2}{82k} - I_0(1+r),0\right] + (1-q)\max\left[\frac{dN^2h^4\omega^2}{82k} - I_0(1+r),0\right]\right\}$$
$$= \begin{cases} 0, & \text{if } N^2h^4 \prec \frac{1}{u}\frac{k82I}{\omega^2} \\ \frac{q}{1+r}\frac{uN^2h^4\omega^2}{82k} - I_0(1+r), & \text{if } \frac{1}{u}\frac{k82I}{\omega^2} \le N^2h^4 \prec \frac{1}{d}\frac{k82I}{\omega^2} \\ \frac{1}{1+r}\left[\frac{uN^2h^4\omega^2}{82k} + (1-q)\frac{dN^2h^4\omega^2}{82k} - I_0(1+r)\right], & \text{if } N^2h^4 \succ \frac{1}{d}\frac{k82I}{\omega^2} \end{cases} \tag{1}$$

(2)

$$ENPV_{DFDF} = ROV_{LQL} = \frac{1}{1+r}\{q\max[\pi^{u} - I\ ,0] + (1-q)\max[\pi^{d} - I,0]\}$$

$$= \frac{1}{1+r}\left\{q\max\left[\frac{uN^2h^4\omega^2}{1309k} - I_0(1+r),0\right] + (1-q)\max\left[\frac{dN^2h^4\omega^2}{1309k} - I_0(1+r),0\right]\right\}$$

$$= \begin{cases} 0, & \text{if } N^2h^4 \prec \frac{1}{u}\frac{k82I}{\omega^2} \\ \frac{q}{1+r}\frac{uN^2h^4\omega^2}{1309k} - I_0(1+r), & \text{if } \frac{1}{u}\frac{k1309I}{\omega^2} \le N^2h^4 \prec \frac{1}{d}\frac{k1309I}{\omega^2} \\ \frac{1}{1+r}\left[\frac{uN^2h^4\omega^2}{1309k} + (1-q)\frac{dN^2h^4\omega^2}{1309k} - I_0(1+r)\right], & \text{if } N^2h^4 \succ \frac{1}{d}\frac{k1309I}{\omega^2} \end{cases}$$

Finally, in case of monopoly conditions, the case where one player invests while the other abandons the investment the ENPV (ROV) is given by expressions 3.

(3)

$$ENPV_{DFDF} = ROV_{M} = \frac{1}{1+k}\{q\max[\pi^{u} - I\ ,0] + (1-q)\max[\pi^{d} - I,0]\}$$

$$= \frac{1}{1+r}\left\{q\max\left[\frac{uN^2h^4\omega^2}{64k} - I_0(1+r),0\right] + (1-q)\max\left[\frac{dN^2h^4\omega^2}{64k} - I_0(1+r),0\right]\right\}$$

$$= \begin{cases} 0, & \text{if } N^2b^4 \prec \frac{1}{u}\frac{k64I}{\omega^2} \\ \frac{q}{1+r}\frac{uN^2h^4\omega^2}{64k} - I_0(1+r), & \text{if } \frac{1}{u}\frac{k64I}{\omega^2} \le N^2h^4 \prec \frac{1}{d}\frac{k64I}{\omega^2} \\ \frac{1}{1+r}\left[\frac{uN^2h^4\omega^2}{64k} + (1-q)\frac{dN^2h^4\omega^2}{64k} - I_0(1+r)\right], & \text{if } N^2h^4 \succ \frac{1}{d}\frac{k64I}{\omega^2} \end{cases}$$

In order to estimate the ENPV for waiting strategies, we divide the demand spectrum into four zones as given below by equations 4 and 5 for low and high quality firms respectively.

$$\begin{aligned} &\text{Zone L1:} && N^2h^4 \prec \frac{1}{u}\left(1309kI/\omega^2\right) \\ &\text{Zone L2:} && \frac{1}{u}\left(1309kI/\omega^2\right) \le N^2h^4 \prec 1309kI \\ &\text{Zone L3:} && 1309kI \le N^2h^4 \prec \frac{1}{d}\left(1309kI/\omega^2\right) \\ &\text{Zone L4:} && N^2h^4 \succ \frac{1}{d}\left(1309kI/\omega^2\right) \end{aligned} \tag{4}$$

$$\begin{aligned} &\text{Zone H1:} && N^2h^4 \prec \frac{1}{u}\left(82kI/\omega^2\right) \\ &\text{Zone H2:} && \frac{1}{u}\left(82kI/\omega^2\right) \le N^2h^4 \prec 82kI \\ &\text{Zone H3:} && 82kI \le N^2h^4 \prec \frac{1}{d}\left(82kI/\omega^2\right) \\ &\text{Zone H4:} && N^2h^4 \succ \frac{1}{d}\left(82kI/\omega^2\right) \end{aligned} \tag{5}$$

In each zone for low and high quality firm, we compare ENPV when both players defer investment with NPV when both invest immediately at t=0. The target is to estimate the market demand level where waiting instead of investing is more profitable. We present our analysis for high quality firm, while it is similar for low quality firm. In zone H1, demand is so low that the value of investment is zero for both cases. Thus in zone 1 the strategy is to wait. In zone H2 the waiting as seen is better that investing, as the later gives 0. In zone H3 the $ENPV_{DFDF}$ is given by equation 6.

$$ENPV_{DFDF} = \begin{cases} \frac{q}{1+k}\left[\frac{uN^2h^4\omega^2}{82k} - I_0(1+k)\right] \succ 0 & \text{if waiting} \\ \frac{N^2h^4\omega^2}{82k} - I_0 \succ 0, & \text{if investing immediately} \end{cases} \tag{6}$$

Waiting will be more profitable than investing if ENPV(wait) – NPV(invest) >0. It is easy to show that this equation is met. Hence, in the zone H3 waiting is more profitable than investing immediately.

$$ENPV_{DFDF} - NPV_{ININ} = \frac{q}{1+r}\left[\frac{uN^2h^4\omega^2}{82k} - I_0(1+r)\right] - \frac{N^2h^4\omega^2}{82k} - I_0 \succ 0 \qquad (7)$$

$$\frac{q}{1+r}\frac{uN^2h^4\omega^2}{82k} - \frac{N^2h^4\omega^2}{82k} + (1-q)I_0 \succ 0$$

Finally, in zone H4 investment provides higher value if the firm invests immediately than waits. Hence, the equilibrium will be (DF, DF) if demand is below the value $N^2h^4 \succ \frac{1}{d}\left(82kI/\omega^2\right)$, (IN, IN) if demand is above this level. Hence, the threshold of demand between waiting and investing is given by equation 8.

$$N^2h^4 = \frac{1}{d}\left(82kI/\omega^2\right) = u\left(82kI/\omega^2\right) = e^{\sigma\sqrt{\Delta T}}\left(82kI/\omega^2\right) \qquad (8)$$

The same applies for the low quality case. We assume that $u = e^{\sigma\sqrt{\Delta T}}$ and $d = e^{-\sigma\sqrt{\Delta T}}$ (Trigeorgis, 1996). The investment threshold is a function of the uncertainty (here, measured by the volatility) of the market demand, the coefficient of the development cost and the overall investment infrastructure (one time) cost. The competitors will choose to wait more if the market demand is more volatile, and the infrastructure implementation costs more. Particularly, the uncertainty of the market demand increases the ROV and provides arguments for waiting more. As it can be seen in Appendix, in case of the price competition the competitor with the best quality attribute is able to charge higher prices and so experience higher revenues. From (8) we can see that the investment threshold of the two period game is higher than the threshold of the one period game. The conclusion is that the size of the investment cost (one time – sunk cost) as well the market size (number and type of consumers) are key factors to the entry decision and so the investment equilibrium. Also, the afore-mentioned discussion and results for a two-period game show the precise conditions under which competitors will enter the market. In Figure 2, we present the two dimensions of the customers demand domain. Under full symmetry among players, the demand thresholds are the same for both players. It may be subject of further work to adopt business asymmetries between players as a more realistic case.

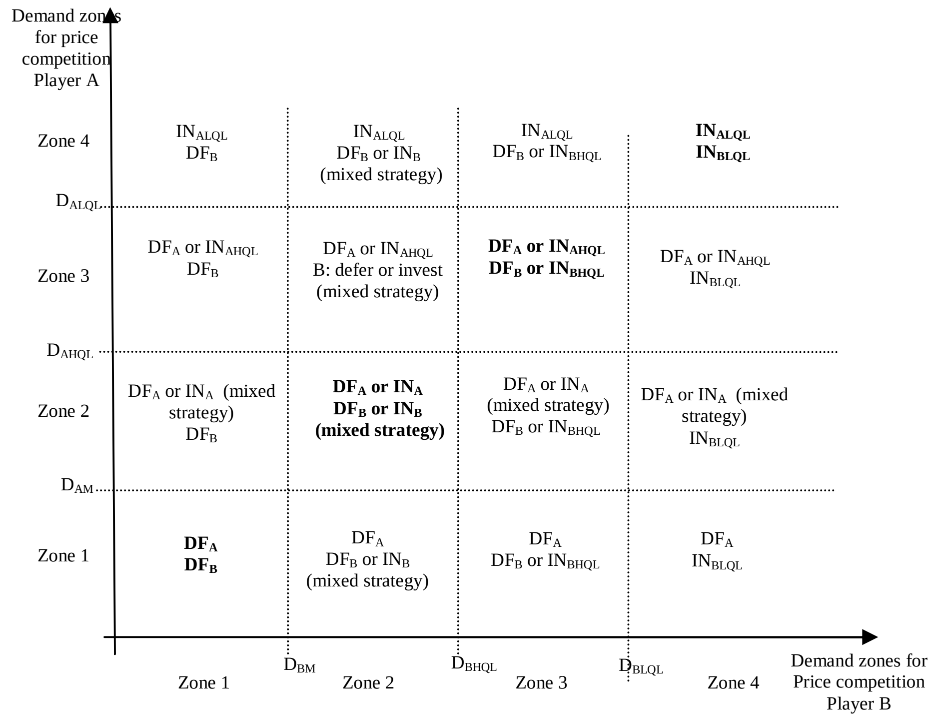

Figure 2. Game equilibrium for symmetrical players.

4 A CASE STUDY ANALYSIS

To illustrate the proposed analysis we apply it to a hypothetical organization such as a public university (PU). PU is interested in entering in entering into the e-learning business field and exploiting its high experience in typical upper level education. The PU examines the possibility of setting up a subsidiary company named “PU e-services” and entering the e-business field. The analysis is based on the Mantzari and Economides (2004) case study. They examined a business activity to establish an enterprise which will offer services for learning foreign languages through the World Wide Web. The customers will be students and adults having access to the Internet. The base scale investment concerns learning English. Quality attributes may concern English for specific purposes such as business, technical, medicine, literature. It may also concern similar services for other foreign languages. The courses are developed digitally on a special educational software platform that is purchased to cover the needs of the “PU e-services” company and it is installed on the collocated server. Afterwards the users of our services submit their own personal passwords and ID’s in order to get connected to the server and attend the lessons through the Internet. Competitive advantages of such business model for providing distance-learning services comparing to the conventional syllabus are: i) the absence of traditional classrooms which leads to reduced Operating Costs, ii) the absence of traditional way of teaching which reinforces autonomous learning, iii) offering services 24h a day, 7days a week that leads to maximum exploitation while at the same time it is more convenient for the users, iv) flexible pace of attending the lessons, and v) reduced fees due to the continuous functioning and the reduced operating costs.

From PU e-services perspective a decision to enter the e-learning business can be a matter of timing. Particularly, it is examined whether PU can afford to wait or should move rabidly sacrificing uncertainties’ control in order not lose part or even more overall of the business value (monopoly case for the competitor). By waiting, PU expects that uncertainties, related to the acceptance of e-learning services in the specific market and the organizational capabilities of it, would be resolved. By waiting, PU could learn more about the potential returns on such investments. For example, the acceptance rate for such services might increase as customers become more aware of these services. In parallel, PU could take actions to lower its market entry risk (e.g. by seeking corporate alliances for common exploitation of the specific market). With these concerns in mind PU is addressed to the question: how long should PU wait to enter the e-learning market? A two players’ game is considered where one player is PU and the other player is a competitive private educational organization on a national level. The decision making process has to find the balance between investing now or wait till the moment where the business value is higher than its expected value in the future up to the time moment where the investment is still available to the PU. During the waiting period, some of the decision factors may change and even if some of them are perfectly predictable the decision maker has to estimate the pros and cons of an early or late decision.

As mentioned before, it is more profitable for the PU to offer higher level of e-learning services, being able to charge it with higher price than its competitor. Also the optimum time to enter the market is defined by the expected customers demand level where the expected ENPV is the higher possible. Concerning the quality attributes, the analysis focuses on one dimension perspective, while it may be a subject of further work to consider multi-attribute analysis. In general the most important ICT service attributes could be reliability, fit for purpose and keeping promises to the customers. Especially, regarding the e-learning services provision by institutions the demand for quality and accountability is continuously increasing. In overall, the factors constitute the online learning are as follows (MacLeod 2002, Alley & Jansak 2001, McLoughlin & Visser 2003):

- Engage students in active, experiential learning.
- Build and sustain motivation by providing prompt and regular feedback.
- Make expectations explicit and cultivate self-directed learners.
- Provide interaction with others which allows negotiation and construction of knowledge.
- Provide activities that allow for practice of new skills and foster transfer of new knowledge.
- Allow time and space for reflection on learning.
- Balance individual and collaborative tasks for learning so that interpersonal and social elements are well integrated.
- Align assessment processes with learning outcomes.

- Provide accessible and structured support for student learning.
- Ensure that teacher-student and student-student interaction are provided.

In particular, the quality attribute may be composed by a number of the aforementioned criteria and so defined as a vector of such factors.

5 DISCUSSION AND FUTURE RESEARCH

The ICT industry is one of the most capital intensive among the high-technology industries. ICT business analysis, especially after the industry deregulation, has become a difficult task. ICT investments contain uncertainties concerning, demand, technology, organizational, financial and environmental aspects. Traditional quantitative cost-benefit analysis concerning investment decisions is by no means sufficient for capturing the complexity of the problem in its entirety. In addition, ICT businesses contain growth aspects modeled by staged evolution, while each growth stage may experience different competition characteristics. Especially, the ICT competition is mainly related to the oligopoly conditions where there are only few players and game theory is suitable for modeling these conditions.

So far in the ICT literature competition modeling by GT and ROs does not contain multi-period analysis. The proposed model addresses the research question of "when and how much to offer" for a service (product) in the ICT market. ICT products can be mainly characterized by high fixed infrastructure costs and very low variable costs. Normally, fixed costs are sunk costs, not recoverable, if business fails. Also, some of ICT business fields may experience significant capacity constraints such as broadband backbone network, while in some other ICT fields not so significant such as e-learning activities and more generally information services. Price competition rationally leads to products differentiation for avoidance of intense price competition. In addition, uncertainties control proposes the adoption of the ROs as already proposed in the ICT literature (Angelou and Economides, 2009; Mun, 2002; Trigeorgis 1996).

In the light of the aforementioned characteristics and research proposals, this study provides a multi-period price competition model for ICT business activities. For each period of the overall business game the competitors watch and analyze the overall market demand and recognize the market size as well as the optimum entry point for them. According to the market demand there may be space for one, for two, or for none of the players to enter the market. Also a case study is, intuitively, discussed regarding a public university as an interest business investor to enter the e-learning business field.

Most ICT industries exhibit network effects. Angelou and Economides (2009) discussed network effects under qualitative thinking in the basis of ROs and game theory integration. Network effects concern both sequential and simultaneous decision modes. In a market where 'tipping' effects are strong (e.g., computer software market, satellite broadcasting market) the first firm to establish a base tends to dominate the whole market in due course. In addition, in some instances a firm's investment project has higher value if another firm also invests; in this case the investments of the two firms are said to be complementary. For example, as long as competitive effects are not too strong, a firm may benefit from the advertising expenditure of other firms to the extent that this creates demand for the product class as a whole, not just the output of the particular producer. Finally, simultaneous investment may involve strategic alliances benefits which may include the allocation of complementary resources from all parties. If both players act (invest) simultaneously they can achieve an aggressive market entry. Someone may examine in a quantitative way all these aspects and how they can influence the decision equilibrium of the proposed analysis. Another, extension of the analysis could be the assumption that in the first period, only low quality of investment is possible, while in the second period, both high and low quality investment is available. Furthermore, investment cost can be lower for the second period (Demirhan et. al. 2006, Demirhan et. al. 2007). Also, this study could include a multi-criteria analysis taking into account both quantitative and qualitative factors. In addition, future research could examine more players in the market, which is more realistic in the new era of the telecommunication markets. Finally, a real life case study could prove the real applicability of the proposed analysis.

6 CONCLUSION

The quantitative game theoretic analysis is already well known for single business, and extended analysis of basic price and quantity competition games is already present in the basic industrial organization literature. However, this paper adds in the overall competition modeling dimension beyond that by introducing a multi-period competition perspective by integrating ROs and game theory analysis. In addition, it is the first time where ROs and game theory are integrated in the e-learning field under price competition modeling.

It examines the two players' game (duopoly case). Duopoly provides a starting point for research investigating strategic impacts of ICT investments. Particularly, in telecommunication markets there are normally two or three strong players and a number of weaker players that normally follow the strong ones. One perspective of our analysis could be the case where the game concerns two parties, one is the firm of interest and the other is the rest of the competition as one entity. Finally, a case study, from e-learning business field, is intuitively examined showing how the model can be formulated.

Appendix

Price competition analysis

The business opportunity is available only for one period. Particular, if one competitor invests and the other does not invest there are monopoly conditions. If both invest at t=0 there are simultaneous decisions, while if none of them invests there is no business at all.

We consider the following time order of events (actions) and decisions. First, the firms decide to invest in the business field where price competition will take place. Second, service (product) quality attributes are chosen by the players. Finally, each firm chooses its price to maximize its respective profits. We focus in the broadband market and especially the bandwidth provision. We assume that customers prefer higher bandwidth, however they vary in their willingness to pay for it. The notations used in the analysis are given in Table A-1.

Notation	***Definition***
D	Customers demand at time period t
d_nD	Decrease of demand moving down by d_n (binominal process) at time period t+1
u_pD	Increase of demand moving up by u_p (binominal process) at time period t+1
D_{iM}	Customers demand threshold for monopoly case (i=A,B)
D_{iHQL}	Customers demand threshold for high quality case
D_{iLQL}	Customers demand threshold for low quality case
l	Lower index of customers type of the market being interest to by service (product) with specific quality attributes
h	Higher index of customers type of the market being interest to by service (product) with specific quality attributes
N	Number of customers for each customer type.
NPV	Net Present Value of business opportunity where no ROV exists (No ROV)
ENPV	Expanded Net Present Value of business opportunity which contains the ROV
ROV_M	Real option value (ROV) of business opportunity for monopoly case
ROV_{HQL}	Real option value (ROV) of business opportunity for high quality service
ROV_{LQL}	Real option value (ROV) of business opportunity for low quality service
IN_i	Invest for player i (i=A,B) under monopoly conditions
DF_i	Defer for player i (i=A,B) under monopoly conditions
IN_{iLQL}	Invest for player i (i=A,B) with low quality
DF_{iHQL}	Defer for player i (i=A,B) with high quality

DF_{iLQL}	Defer for player i (i=A,B) with low quality
I_o	Business infrastructure cost (one-time cost) at the time period t
I	Business infrastructure cost (one-time cost) at the time period t+1
r	Discount factor
π	The expected revenues from business opportunity (π_M monopoly case)
C	The overall operational cost function
k	The coefficient of the development cost
c	Marginal cost of service/product offer
t	Type of consumers
t_k	Type of consumers that that are indifferent between products (u_1,u_2)
p	Price of product/service offered
u	Quality of product/service offered (u_M monopoly case)
u_1	Service quality charged with p_1
u_2	Service quality charged with p_2
σ	Demand volatility
$U^t_{customer}$	Customers' overall utility
ω	Coefficient factor that is related the service (product) value for the customer

Table A-1: Notations Used in our Model

We index the customers' types with the variable t. We consider that t is uniformly distributed over the interval [l,h], where h>l>0. Customers with t=h have the higher interest in the service (product), while with t=l have the less interest in the product. The density of customers is N per unit of the type index. Hence, the total number of customers (overall market size) is N(h-l). Customers choose to buy the services if their utility (or net value) is positive. Particularly, we define the utility value for customer t for product with attribute u (u>0) at the price p to be the difference between the value of this (i.e. quality in our case) and the price p that the customer pays.

$$U^t_{custoemer}(t,u,p)=V(t,u)-p \qquad \text{(A-1)}$$

Where

$$\frac{\partial V}{\partial u}>0,\ \frac{\partial V}{\partial t}>0$$

We use a specific function for utility in order to discuss on specific results proposed by Zhu (1999).

$$U^t_{customer}(t,u,p)=\omega ut-p \qquad \text{(A-2)}$$

The type t customer will buy the product if the utility value is positive

$$t_o\geq\frac{p}{\omega u}$$

Since all customers in [t_o,h] will choose to buy the product, the total demand, D, is

$$D=N(h-p/\omega u) \qquad \text{(A-3)}$$

We assume that the marginal cost of producing each unit (e.g a new student enrolment) is c. The development cost is ku^2. Hence, the overall cost function C is

$$C(u,D)=ku^2+cD \qquad \text{(A-4)}$$

where k may be the coefficient of the development cost. It is related to the technology used to develop the service (product). Particularly, for e-learning software products, k is related to the programming platform for the application development as well as to the personnel cost development. The quadratic term represent that the marginal development cost increases as the quality of the service (product) increases. The time order of events is as following. First, the competitors pay an investment cost in entering the e-learning market, then they choose the qualities (attributes) of their respective service (product) and then they compete in the price domain. The competitors choose whether or not to make a fixed, irreversible investment to enter the market. At the end of this choice, each competitor recognizes his competitors, which have entered and which have not. Second, each competitor chooses the quality attribute per enrolment type (e.g. business English, academic English, engineering English). Higher bit rate requires higher investment (development) installation cost. Finally having looked the competitor's service attributes, each firm chooses its price for optimizing its business utility.

Monopoly competition

In case of a monopoly, we consider that firm decides the product quality u and the price p having in mind to maximize the business profit π.

$$\max_{u,p_1} \pi = p\,.D - C\left(u, D\right) = \left(p - c\right)D - ku^2 = \left(p - c\right)\left[N\left(h - {p}/{\omega u}\right)\right] - ku^2 \qquad \text{(A-5)}$$

For simplicity, without loss of generality, we assume c=0 and the solution of the optimization problem is

$$u_M = \frac{Nh^2\omega}{8k},\ p_M = \frac{Nh^3\omega^2}{16k},\ \pi_M = 0{,}01222\frac{N^2h^4\omega^2}{64k}$$

Duopoly competition

The competition model, to be analyzed, corresponds to two firms entering a new market, while there is no prior leader. To find the game equilibrium, we first start with the final choice of the price selection, considering that each player knows the decision of his competitor and the attributes of his products. First, the two competitors simultaneously choose service (product) attribute (e.g. bandwidth provision). Then each competitor, having recognized the other firm's choice, simultaneously chooses a price for its product. More clearly, the prices are chosen after service (product) attributes choice, because the prices can be changed more readily (Zhu, 1999).

We consider two products on the market, with bandwidth and price (u_1,p_1) and (u_2,p_2) respectively. We also consider that u_2>u_1. Customer t will buy product i if

$\omega u_i t_i - p_i > 0$ and $\omega u_i t_i - p_i > \omega u_j t_j - p_j$, where i#j

If t_k is the type of customers that are indifferent between product (u_1,p_1) and (u_2,p_2), then

$$\omega u_1 t_k - p_i = \omega u_2 t_k - p_2$$

Hence,

$$t_k = \frac{p_2 - p_1}{\omega(u_2 - u_1)}\text{, where } t_k>0$$

The customers are grouped into three parts: $\left[l, \frac{p_1}{\omega u_1}\right], \left[\frac{p_1}{\omega u_1}, t_k\right], [t_k, h]$ where customers buy nothing, buy product u_1, and buy product u_2 respectively.

Given u_1 and u_2, both competitors try to maximize their profits by determining specific prices for their products.

$$\max_{p_1} \pi_1 = p_1.q_1 - c_1(u_1, d_1) = p_1.N\left[t_k - \frac{p_1}{\omega u_1}\right] - k.u_1^2 \quad \text{(A-16)}$$

$$\max_{p_2} \pi_2 = p_2.q_2 - c_2(u_2, d_2) = p_2.N[h - t_k] - k.u_2^2 \quad \text{(A-17)}$$

The solution of the optimization problem provides

$p_1^{opt} = \frac{h\omega u_1(u_2 - u_1)}{4u_2 - u_1}$ and $p_2^{opt} = \frac{2h\omega u_2(u_2 - u_1)}{4u_2 - u_1}$

So, the competitor with the higher product quality is able to set a higher price.

Working backwards, we solve the second phase of the game. Each firm sets its product quality level in order to maximize its profit.

$$\underset{u_1}{\mathrm{Max}}\,\pi_1 = p_1^{opt}.N\left[t_k - \frac{p_1}{\omega u_1}\right] - k.u_1^2 \quad , \quad \underset{u_2}{\mathrm{Max}}\,\pi_2 = p_2^{opt}.N\left[h - t_k\right] - k.u_2^2 \qquad \text{(A-18)}$$

Taking values for the optimum prices for both players and having

$\frac{\partial \pi_i}{\partial u_i} > 0$ We have the following equations:

$$Nh^2\omega u_2^2(4u_2 - 7u_1) - 2ku_1(4u_2 - u_1)^3 = 0 \; , \; 2Nh^2\omega(2u_1^2 - 3u_1u_2 + 4u_2^2) - k(4u_2 - u_1)^3 = 0 \qquad \text{(A-19)}$$

Solving these equations and using the afore mentioned also equations we find the equilibrium prices, qualities (service attribute), and profits for the two competitors, which are respectively,

$$u_1^{opt} = 0.02412\frac{Nh^2\omega}{k}, \; p_1^{opt} = 0{,}00513\frac{Nh^3\omega^2}{k}, \; \pi_1^{opt} = 0{,}000764\frac{N^2h^4\omega^2}{k}$$

$$u_2^{opt} = 0.12666\frac{Nh^2\omega}{k}, \; p_2^{opt} = 0{,}05383\frac{Nh^3\omega^2}{k}, \; \pi_2^{opt} = 0{,}01222\frac{N^2h^4\omega^2}{k}$$

Finally, it can easily be estimated $t_k = 0.475b, \; t_1 = 0{,}213b, \; q_1^{opt} = 0.2625Nb, \text{ and } q_2^{opt} = 0.525Nb$ indicating that the two competitors would support 78.75% of the overall market. As seen in the present analysis the two competitors choose different qualities because if they choose the same service attribute (quality) bandwidth, they compete strictly on price and price will fall to marginal cost, which for telecommunication services goods is almost zero, so fail to recover their development, sunk, irreversible costs 0.

In the last phase of the game we consider the decision whether to make the initial investment to initiate business activity and enter the market.

Demand zones analysis and decision mode for a single period analysis.

The equilibriums to make investment and exercise the business option are defined by the market demand thresholds that make investment profitable (i.e. NPV=π-I>0).

$$(IN_{iLQL}, IN_{iLQL}), \text{if } N^2h^4 > 1309k\,{}^{I}\!/_{\omega^2}, \quad (DF_{iHQL}, I_{iHQL}), \text{if } 82k\,{}^{I}\!/_{\omega^2} < N^2h^4 \le 1309k\,{}^{I}\!/_{\omega^2},$$

$$(DF_i, DF_i), \text{if } N^2h^4 \le 64k\,{}^{I}\!/_{\omega^2}, \quad \text{mixed strategy}\,(IN_i, DF_i)\,\text{or}\,(DF_i, IN_i), \text{if } 64k\,{}^{I}\!/_{\omega^2} < N^2h^4 \le 82k\,{}^{I}\!/_{\omega^2}$$

where I is the investment (infrastructure) cost for players, Figure A-1.

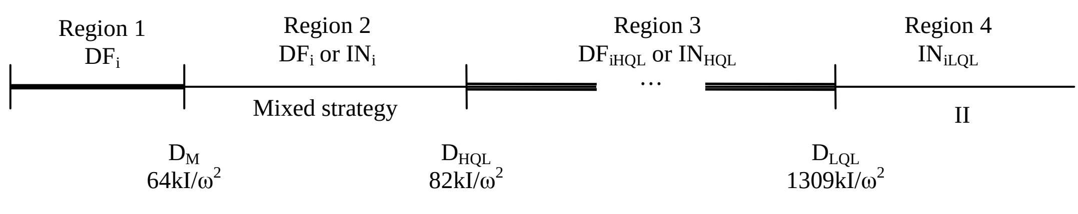

Figure A-1. Demand regions analysis of one-period game

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