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STAGED COMPETITION MODELING IN BROADBAND BUSINESS FIELD

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ABSTRACT

After the deregulation of the telecommunications' market, municipalities and utility-based firms which own physical resources are capable of entering in this market. This paper focuses on the broadband business field and provides a model for analyzing the new perspectives for new investors in the field. It integrates, for the first time in the literature, Real Options and Game Theory under a multistage business perspective. It considers price and quantity competition for various stages of the business game in order to find the optimal business strategy. Particularly, it examines the optical fiber passive and active network implementation as business stages for entering in the broadband field.

KEYWORDS

Broadband Communications, Business Model, Competition, Decision-making, Fiber Optics Networks, Telecommunications Operators.

1. Introduction

In the new era of the telecommunications business field with a high number of potential investors, the Information and Communication Technologies (ICT) service providers should seek access network solutions with even more bandwidth. The most viable solution for high bandwidth provision, especially in access networks, is the optical fibers technology. Hence, the installation of the optical fibers and their commercial exploitation is a very challenging business activity. Authorities that own physical infrastructure such as service utility companies (water, electricity, and transportation) and local municipalities experience competitive advantage over typical telecommunications operators. These advantages are mainly coming from the lower installation and implementation costs of optical fibers networks. Such kinds of initiatives are already taken place also in Greece. These infrastructures are based on local municipalities and service utility companies and should be operated in an effective way. Therefore, demanding business modeling should be applied. The telecommunications market deregulation and technological innovations have made it possible for the so-called "facility-based" or "utility-based" firms to roll out proprietary networks and to rely mainly on their own infrastructures in order to provide services to end-customers. Contrary to the facility-based firms and local municipalities, "service-based" firms do not invest in facilities but lease access to the networks of the facility-based firms in order to offer services on retail markets.

The potential business investors in the field of broadband technology face the dilemma of selecting the time entry into the market and the type of business activity to be involved. Especially, facility-based firms may focus on a three basic parts, or stages, of a new broadband business field activity. The fist part is the Dark Fiber (DF) installation and optical network implementation. The second part is the DF activation, light the fiber, and bandwidth services' supply. Finally the third part is the basic services' provision such as Video on Demand (VoD) or remote surveillance. This study treats these opportunities using option thinking and applies game theory to model competition for the aforementioned business stages. Option thinking has been already applied in the ICT field [1][2][8]. Also, options analysis in broadband business field and especially concerning broadband technologies upgrade from ADSL (Asymmetric Digital Subscriber Loop) to VDSL (Very High Data Rate Subscriber Loop) has been examined in [4][5][6][11]. For a survey of options theory applications in the ICT field, the interest reader is referred to [3]. This work adopts quantity and price competition for the available business stages according to their specific business characteristics. The main aim of the paper is to provide a decision making model, where initial investment owns future opportunities treated as real options. The interest investor 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 preempt possible competitors, which are also owning the specific business opportunity?"

The paper is organized as follows. Section 2 presents the background of the broadband industry, which motivates the proposed analysis. Section 3 describes the model and the proposed analysis. Section 4 discusses a real life case study. Finally, section 5 concludes and presents a few suggestions for future research.

2. Industry Background

2.1 The Broadband market and business opportunity

Broadband services enable consumers to access the Internet at high-speed rates. In most industrialized countries, broadband is developing fast [7][9]. Further to the previous decade deregulation of the telecommunications markets, broadband business opportunities are supported by the state authorities who recognize that broadband technology can improve citizens' quality of life. Among others, European Commission (EC) indicated the necessity of broadband development in all member countries. It tried to offer to its citizens "an Information Society for all" supporting a vision for the next years called i2010. Many projects were co-funded by EC and national resources. Although the cost of broadband infrastructures has decreased, the required investments remain an obstacle for private sector [9]. Utility-based companies experience significant competitive advantages since they own a number of physical resources or installation rights that in overall decrease the optical fibers implementation cost. Greece holds one of the lowest positions in the EU with respect to the broadband penetration. Broadband in the country is still at the early stages of growth with a penetration rate of 7% in 2007 [4]. However, Greece planned to fund the deployment and operation of broadband metropolitan networks and services. The owner of these infrastructures will be the municipalities which participate in this initiative. They will be free to make joint ventures with telecommunications private companies for ensuring the required experience in the specific business field [9] [8].

The discussion of this work focuses on facility-based firms, normally utility companies, as well as municipalities that own a number of physical resources. Such resources may be transportation networks, sewerage and water pipes and electrical wires poles and pylons. Based on this infrastructure the legal owner of it may install dark optical fiber for implementing a passive optical network. Then the next business stage initiated by the utility firm itself or by an experienced telecommunications' company will be the activation of passive network (light the fiber). Finally, the third stage will be the specific services' provision. The overall broadband business opportunities for transportation utility-based firms which are willing to act in this field were discussed in [8], while [2] applied options thinking for staged broadband investments under exogenous competition modeling. We consider the present study as an extension of that work. The proposed analysis aims at finding answers to the following questions: a) which are the stages of the specific business that is available to utility firms and municipalities? b) what kind of competition is experienced by the interest investor for each business stage? c) what is the optimum time and scale to implement each stage of the overall broadband business?

Let call NewTelCo, the interest investor. NewTelCo faces competition at various stages of its future business activity. NewTelCo is normally a subsidiary of the parent utility company. In the following, we examine the various types of competition for each of the business stages. We provide arguments for considering various types of competition for each business stage.

2.2 Competition modeling for these opportunities – Price or quantity competition?

The industrial organization literature has investigated circumstances under which each type of competition is more likely to occur. In the aircraft case, 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. 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 this case, competition is in quantities. Such case might be the dark fiber infrastructure installation at distribution and especially access network layer, and the quantity could correspond to the geographical coverage. 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: they cannot produce any larger output. Under these circumstances, there is no reason to cut price, since output cannot be increased beyond its present levels in either firm. 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 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 would 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 a monopoly but more than 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 aircraft, 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, 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 will have planned it that way.

3. Analysis and Model Presentation

3.1 The business case - the game to be solved

A number of identical firms may enter the broadband business field in the deregulated telecommunications market. We consider a staged business game where in each stage the optimum investment decision in terms of time, quantity and price is estimated according to competition conditions. Our target is to find the overall business equilibrium for all the players in the specific business field. We start our analysis with two firms to be involved in the specific under investigation business entry. We may easily extent this assumption by considering more firms to compete.

3.2 Analysis presentation

We consider three business stages in the analysis: 1) the passive network (PasNet) stage, 2) the active network (ActNet) stage, and 3) the service stage. The PasNet includes dark fiber, ducts and microducts. The ActNet includes all these equipment that lights the fiber and provides capability for bandwidth dealing on the physical transmission mean. The ActNet will provide wholesale access for Service Providers (telcos, internet service providers, video providers etc.) or any third part which will want to lease a part of the funded infrastructure. The supported services will be triple-play (Voice, Data and Video) and in the near future we are going to talk about quad play (Plus Video, Mobile). Table 1 summarizes the aforementioned discussion and the business roles, business stages, which are available to utility companies. Also, we present the critical success factors and some comments for each business role.

Table 1 Business roles for broadband business field

Role	Description	Critical Success Factors	Comment
Service Provider	Internet, TV, Telephony, & other services	Customer base, brand, services platforms, marketing know-how	It requires a joint venture with an IT company, since utility companies and local municipalities present poor IT business culture.
ActNet	operates the active network and provides equal access to service providers	Network operations know-how	It normally requires the involvement of Telecommunication experienced people. This can be realised provided the right people are attracted to the new company.
PasNet	builds and owns the passive network	Funding for investment in passive network infrastructure	Normally, utility company and municipalities may ensure funds by national or European Union sources for a passive network deployment

1) Dark fiber installation - Infrastructure decision-Passive Netowrk

In the first stage, firms decide whether and where to build a passive optical fiber network. It is the decision to invest the basic infrastructure, which is the dark fiber installation. That decision may be related to dark fiber installation for backbone, distribution, access network. In this stage firms choose geographical area (coverage) of dark fiber deployment. We consider it as quantity competition, because such investment takes a long time and so firms prefer to commit themselves with a specific quantity (here, geographical coverage). Quantity competition equilibrium is estimated using game theory analysis for both simultaneous and sequential decisions **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**[12]. Appendix provides specific analysis for quantities and revenues equilibrium for sequential and parallel decisions.

2) Active equipment installation

In the second stage, firms choose capacity (size of routers, switches, portion of fiber to “light”, etc.) for each market segment; this capacity choice determines the maximum percentage of telecommunications providers, but also households and business customers in the firm’s market segment that can be served in the final stage. Firms may install different capacities in different segments. Appendix provides specific analysis for quantities and revenues equilibrium for price competition.

3) Service and application provision - Products/Service attributes decision

In this stage firms choose services with specific attributes to offer to the customers. Such services might be double or triple play ICT services with specific bandwidth values. We consider price competition. Particularly, competitors choose price and offer service to consumers who choose whether or not to buy service based on these prices; consumption takes place and profits are realized. Hence, firms choose price of the products/services offered and customers choose quantities. In conclusion, we consider that physical infrastructure competition (dark fiber) is related to quantity competition, while bandwidth, broadband access services competition is related to price competition. Similarly, services provision competition will concern price competition. In this work we focus on the business layer analysis and model the competition for dark fiber and active equipment business involvement.

The overall business utility (OBU) function including all stages of the business opportunity is given by the following.

$$OBU_{\pi} = \sum \pi_J \left(+\pi_{J-1}\left(+\pi_{J-2}\left(\ldots\left(+\pi_{J-j}\right)\right)\right)\right) \quad (1)$$

where π is the business profit for business stage j, and J is the total number of business stages. In case we consider no dependency between business stages the overall business utility is given by the sum of each business stage profit.

$$OBU = \pi_{DF} + \pi_{AF} + \pi_{BS} \quad (2)$$

where the business profit indexes indicate dark fiber (DF), active fiber (AF) and broadband services (BS).

As it can be seen in Appendix, stage one and quantity competition analysis indicates that the firms should be first movers (FMs), since they will experience higher profits. However, since both competitors recognize it, under symmetrical conditions they will normally move simultaneously fighting so and gaining less. In addition, in the price competition case the competitor with the best quality attribute (here, bandwidth or number of optical fibers per connection) is able to charge higher prices and so experience higher revenues.

4. A Real Case Study Analysis

To illustrate the proposed analysis we apply it for a growing Water Supply & Sewerage Company, which we refer to as WSSC to protect its identity and its projects. WSSC is interested in entering in the broadband business field and exploiting its physical infrastructure (water and sewerage pipes). The company examines the possibility of both setting up a subsidiary company named NewTelco Services and entering the telecommunications business as a wholesale infrastructure provider and in parallel developing retail fiber access-based telecommunications services. The NewTelco Services may undertake the roles PassNet and ActNet.

The overall competition of the WSSC in the area of interest plans to deploy its own fiber network. NewTelco Services should work closely with ISPs and other providers to address their requirements concerning methods of interconnection and network reliability & redundancy aspects. Regarding the regulation, which demands open access networks, the new network should be promoted as an open access network. Also, local authorities have a time consuming licensing processes. Particularly, it is difficult to obtain permission for installation (digging etc.) of fiber optics. In addition, there are problems regarding construction issues (e.g. problem of traffic handling). All these problems, which also apply to the region of interest, give an advantage and a monopoly to the companies that have the capability to overcome these, or have already installed fiber cables, for the next 5 years. WSSC may gain by all these since no permission for digging is needed for its case since the optical fiber can be installed through its sewerage pipes. However, WSSC does not have enough experience for such type of business activities, while the new subsidiary will require some time to be activated and efficiently organized. This fact promotes a required time of delay for clarifying some organizational issues in the new subsidiary. Thus, from WSSC's perspective a decision to enter the broadband business can be a matter of timing. It is examined whether WSSC can afford to wait and act as second mover or should move really rabidly as first mover sacrificing uncertainties clearness in order not loose its competitive advantage and even more the overall business value. By waiting, WSSC expects that uncertainties, related to the acceptance of broadband services in the region, and the organizational capabilities of it, would be resolved. By waiting, WSSC 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, WSSC could take actions to lower its market entry risk (e.g. by seeking corporate alliances for common exploitation of the specific regional market). A two player's game is considered where one player is WSSC and the other player is OTE, the national incumbent operator. The content and business characteristics of the specific case study, though no specific financial figures are given, are based on extensive discussions between the authors and WSSC ICT management. The decision making process has to find the balance between investing now or waiting and acting as second mover. There might be a case where a first mover advantage exists, while another case where a second mover advantage exists **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**. The quantities, prices and revenues for business are derived in Appendix. For NewTelCo Services is more profitable to offer higher level of bandwidth, being cable to charge it with higher price than its competitor. Moreover, the overall business initialization and DF installation is more profitable for NewTelCo Services by acting as first mover against its competitor.

5. Conclusion and Future Research

This work examines business activities for municipalities and utility companies in the broadband business field. It models competition and provides an overall analysis for the whole business, which can be divided in stages. It adopts different type of competition for each stage and estimates the equilibrium quantities and revenues for a two-player business game. A duopoly case is considered with the anticipation that some of the results obtained from this analysis can provide insights for other kinds of markets (e.g. oligopoly) as well. The more players included in the game the more complicated the analysis becomes and each of the players has to define higher number of business alternatives to be considered. This could be a limitation of the analysis. However, in telecommunication markets there are normally two-three strong players and a number of weaker players that normally follow the strong ones. One perspective of the analysis could be the case where the game includes two parties, one is the firm of interest and the other is the rest of competition as one entity. Especially, in the case of utility based companies the physical resources owners is the new player against the usual competition, the telecommunication companies. An extension of the work can include a multi-criteria analysis including both quantitative and qualitative factors. Finally, in this paper each business stage is independent from the following ones. Someone may relax this assumption and consider inter-dependencies among the various business stages.

Appendix

Sub game equilibrium outcomes for quantitive competition

The quantitative analysis is based on game theory under quantity competition. We consider that there are two possible decision modes: simultaneous investments and sequential investments. The equilibrium quantities and payoffs are derived. Suppose P(D, Q) is the inverse demand function, i.e.,

$$P(D,Q) = D - b(q_A + q_A) \qquad \text{(A-1)}$$

where D is the demand parameter. Parameter b measures the elasticity of demand, which is inversely related to the quality of the product. $Q=q_A+q_B$ is the aggregate quantity on the market, where q_A and q_B are the quantities offered by firms A and B. Assuming a cost function $C_i(q_i)=c_iq_i$ where c_i is the marginal cost of the provided service. The following quantities and profits are derived

Simultaneous investments

If firms A and B make their decision without observing each other, this is equivalent to the situation in which they decide simultaneously (SIM). Each firm determines its optimal quantity so as to maximize its profit:

$$\max_{q_i} P_i(q_i, q_j) = \max_{q_i}\left[P(D,(q_i + q_j))q_i - c_i q_i\right] \qquad \text{(A-2)}$$

where $P_i(i = A,B)$ is firm i's profit, and q_i, q_j are quantities of firms i and j respectively. Solving the optimization problem, the equilibrium quantities and profits for firm A and B are given by:

$$q_A^{SIM} = q_B^{SIM} = (D - 2c_A + c_B)/3b \qquad \text{(A-3)}$$

$$\pi_A^{SIM} = \pi_B^{SIM} = (D - 3c_B + 2c_A)^2/9b \qquad \text{(A-4)}$$

Sequential investments

If the two firms invest sequentially, the game would proceed in an information structure that one firm can observe the other's move. Supposing that firm A invests first and firm B follows (adopting the strategy to wait for a period where the opportunity is still available), the backward induction method to solve the problem is adopted. Assuming that A is already in the market, the B's decision is

$$\max_{q_B} P_B(q_A^*, q_B) = \max_{q_B}\left[P(D,(q_A^* + q_B)) - c_B\right]q_B \qquad \text{(A-5)}$$

Anticipating the second mover's (SM) move the first mover's (FM) decision is

$$\max_{q_A} P_A(q_A, q_B^*(q_A)) = \max_{qA}\left[P(D,(q_A + q_B^*(q_A))) - c_A\right]q_A \qquad \text{(A-6)}$$

Similarly, solving the optimization problem the equilibrium quantities and profits for firm A and B are given by:

$$q_{A,B}^{FM} = (D - 2c_A - c_B)/2b \qquad \text{(A-7)}$$

$$q_{A,B}^{SM} = (D - 3c_A - 2c_B)/4b \qquad \text{(A-8)}$$

$$\pi_{A,B}^{FM} = (D - 2c_A + c_B)^2/8b \qquad \text{(A-9)}$$

$$\pi_{A,B}^{SM} = (D - 3c_A + 2c_B)^2/16b \qquad \text{(A-10)}$$

where c_A and c_B are the marginal costs for players A and B respectively. As seen FM profit are higher to SM one, while SIM decisions results are somewhere in the middle.

The analysis considers no asymmetries between players ($c_A = c_B$). Supposing the investment can produce revenues infinitely, the NPVi of the perpetual cash flows would be:

$$NPV_i = V_i - I_i = \pi_t/k - I_i \qquad \text{(A-11)}$$

where I_i is the investment cost for players A, B ($I_A .= I_B$). Next we go backwards and consider the decision whether to make the strategic investment in the first stage. Without the initial investment we consider that no business activity for each one of the competitors exists. Particularly, the final market result will be monopoly, symmetric or asymmetric Cournot equilibrium, or no investment and so business activity. The four possible outcomes are (I,I), (I,D), (D,I), and (D,D), where I means "invest" and D "defer". Reference [13] shows that the equilibriums to make investment and exercise the business option are

$$(I,I), \text{ if } D > c + 3\sqrt{bkI},$$

$$(D,D), \text{ if } D \leq c + 2\sqrt{bkI},$$

$$\text{mixed strategy } (I,I) \text{ or } (D,I), \text{ if } c + 2\sqrt{bkI} < D \leq c + 3\sqrt{bkI}$$

Price competition analysis

We consider the following time order of events/actions and decisions. First, 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 on 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. 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. I 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). Particularly, customers' types may be given per unit bandwidth, i.e. 10 Mbps for FTTH for broadband access or even 10 Gbps for LAN, MAN implementation or even telecommunications providers switching centers connections. Customers t choose to buy if his 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 or bandwidth (in our case) and the price p that the customer pays.

$$U^t_{custoemer}(t,u,p) = V(t,u) - p \qquad \text{(A-12)}$$

where $\partial V/\partial u > 0,\ \partial V/\partial t > 0$. We adopt a specific function for utility estimation proposed by [13] in order to discuss on specific results.

$$U^t_{custoemer}(t,u,p) = \omega ut - p \qquad \text{(A-13)}$$

The type t customer will buy the product if the utility value is positive $t_o \geq p/\omega u$. Since all customers in $[t_o,h]$ will choose to buy the product, the total demand, D, is

$$D = N(h - p/\omega u) \qquad \text{(A-14)}$$

We assume that the marginal cost of producing each unit (e.g FTTH connection) is c. The development cost is $k.u^2$. Hence, the overall cost function is

$$C(u,q) = ku^2 + cD \qquad \text{(A-15)}$$

where k may be the coefficient of the development cost. The quadratic term represent that the marginal development cost increases as the service/product attribute (e.g. bandwidth or fibers per connection) increases. The proposed price competition analysis is based on a three-phase game. First, competitors pay an investment cost in entering the broadband bandwidth market "lighting up the dark fiber", then they choose the qualities (attributes, here bandwidth) of their respective service/product and then they compete in the price domain. To analyze, and find the subgame equilibrium, we first start with the final phase of the game, which is the choice of the price considering that the players know the number of entrants and the attributes of their respective products. Particularly, the competitors simultaneously choose service/product attribute. 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, because the prices can be changed more readily. 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, $t_k = (p_2 - p_1)/\omega(u_2 - u_1)$, where $t_k>0$.

The customers are grouped into three parts: $[l, p_1/\omega u_1], [p_1/\omega u_1, t_k], \text{and} [t_k, h]$ 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 a specific price for their product.

$$\underset{p_1}{\text{Max}}\, \pi_1 = p_1.q_1 - c_1(u_1,q_1) = p_1.N[t_k - p_1/\omega u_1] - k.u_1^2 \qquad \text{(A-16)}$$

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

The solution of the optimization problem provides

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

As seen competitor with higher product quality is able to set 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.

$$\underset{u_1}{\text{Max}}\, \pi_1 = p_1^{opt}.N[t_k - p_1/\omega u_1] - k.u_1^2 \qquad \text{(A-18)}$$

$$\underset{u_2}{\text{Max}}\, \pi_2 = p_2^{opt}.N[h - t_k] - k.u_2^2$$

Taking values for the optimum prices for both players and having $\partial\pi_i/\partial u_i > 0$ we have the following expressions:

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

$$2Nh^2\omega(2u_1^2 - 3u_1u_2 + 4u_2^2) - k(4u_2 - u_1)^3 = 0$$

Solving these equations and using the afore mentioned also expressions we find the equilibrium price, quality (service attribute), and profit 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 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 and price will fall to marginal cost, which for information goods is zero, so fail to recover their development, sunk, irreversible costs [13]. 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. The four possible outcomes are (I,I), (I,D), (D,I), and (D,D), where I means "invest" and D "defer" Reference [13] shows that the equilibriums to make investment and exercise the business option are

$$(I,I), \text{if } N^2h^4 > 1309k\ I/\omega^2,$$

$$(D,I), \text{if } 82k\ I/\omega^2 < N^2h^4 \leq 1309k\ I/\omega^2,$$

$$(D,D), \text{if } N^2h^4 \leq 64k\ I/\omega^2,$$

$$\text{mixed strategy } (I,D) \text{ or } (D,I), \text{if } 64k\ I/\omega^2 < N^2h^4 \leq 82k\ I/\omega^2$$

where I is the investment cost for players.

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