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A multi-criteria game theory and real-options model for irreversible ICT investment decisions

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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. Traditional quantitative cost–benefit analysis concerning investment decisions is by no means sufficient for capturing the complexity of the problem in its entirety. This work combines quantitative and qualitative analyses for modeling competitive interactions between players in the ICT business field. The proposed decision analysis model combines real options, game theory, and analytic hierarchy process for analyzing ICT business alternatives under the threat of competition. The proposed model is applied to a real broadband technology business case, showing how it can be formulated and solved.

1. Introduction

After the deregulation of information and communication technology (ICT) markets, their related business activities are not possessed exclusively by a single firm but rather are shared by many competitors. Examples of ICT markets with a limited number of players are manufactures in operating systems such as Microsoft, Apple, Sun, and Linux, in CPUs such as Intel, Sun, and in mobile phones such as 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 scale taking into account the threat from competition that the potential competitor can eliminate. Although it is useful to take into account the traditional quantitative cost–benefit analysis, it is by no means sufficient for capturing the depth of complexity of the problem in its entirety. Actually, traditional methods do not properly account for the flexibility inherent in most ICT investment decisions to launch them at the right time and the right scale. Real-option (RO) 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). However, RO models are strictly quantitative, while ICT investments experience tangible and intangible factors and the latter can be mainly treated by qualitative analysis. In addition, RO analysis in itself brings to the "surface" a number of factors that cannot be quantified, at least easily, by existing RO models and methodologies. Particularly, even though it may be difficult to precisely calculate the value of ROs, it is plausible that managers ascribe a higher value to a project with one or more embedded options than they would to the same project

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without any embedded options. In an exploratory survey of managerial practice surrounding ROs, Busby and Pitts (1997) found that "very few decision makers seemed to be aware of RO research but, mostly, their intuitions agreed with the qualitative prescriptions of such work". Kogut and Kulatilaka (2004) indicated that interviews with managers have shown that RO valuation is rarely used, but, even when this is the case, managers may still be engaging in RO thinking. Fichman, Keil, and Tiwans (2005) presented several case examples in which information technology managers took actions and/or gave rationales consistent with option thinking, even though ROs were not a formal part of the project assessment. Formally or not, RO application in business decisions analysis requires a basic assumption, which is to defer investment until more information is available before deciding to proceed to the implementation of the investment. However, this delay is under high criticism since during waiting a possible competitor may preempt the firm of interest (decision maker) and decrease or eliminate business value.

Two directions have been followed to integrate the ROs and competition modeling in the ICT business field: exogenous and endogenous competition modeling (Angelou & Economides, 2008b; Smit & Trigeorgis, 2004; Zhu, 1999). However, in real telecommunication markets, especially after their liberalization, the situation is more efficiently characterized as an oligopoly and not as a perfect competition. Specifically, the deregulation of telecommunications did not result in a many-player "wild race" but rather in an oligopoly market. In such a market there are only a few companies present, who know about each other's activities and take into account the other competitors actions (Fekete & Konkoly, 2004). Situations like that can be more efficiently modeled by game theory (GT) under endogenous competition modeling (Smit & Trigeorgis, 2004; Zhu, 1999).

The business problem to solve is an ICT business opportunity, which is shared by the "competitors" (potential investors—players) in the market. The players have to decide, if they proceed in the implementation of investment opportunity, when and how much to produce (offer in the market, capture of the market share—MS). Under the threat of competition, the decision to exercise options strategically depends on the trade-off between overall quantitative and qualitative benefits and costs of going ahead with an investment against waiting for more information. Waiting can have an informational benefit (Trigeorgis, 1996). However, if a firm chooses to defer exercising its option until better information is received (thus resolving the uncertainty), it runs the risk that another firm may preempt it by exercising first (Zhu, 1999). Such an early exercise by a competitor can erode the profits or even force the option to expire prematurely. Despite its importance, competition has been typically ignored in most of the RO literature. Only a few recent papers have started to address this issue. Among others, Trigeorgis (1996), Grenadier (1996, 2002), Smit and Trigeorgis (2004), Joaquin and Butler (2000), Kulatilaka and Perotti (1998), and Zhu and Weyant (2003a, 2003b) provided various treatments of the intersection between ROs and GT.

In addition, in a wider perspective concerning integration efforts in GT itself between the preemption motive and the RO motive, McGahan (1993) studied uncertainty in a game-theoretic context where a first mover (FM) may commit in order to deter entry by a newcomer. He showed the effects of incomplete information about demand on preemption and explored the tension between competitive pressure to invest and the RO value in an entry opportunity under uncertainty about demand. Particularly, if the competitors' expectation about customers' demand makes the investment (entry in the market) less attractive and if a player (e.g. an incumbent) can keep proprietary its updated information about demand, then it may be able to secure its possible advantage and partially deter competitors' entry without a substantial initial investment entry.

Also, Spencer and Brander (1992) looked at waiting with a decision as a response to uncertainty in an oligopoly game, while Choi (1996) examined the fact that uncertainty can also lead a firm to experiment rather than to standardize too early, where standardization is also a form of commitment. These cases were treated using quantitative analysis. They focused on revenues, or cost of investment modeling, and found the equilibrium strategies between usually two competitors. However, investment decision in the deregulated ICT business field is a very difficult task that requires complex modeling of a large number of criteria. Hence, a holistic methodology should be developed in order to assist executives and decision makers in formulating problem's parameters, understanding their interactions, estimating their contributions to the overall business value, and so valuating effectively new ICT business activities.

The goal of this paper is to show how RO and GT theories can be merged to enrich the theory of ICT investment valuation under a multi-criteria perspective. These theories are applied to analyze oligopoly competition and to highlight possible further applications and research topics.

Angelou and Economides (2008a) provided a decision analysis model called ROAHP, which combines quantitative and qualitative analysis of ROs. This paper extents this work, by adopting GT and combining ROs and analytic hierarchy process (AHP) in a multi-criteria decision analysis framework for ICT investments in the liberalized market. It analyzes joint effects of the flexibility offered by ROs and the competitive interaction between players offered by GT. A multi-criteria model is developed to evaluate investment decisions based on an AHP structure.

AHP is a multi-criteria decision analysis technique. It aims at choosing from a number of alternatives based on how well these alternatives rate against a chosen set of qualitative as well as quantitative criteria (Saaty & Vargas, 1994; Schniederjans, Hamaker, & Schniederjans, 2005). The main advantage of the AHP approach is that different criteria with different measures can be easily transformed into a single utility measure. For a review of AHP applications to ICT the reader is referred to Angelou and Economides (2008a).

It is the first time in the literature where ROs, GT, and AHP are integrated into a common decision analysis model, called ROGT–AHP. The model is expressed by a mathematical equation and a multi-criteria hierarchical structure. Finally, the proposed model is applied to a real case study, showing how it can be formulated and solved.