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Decision Support

Capacity switching options under rivalry and uncertainty ☆

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ABSTRACT

Deregulated infrastructure industries exhibit stiff competition for market share. Firms may be able to limit the effects of competition by launching new projects in stages. Using a two-stage real options model, we explore the value of such flexibility. We first demonstrate that the value of investing in a sequential manner for a monopolist is positive but decreases with uncertainty. Next, we find that a typical duopoly firm's value relative to a monopolist's decreases with uncertainty as long as the loss in market share is high. Intriguingly, this result is reversed for a low loss in market share. We finally show that this loss in value is reduced if a firm invests in a sequential manner and specify the conditions under which sequential capacity expansion is more valuable for a duopolist firm than for a monopolist.

1. Introduction

Deregulation of many infrastructure industries worldwide, such as energy and telecommunications, has been motivated by the desire to improve economic efficiency (Wilson, 2002). Policymakers have posited that a liberalised framework can deliver greater benefits for consumers in terms of choice and innovation. Such reforms have enticed multinational firms with active research and development (R&D) arms to enter these formerly state-regulated domains. Driven by growing demand for more energy-efficient technologies and versatile mobile devices, conglomerates such as Mitsubishi and Siemens are proceeding with new R&D projects in order to launch products that will enable them to capture market share over their rivals. For example, in the area of renewable energy, the vast offshore wind potential of Scotland has spurred many such engineering firms to establish wind-turbine manufacturing and R&D centres in northern England and Scotland, often with support from local authorities (The Economist, 2011a).

Besides providing opportunities, deregulation exposes firms in such industries to previously unencountered risks, viz., volatile prices and demand, loss in market share, and a greater rate of technological obsolescence. As countermeasures against these threats, some firms have responded by rolling out new products sequentially and forging strategic alliances or outright mergers. For example, the recent union between AT&T and T-Mobile in the US is opposed by some regulators because it will potentially deprive consumers of choice by leaving much of the wireless market concentrated in a few hands. Indeed, a similar situation in Canada (with 95% of the market under the control of three principals) led to relatively high charges for consumers and low rates of innovation (The Economist, 2011b). Hence, the comparison of outcomes, viz., entry thresholds and relative firm values, under different industry settings when firms face uncertain prices and have the flexibility to launch new products sequentially is relevant for economic policymakers.

In this paper, we examine a stylised industry with a stochastic output price, lumpy and modularised capacity investment, and rivalry. We, thus, capture the salient features of deregulated infrastructure industries in order to provide insights about firms' behaviour under different industrial settings in response to market uncertainty. The structure of this paper is as follows:

- Section 2 discusses the related literature in order to provide context for our effort.
- Section 3 states the assumptions of our model and formulates the problem.

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- Section 4 solves the model under various settings and provides analytical insights.
- Section 5 presents numerical examples to illustrate the main findings.
- Section 6 summarises the results, discusses the work's limitations, and offers directions for future research in this area.

2. Related work

Since at least Black and Scholes (1973), analytical solutions for pricing options have been known. However, it was not until Brennan and Schwartz (1985) that such techniques were applied to valuing flexibility in real projects. Indeed, until the 1980s, there was little need for capturing managerial discretion in decision making as many infrastructure industries were still subject to state regulation. Consequently, the lack of exposure to competition and uncertainty meant that the net present value (NPV) method was sufficient for decision support. Deregulation of many infrastructure industries, e.g., energy and telecommunications, in the 1980s changed this paradigm. The subsequent uncertainty in market prices and demand along with greater competition made it worthwhile to consider flexibility over investment timing, operations, capacity sizing, and modularity. Besides Brennan and Schwartz (1985), who evaluate the optimal operation of a copper mine under uncertainty, McDonald and Siegel (1985) address investment timing for a project with a shutdown option. As summarised by Dixit and Pindyck (1994), the main finding of the real options approach with a single decision maker is that the discretion to defer investment makes a project more valuable relative to the now-or-never NPV approach. Yet, at the same time, the opportunity cost of investment is also higher, thereby increasing the optimal threshold at which to commence projects. By contrast, greater operational flexibility in the form of suspension and resumption options not only adds value but also facilitates investment as the adoption decision is less irreversible.

In addition to timing and operational flexibility, the real options approach accommodates other forms of managerial discretion that are impossible to evaluate via the traditional now-or-never NPV approach. For this reason, it has found applications in the analysis of various infrastructure industries, e.g., energy (Takashima et al., 2008; Siddiqui and Maribu, 2009), telecommunications (Shibata and Yamazaki, 2010), and water (Seo et al., 2008; Suttinon and Nasu, 2010). Two types of flexibility that are pertinent for such industries are capacity expansion and modularity. Infinitesimal capacity expansion with operational flexibility under market uncertainty is explored by Pindyck (1988), while Dangl (1999) addresses simultaneous investment timing and continuous capacity sizing. Similarly, Dixit (1993) and Décamps et al. (2006) consider capacity choice among discrete alternative projects. The issue of incremental or sequential capacity expansion with lags is the subject of Majd and Pindyck (1987) and Bar-Ilan and Strange (1996). Here, a project is completed in stages with a finite construction rate, which implies that the optimal price threshold for proceeding with each module is different. Gollier et al. (2005) apply this result to compare direct and sequential approaches in constructing nuclear power plants. On the one hand, building all units at once results in a lower investment cost due to economies of scale. A sequential approach, on the other hand, provides greater flexibility to the power plant in exchange for a higher overall investment cost. In effect, the sequential approach enables the decision maker to time the installation of additional units with the right precision in response to an uncertain electricity price. Other applications of sequential investment in the energy sector are by Fleten et al. (2007) and Siddiqui and Maribu (2009) to the cases of wind turbines and cogeneration, respectively. Finally, Kort et al. (2010) theoretically compare direct and sequential investment approaches for a project with two stages. Assuming uncertain project cash flows that follow a geometric Brownian motion (GBM), an investment premium for using the sequential approach, and relative economies of scale in the first stage, i.e., its investment cost per capacity is less than that of the second stage, they find the critical investment cost premium up to which the sequential approach is preferred. This critical value is shown analytically to decrease with uncertainty and to increase with the relative size of the initial stage. Intuitively, greater uncertainty reduces the relative value of flexibility as it is warranted to delay any kind of investment, while greater first-stage capacity enables the decision maker to take advantage of the first stage without incurring costs for the second one.

Although it accommodates managerial flexibility, the strand of real options literature with a single decision maker is limited by its omission of strategic interactions. Extending the deterministic pre-emptive duopoly framework of Fudenberg and Tirole (1985) to a stochastic setting, Huisman and Kort (1999) show how the threat of pre-emption by a rival can induce a firm to enter at a lower price threshold than the traditional real options setup indicates. They also derive conditions on parameter values that entail a simultaneous equilibrium à *la* Grenadier (1996). Mason and Weeds (2010) formalise the comparative statics for the pre-emptive leader's entry threshold and prove that it may decrease with uncertainty when there exists a lasting first-mover advantage. The case of a non-pre-emptive duopoly, in which the role of a leader is assigned exogenously, is examined by Paxson and Pinto (2005). In contrast to the pre-emptive duopoly, since the leader does not have to worry about losing its position, its value of waiting is restored, i.e., it invests at the same threshold as a monopolist. Paxson and Pinto (2005) also allow for a stochastic demand that is correlated with the output price and use the homogeneity of value functions in order to derive analytical solutions when possible. The pre-emptive model is generalised to an n-firm oligopoly by Bouis et al. (2009), who find a counterintuitive accordion effect due to greater uncertainty. For example, with three firms, as the third one's entry threshold increases due to higher uncertainty, the second firm's entry threshold decreases as its market share dominance lasts longer, thereby increasing its payoff from entry. Meanwhile, the first firm's entry threshold increases due to the erosion in its market share from the second firm's entry at a relatively lower threshold. Other extensions to the game-theoretic model include asymmetric competitors (Kong and Kwok, 2007; Takashima et al., 2008), e.g., firms with different sunk costs in general or generators in an electricity industry, and exit decisions (Murto, 2004). Interaction with technological uncertainty reveals an increased incentive to wait for a higher entry threshold price by a pre-emptive duopoly leader (Weeds, 2002; Huisman and Kort, 2004). By contrast, Huisman and Kort (2009) find that endogenous continuous capacity sizing can also be used strategically in a pre-emptive duopoly by the leader to deter (accommodate) the follower if the uncertainty is high (low). Finally, Goto et al. (2008) exploit the symmetry of a non-pre-emptive duopoly to find optimal entry and exit thresholds, while Chronopoulos et al. (2011) rework the duopoly problem under risk aversion. Overall, strategic real options are nicely summarised by Chevalier-Roignant et al. (2011).

Our work contributes to the literature by exploring the extent to which sequential decision making offsets the effect of competition. We use the symmetric, non-pre-emptive duopoly of Goto et al. (2008) by incorporating the sequential decision making for capacity expansion of Kort et al. (2010). Our duopoly setup is similar to that of Shibata and Yamazaki (2010) in that they also tackle sequential investment. However, their assumptions and research objectives are different since they examine asymmetric firms where the leader makes a single investment. Subsequently, the