European Journal of Operational Research 254 (2016) 40–50

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Continuous Optimization

How to escape a declining market: Capacity investment or Exit?[☆]

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ARTICLE INFO

Article history:
Received 20 October 2015
Accepted 6 April 2016
Available online 13 April 2016

Keywords:
Investment analysis
Exit
Capacity investment
Declining market
Real options

ABSTRACT

This paper considers a firm that faces a declining profit stream for its established product. The firm has the option to invest in a new technology with which it can produce an innovative product while having the option to exit at any point in time. In the presence of an exit option, earlier work determined the optimal timing to invest, where it was shown that higher uncertainty might accelerate investment timing.

In the present paper the firm also decides on capacity. This extension leads to monotonicity, i.e. higher uncertainty delays investment timing. We also find that higher potential profitability of the innovative product market increases the incentive to invest earlier, where, however, we get the counterintuitive result that the firm invests in smaller capacity. Finally, if quantity has a smaller negative effect on price, the firm wants to acquire a larger capacity at a lower investment threshold.

1. Introduction

The photography industry underwent a disruptive change in technology during 1990s when the traditional film was replaced by digital photography (see e.g. The Economist January 14th 2012). In particular Kodak was largely affected: by 1976 Kodak accounted for 90 percent of film and 85 percent of camera sales in America, making it the owner of a near-monopoly in America. While Kodak's revenues were nearly 16 billion in 1996, in 2011 it has decreased to 6 billion.[1]

Kodak tried to get (squeeze) as much money out of the film business as possible and it prepared for the switch to digital film. The result was that Kodak did eventually build a profitable business out of digital cameras, but it lasted only a few years before camera phones overtook it. According to Mr. Komori, the former CEO of Fujifilm of 2000–2003, Kodak aimed to be a digital company, but that is a small business and not enough to support a big company. 'For Kodak it was like seeing a tsunami coming and there is nothing you can do about it', according to Mr. Christensen in The Economist (January 14th 2012).

This paper focuses on investment and exit decisions of a firm that has to deal with technological change. The above example showed that this can be a burden. However, there are enough examples of firms for which technological change brought fruitful times in terms of profits. One example is Activision, a successful company in the video game industry, where innovation plays a big role. Activision saw its worldwide sales increase with dollar 650 million in the first five days, when the new video game "Call of Duty: Black Ops" replaced its predecessor, "Call of Duty: Modern Warfare 2" , in November 2010 (The Economist, December 10th 2011). Another example is the iPhone launched by Apple which was described by Time Magazine as 'the invention of the year 2007'. Apple's 2011 net income was dollar 7.31 billion in the three months up to June 25th, 125 percent higher than the previous year, making it the firm's record quarterly profit. Another quarterly record was the revenue during that time period, a revenue of dollar 28.6 billion.

We study the problem of a price setting firm that produces with a current technology that faces a declining sales volume. The firm can either exit this industry or invest in a new technology with which it can produce an innovative product. The firm is a monopolist in a market characterized by uncertain demand, where the inverse demand function depends on a geometric Brownian motion process. Demand for the established product is characterized by a negative drift. Upon investment the firm is able to produce a new

☆ The authors would like to thank two anonymous referees for valuable comments and Pedro Jesus for research assistance. The work of C. Nunes was partially supported by the Portuguese Scientific Foundation under Grant UTA_CMU/MAT/0006/2009.

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[1] See, for example, the Wall Street Journal on January 19, 2012 (http://blogs.wsj.com/deals/2012/01/19/kodak-bankruptcy-by-the-numbers/).

http://dx.doi.org/10.1016/j.ejor.2016.04.009
0377-2217/

product, the demand of which is higher than demand of the established product. However, demand could still have a negative drift.

The question we study is when and if it is optimal to enter the innovative product market. In case the firm decides to launch the new product we also analyze the optimal capacity choice. Besides adopting the new technology, the firm also has the option to exit the market at any point in time. It can exit if it considers that the potential of the new product market is not profitable enough to invest and thus decides to exit instead of launching the new product. The exit option is conserved beyond the time of that potential investment in the new product. Therefore, the firm can also exit the market of the new product irrevocably at any time. Previous literature (Kwon, 2010; Matomaki, 2013) considering the option to exit in combination with deciding about the optimal time to invest, found that it could be optimal to invest earlier when uncertainty goes up. We extend these papers by letting the firm also determine the optimal capacity size that should be acquired at the moment of investment, where the firm produces at capacity.

We derive the result that the optimal policy of the considered stopping problem exists and is unique. In addition we show that as uncertainty goes up, the firm invests in more capacity, which is an additional cause for investment delay. Unlike Kwon (2010) and Matomaki (2013), we find that this generates monotonicity regarding the effect of uncertainty on investment timing: when uncertainty goes up the firm invests later in a larger capacity level.

It turns out that innovative product market growth has a surprising effect in that the firm reduces investment size when the trend is higher. This is because timing is leading: a firm is eager to invest early in a fast growing market. Then the innovative output price is still low, which leads to a lower optimal capacity. An important characteristic of the new market is also in how strong output price is negatively affected by quantity sold. In fact this quantity is equal to the firm's capacity level because the firm produces at capacity. If this effect is larger the firm of course invests in a smaller capacity. Concerning timing, we conclude that if quantity is strongly affecting price, the profitability of the new market is relatively low, which drives the firm to invest later.

This paper is organized as follows. We review related literature in Section 2. Our model is presented in Section 3, whereas Section 4 contains a benchmark model where the firm cannot exit. The comparative statics analysis of the optimal policies is conducted in Section 5. Our main results are presented in Section 6 and we conclude in Section 7. The appendix contains the proofs of all the propositions.

2. Related literature

A number of existing research contributions have analyzed several aspects of optimal technology adoption and exit decisions under uncertainty. There is extensive literature dealing with technology adoption (see Bridges, Coughlan, and Kalish, 1991 for an early review). Many papers formulated adoption decisions of new technology as stopping time problems. We refer to Hoppe (2002) for an extensive review of papers and Kwon (2010) for a review of more recent literature. We use a real options framework to model the technology investment decision.

Farzin, Huisman, and Kort (1998) (see also Doraszelski, 2001) study the optimal timing of technology adoption when technology choice is irreversible and the firm faces a stochastic innovation process modeled by a compound Poisson process. Besides the uncertainty about the speed of the arrival the value of future improvements is assumed to be uncertain as well. They allow for multiple investments in new technology. Contrasting the optimal decision rule derived under the real options approach with that obtained under the net present value method, Farzin et al. (1998) show that the former implies a more cautious and slower pace of adoption than implied by the latter. This finding is in line with the conventional insight of real options literature about the effect of uncertainty on investment decisions: as uncertainty increases, it is optimal to wait longer before investment, reflecting the value of waiting (Dixit & Pindyck, 1994). In Farzin et al. (1998) the improvement of new technology follows a compound Poisson process. Recently, Hagspiel, Huisman, and Nunes (2015) extended Farzin et al. (1998) to a time-dependent intensity rate of new arrivals. They show that larger variance can accelerate investment in case the arrival rate rises while it can decelerate investment in case the arrival rate drops. Depending on whether the arrival rate is assumed to change or be constant over time, Hagspiel et al. (2015) show that the optimal technology adoption timing changes significantly.

Alvarez and Stenbacka (2001) characterize the optimal timing of when to adopt an incumbent technology, incorporating the opportunity to update this technology to future superior versions. In their study a switch of technology is assumed to generate a structural change in the cash flow, whereas the underlying stochastic process is assumed to be unchanged. They characterize how the real option values depend on market uncertainty and on the uncorrelated technological uncertainty regarding future new generations of technology. They show that in case the market uncertainty follows a geometric Brownian motion, an increase in uncertainty related to market as well as technological uncertainty delays optimal investment.

Some of the earliest work on entry and exit decisions goes back to Mossin (1968). McDonald and Siegel (1985), Brennan and Schwartz (1985) as well as Dixit (1989) are among the pioneering works that evaluate those decisions in the context of real options. McDonald and Siegel (1985) contemplate a case where operations can be suspended (mothballing decision), when operating profits are negative, and resumed at no additional costs if they turn positive again. Brennan and Schwartz (1985) introduce a model to optimally decide on opening, closing, and abandoning a mine. Dixit (1989) generalizes their framework assuming that there might be costs related to switching between suspension and an operating mode.

In our model the firm has the option to exit the market, which is considered to be an irreversible decision. This option to exit remains available also after investment. To our knowledge, there are only two papers that consider an exit option both before and after a possible investment. The first one to study this problem was Kwon (2010). Kwon (2010) analyzes the impact of uncertainty on a firm's optimal investment and exit decisions given that profit is expected to decline over time, in case the firm does not invest. The firm has the opportunity to make an investment that boosts the project‘s profit rate. He shows that it can be optimal to invest even in a declining market, and exit if the profit rate has deteriorated sufficiently.

(Matomaki, 2013, Article I) generalizes Kwon (2010), whose work relies on a Brownian motion with negative drift as underlying diffusion. He proves the existence and uniqueness of an optimal strategy when the stochastic process satisfies a general linear Itô diffusion with different drifts and volatilities before and after the possible investment. Matomaki (2013) shows that for the case of a geometric Brownian motion with the same volatilities before and after investment (i.e. under the same assumptions as in this work), the effect of uncertainty on the investment threshold can be non-monotonic when the boost on the profit flow upon investment is relatively large. Specifically, the investment threshold first decreases and then increases in uncertainty.

We extend Kwon (2010) and Matomaki (2013) by also considering the size of the investment. This contrasts with the bulk of papers in the real options literature that only considers the time to invest. However, an investment decision is not only about timing