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A patent race in a real options setting: Investment strategy, valuation, CAPM beta, and return volatility

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Abstract

In this paper, we study financial properties of R&D intensive firms through a continuous-time real-options patent-race model. Numerical analysis in this study shows that intense competition drives a firm to invest more aggressively, which then pushes up its cost of capital and return volatility while introducing negative return correlation with its competitor. Furthermore, we find that a firm's position in competition has important impacts on its financial properties. For instance, a firm's cost of capital is a non-monotonic function of its relative position in the race. In addition, the relationship between cash flow uncertainty and investment can be negative when a firm is far ahead or far behind, or positive when firms are close in the race.

JEL Classification: C73; G12; G31; O31; O32

Keywords: Strategic real options; Patent race; R&D investments; Stochastic game

1. Introduction

This paper uses a continuous-time real-options methodology to develop a duopoly patent-race model, which is applicable for examining financial properties of R&D intensive firms such as firms in the business of creating new software, inventing NANO or WI-FI technology, or innovating new drugs. Many of these firms are early stage, private, venture

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capital backed startups, with limited available financial data.[1] Therefore, investors, financial analysts, and other market participants often have difficulty analyzing their financial properties. For instance, how do these firms make investment decisions? How are they valued? How are their cost of capital and the pattern of their return volatility and return correlation with competitors determined? This paper aims to answer these questions and develop a model to serve as guidance for future empirical work.

R&D intensive firms face three primary types of uncertainty during the innovation process, namely, cash flow, technological feasibility, and competitive uncertainties. As a firm typically does not receive any cash inflows until the creation/innovation of a new product/technology is completed (like a biotechnological project), there is cash flow uncertainty. If a firm is uncertain about its technological ability or feasibility of its project (like a new software product), then it faces technological uncertainty. R&D intensive firms typically operate in highly competitive environments. A patent, like any intellectual property protection, is granted to the first inventor. So, firms face competitive uncertainty resulting from their changing relative position in a patent race. As a result, each firm has to strategically interact with its competitors when making investment decisions.

We build these three uncertainties into our duopoly model in which two firms compete to invent a new technology. Each of the two firms chooses an investment rate at which it develops the new technology. The winner of the race is awarded a patent, from which point it receives a sequence of cash flows, which we value by using the Capital Asset Pricing Model (CAPM). The loser of the race receives nothing. A duopoly competition for a patent is modeled as a stochastic game in which there are three publicly observable state variables: the value of the patent and the expected cost-to-completion of each of the two firms. Each state variable is governed by its own source of risk. The value of the patent is the present value of the cash flows received upon winning, which follow a geometric Brownian motion subject to both systematic and idiosyncratic risks. The overall uncertainty underlying the patent value is referred to as "cash flow uncertainty," which gives the firms real options to delay their investment and wait for more information about the profitability of the patent. The position of each firm in the race is described by a state variable called the expected "cost-to-completion," which measures the expected amount of money a firm needs to succeed in developing the new technology and winning the patent race (the "follow-on" capital). Each firm's expected cost-to-completion follows a diffusion process governed by its own idiosyncratic technological risk, which is a special case of the technology described by Pindyck (1993).[2] Given a firm's individual technological uncertainty, it has an incentive to learn more about the difficulty of the project and to invest in order to resolve this uncertainty ("learning by doing"). A firm's investments may lead to technological improvements as well as setbacks. Faced with competitive uncertainty, a firm receives either preemptive threats to invest or incentives to withhold investments depending on the relative position of this firm to its competitor. In an environment with multiple sources of uncertainty, when making strategic investment decisions, a firm has to strike a balance among the real options to wait, the incentives to invest or withhold investments, and the preemptive threats to invest.

[1]For startups backed by venture capitals, VentureXpert provided by Venture Economics and VentureSource provided by VentureOne are good data sources.

[2]The general process of the expected cost-to-completion proposed by Pindyck (1993) includes technological risk as well as input cost risk. We ignore the input cost risk for simplicity.