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Real options game over the business cycle

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ABSTRACT

This paper studies the impact of business cycles on firms' strategic investment decisions by developing and solving a continuous time regime-dependent real options game in an asymmetric duopoly. The value functions, roles and optimal investment timing decisions of the two firms in the expansion and recession states are jointly determined. We show that the preemptive investment equilibrium, where the leader invests earlier than its own first-best investment timing, is pro-cyclical. Moreover, the simultaneous investment equilibrium, where the firms simultaneously invest late and enjoy waiting flexibility as a tacit collusion, is counter-cyclical. In addition, we specifically demonstrate that the values of the leader and follower in the expansion state are smaller than those in the recession state when the preemptive equilibrium prevails in the expansion state and the simultaneous equilibrium prevails in the recession state.

1. Introduction

Since two seminal papers of McDonald and Siegel (1986) and Majd and Pindyck (1987) and one pronounced book by Dixit and Pindyck (1994), the real option approach has become a standard tool for analyzing firms' investment decisions under uncertainty. Recently, literature pays more attention to respectively explore the impacts of macroeconomic conditions and product market competition on firms' investment decisions due to the stylized facts that a firm's investment policy is usually dependent on business cycle and is frequently affected by its competitors' investment decisions as in an oligopoly. The two effects must be analyzed in a unified dynamic model, but surprisingly real options literature has not yet investigated how the interactions between a firm's and its rivals' investment decisions vary with macroeconomic conditions. This paper intends to fill this gap by developing and solving a continuous-time regime-dependent real options game model which integrates the setup of business cycle from Guo et al. (2005) into an asymmetric duopoly real options game framework of Pawlina and Kort (2006). In particular, we can investigate the effects of business cycle on the equilibriums of an investment timing game and on the firms' optimal investment strategies as well as values.

Using Markov chain to model regime shifts, Guo et al. (2005) analyze a firm's optimal investment policy, taking account of the possibility of future macroeconomic condition shift. This methodology is recently employed to investigate various issues, such as capital structure (Bhamra et al., 2010; Hackbarth et al., 2006), credit risk (Chen, 2010), and agency problem (Chen and Manso, 2010). However, they are all based on a single-firm assumption, and therefore ignore the interdependent effect of the firm's and its rivals' investment policies. In a more related paper, Du and Mackay (2011) analyze investment and disinvestment timing decisions in both monopoly and competitive markets when firms are subject to macroeconomic conditions. They particularly show that monopoly and competitive firms still adopt identical policies under some realistic environment. Yet, they do not investigate a firm's investment decision in an oligopoly where the firm competes with its rivals in investing the same investment project.

Assuming firms are symmetric in Cournot–Nash oligopoly equilibrium, Grenadier (2002) analyzes a firm's delay option on an incremental investment project, while Jou and Lee (2008) focus on that option on a lumpy investment project. In addition, Aguerrevere (2009), with the same assumption, specifically demonstrates the relationship between the degree of competition and the assets' expected rates of return varies with product market demand. As mentioned by Back and Paulsen (2009), the symmetric Nash equilibriums in the models do not satisfy the requirement of subgame perfection and hence are open-loop equilibriums.

Firms, however, are seldom identical. The extensive literature on real options games suggests that, when a relative small number of firms compete, there often exists a first-mover advantage (FMA). For example, winning patent races and can be characterized by a persistent FMA, that is, the first to invent gains an exclusive right over the technology. The simple asymmetric duopoly equilibrium is often employed to analyze a firm's irreversible investment decision while the two firms have different investment costs. Pioneered by Fudenberg and Tirole (1985) that capture the threat of preemptive investment, Pawlina and Kort (2006) and Mason and Weeds (2010) examine the irreversible

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investment behavior when there is a competitor who can potentially preempt the investment project. They show that a greater FMA will lead a firm to adopt a preemptive investment threshold which is significantly lower than its optimal investment trigger. Recently, Carlson et al. (2011) focus on the effects of a firm's expansion and contraction options on risk dynamics of the required returns when there exists a rival firm owning the same flexibilities. In sum, they generally find that competition will erode the values of wait-and-see options and their Nash equilibriums meet the requirement of Markov perfect closed-loop equilibriums which satisfy continuous-time dynamic subgame perfection. Nevertheless, none of existing real options game literature takes macroeconomic conditions into consideration.

Some empirical studies show supportive evidence that competition precipitates investment. For example, Driver et al. (2008) show that a FMA of investment created by R&D and advertising expenditures offsets the irreversibility effect of investment. In particular, Akdoğu and MacKay (2008) indicate that the value of investing strategically can outweigh the value of waiting in an oligopolistic industry. On the other hand, some studies propose that both macroeconomic conditions and industry-specific competition play important roles in determining a firm's optimal investment decision. For example, Martynova and Rennegoog (2008) provide further evidence that waves of corporate takeovers tend to occur following economic recovery from previous recessions.[1]

As pointed out by Ghemawat (2009), "At the bottom of the business cycle, firms seem to overemphasize the financial risk of investing at the expense of the competitive risk of not investing. Once-in-a-cycle errors of this sort can create a lasting competitive disadvantage." This calls for a new dynamic model to analyze a firm's investment decision that encompasses both macroeconomic conditions and industry competition. By integrating the business cycle framework of Guo et al. (2005) into the two-player real options game model of Pawlina and Kort (2006), we investigate the interdependent effects between macroeconomic conditions (expansion and recession) and industry-specific strategic interaction on firms' optimal investment timing decisions and firm's value functions in an asymmetric duopoly.

Theoretically, we develop and solve a continuous time real options game, where the regime-dependent value functions, roles and optimal investment timing decisions of the two firms are jointly determined. We specifically demonstrate that the preemptive investment equilibrium, where the leader invests earlier than its own first-best investment timing, is pro-cyclical, i.e., the leader tends to adopt a more aggressive strategy to preempt in the expansion state. In addition, the simultaneous investment equilibrium, where the firms simultaneously invest late and enjoy waiting flexibility as a tacit collusion, is counter-cyclical, i.e., the tacit collusion to invest late is more significant in the recession state. We particularly show that the values of the leader and follower in the expansion state are smaller than those in the recession state as the preemptive equilibrium prevails in the expansion state and the simultaneous equilibrium prevails in the recession state.

The paper is organized as follows. In section 2 we present the model setup and two special cases. Section 3 demonstrates value functions and solution concept and section 4 explains three types of game equilibriums and provides numerical examples. Finally, section 5 concludes.

2. The model

This section details the basic setup of our model. We employ the basic framework of Pawlina and Kort (2006) with the essential difference that we consider the two-state regime swifts rather than only one state to reveal the characteristic of the business cycle. The two risk neutral firms, Firm 1 and Firm 2, compete in the product market and have a single investment opportunity to raise their instantaneous profits. The common uncertainty of the two firms' profits, $x(t)$, is governed by

$$dx_t = \mu_{\varepsilon_t} x_t dt + \sigma_{\varepsilon_t} x_t dW_t, \text{given } x(0, \varepsilon_0) = x \geq 0, \quad (1)$$

where μ_{ε_t} and σ_{ε_t} are the drift and diffusion terms, and W_t is a Wiener process. ε_t is a continuous time Markov chain with two states R (Recession) and E (Expansion). The intensity λ_R (λ_E) shows the leaving rate of state R (E) to state E (R). Consequently, μ_{ε_t} and σ_{ε_t} can be respectively explained as the industry growth rate and volatility which vary over business cycle. The riskless interest rate is r, and we assume that $r - \mu_{\varepsilon_t} > 0$ for ensuring finite valuation. Following Guo et al. (2005), we assume $\mu_E > \mu_R$ and $\sigma_E < \sigma_R$, and the relationships between the optimal investment triggers of the leader and follower in the expansion and recession states are given by: $x_i^{L,E} < x_i^{L,R}$, $x_i^{F,E} < x_i^{F,R}$, $x_i^{L,E} < x_i^{F,E}$ and $x_i^{L,R} < x_i^{F,R}$, $i = 1,2$, showing that the leader and follower both invest earlier in expansion state, and the leader invest earlier than the follower in both states. For simplicity, we further assume that $x_j^{L,E} < x_j^{L,R} < x_i^{F,E} < x_i^{F,R}$, $i \neq j$, where $i,j = 1,2$.

The instantaneous profits of firms are given by $\pi_{mn} = xD_{mn}$, $m,n = 0,1$, in an asymmetric duopoly, where D_{mn} stand for the deterministic part of profit function. The profits of the leader and follower are xD_{00} when the two firms have not invested and are xD_{11} when the two firms have already invested. xD_{10} and xD_{01} are respectively the profits of the leader and follower when the leader has invested and the follower has not. We assume that $D_{10} > D_{00}$, $D_{10} > D_{11}$, $D_{11} > D_{01}$ and $D_{00} > D_{01}$ to assure that there is a first-mover advantage and a second-mover disadvantage.

The two firms both face a perpetual, irreversible investment (growth) opportunity. Without loss of generality, we suppose the investment cost of Firm i is I_i, $i = 1,2$, where $I_1 = I$ and $I_2 = \kappa I$, $\kappa > 1$. Firm 1 is therefore the low-cost firm and Firm 2 is the high-cost firm. We also assume the initial realizations of the process underlying both firms' profits are low enough in both macroeconomic states so that immediate investment decisions are not optimal for both firms.

3. Value functions and investment thresholds

There are three possible investment timings for the two firms in both recession and expansion states. First, Firm i can invest first as the leader, and alternatively, Firm j can invest earlier and Firm i is hence the follower. Finally, the two firms can invest simultaneously. In this section, we will establish the two firms' value functions and investment thresholds associated with the three possibilities in two economic states. At the beginning, we analyze the case of simultaneous investment, which can be helpful to explain how possible regime shifts affect the firms' value functions and investment thresholds. Following the standard approach to solve a dynamic game backward in time, we subsequently introduce the leader's and follower's value functions and follower's optimal investment threshold when the leader has invested but the follower has not. Finally, we analyze the leader's and follower's value functions and leader's optimal investment threshold when both of the firms have not invested yet.

3.1. When the two firms invest simultaneously

Let $V_i^{S,E}$ and $V_i^{S,R}$ and $x_i^{S,E}$ and $x_i^{S,R}$, $i = 1,2$, respectively denote the two firms' value functions and investment thresholds in states E and R when Firm 1 and Firm 2 invest simultaneously. Fig. 1 illustrates the relationships between the value functions and investment thresholds. When $x \geq x_i^{S,R}$, the two firms have already invested in both states and receive perpetual profit flows xD_{11}. The value functions $V_E^{D_{11}}$ and $V_R^{D_{11}}$ can switch between the two states even after the two firms have both invested.

In general, $V_E^{D_{mn}}(x)$ and $V_R^{D_{mn}}(x)$, $m,n = 0,1$, denote the value functions when the two firm's instantaneous profit flow is given by xD_{mn}

[1] Some mergers and acquisitions can result from a strategic motive to compete with industry rivals.