European Journal of Operational Research 215 (2011) 688–696

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Innovative Applications of O.R

Interactions between investment timing and management effort under asymmetric information: Costs and benefits of privatized firms ☆

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ARTICLE INFO

Article history:
Received 29 November 2010
Accepted 22 June 2011
Available online 1 July 2011

Keywords:
Investment timing
Agency
Incentives
Privatization

ABSTRACT

In this paper, we examine the interactions between investment timing and management effort in the presence of asymmetric information between the owner and the manager where the manager has an informational advantage. We find that investment timing is later under asymmetric information than under full information, implying a decrease in the value of equity option. However, in order to minimize any distortion under underinvestment, management effort is greater under asymmetric information than under full information. We show that there are trade-offs in the efficiencies of investment timing and management effort under asymmetric information. These results fit well with the findings of past empirical studies concerning the costs and benefits of privatized firms.

1. Introduction

The standard real options approach examines project option value along with investment timing. The main result obtained in this standard framework is that an increase in uncertainty increases both the project option value and the threshold required to undertake investment. One implication is that the firm displays more inertia in its investment behaviour given greater uncertainty. For the interested reader, Dixit and Pindyck (1994) provide an excellent overview of the real options approach.

In the standard real options model, there are no agency conflicts between owners and managers, because the firm is assumed to be managed by the owners. In most modern corporations, owners delegate the investment decision to managers, taking advantage of managers' special skills and expertise. In this situation, there is likely to be asymmetric information. Asymmetric information is the situation where managers privately observe a portion of the underlying state variable not observed by owners. Managers with private information then have an incentive to provide false reports and to divert free cash flows to themselves. Thus, asymmetric information leads to what is commonly referred to as agency conflicts.[1]

Several comparatively recent studies have already begun the task of incorporating the agency conflicts arising from asymmetric information into the real options model.[2] Grenadier and Wang (2005), Nishihara and Shibata (2008) and Shibata (2009) develop models of investment timing in the presence of asymmetric information between owners and managers. In this situation, owners must design a contract to provide incentives for managers to reveal private information truthfully.[3] The implied investment timings are then later than in the full information setting. Importantly, although these strategies turn out to be suboptimal, they reduce the owner's losses because of asymmetric information. In the absence of any incentive mechanism that induces the manager to reveal private information truthfully, owners suffer further distortion.

☆ This research was partially supported by a Grant-in-Aid by the Excellent Young Researcher Overseas Visit Program (21-2171), the Japan Economic Research Foundation, KAKENHI (21241040, 22710142, 22710146, 23310103), and the Telecommunications Advancement Foundation.

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[1] Useful overviews of the literature on asymmetric information can be found in Fudenberg and Tirole (1991) and Laffont and Martimort (2002).

[2] The standard real options model has recently been extended in several ways. For example, Huisman and Kort (2004) and Kong and Kwok (2007) consider the investment timing problem by taking into account strategic interactions, while Nishihara and Fukushima (2008) and Shibata (2008) analyse investment decisions under incomplete information.

[3] Grenadier and Wang (2005) consider a contract with an incentive mechanism, while Nishihara and Shibata (2008) and Shibata (2009) design a contract with an incentive-disincentive mechanism.

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doi:10.1016/j.ejor.2011.06.025

In this paper, we consider the interactions between management effort and investment timing under asymmetric information. In particular, we extend the single-stage optimization problem in Grenadier and Wang (2005) to a two-stage optimization problem by incorporating the management effort decision. In the seminal work on the dynamic asymmetric information model developed by Grenadier and Wang (2005), management effort is an exogenous variable. By contrast, we have solved the two-stage optimization problem. More precisely, we first solve the optimal investment timing strategies for fixed management effort, and then we solve the optimal management effort given the optimal investment timing strategy. Thus, investment timing as well as management effort are optimally decided *endogenously*.[4] Our main contribution in this model is to examine the interactions between investment timing and management effort decisions under asymmetric information.

In terms of results, we show that investment timing is later under asymmetric information than under full information, as in Grenadier and Wang (2005). However, management effort is greater under asymmetric information than under full information in all of our numerical examples. These results imply that the efficiency of investment is lower under asymmetric information than under full information, while the efficiency of management effort is higher under asymmetric information than under full information. Thus, we find that there are trade-offs between investment and management effort under asymmetric information.

We apply our model to the evaluation of the costs and benefits of a privatized firm. In particular, our model is regarded as a dynamic version of Schmidt (1996a) and Schmidt (1996b). As in Schmidt's work, we assume that the government has two possible courses of action. The first is that the government nationalizes the firm and controls production directly. The second is that the government privatizes the firm and delegates the investment decision to the private owner. Thus, the nationalized firm's problem is the no-agency problem under full information, while the privatized firm's problem is the agency problem under asymmetric information. In other words, the owner of a privatized firm faces an informational disadvantage. As a result, the investment timing of a privatized firm takes place later than that of a nationalized firm. However, in taking into consideration the inefficiency in investment timing, the management of a privatized firm is larger than that of a nationalized firm. These results are consistent with empirical findings by Vickers and Yarrow (1991), Megginson et al. (1994), Villalonga (2000), Lin and Li (2008). Moreover, and unlike the static models in Schmidt (1996a) and Schmidt (1996b), we can evaluate the costs and benefits of a privatized firm quantitatively, not just qualitatively.

The remainder of the paper is organized as follows. Section 2 describes the setup of the model, and as a benchmark, provides the solution to the full information problem. Section 3 formulates the asymmetric information problem and derives the optimal contracts. Section 4 considers the costs and benefits under asymmetric information, comparing them with those under full information. Section 5 provides a practical example of our model corresponding to the evaluation of the costs and benefits of a privatized firm. The appendix contains details of the derivation of the solution. Section 6 concludes.

2. Model

In this section, we begin with a description of the model. We then, as a benchmark, provide the solution to the optimization problem under symmetric (full) information.

[4] Because the mathematics involved is necessarily more complex than in Grenadier and Wang (2005), it leads to a problem that is often solved solely using numerical procedures.

2.1. Setup

Consider an owner (a firm) that has an option to invest in a project. We assume that the owner delegates the investment decision to a manager. Throughout our analysis, we assume that all agents are risk neutral and aim to maximize their expected pay-off.

If the investment option is exercised at time t, the firm pays the fixed cost $I > 0$ and receives the project value $X(t)$, which follow a geometric Brownian motion:

$$dX(t) = \mu X(t)dt + \sigma X(t)dz(t), \quad X(0) = x, \tag{1}$$

where $z(t)$ denotes the standard Brownian motion, and $\mu > 0$ and $\sigma > 0$ are positive constants. For convergence, we assume that $r > \mu$, where r is a constant interest rate.

We also assume that the one-time fixed cost, I, takes one of two possible values: I_1 or I_2 with $I_2 > I_1$ where $I_k > 0$ ($k \in \{1,2\}$). We denote $\Delta I \equiv I_2 - I_1$. We assume that I_1 represents "lower cost" expenditure and I_2 "higher cost" expenditure.

Let $V(x;I_k)$ denote the option value for $I = I_k$ ($k \in \{1,2\}$). The option value, $V(x;I_k)$, is formulated as:

$$V(x;I_k) \equiv \sup_{\tau_k} \mathbb{E}^x[e^{-r\tau_k}(X(\tau_k) - I_k)], \quad k \in \{1,2\}. \tag{2}$$

Here, $\mathbb{E}^x[\cdot]$ denotes the expectation operator given that $X(0) = x$, and τ_k is the stopping time at which the investment is exercised once $X(t)$ arrives at the trigger $x_k \equiv x(I_k)$, i.e., $\tau_k \equiv \inf\{t \geqslant 0; X(t) \geqslant x_k\}$. In this paper, we assume that the current state value $X(0) = x$ is sufficiently low that the investment is not undertaken immediately. Using standard arguments, the option value for $I = I_k$ is:

$$V(x;I_k) \equiv \max_{x_k} \left(\frac{x}{x_k}\right)^{\beta} (x_k - I_k), \tag{3}$$

where $\beta \equiv 1/2 - \mu/\sigma^2 + \sqrt{(\mu/\sigma^2 - 1/2)^2 + 2r/\sigma^2} > 1$.

The management effort at *time zero* has an impact on the likelihood of drawing a lower cost expenditure $I = I_1$. If the manager exerts management effort ξ, he/she incurs a cost $c(\xi) = b\xi$ where $b > 0$ is a measure of efficiency in the cost function for management effort, but this effort increases the likelihood of drawing $I = I_1$, which is denoted by $q(\xi)$. Thus, the level of ξ affects the probability distribution over the possible states of I. More precisely, nature draws $I = I_1$ with probability $q(\xi)$ and $I = I_2$ with probability $1 - q(\xi)$, where $q(\xi)$ is increasing and concave in ξ with $q(0) = 0$ and $\lim_{\xi\uparrow+\infty} q(\xi) = 1$. Immediately after exerting the management effort at *time zero*, either $I = I_1$ or $I = I_2$ occurs.

We assume that the project value, $X(t)$, is observed by both the owner and the manager. However, the one-time fixed cost, I, is privately observed only by the manager.[5] Immediately after exerting effort at time 0, the manager observes whether the cost is I_1 or I_2. However, the owner cannot observe the realized value of I. Then, the manager could attempt to report I_2 when the realized value is I_1, while he/she would not attempt to report I_1 when $I = I_2$. Therefore, the shareholder must induce the manager to reveal private information truthfully at the time when the manager undertakes the investment; otherwise, the shareholder suffers further losses. At equilibrium, the manager will report the true value to the shareholder by designing the incentive scheme.

The structure of the game is as follows. First, the manager chooses the management effort. The level of management effort then affects the probability distribution over I. Next, immediately after exerting the effort action, either I_1 or I_2 is realized. Depending on the realized value I_k, the investment threshold is optimally

[5] The assumption that a portion of the project value is privately observed by only one person (here, the manager) and not observed by the other (here, the owner) is quite common in the asymmetric information literature. See Fudenberg and Tirole (1991) and Laffont and Martimort (2002).