Journal of Banking & Finance 37 (2013) 1160–1175

Contents lists available at SciVerse ScienceDirect

# Journal of Banking & Finance

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

# The effects of external financing costs on investment timing and sizing decisions

Michi Nishihara [a,*], Takashi Shibata [b]

[a] Graduate School of Economics, Osaka University, 1-7 Machikaneyama, Toyonaka, Osaka 560-0043, Japan
[b] Graduate School of Social Sciences, Tokyo Metropolitan University, 1-1 Minami-osawa, Hachioji, Tokyo 192-0397, Japan

ARTICLE INFO

*Article history:*
Received 17 April 2012
Accepted 16 November 2012
Available online 13 December 2012

*JEL classification:*
G13
G31
G32

*Keywords:*
Investment timing
Investment size
Costly external financing
Optimal stopping

ABSTRACT

We develop a dynamic model in which a firm exercises an option to expand production on either a small or large scale with cash reserves and costly external funds. An intermediate level of cash reserves, which is insufficient for the large-scale investment but sufficient for the small-scale investment, provides an incentive for the firm to invest early in the small-scale project. These results fill the gap between two types of results: (i) empirical findings of a U-shaped relation between the investment volume and internal funds and (ii) empirical predictions of a U-shaped relation between the investment timing and internal funds. In addition, our results have real-world implications for investment in alternative projects.


## 1. Introduction

Subsequent to the departures from Modigliani and Miller's (1958) irrelevance proposition in a frictionless market, there has been a long tradition in corporate finance to investigate the effects of various frictions on financing and investment decisions. Recently, an increasing number of papers have analyzed not only the static but also the dynamic behavior of corporate financing and investment in the presence of frictions.[1] Among these, a real options approach plays an important role in unveiling investment timing decisions in the presence of such frictions as liquidity constraints (Boyle and Guthrie, 2003), shareholders-debtholders conflicts (Mauer and Sarkar, 2005; Sundaresan and Wang, 2007), and asymmetric information (Grenadier and Wang, 2005; Shibata and Nishihara, 2010; Morellec and Schürhoff, 2011; Grenadier and Malenko, 2011).

We extend this line of research by revealing the interactions of costs of external financing, investment timing, and investment size. We analyze the following model: A firm owns an option to expand production on either a small or large scale, where the price of the output follows a geometric Brownian motion. The sizing choice is mutually exclusive. The investment project is financed with cash reserves and costly external funds. The firm's cash reserves gradually increase as its existing production generates cash flows. If the firm waits for a sufficient level of cash reserves for each project, the investment can be financed entirely with cash reserves. However, the firm will not receive increased cash flows during the waiting period but only after the expansion. Alternatively, the firm must rely partially on costly external financing but can receive the increased cash flows sooner. The cash necessary for the small-scale expansion is less than that for the large-scale expansion. Considering the trade-off, the firm determines its financing, investment timing, and investment sizing policy.

As in the standard real options literature (e.g., McDonald and Siegel, 1986; Dixit and Pindyck, 1994), our model assumes the irreversibility of investing as a friction. A key difference from most of the related papers is that we incorporate the investment sizing decision in addition to the investment timing decision. The assumption of either a small- or large-scale choice builds on Dixit (1993) and Décamps et al. (2006). Indeed, our model generalizes their models to a case with costs of external financing. The financing costs are known as one of the most influential frictions in the corporate finance literature (e.g., Altinkilic and Hansen, 2000; Hennessy and Whited, 2007). According to the pecking order hypothesis, asymmetric information problems associated with external funding generate higher costs; therefore, managers prefer internal over external financing (Myers, 1984; Myers and Majluf, 1984). As a proportional cost accounts for the largest part of external financing costs, we focus on the case with a proportional cost.

* Corresponding author. Tel.: +81 6 6850 5242; fax: +81 6 6850 5277.
*E-mail addresses:* nishihara@econ.osaka-u.ac.jp (M. Nishihara), tshibata@tmu.ac.jp (T. Shibata).

[1] An incomplete list includes Hennessy and Whited (2005, 2007), Hennessy et al. (2007), Tsyplakov (2008), Tserlukevich (2008), and Morellec and Schürhoff (2011).

0378-4266/$ - see front matter 
http://dx.doi.org/10.1016/j.jbankfin.2012.11.014

Our model potentially can be applied to several real-world cases. As documented by Dixit (1993), in many investment projects such as buildings, factories, ships, and dams, the investor has to optimize the investment size as well as the investment timing. Our model approximates such situations by considering a simple case with two alternative scales. A more concrete example is investment in power generation. Fleten et al. (2007) and Siddiqui and Fleten (2010) apply the alternative investment model of Décamps et al. (2006) to this problem. According to Fleten et al. (2007), a power company usually chooses from among generators with different capacities when investing. In some cases, the company may choose from among alternative-energy technologies (Siddiqui and Fleten, 2010). Although we talk broadly of large or small scales in this paper, our model applies directly to investment in alternative technologies. Our model is potentially useful for start-ups and growth firms that tend to have insufficient cash holdings and to face high costs of external financing to better understand investment in alternative projects.

Now, we discuss the results.[2] The presence of financing costs, unlike previous results with no financing cost in Décamps et al. (2006), leads the firm to adopt a financing and investment policy contingent not only on the cash flow dynamics but also on the cash reserves dynamics. This finding is consistent with the standard literature regarding internal financing constraints (e.g., Cleary et al., 2007; Guariglia, 2008). Specifically, higher financing costs enhance the firm's incentive to wait for a sufficient level of cash reserves and use entirely internal financing, especially for the small-scale project. These effects of financing costs are in line with the standard results (e.g., Hennessy and Whited, 2007; Hennessy et al., 2007). The investment behavior of growth firms with low internal funds could be different than that of mature firms with high internal funds in the sense that the cash reserves dynamics more greatly affect growth firms' investment.

The investment threshold for the large-scale project monotonically decreases with cash reserves. This monotonic relation is straightforwardly consistent with conventional views of underinvestment due to financing constraints (e.g., Fazzari et al., 1988; Hubbard, 1998). On the other hand, the small-scale investment is encouraged with cash reserves until cash reserves reach the investment cost and, after that, the investment is discouraged with cash reserves. The rationale behind the non-monotonic relation is that the firm optimizes not only investment timing but also investment size. Consider the ratio of the total cost associated with the large-scale expansion to that of the small-scale expansion. This ratio, which changes with cash reserves, is maximized when cash reserves are equal to the amount of the small-scale investment cost. Indeed, at that moment the small-scale project requires no external funds while the large-scale project requires a large amount of external funds. The greatest advantage of the small-scale project over the large-scale project plays a role in speeding up the small-scale investment at the intermediate level of cash reserves.

Most notably, our results can link two significant results in corporate finance. The first one is a U-shaped relation between the investment volume and internal funds. Since arguments among Fazzari et al. (1988), Kaplan and Zingales (1997), and Hubbard (1998), investment-cash flow sensitivities have been the center of attention in corporate finance. In particular, empirical evidence regarding this issue shows that the investment volume does not necessarily decrease with internal funds but can have a U-shaped relation with internal funds (Cleary et al., 2007; Guariglia, 2008).

The second result is an empirical prediction that the investment threshold has a U-shaped relation with internal funds. The prediction has been seen in the recent real option literature. Boyle and Guthrie (2003) examine the effects of a liquidity constraint to the investment timing decision and predict that the investment threshold has a U-shaped relation with internal funds in the presence of a liquidity constraint. Shibata and Nishihara (2012), who examine the effects of a debt capacity constraint in a dynamic financing and capital structure model, show that the investment threshold has a U-shaped relation with a degree of the debt capacity constraint.[3]

If one identifies "earlier" investment as "increased" investment, the two results are inconsistent with each other. However, this argument pays no attention to the point that the investment timing studies consider fixed-scale investment models. Our results can explain both types of results in terms of the interactions of investment timing and sizing decisions with costly external financing. In the presence of financing costs, cash reserves influence the tradeoff between the two choices: small- or large-scale expansion. When cash reserves are close to the amount of the small-scale investment cost, the firm has a great incentive to invest in the small-scale project for which the investment threshold is relatively low. When cash reserves are much higher or lower than that level, the firm is likely to undertake the large-scale expansion for which the investment threshold is relatively high. This mechanism can explain U-shaped relations regarding both the investment volume and timing in the previous studies.

In summary, the main contributions of this paper are as follows. First and most importantly, this paper fills the gap between two types of results in the corporate finance literature: (i) empirical evidence regarding a U-shaped relation between the investment volume and internal funds and (ii) predictions of a U-shaped relation between the investment timing and internal funds. Second, this paper complements the investment timing and sizing literature by proving that costs of external financing greatly distort the firm's investment behavior and result in a policy contingent on the dynamics of the cash flow and reserves. The results have many implications regarding effects of internal and external financing constraints, and most of them are consistent with empirical findings.

The remainder of this paper is organized as follows. Section 2 presents the setup and the results in the case with no financing costs. Section 3 presents the analytic results in the case with financing costs, while Section 4 numerically examines comparative statics with respect to cash flow volatility and financing costs. Section 5 summarizes empirical implications derived from the previous sections. Section 6 concludes the paper. All proofs appear in Appendix A.

## 2. Preliminaries

### 2.1. Setup

Consider a risk-neutral firm that produces a commodity at a constant rate. The output is sold at the market price $X(t)$, which follows a geometric Brownian motion

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

where $B\ (t)$ denotes the standard Brownian motion defined in a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ and $\mu$, $\sigma(> 0)$ and $x(> 0)$ are constants.

[2] Although most of the related paper (e.g., Boyle and Guthrie, 2003; Hirth and Uhrig-Homburg, 2010b; Shibata and Nishihara, 2012) show their results only by numerical examples, this paper analytically proves the properties of the dynamic corporate financing and investment policy by extending techniques in the mathematical finance literature (e.g., Broadie and Detemple, 1997; Detemple, 2006).

[3] Regarding the relation between the investment timing and cash holdings, Hirth and Uhrig-Homburg (2010b), who extend Boyle and Guthrie (2003) to a case with financing costs, point out the possibility of various non-monotonic relations, and Nishihara and Shibata (2011) prove that a fixed cost of external financing leads to a non-monotonic relation.