Journal of Banking & Finance 55 (2015) 142–156

Contents lists available at ScienceDirect

Journal of Banking & Finance

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

Investment policy with time-to-build

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ARTICLE INFO

Article history:
Received 29 April 2014
Accepted 15 February 2015
Available online 23 February 2015

JEL classification:
G3

Keywords:
Implementation lag
Time-to-build
Investment trigger

ABSTRACT

Most capital projects have an implementation lag. We examine the effect of implementation lag on a levered firm's investment decision. The main finding is that implementation lag can potentially have a substantial effect on a levered company's investment trigger, and this effect can be significantly different from that of an unlevered company. The exact relationship between lag and investment trigger depends on the level of debt used by the firm. For an optimally-levered firm, a crucial determinant of the lag-investment relationship is the fraction of investment cost that has to be incurred upfront. If this fraction is small, investment trigger is a decreasing function of implementation lag and the effect can be economically significant. If this fraction is large, investment trigger can be either increasing or decreasing in lag, depending on parameter values, but the magnitude of the effect is not large. Optimally levering a firm makes the implementation lag more investment-friendly relative to an unlevered firm, thus it is possible that the lag has a negative effect on investment if the firm is unlevered but a positive effect if the same firm is optimally-levered. For an optimally-levered firm, implementation lag generally has a non-negative effect on investment.

1. Introduction

Real-option models of corporate investment generally assume that, when the investment decision is taken, the project is completed instantaneously and starts delivering cash flows immediately (Dixit and Pindyck, 1994; Mauer and Ott, 2000; McDonald and Siegel, 1986). However, it is well known that most capital projects involve significant time to completion before they start generating cash flows (Agliardi and Koussis, 2013; Koeva, 2000; Bar-Ilan and Strange, 1996). This time lag is known in the literature as "implementation lag" or "time-to-build." In recent research, some attempts have been made to study the effect of implementation lag on the investment decision (Alvarez and Keppo, 2002; Bar-Ilan and Strange, 1996; Sarkar and Zhang, 2013), but they are limited to all-equity (unlevered) firms.

Most firms use some leverage, which affects firm value via tax shields and bankruptcy costs; thus, leverage affects the project value and thereby changes the attractiveness of the project. Clearly, then, leverage should affect the investment policy. Implementation lag plays a role in the investment policy because it impacts the leverage ratio, which, as mentioned above, affects the investment policy. Thus the effect of implementation lag could be different for levered firms than for unlevered firms. This motivates our paper, the main objective of which is to determine the effect of implementation lag on a levered firm's investment decision. This issue has not yet been addressed in the literature, to our knowledge.[2]

We examine the effect of time-to-build on a levered firm's investment timing. Time-to-build is incorporated in the manner of Margsiri et al. (2008), which allows us to develop a tractable model with quasi-analytical solutions. Specifically, the project is assumed to be implemented in two stages, with an initial (or first-stage) investment and a final (second-stage) investment. The project starts generating cash flows only after the second-stage investment. The implementation lag is then simply the time elapsed between the first-stage and the second-stage investments.

This paper contributes to the literature by establishing the effect of the ubiquitous implementation lag on corporate

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[2] Agliardi and Koussis (2013) determine the optimal capital structure with time-to-build, but do not consider optimal investment policy (assuming instead that investment is made at time $t = 0$). Egami (2009) and Tsyplakov (2008) examine the firm's decision to expand its existing operations rather than the initial investment decision. Since the implementation lag is more important for an initial investment decision than for an expansion decision (Sarkar and Zhang, 2013), our model focuses on the initial investment, unlike Egami (2009) and Tsyplakov (2008).

http://dx.doi.org/10.1016/j.jbankfin.2015.02.016
0378-4266/

investment decisions. The main results are as follows. The time-distribution of investment cost plays a crucial role in determining the effect of implementation lag on the investment trigger. For an unlevered firm, when the investment is front-loaded (i.e., the first-stage investment fraction is large), the optimal investment trigger is an increasing function of implementation lag; otherwise, the trigger is a U-shaped function of lag. However, when the first-stage investment fraction is small, the optimal investment trigger is strictly decreasing for all realistic lags (below 12 years). These are new results, since the role of the time-distribution of investment cost has not been examined in the literature; earlier papers ignore this issue by assuming the entire investment cost is incurred at one point in time (either at the end or at the beginning).

For a levered firm, the relationship is more complicated: implementation lag could potentially have a significant effect on the investment trigger, but the exact effect depends on the level of debt used. We briefly examine the case of exogenously-specified debt level, but the main focus of our paper is on the optimally-levered firm, for which we obtain the following results. When the initial investment fraction is small, optimal investment trigger is a decreasing function of implementation lag, and the effect can be economically significant. When the investment cost is front-loaded, the investment trigger is not very sensitive to implementation lag, and can be either increasing (when growth rate and tax rate are low, and interest rate is high) or decreasing (all other cases). Optimally levering a firm causes the implementation lag to have a more favorable impact on investment relative to using no leverage. Thus, if for an unlevered firm the investment trigger is a decreasing (increasing) function of implementation lag, then for an optimally-levered firm it will be a more decreasing (less increasing or even decreasing) function of lag. Overall, for an optimally-levered firm, implementation lag has a positive effect or a minor negative effect on investment; this is very different from an unlevered firm, particularly for front-loaded investment projects.

Although our paper's main focus is investment policy, we also take a brief look at financing policy and find that the optimal leverage ratio is an increasing function of implementation lag, consistent with Agliardi and Koussis (2013).

The main practical implication of our paper is that, for optimally-levered firms, implementation lag will have a positive effect on investment, except when the initial investment fraction is large, interest rate is high, and tax rate and growth rate are low, in which cases it might have a minor negative effect.

The rest of the paper is organized as follows. Section 2 develops the model, describes the implementation lag in detail, and evaluates the investment decision for an unlevered firm. Section 3 examines the more important case of a levered firm. Section 4 presents the results, and Section 5 concludes.

2. The model

As in traditional real-option models (Mauer and Sarkar, 2005; Roques and Savva, 2009), we assume that the firm has an investment opportunity which costs \$I to implement, and it can choose the time of investment. Prior to the investment, the firm consists of just the investment option. Unlike the above models, however, there is an implementation lag or time-to-build, because of which the project starts generating earnings or cash flows not immediately but only after a lag (the implementation lag). Implementation lag is modeled as in Margsiri et al. (2008) and discussed in Section 2.1 below.

After the implementation lag, the project generates a continuous cash flow stream of $\$x_t$ per unit time, which is assumed to follow the usual lognormal process:

$$dx = \mu x dt + \sigma x dz \qquad (1)$$

where μ is the expected growth rate and σ is the volatility of the earnings process, both assumed constant, and dz is an increment to a standard Brownian Motion Process. The firm's earnings (after interest, if any) are taxed at a constant rate of τ, and all cash flows are discounted at a constant discount rate of r. Shareholders receive all residual cash flows after interest and taxes.

2.1. Implementation lag

The existing literature on implementation lag generally treats the lag as a fixed length of time that is known in advance, e.g., Alvarez and Keppo (2002), Bar-Ilan and Strange (1996), Sarkar and Zhang (2013). Our paper uses a different approach (described below) following Margsiri et al. (2008), where implementation lag is denoted by a parameter β.[3]

If the firm wants to implement the project, it must invest in two stages, with some elapsed time between the two stages, before it can realize any benefits from the project. Thus, investment takes place in two stages – in the first stage, the firm invests a fraction θ of the total investment cost (or \$θI) and receives a fraction θ of the total set of assets of the project, where $0 \leqslant \theta \leqslant 1$. The first-stage investment allows the firm to proceed to the second stage. In the second stage, the firm pays the remainder of the investment cost, or $\$(1-\theta)I$, and receives the remaining fraction $(1-\theta)$ of the assets. The project starts generating cash flows only at the second stage, hence there are no cash inflows between the first and the second stage.

To represent the implementation lag, we specify that if the first-stage investment takes place at a certain level of x (say, when x rises to x_f), then the second-stage investment must take place (and cash flows will start) when x rises to $x = \beta x_f$, where $\beta > 1$. Thus, some time has to elapse between the first stage and the second stage, i.e., the time required for x to increase from x_f to βx_f. This elapsed time is the implementation lag.

Since x is stochastic, the implementation lag is a random variable, with an expected value of[4]:

$$E(L) = \frac{\ln \beta}{\mu - 0.5\sigma^2} \qquad (2)$$

An increase in β implies a longer expected lag. The distribution of implementation lag is independent of the first-stage investment threshold x_f, hence the expected lag is unaffected by x_f.

Note that in our representation, the implementation lag is stochastic, as opposed to the known (i.e., with no uncertainty) implementation lag in earlier papers such as Alvarez and Keppo (2002), Bar-Ilan and Strange (1996) and Sarkar and Zhang (2013).

2.2. Time-distribution of investment cost (θ)

In all the existing papers, the entire investment cost is incurred either at the beginning (Bar-Ilan and Strange, 1996) or at the end (Alvarez and Keppo, 2002, and Sarkar and Zhang, 2013). In contrast, our model makes the more general assumption that the firm incurs investment cost of θI at the beginning and $(1-\theta)I$ at the end. As shown in Sections 2.3 and 4, the parameter θ plays an important role in determining how implementation lag affects the investment trigger. A higher θ means that a larger fraction of the total investment cost has to be incurred upfront. Then the effect of a higher θ is to increase the effective investment cost (in present value terms), which should result in a higher investment trigger. This is confirmed by the numerical results of Section 4.2.

[3] This approach has the advantage of tractability. As Margsiri et al. (2008) confirm (footnote 8, p. 643), the main results are not affected if a fixed lag is used.

[4] See Margsiri et al. (2008), Section 2.4.