



Investment timing, reversibility, and financing constraints



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ABSTRACT

This paper examines the optimal financing and investment decisions problem of a firm that is constrained by an upper limit of debt issuance based on liquidation (collateral) value. Our model provides five new results. First, an upper limit of debt issuance does not always delay corporate investment. Second, an upper limit does not affect the determination of investment quantity. Third, an upper limit may change bankruptcy strategies during financial distress via a change of capital structure. Fourth, an upper limit may induce the debt to move from risky to riskless. Fifth, an upper limit always decreases the leverage, credit spread, and default probability.

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1. Introduction

The standard real options approach examines the option value of a project along with investment timing. Although the seminal study by McDonald and Siegel (1986) assumes an all-equity financing to incur the investment cost, recent studies examine debt–equity financing. However, most recent studies have assumed the complete irreversibility of investment and no upper limit of debt issuance. With the assumption of a completely irreversible investment, the residual value at bankruptcy is the value derived *not* by the investment cost *but* by the cash flow. Without any upper limit of debt issuance, an amount of debt issuance larger than the investment cost is allowed for the firm. These two assumptions are impractical and illegal, respectively.¹

During the past 20 years, several empirical studies have investigated the effect of partial reversibility of investment on capital goods. During the same period, other empirical studies have analyzed the effect of financing constraints on corporate investment dynamics. Thus, in practice, it makes sense that investment cost is partially reversible, not completely irreversible, and the firm encounters financing constraints at the time of investment. For example, if the firm goes bankrupt, some portion of the capital goods installed by incurring the investment cost can be sold to a third party, although the resale price of capital goods is

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¹ If the firm issues an amount of debt issuance larger than investment cost, the excess is distributed to equity holders. This is illegal in practice, although it can be mathematically feasible.

discounted. The portion of investment cost that is partially reversible is regarded as the residual value. In addition, at the time of investment, the amount of debt issuance is likely restricted, depending on the liquidation (collateral) value. The collateral (e.g., the residual value defined as some portion of investment cost) can be required by debt holders for debt financing.²

The motivation of this paper is to respond to the fact that the *partial reversibility* of investment and *upper limit of debt issuance* have always been analyzed in isolation. On the one hand, several papers incorporate the notion of *partial reversibility* for investment cost. An incomplete list includes Abel and Eberly (1994, 1996, 1999), Abel et al. (1996), Hartman and Hendrickson (2002), Wong (2010a), and Cui and Shibata (2017a). However, these papers do not consider debt financing constraints because all-equity financing is assumed. On the other hand, several papers incorporate the notion of *upper limit of debt issuance* in financing the investment cost. An incomplete list includes Hirth and Uhrig-Homburg (2010), Shibata and Nishihara (2012, 2015a,b), Wong (2010b).³ However, these papers do not consider the effects of partial irreversibility of investment because investment is assumed to be completely irreversible.

To the best of our knowledge, there is no examination of interaction between partial reversibility of investment and upper limit of debt issuance in the financing (capital structure) and investment decisions problem. The contribution of this paper is to incorporate two extensions. With two extensions, the upper limit of debt issuance as a financing constraint is restricted by the liquidation value, defined as the partial reversibility of the investment cost. This is more practical.

To incorporate *partial reversibility* of investment and *upper limit of debt issuance*, we introduce the following two properties. First, in introducing reversibility of investment, the residual value at liquidation bankruptcy is the value of partially reversible investment cost. Then, depending on the magnitude of its residual value, the firm takes one of two types of bankruptcy: *operating concern bankruptcy* (represented as “default”) and *liquidation bankruptcy* (represented as “shutdown”). By contrast, because reversibility of investment has not been considered in previous papers such as Shibata and Nishihara (2012, 2015a,b), Sundaresan and Wang (2007), Wong (2010b), previous studies have not examined whether bankruptcy constitutes default or shutdown.

Second, in incorporating upper limit of debt issuance as a financing constraint, the maximum amount of debt issuance can be restricted, depending on the liquidation value. Because liquidation value, defined as the resale price of partial reversible investment cost, is regarded as the value of corporate collateral, the maximum amount of debt issuance is restricted by the value of corporate collateral. This constraint is called collateral constraint and was originally developed by Kiyotaki and Moore (1997).⁴ To the best of our knowledge, this is the first paper to incorporate collateral constraint in the financing and investment decisions problem.⁵

In addition to two extensions, we incorporate *endogenous* investment quantity, which causes *endogenous* investment reversibility and *endogenous* financing constraint. To be more precise, determining the investment quantity is equivalent to determining the cost of investment, which is equivalent to determining the amount of reversible investment. Moreover, because the upper limit of debt issuance depends on the amount of reversible investment, determining the investment quantity is equivalent to determining the upper limit of debt issuance. Thus, the amount of reversible investment and the upper limit of debt issuance are regarded as endogenous. As a result, our collateral constraint is regarded as endogenous. In our model, under such a collateral constraint, we consider the interactions between financing (capital structure) and investment decisions.

We provide five novel results. The first result relates to the investment timing strategy. Recall that debt financing decreases the investment threshold (i.e., accelerates corporate investment) and increases the option value of investment when there are no financing constraints. We call such properties a *symmetric relationship* between the decreased threshold and the increased value. Based on this symmetric relationship, we intuit that the symmetric relationship is obtained even under financing constraints, where an upper limit constraint of debt issuance increases the investment threshold (i.e., delays corporate investment) and decreases the option value of investment. However, we show that a symmetric relationship is *not always* maintained under financing constraints. To be more precise, an upper limit constraint may decrease the investment threshold (i.e., accelerate corporate investment) although it always decreases the option value of investment. These results are contrary to our intuition. The intuitive reason for this is that there are two conflicting effects of an upper limit constraint. In particular, an upper limit always decreases coupon payment, which decreases firm value. Then, the investment threshold is decreased via a decrease in coupon payment, while it is increased via a decrease in firm value. According to the magnitude of these two effects, the threshold is increased or decreased. This implies a nonmonotonic (U-shaped) relationship between the investment threshold and the upper limit of debt issuance. This result is consistent with the findings of previous papers such as Boyle and Guthrie (2003), Cleary et al. (2007), Shibata and Nishihara (2012), and Wong (2010b). Thus, in our model, even if the firm encounters the upper limit constraint of debt issuance depending on the reversible portion of investment, we show a nonmonotonic relationship.

The second result is that an upper limit of debt issuance does not affect the magnitude of investment quantity. This result is similar to that of previous papers such as Wong (2010b) and Shibata and Nishihara (2015a). In our model, by introducing the partial reversibility of investment, we are forced to consider the separation of default (“operating concern bankruptcy”) and

² Because the demand for collateral has been growing since the subprime crisis and the euro sovereign debt crisis, collateral plays an essential role in the current financial markets.

³ These papers incorporate financing constraints on the investment decision problem under debt-equity financing such as Brennan and Schwartz (1984), Hackbarth et al. (2007), Mauer and Triantis (1994), and Sundaresan and Wang (2007).

⁴ In this paper, note that collateral constraint is endogenous.

⁵ A partial list of papers that estimate nonstochastic dynamic models that incorporate collateral constraints includes Bianchi (2010), Jeanne and Korinek (2010), Kiyotaki and Moore (1997), Rampini and Viswanathan (2010), and Gottardi and Kubler (2015).

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