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Irreversible investment under uncertainty and the threat of bankruptcy

James Vercammen*

*University of British Columbia and University of Melbourne, Faculty of Commerce and Business Administration,
2053 Main Mall, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z2*

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Abstract

The firm-level theory of irreversible investment under uncertainty is extended to account for bankruptcy. With a sufficiently large risk of bankruptcy, firms prefer to defer their investment decision to a later date. Simulated option values reach as high as 30 percent. © 2000 Elsevier Science S.A. All rights reserved.

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1. Introduction

The literature on firm-level investment with irreversibility and uncertainty has grown rapidly over the last decade. The standard problem, first examined by McDonald and Siegal (1986), is comprised of a firm who must decide when to invest a fixed amount P in exchange for a project with value V where V is continually changing over time. The decision to invest is irreversible and thus an option value associated with waiting normally exists. That is, P must be sufficiently less than V in order for the investment to occur.

There have been many extensions of this basic model, much of which is described by Dixit and Pindyck (1994). For example, Leahy (1993) and others have examined option values in the context of a competitive equilibrium. Recent papers on irreversible investment under uncertainty and oligopoly include Fatas and Metrick (1997) and Baldursson (1998). Dixit (1991) examined the problem in the context of price ceilings and Dixit (1995) considered the role of scale economies. Sequential

*Corresponding author. Tel.: 001-604-822-5667; fax: 001-604-822-2184.

E-mail address: vercamme@unixg.ubc.ca (J. Vercammen)

investment and incremental investment have also been considered in several studies. Finally, Chang (1988) examines how irreversible investment impacts the incentive for horizontal merger.

Despite its importance for the decision making of most firms, bankruptcy has not yet been formally examined in the context of irreversible investment. Specifically, suppose in the standard model, the firm must borrow funds to finance the investment. If the firm is unlucky, outstanding debt may increase and exceed the value of the collateralized investment asset. At this point, the lender will foreclose by seizing the asset and the firm will lose access to the future revenue stream. Making an investment increases the probability of foreclosure. Therefore, waiting to invest may be valuable because waiting allows the firm to reduce its debt and also to avoid the investment if the risk of foreclosure increases.

The purpose of this paper is to develop a simple model of irreversible investment with foreclosure risk. To isolate the option value solely attributable to foreclosure risk, the model is constructed such that an option value does not exist in the absence of bankruptcy considerations. The normal assumption is that the value of the project follows some type of Brownian motion stochastic process. Suppose instead that returns are continuously and independently normally distributed. In the standard model, there is no value from waiting if the project's value is stationary over time. Thus, any option value arising within the current model is due to the foreclosure risk.

An important assumption within the model concerns the form of the foreclosure rule. The standard rule, 'foreclose if the firm becomes insolvent (i.e., outstanding debt exceeds the collateralized value of the assets),' is employed. This rule is not necessarily efficient because an insolvent firm may expect to eventually become solvent if it is allowed to continue operating¹. In this model, returns are stationary and the project is assumed profitable at date 0, implying that foreclosure is always inefficient/premature. However, lending without foreclosure (in which case the option value results of this paper vanish) would typically require an unbounded risk premium within the lending rate. For institutional and transaction cost reasons, lenders typically do not employ this strategy².

2. The model

At time 0 a firm owns a plant (financed partially with debt) that continuously generates a stochastic level of net returns. These returns are independently and normally distributed with mean R and standard deviation σ . The plant cannot be sold until time T , at which point its value is P . If bankruptcy occurs prior to time T , the value of the plant to the foreclosing lender is also P . At time 0 the firm's outstanding debt is $D_0 < P$. The lender can instantly and costlessly foreclose (i.e., seize and resell the plant) and thus bears no risk because the following rule is assumed: 'foreclose instantly if outstanding debt rises to level P '. Consequently, the interest rate set by the lender, ρ , equals the risk-free cost of

¹If inefficient foreclosure is interpreted as a bankruptcy cost, then the results of this paper are still consistent with the Modigliani and Miller theorem. In the absence of bankruptcy costs, this theorem implies that, regardless of the level of debt, a firm's investment reserve price equals the discounted presented value of expected returns.

²The lender may not have complete information about the firm's future revenue possibilities. Or perhaps a 'rules' based approach rather than a 'discretionary' approach is used because of internal agency problems.

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