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Repeated real options: optimal investment behaviour and a good rule of thumb

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Abstract

This paper extends the standard investment-under-uncertainty set-up with a single investment option to the case of infinitely repeated options. Analytical solutions are derived, and it is shown that repeated options not only imply a smaller value of waiting than in the case of a single option, but also that the optimal stopping rule is affected differently by changes in underlying parameters. This is shown to allow for the use of a simple hurdle-rate rule as a good and robust approximation to optimal behaviour when investment options are repeated – something which is unlikely in the single-option case.

JEL classification: D81; O33

Keywords: Repeated real options; Rule of thumb; Geometric Brownian motion

1. Introduction

During the last two decades, a large number of studies have analysed the real-option approach to investment decisions. See Dixit and Pindyck (1994) for a unified account of this approach. The object of analysis is optimal investment behaviour

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when: (i) investments are irreversible and indivisible; (ii) there is uncertainty about the future, for example, about the cost and profitability of an investment; and (iii) there is an option to postpone the investment. It is argued that incorporating these features into the optimisation problem often provides a more appropriate description of the investment decision than more orthodox and static formulations using a simple net-present-value (NPV) criterion. Furthermore, since (i)–(iii) usually create a (considerable) value of waiting, the derived decision rules are often significantly different from those implied by the simple NPV criterion.

The core model in Dixit and Pindyck (1994), and in much of the related literature, is a single-option model first developed by McDonald and Siegel (1986). In this model, the option to invest is "killed" when the investment is undertaken. Hence, no future re-investment can take place. While this type of model has rightly received considerable attention in the literature, there exist situations where it is less appropriate.

As an example, think of an individual or a firm considering when to invest in IT equipment. New and more productive equipment is continuously introduced at the market and prices are constantly changing. Furthermore, an investment of this type is indivisible – at least to some degree – and also irreversible in the sense that the resale value decreases rapidly. Hence, the features (i)–(iii) above are clearly present in this decision problem. However, the agent knows that the current IT investment is not an isolated event. In a few years, it will be optimal for him to buy an even bigger IT system. Therefore – being rational – he cannot consider the current investment option as independent of future options. When he buys the IT equipment, he "kills" the current option, but he immediately receives a new option: The option to buy even newer IT equipment. The optimal timing of his current investment is therefore likely to depend on and influence the pattern of future investments.

The aim of the present paper is to extend the methodology of the real-option literature to include this repeated-options aspect, and to analyse the implications for optimal investment behaviour. By allowing for the fact that many real-investment options are repeated, the irreversibility feature of the real-options literature is relaxed somewhat. Still, however, the formulation retains most of the features common to the literature. A central question therefore becomes: Do the insights derived from the well-known single-option model carry over to the case of repeated options, or does the single-option model yield invalid descriptions of optimal behaviour when investment options are indeed repeated?

In this paper, the intertemporal decision problem is modelled as follows: In each period, production is assumed to depend only on the productivity of installed technology. There is no effort or input of other factors. Productivity may be increased by investing in the currently available technology in the economy. All investments are irreversible and indivisible, in the sense that the agent has to pay for the productivity *level* of the exogenous technology, not just the *difference* in productivity levels between installed and exogenous technology. While focusing on the case where only the productivity of exogenous technology evolves stochastically, the paper derives a general analytical solution in the case where both the productivity