Journal of Economic Dynamics & Control 51 (2015) 240–256

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

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

Explicit investment rules with time-to-build and uncertainty ☆

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ARTICLE INFO

Article history:
Received 29 May 2014
Received in revised form
17 October 2014
Accepted 24 October 2014
Available online 1 November 2014

JEL classification:
C61
D92
E22

Keywords:
Optimal capacity
Irreversible investments
Singular stochastic control
Time-to-build
Delay equations

ABSTRACT

We establish explicit socially optimal rules for an irreversible investment decision with time-to-build and uncertainty. Assuming a price sensitive demand function with a random intercept, we provide comparative statics and economic interpretations for three models of demand (arithmetic Brownian, geometric Brownian, and the Cox–Ingersoll–Ross). Committed capacity, that is, the installed capacity plus the investment in the pipeline, must never drop below the best predictor of future demand, minus two biases. The discounting bias takes into account the fact that investment is paid upfront for future use; the precautionary bias multiplies a type of risk aversion index by the local volatility. Relying on the analytical forms, we discuss in detail the economic effects. For example, the impact of volatility on the optimal investment is negligible in some cases. It vanishes in the CIR model for long delays, and in the GBM model for high discount rates.

1. Introduction

How to track demand when the time-to-build retards capacity expansion? When to invest and how much? We answer these questions with a model of irreversible investment. The objective of the decision-maker is to maximize the expected discounted micro-economic social surplus, i.e., the sum of the consumers' net surplus and of the firms' profit. We are able to show in particular that the solution is implementable as a competitive equilibrium. We are able to calculate explicit, compact, decision rules.

In many capitalistic industries, construction delays are essential. In this paper, we focus on electricity generation. In this sector, construction delays can be considerable: they could be only one year for a small wind-farm but could be three years for a gas turbine and eight to ten years for a nuclear plant. The scenarios of the evolution of demand with their trends, their drag force, and their stochastic parts require particular attention. To this purpose, we develop the comparative statics and

☆ This study was supported by FiME (Laboratoire de Finance des Marchés de l'Energie) and the "Finance et Développement Durable - Approches Quantitatives" Chair. We are grateful to both referees for their useful comments.
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http://dx.doi.org/10.1016/j.jedc.2014.10.010
0165-1889/

economic interpretations for three demand models applied to electricity generation. The intercept of the price sensitive demand function follows either an arithmetic Brownian motion as in Bar-Ilan et al. (2002), or a geometric Brownian motion as in Bar-Ilan and Strange (1996) and Aguerrevere (2003), or the Cox–Ingersoll–Ross (CIR) model. The latter is a mean-reverting process, and, to our knowledge, no real options investment model exists in the literature with time-to-build and a process of this type. The basic existence and regularity results are provided in a companion paper (Federico and Pham, 2014), but we simplify the specification for the sake of calculability.

An exact decision rule facilitates the clear understanding of the effects at play. The decision rule stipulates what the committed capacity should be, that is, the installed capacity plus capacity under construction. The action rule, given the current conditions, is that the committed capacity must not fall below the best predictor of demand after the delay, minus two biases. The first bias is a pure discounting bias unrelated to uncertainty: because the investment is paid for upfront but only produces after the delay, the required committed capacity is reduced. The second one is a precautionary bias where a risk aversion index is multiplied by local volatility.

We also illustrate the practical importance of a possible saturation of the demand with the CIR model. Indeed, one can observe in Fig. 1 that the electricity consumption in several developed countries slows down and seems to reach some ceiling. The saturation is clearer for per capita electric consumption. We show that the investors' behavior is very different depending on whether demand is above or below the long-run average, or target. When demand is above the target, the investor is almost insensitive to the current demand, except if the return speed is very slow. Below the target, the comparison between the time-to-build and the expected time-to-target is critical: if the time-to-build is longer, then the optimal committed capacity is practically the target itself minus the biases; if the time-to-build is shorter, then the investors observe the process and invest progressively.

The literature on the topic provides a number of insights. Table 1 provides a tentative classification. The competitive pressure matters: competition kills the value of waiting and thus accelerates investment. Grenadier (2000, 2002) and Pacheco de Almeida and Zemsky (2003) follow this line of thought. We exclusively use a competitive market and show that this effect is completely internalized. The seminal work McDonald and Siegel (1986) on the option to wait in the case of irreversible decisions shows that uncertainty has a negative effect on investment. Strong support for this result is that with greater volatility, investment is triggered by a higher current product price, i.e. a smaller probability of a market downturn. Several extensions provide conditions under which this result does not hold or might be mitigated. Construction delays, that is, the time between the decision and the availability of the new capacity, have attracted the attention of economists. In particular, the models in Bar-Ilan and Strange (1996), Bar-Ilan et al. (2002), and Aguerrevere (2003) exhibit situations where an increase in uncertainty leads to an increase in investment.

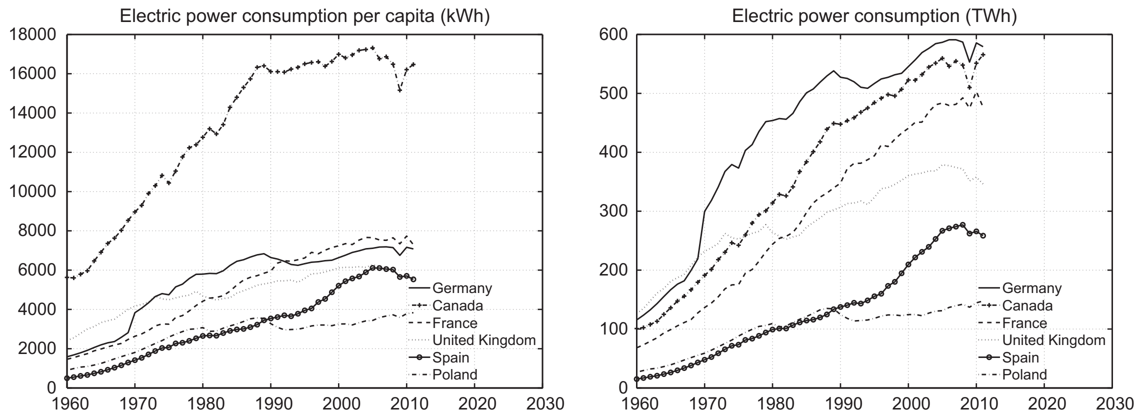

Fig. 1. (Left) Electric power consumption per capita. (Right) Electric power consumption.
Source: World Bank.

Table 1
Papers on investment with uncertainty and time-to-build.

Paper	Objective	Competition	Investment
Majd and Pindyck (1986)	Firm	No	Irreversible
Bar-Ilan and Strange (1996)	Firm	No	Reversible
Grenadier (2000)	Firm	Perfect	Irreversible
Bar-Ilan et al. (2002)	Planner	No	Irreversible
Grenadier (2002)	Firm	Imperfect	Irreversible
Aguerrevere (2003)	Planner/firm	Perfect/imperfect	Irreversible with flexible production