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Modeling technology adoption as an irreversible investment under uncertainty: the case of the Turkish electricity supply industry☆

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Abstract

This paper studies energy conversion technology adoption in the electricity supply sector from the perspective of irreversible investments under uncertainty and with a particular interest in environmental sustainability. We develop a dynamic technology adoption model that is firmly rooted in economic theory and that takes important determinants of optimal investment in available technologies (e.g., life cycle capital and operation cost) explicitly into account. Uncertainty is introduced for the demand for peak-load capacity, unit generation costs, and for the average electricity price. We test the model empirically by applying it to data for the Turkish power supply industry. The model-guided optimal investment schedule based on net present value considerations exhibits significant deviations from the actual investment outcome. We find that the increased adoption of natural-gas-fired power generation technologies in Turkey in recent years, while

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contributing to environmental sustainability, has had doubtful merits from an investor's perspective.

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1. Introduction

Increasing concern about the adverse socioeconomic and environmental impacts of current energy use patterns, in many cases coupled with staggering levels of fossil fuel import dependence, call for substantial changes in the energy technology and fuel mix towards a more sustainable energy supply system. Technology adoption and diffusion models (e.g., see Thirtle and Ruttan, 1987; Sarkar, 1998), both at the microeconomic and the aggregate level, can provide valuable insights for a better understanding of actual and required transitions in the energy-converting capital stock composition, related fuel consumption patterns, underlying investment decisions, and technological trajectories followed.

In this paper, we study energy conversion technology adoption in the electricity sector from the perspectives of irreversible investment under uncertainty and environmentally sustainable development. Particularly, we develop a dynamic technology adoption model that features elements from real options theory (Dixit and Pindyck, 1994) and apply it to detailed industry level time series cross-sectional data for Turkey (e.g., for installed capacities, unit generation costs, and input fuel and electricity consumption and prices). The model developed is firmly rooted in economic theory and rests on important determinants of investment in available technology options, such as (expected) capital and operation costs over the lifetime of a certain vintage of a specific technology.

Investment decisions in liberalized markets, in contrast to noncompetitive markets, are based on market-driven value maximization criteria. Because the profitability of investment projects is contingent upon input and output price variations, project values evolve dynamically over time. Therefore, it is optimal to invest in some physical asset ('real option') when the present value of the expected cash flow exceeds the cost of investment by a (strictly) positive amount that is at least equal to the compensation for the loss of forfeiting the real option.

Two alternative approaches are discussed in the literature to derive the optimal investment rule and the value of the optimal investment in a real asset. While *contingent claims analysis* is essentially rooted in the finance literature, *dynamic programming* starts from a given discount rate and considers the maximization problem of the expected value of discounted cash flows. The two methods are linked through the equivalent risk-neutral valuation principle, and although they make different assumptions about financial markets and the rates firms use to discount future cash