Strategic capacity investment in renewable energy technologies under uncertainty

Topic: (6) Industry
Matthias ONDRA[(1)], Thomas DANGL[(1)]
[(1)] Vienna University of Technology, Institute of Management Science,
Matthias.ondra@tuwien.ac.at, Thomas.dangl@tuwien.ac.at

Introduction

Nowadays, energy managers of industrial firms are facing investment decisions in power generation facilities in a risky environment where multiple sources of uncertainty arise. Renewable energy sources (RES) are more sustainable investment choices from an environmental point of view but are capital intensive and exposed to uncertain production volumes (wind and solar power), which increases the shortfall risk in the power supply. In order to overcome the investment burden in RES remuneration policies like feed-in-tariffs (FIT) are put into place which promote environmentally friendly power technologies. The level of the FIT is also subject to policy uncertainty and is expected to decrease in the future. Furthermore, technological learning decreases the prices of the investment goods (especially solar technology) by active research and development. Such exogenous technological innovation shocks occur randomly over time and thus introduce another source of uncertainty in the investment decision. In this paper we consider the energy manager of an industrial firm who aims at minimizing the firm's expected costs of power supply by investing in renewable self-generation facilities (wind and solar technology) in an uncertain environment. We propose a dynamic investment model under uncertainty, where the timing of the investment in RES is not exogeneously fixed but can be chosen by the energy manager. Therefore, the energy manager has to determine simultaneously: (i) the optimal renewable energy portfolio (subject to a budget constraint) and (ii) the optimal timing of the investment.

Methodology

We consider a risk-neutral energy manager who determines the expected costs of the firm's power supply by: (i) the investment costs in self-generation facilities, (ii) expected costs in case of a shortfall of the energy park and (iii) expected remunerations for selling surplus power to the grid. The shortfall distribution of the energy park is simulated by using real-world output data of the wind speed and the solar irradiance for a typical location in Central Europe. We analyze the investment problem in a real options framework and determine the value of the investment opportunity in RES by using dynamic programming methods based on Bellman's Principle of Optimality. Policy risk is modeled by assuming that the level of the FIT is subject to multiplicative geometric Brownian shocks. Since support schemes for RES are gradually withdrawn, the drift of the geometric Brownian motion is assumed to be negative. Due to technology diffusion and technological learning, the price of solar power is subject to random exogenous innovation shocks, where the expected size of the technological innovation and the probability to obtain an innovation in the future is exogenously fixed.

Conclusion

The power output per unit of installed capacity is different for solar and wind technology and therefore each technology exhibits different exposure to the shortfall risk. By choosing optimally installed capacities in both technologies, the energy manager is able to shape the underlying risk distribution of a shortfall in the power supply. Hence, by diversifying the energy portfolio the energy manager can lower the power shortfall risk which introduces the renewable energy portfolio effect. In contrast to classical portfolio theory, where the risk diversification effect is due to maximizing a risk-averse (i.e. concave) utility function, in this approach the diversification effect is formally introduced via the underlying non-linear pricing relation of expected surplus and expected shortfall costs. In the dynamic optimization framework that allows for this diversification effect, we find that the optimal investment decision is not necessarily to invest immediately in the renewable energy technology that refers to the highest power output per unit of capital invested but to follow a staged investment strategy with an early investment in wind technology or to defer the investment opportunity to the future. These results can be used to derive policy implications about the optimal policy design of subsidy retraction rate associated with the level of the FIT. By quantifying the boundary region indicating indifference of investing immediately in RES or postponing the decision, the energy manager can be incentivized by a regulator who is in charge of setting the appropriate subsidy retraction rate.