Multi-objective infrastructure investment under uncertainty

Verena Hagspiel[1], Maria Lavrutich[1]

[1]*Department of Industrial Economics and Technology Management,*

Norwegian University of Science and Technology, 7491 Trondheim, Norway

January 31, 2019

Abstract

We study optimal infrastructure investment decisions of a social planner (SP) that has to anticipate capacity investment of a private company (PC) in a market characterized by uncertain demand. The proposed model captures the investment decisions of the SP and PC and accounts for the conflicting objectives and game-theoretic interactions of the distinct agents. Taking an option-based approach allows us to study the effect of uncertainty on the investment decisions, and to take the agents discretion over investment timing as well as size into account. We show, if and how the SP can align the decision of the PC with the social optimum using the fact that the PC is dependent on the infrastructure provided.

1 Extended abstract

In the Norwegian province of Trøndelag, several companies discussed the prospect of building Europes largest onshore wind project. The realization of this project however, required a better connection of this region to the main Norwegian transmission grid. In Norway, the transmission system operator (TSO) Statnett is responsible for the transmission system investment. Statnett had prior to that promised to extent the Norwegian transmission grid so that a certain amount of wind energy can be connected. When taking this transmission investment decision, Statnett had to anticipate the subsequent generation investment. In today's deregulated electricity markets, the generation investment decisions are at the discretion of power

companies that will optimally decide generation investment given their objective to maximize profit, while transmission in many countries as in Norway is still regulated. This means that studying this problem one needs to account for strategic aspects. Another complicating factor is that these are investment decisions under considerable amount of uncertainty. There are many other infrastructure investments with similar features. Large infrastructure investments are often characterized by high uncertainty and irreversibility. Another aspect typical for such large infrastructure projects is the involvement of public money. These capacity investment decisions are therefore, taken by different actors with different objectives that are dependent on the others investment decision.

We consider two decision makers, a social planner (SP) and a private company (PC), that serve a market characterized by uncertain demand. The SP holds an option to undertake a public investment, which provides infrastructure of a certain capacity, K_S, to a potential industry or residential location. This can be, for example, an investment in a new transmission line to connect a power park to the main grid, investment in hard infrastructure like roads, railways and bridges, port investment, or providing water supply, sewage, or telecommunications to potential real estate projects. SP has the flexibility to choose both size and timing of the investment. Any investment by the PC is constrained by the availability of the infrastructure capacity. For example, if there is no transmission capacity available, the power company would not be able to transmit the generated electricity, and, therefore, receive profits. We consider the decision of the PC to invest in new production capacity, K_P, that is dependent on infrastructure provided by the SP, i.e. $K_P \leq K_S$. We acknowledged that the PC has both timing and sizing flexibility with regards to the possible investment. Both investments are characterized by substantial sunk investment outlays, and, hence, are considered to be irreversible. In out model the two agents have different objectives. The SP strives to maximize social welfare, while the PC maximizes its profit. We assume perfect information implying that the SP can anticipate the investment decision of the PC. Therefore, the problem is similar to a Stackelberg game with the SP as the leader and the PC as the follower. However, as infrastructure capacity complements production capacity rather than substitutes it, the considered problem does not have the same competitive aspects as the traditional Stackelberg model where companies compete on market share. Instead, each agent's value is dependent on the other agent's investment and production decision. The PC is dependent

on the decision of the SP to invest in infrastructure capacity, whereas the SP's objective is dependent on the amount of goods and services produced by the PC. The SP in this setting strives to align the decision of the PC with the social optimum by using the fact that the PC is dependent on the capacity provided.

We find that if infrastructure and production investment would be chosen with the objective to maximize profit, the social planner would investment in twice the capacity at the same time. If the SP can constrain the PC, then two things can happen. If uncertainty in the market is low enough and/or the investment cost of the SP is large enough, then the SP can in fact align the decisions of the PC with the social optimum by setting a upper constraint for capacity and a lower constraint for timing. In a more uncertain environment and for smaller investment cost of the SP, however, the SP will adjust both capacity and timing. Int he latter case anticipating the PC investment decisions spares the SP overinvestment.