ADAPTING LONG-LIVED INFRASTRUCTURE TO UNCERTAIN AND TRANSIENT CHANGE

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Overview

How should long-lived infrastructure be adapted to ongoing and uncertain change? Shall it be designed more robustly if uncertainty increases, or shall economic live-times be reduced? One prime example is uncertainty of climate change that negatively affects infrastructure by extreme weather events and slow-onset impacts. Design options include the type of material used for building roads, rail track, airports, bridges, water pipes, or electricity transmission lines (cf. IPCC (2014)). Another example is the rising capacity of fluctuating renewables, being prone to political and technological uncertainty that needs to be considered in electricity grid investment.

Generally, investment and adaptation of infrastructure are associated with high sunk costs, and current decisions shape the effects of changes in exogenous conditions up to multiple decades into the future. It might be one intuitive option to increase the robustness of infrastructure to climate change. Although that might increase costs in the present, it will reduce losses in the future. A more robust technical design will also increase the life-time of the infrastructure. Furthermore, if a retrofit of technical design parameters is expensive, irreversibility together with uncertainty leads to an option value, so that abandoning the investment might be delayed (cf. Dixit and Pindyck (1994)). In contrast, a shorter life-time might enable more efficient rolling adjustments to transient change (cf. Hallegatte (2009)). This work in progress addresses these questions by determining and comparing the optimal infrastructure life-time and design for different settings.

Methods

Our optimal stochastic control model maximizes the infrastructure's expected present value net benefit. A stopping problem (cf. Seierstad (2009)) defines the optimal infrastructure's expected life-time, which depends on the technical design that can only be chosen at the time where the investment is made. We assume that the exogenous conditions evolve according to a stochastic process with geometric brownian motion. Therefore, condition's changes over time depend on a certain rate as well as on the uncertain stochastic process including a standard deviation parameter. The current net benefit of the infrastructure is highest if the technical design fits exactly to the exogenous conditions. After finding the optimal life-time and technical design, related comparative statics will be applied. Results will be derived by using theoretical modeling as well as algebraic and numerical software.

Results

Preliminary results derive a value function and optimal stopping rule for the problem. First comparative statics results for the optimal life-time with respect to the certain change rate and the standard deviation of the stochastic process are indicated. Certain parameter restrictions are required for the solution to exist. For example, the discount rate being not too large compared to the certain change rate.

Comparative statics results (without optimal chosen technical design) show that an increase in the (expected) certain rate of change leads to shorter optimal life-times. Deviations between the exogenous conditions and the technical design increase over time since the design will be only chosen at the beginning.

For higher uncertainty about change in the exogenous conditions the direction of the results depends on specific relationships between exogenous parameters (for example, the discount rate and the certain change rate). Therefore, scenarios both with rising as well as decreasing optimal life-time due to higher uncertainty exist. Life-time might increase when there is an increase in the option premium for waiting to end the infrastructure's life-time: More information might appear that helps to decide when to shut down. On the other hand, as the technical design cannot be changed interim, higher uncertainty leads to higher risks, which can incentivize shorter life-times.

Furthermore, higher discount rates lead to rising optimal life-times for lower uncertainty levels. An explanation might be higher discounting of possible benefit losses. Moreover, higher certain change rates lead to decreasing optimal life-times for higher uncertainty levels. A higher change rate causes a rise in the variance of the exogenous conditions, and the risk of higher uncertainty might exceed profits from getting more information.

Conclusions

Ongoing work will expand and substantiate the comparative statics, its interpretation, and possibly alternative model formulations. Specifically, optimal technical design with respect to the value function of the optimal stopping problem will be derived. Afterwards, optimal technical design will be included in the stated comparative statics analysis: Will there be a change in comparative statics, and if yes, what are possible explanations and interpretations? In addition, comparative statics results for optimal technical design will be derived as well.

References

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