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THE ROLE OF STORAGE AND HEDGING IN RISK-AVERSE ELECTRICITY MARKETS EQUILIBRIUM

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Overview

We analyse the role of storage in multi-period risk-averse energy market equilibria. In particular, we consider two types of market agents, namely electricity producers with storage facilities and electricity consumers, whose objective is profit maximisation. Each agent is price-taking and optimises simultaneously under endogenous prices. Apart from the electricity spot market, we consider a concurrent futures market where the agents can trade futures contracts to hedge their risk. In a risk-neutral world, it is well known that the optimal production/consumption decision of the agents in a market equilibrium is equivalent to the solution of the cost-optimal social planner. However, in our case of risk-averse agents, the equivalence no longer holds in general. In such an incomplete market setting, we investigate how the risk trading and storage affect decision-making of the agents. The main focus of the work is to analyse with an analytically tractable model under which conditions large-scale storage owners can influence electricity spot and futures prices in electricity markets, and how futures price formation can be explicitly expressed by the cost-of-carry of this storage.

Methods

We consider in a base case hydropower storage, where the producers can store energy in water reservoirs and the stochastic exogenous variable is the nature inflow. This approach is general enough to cover also other storage types in principle (e.g. electric batteries). To keep the model analytically and numerically tractable, we use a multi-stage scenario tree, where uncertainty unfolds over time and market clearing happens in the tree nodes. We assume each agent optimises using the dynamic Conditional Value-at-Risk as risk measurement, and the agents can have different levels of risk-aversion represented by corresponding risk sets. The market equilibrium is then given by the combined optimisation problems of all agents along with the market clearing conditions of the spot and futures market in each node of the scenario tree. We derive a solution from the optimality conditions of the convex problems of the agents, which describes the dependence of storage cost the availability on spot and futures prices. We also conduct numerical experiments to verify the analytical findings and compare the risk-averse competitive equilibrium (including or excluding risk trading) with the social planer' solution.

Results

Our main analytical result is the construction of difference between futures and spot prices (the so-called basis) as a function of storage cost and storage availability. It captures two states of the market, contango and backwardation, which is related to the conventional theory of storage and hedging pressure. Because we derive price results, we can also evaluate the profitability of the producer and consumer agents in dependence on the option to own a storage and the parameters of the storage devices. Numerically, we analyse under what conditions contango or backwardation can happen, and investigate how the level of risk-aversion changes the state of the market. It is also shown futures trading as a hedging tool can reduce the downside risk by eliminating low-profit scenarios.

Conclusions

The analytically solvable model provides insights in how storage and risk trading can influence the electricity markets under the condition that agents are risk-averse. In this regard, we can also provide decision support for regulatory issues for upcoming market designs on electricity markets that have a large-scale deployment of storage

and for ensuring that electricity prices can be kept at relatively low levels. Correspondingly, we can investigate price impacts in case sufficient hedging possibilities are available for both producers and consumers. While in this work we assume the market is incomplete, the problem formulation paths the way to investigate potential extension on the current derivative market the equilibrium market solutions is able to converge to a complete market and to the social welfare maximisation solution.

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