ON SENSITIVITIES IN A FUTURE GLOBAL HYDROGEN MARKET

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Overview

Hydrogen is frequently attributed a cornerstone position in the transformation to a sustainable future (IEA 2019; 2022). While the exact role of hydrogen and its derivatives is still subject to debate, several countries have decided upon dedicated strategies to include hydrogen as an energy carrier and or feedstock (IEA 2021).

Traditional fossil fuel importers, such as Germany, have further put a particular focus on importing significant volumes of the expected demand (BMWi 2020; BMWK 2023). However, technological novelty, as well as limited project experience make these strategies rather a statement of political ambition than an adequate forecast of future developments.

Numerical modeling studies investigating the issue frequently employ a version of either implicit or explicit perfect competition models, such as cost-minimizing energy (system) models. However, as known from other fossil fuel sectors, significant risk, and high asset specificity in combination with capital intensity and illiquid or non-existing spot markets imply a significant chance for oligopolistic market structures.

In this study, we investigate the role of hydrogen imports and exports with a simplified model on a global scale and for a wide range of techno-economic parameter assumptions. In particular, we consider varying cost data for infrastructures in renewable energy procurement, storage, conversion, and transportation, as well as varying degrees of competition in the form of conjectural variations.

Methods

This work builds upon a techno-economic model of oligopolistic trade tailored around the value chain of future global hydrogen trade (Barner 2024). Model features include the procurement of renewable energy, as well as electrolytic production of hydrogen. Where desirable for representative players, hydrogen may be liquefied or converted to ammonia. If plausible, storage infrastructures and transport options via ship and pipeline can be realized. Figure 1 depicts a structural overview of the model features.

The design follows a mixed complementarity model structure, where representative players optimize individual profits while anticipating the optimal reactions of all other players. Depending upon parameter specification, the resulting Nash-Equilibrium may either be perfectly competitive or follow a Nash-Cournot game. In addition, conjectural variations can be considered.

The model is solved via reformulation to a convex optimization problem with optimality conditions equivalent to the original complementarity problem.

We analyze the model outcomes for a variety of parameter assumptions evenly distributed around a reference case.

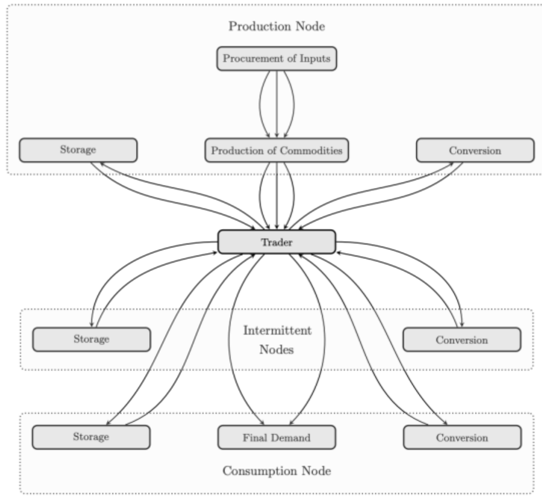

Figure 1: Overview of Model Structure
Source: (Barner 2024)

Results

Preliminary results indicate, that market equilibria depend to a high extent on the underlying model assumptions. While we find robustness in some assumptions, e.g. concerning the limited competitiveness of liquefied hydrogen, this does generally not hold. Overall, equilibria are sensitive to transport cost assumptions for ammonia and gaseous hydrogen, as well as to conversion and storage costs. The extent to which this holds is however dependent upon local characteristics, such as regional renewable potentials and different physical options for trade routes.

An overall trend that can be observed is, assuming competitive domestic supply, exporters see a twofold narrative to not oppose strategic behavior in international trade. Similar to fossil fuel exporting regions, withholding quantities in export reduces prices in domestic markets, as it keeps more of the comparably cheap local resources available for domestic supply, while allowing for an increase in profits. However, allowing for imperfect competition in exports reduces the sparsity in supply structures generally observed under perfectly competitive market outcomes.

Conclusions

The pathway of integrating hydrogen into the energy system of the future remains connected to significant uncertainties.

First project realizations in the upcoming years will give us a better understanding of how reliable assumptions in the energy-economic literature about future technology costs are, and what their effects on international hydrogen trade will be. In the interim, this study aims to provide some intuition for the sensitivities of future hydrogen trade with respect to underlying cost data.

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