Macroeconomic Implications of Energy Price Shocks in a Hydrogen Economy

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Overview

The global economy has faced three major macroeconomic crises induced by energy price shocks since 1945: the oil crises of 1973-74 and 1979-80, and the 2023 natural gas price spike following Russia's invasion of Ukraine. These events had significant economic impacts, particularly in Europe and Germany, where industrial sectors rely heavily on affordable energy. While it is well-established that energy price volatility affects economies dependent on affordable energy, the implications of such shocks in an all-renewable energy world remain unexplored.

While domestic renewable energy generation capacities, such as solar PV and wind turbines, have the potential to reduce dependencies on energy imports, future plans for a hydrogen economy in Germany remain exposed to global hydrogen price volatility due to a reliance on hydrogen imports. With 60% of hydrogen demand expected to be met through imports (BMWK, 2022), the country remains vulnerable to fluctuations in global hydrogen prices, posing challenges to energy security and economic stability. This study investigates the macroeconomic effects of hydrogen import price shocks in Germany using a stock-flow consistent (SFC) macroeconmic model. By transforming today's input-output structure into a hydrogen-based economy and embedding it into an empirically founded SFC model, we are able to simulate potential economic impacts and provide insights into managing price volatility in a future hydrogen economy.

Methods

The study builds on the stock-flow consistent (SFC) modeling principles established by Godley and Lavoie (2007), which ensure that all financial and real flows in the economy are accounted for in a coherent and comprehensive framework. Our model extends the approach of Berg et al. (2015) to incorporate the unique characteristics of a hydrogen-driven industrial energy system within the German economy. The SFC framework is particularly well-suited for analyzing energy transitions due to its ability to integrate sectoral interdependencies, financial flows, and macroeconomic feedback mechanisms.

Data Integration and Parametrization

The model is parametrized using detailed German economic data to ensure empirical relevance:

1. Input-Output Data: Sectoral input-output tables, disaggregated into 72 standard sectors and an additional sector for hydrogen electrolysis, form the backbone of the model. These tables capture the interdependencies between industries and the role of hydrogen in industrial processes.
2. Energy Usage Data: Comprehensive data on energy consumption by sector allows for accurate modeling of the transition from fossil fuels to hydrogen and renewables.
3. Macroeconomic Indicators: National accounts data, including GDP, employment, and trade balance statistics, ensure alignment with observed economic trends.

Hydrogen Economy Transformation

The model simulates the transition from the current fossil fuel-based industry to a hydrogen-based system. This transformation involves domestic hydrogen production through electrolysis powered by renewable energy sources alongside the import of hydrogen to supplement domestic supply and meet overall demand. The transition is modeled dynamically, with input-output coefficients shifting gradually from fossil-based technologies to hydrogen-based alternatives over time. This approach ensures that the model captures the evolution of sectoral dependencies and technological adoption realistically. Additionally, the integration of renewable energy sources into the hydrogen production process is explicitly incorporated, enabling the model to account for feedback effects on energy dependency, production costs, and overall economic dynamics.

Shock Simulations

The model introduces hydrogen price volatility as exogenous shocks, reflecting potential fluctuations in global hydrogen markets. These shocks are simulated under various scenarios, including high dependency on hydrogen imports, increased domestic production capacity, and different levels of renewable energy integration within the hydrogen production process. The macroeconomic impacts of these shocks are analyzed across key indicators such as gross domestic product (GDP), employment levels, trade balances, and sectoral outputs. Particular attention is given to industries heavily reliant on hydrogen, allowing for a nuanced understanding of the vulnerabilities and opportunities presented by such price fluctuations.

Open-Source Implementation
The model is developed using sfctools, an open-source framework created by the German Aerospace Center (DLR). This platform facilitates the rapid development and testing of stock-flow consistent (SFC) models, ensuring both flexibility and robustness. To enhance transparency and reproducibility, the model, along with its associated datasets, will be made publicly available. This open-access approach enables other researchers to replicate the findings, validate the methodology, or extend the model to explore additional scenarios and hypotheses.

Results

Preliminary simulations reveal that hydrogen price shocks could have significant macroeconomic repercussions:

1. **Sectoral Disruption**: Energy-intensive industries, particularly chemicals and heavy manufacturing, experience the most pronounced impacts, with cascading effects on supply chains.
2. **Economic Volatility**: GDP contraction is more severe under scenarios with high import dependency compared to those with increased domestic hydrogen production.
3. **Trade Dynamics**: High hydrogen import prices exacerbate trade deficits, particularly in scenarios with limited diversification of supply sources.
4. **Policy Sensitivity**: Mitigation measures, such as strategic reserves and domestic production incentives, reduce the magnitude of shocks but require upfront investment.

Conclusions

Our findings underscore the critical need for robust policy frameworks to manage hydrogen price volatility in a renewable energy economy. Germany’s reliance on hydrogen imports introduces significant economic risks, which can be mitigated through:

- Diversification of import sources to reduce dependency on volatile global markets.
- Expansion of domestic hydrogen production capacity to enhance energy security.
- Strategic investments in storage and infrastructure to buffer against price fluctuations.

This study highlights the importance of proactive planning in transitioning to a hydrogen economy. By addressing vulnerabilities and fostering resilience, Germany can achieve its decarbonization goals while maintaining economic stability.

References

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