HWWI Hamburgisches WeltWirtschaftsInstitut

Driving Technological Change: Modeling the Hydrogen Market in a CGE Framework

Stephen Sacht
Hamburgisches WeltWirtschaftsInstitut (HWWI)

15th Input-Output Workshop • Osnabrück • University of Applied Sciences

hyBit Hydrogen for Bremen's industrial Transformation

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

NRL Norddeutsches RealLabor

Gefördert durch: Bundesministerium für Wirtschaft und Klimaschutz aufgrund eines Beschlusses des Deutschen Bundestages

Project HyBit

HWWI Hamburgisches WeltWirtschaftsInstitut

Partner:

- Duration: September 2022 – February 2026.
- Funding: 30.2 million € (BMBF).
- 20 partners from science, business sector and politics.

hyBit
Hydrogen for Bremen's industrial transformation

Aims:

- Data collection & development of comprehensive monitoring infrastructure for H_2 hubs.
- Socio-technical & economic analyses & model development.
- Identification of transformation barriers in H_2 hubs.
- Development of cross-sectoral measures for de-fossilization and resilient design of the industrial port of Bremen.
- Establishment of a North German network of H_2 hubs.

Project NRL

HWWI Hamburgisches WeltWirtschaftsInstitut

Partner

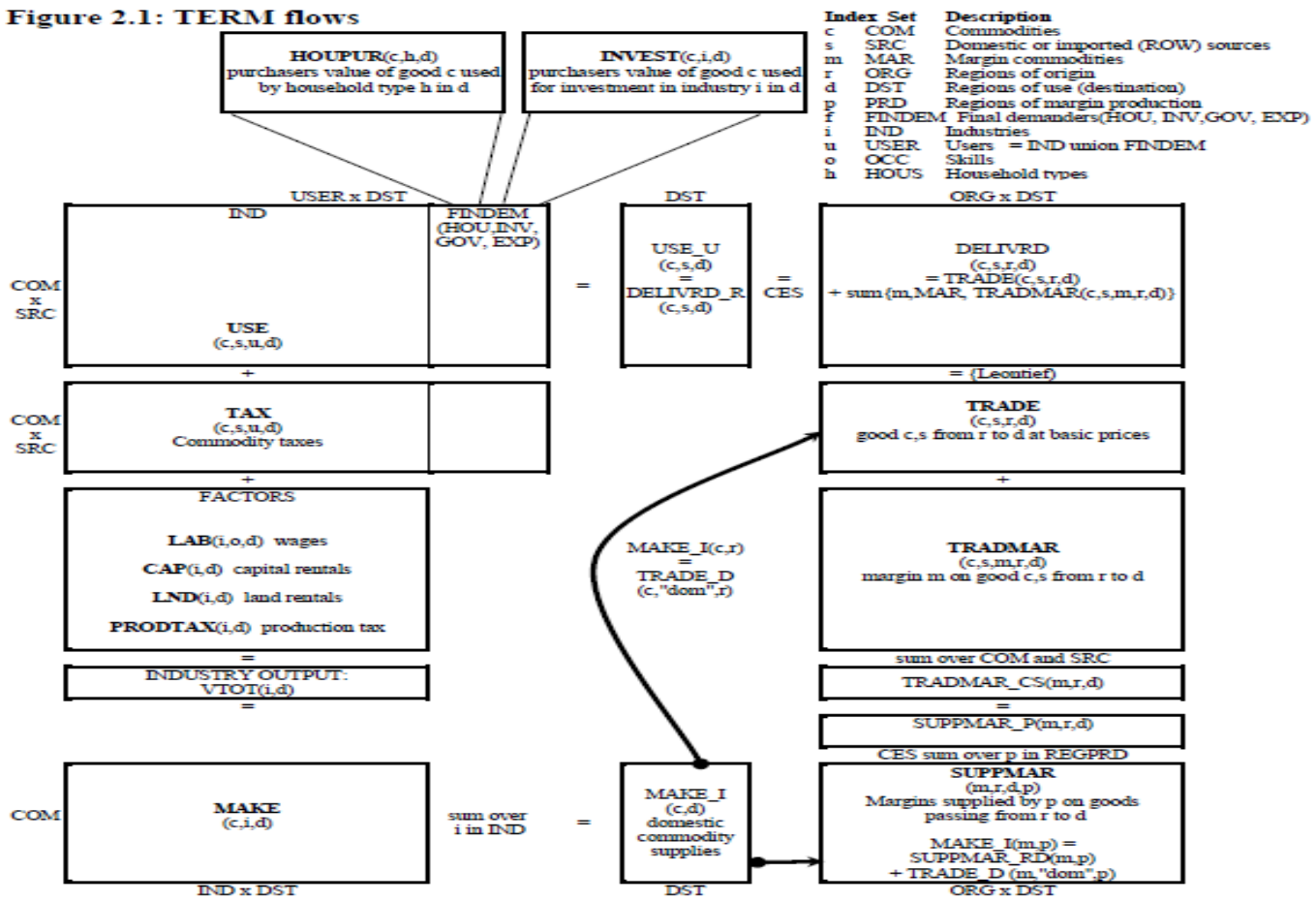
- Duration: April 2021 – March 2026.
- Funding: 55 million € (BMWK).
- 50 partners from science, business sector and politics.

Aims

- Showcasing new paths for a comprehensive transformation of the energy system.
- Accelerating industrial transformation in the North using innovative technologies for rapid expansion of sector coupling (particularly supporting the swift market uptake of H_2).
- Implementation of energy transition with over 20 reference plants, progressively decarbonizing industry, heat supply, and the mobility sector.
- Research encompasses economic, societal, regulatory, and technological aspects of the energy transition.

The CGE Methodology

- CGE (computational general equilibrium) models are used for simulating the effects of changes in external factors (so-called shocks) on the economy.
- A CGE model consists of a (high-dimensional) mathematical system of equations which includes the model variables, as well as the associated data:
  - I-O-matrices depict the economic transactions (flows) between agents (companies, households, government) in prices & quantities.
  - There is also information about elasticities & behavioural rules.



Source: Horridge (2011).

Model Outline: EuroTERM

- The HWWI uses a version of the TERM (The Enormous Regional Model) as a CGE model.
- Since this focus is on developments in Europe, the model is called *EuroTERM.*
- Accurate solutions of the economic model are calculated using the software GEMPACK

  (General Equilibrium Modelling Software).
- The developer and contractual partner is the Center of Policy Studies (CoPS) at Victoria University Melbourne.
- CoPS considers Eurostat & GTAP data, among others, for all five northern German federal states and processes these for a fee.
- Impacts in different regions can be considered through changes in taxes, technology, tariffs and other exogenous variables.
- Each region is viewed as its own economy.

Model Outline: EuroTERM

- Multi-regional: EuroTERM depicts multiple NUTS-2 regions within Germany among others.
  - Each industry selects inputs of labour, capital and materials to minimize the costs of producing its output.
  - Industries within the model alter investment in line with movements in rates of return on capital.
  - The levels of output are chosen to satisfy demands where the latter reflect prices and incomes.
  - Households follow a linear expenditure system of demand subject to a budget constraint.

- Components (*sets*) of the HyBit & NRL versions of the EuroTERM are
  - 35 goods produced in 35 industries
  - NUTS-2 regions for Northern Germany (HH, B, MV, SH, 4xNI) plus
  - aggregations for the rest of Germany, Europe, USA and China

An Illustrative Scenario: The Story

- We try to depict an energy switch based on the data we were given.
- The switch is about substituting out natural gas used in production by hydrogen.
- *Neutral Energy Switch:* in a perfect world, hydrogen is no more expensive than natural gas.
  - What the impact of the energy switch on the economic variables will be?
- *Expensive Energy Switch:* however, in reality we observe right now a price differential regarding natural gas versus hydrogen.
- So, we do not live in a perfect world: hydrogen is actually about 3 times as expensive as natural gas per unit of energy.
  - Does this mean that there are now small economic losses across (Northern) Germany to be observed?

An Illustrative Scenario: Step 1 - Expansion

- We consider 4 different regions (HB=DE50,HH=DE60,MV=DE80,SH=DEF0) and focus on 3 industries (chemical, steel & copper).
- In reality we find low %-changes in electrolysis capacities through investment.
- In our illustrative scenario here, we update the initial database via exogeneous supply and demand shocks to the hydrogen industry, i.e.,
  - an increase in capital usage (uniformely for all regions: +100%),
  - a positive primary-factor-augmenting tech change (+30%) &
  - a positive intermediate tech change (a switch of 10%; see below).
- By doing so we imagine a hydrogen industry going from very small to small levels.

An Illustrative Scenario:
Step 2a – *Neutral* Energy Switch

- The goal is to substitute natural gas out in favor of hydrogen used in production in all of the 3 industries.
- Hence, we reduce natural gas requirements by 10%. At the same time hydrogen requirements go up by the same amount.
- First, we assume that hydrogen is about the same price as natural gas.
- Then we repeat the same excercise once more.
- However, now it is assumed that hydrogen is more expensive initially given a price differential with a factor 3.12.

An Illustrative Scenario:
Step 3 – *Interpretation of the Results*

DE60	Hydrogen		Chemical		Steel		Copper	
Output	22.82	19.45	-5.77	3.71	-0.45	0.27	-0.14	0.13
Price	-2.23	-2.23	0.69	-0.42	0.05	0.03	0.02	-0.02

Expensive Energy Switch | Neutral Energy Switch

- %-change in industry production is positive for hydrogen due to positive supply shocks. Accordingly, the %-change in the price level is negative.
- The differences are virtually non-existing.
  - Hydrogen sector does not suffer from the price differential but the other 3 industries do.
- For a *Neutral* Energy Switch, the effects on output and price will be positive (negative) for all 3 industries.
  - All industries using hydrogen benefit from the price drop.

An Illustrative Scenario:
Step 3 – *Interpretation of the Results*

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Expensive Energy Switch | Neutral Energy Switch

- For an *Expensive* Energy Switch, the initial price differential causes a negative (positive) change in industry output (the price level) for all of the 3 industries.
  - The positive effect of a price drop in hydrogen is outweighed by the existing initial price differential.
- Since the chemical industry uses more natural gas compared to steel (copper), the effect on output is more pronounced in this particular industry.

An Illustrative Scenario:
Step 3 – *Interpretation of the Results*

	DE50		DE60		DE80		DEF0	
Real GDP	+	+	-	+	-	+	-	+
Employment	+	+	-	+	-	+	-	+

Expensive Energy Switch | Neutral Energy Switch

- The overall effect on real GDP and employment is positive for a *Neutral* Energy switch and vice versa.
- The reason is given by the increase in the capital stock in all industries besides hydrogen.
- However, the quantitative effects are very small due to the nature of the shock.
- DE50 is an exception as hydrogen in the initial industry composition is relatively large. Hence, the impact by the technology shock has a stronger effect compared to other regions.

Conclusion: Main Results & The Road Ahead

- In macroeconomic terms regarding real GDP and employment, we are slightly worse off if hydrogen is more expensive than fossil fuels.
- This is the price we pay for trying to mitigate CO_2 emissions.
- But when the price of hydrogen becomes competitive, we are not worse off and at the same time, we are reducing CO_2 emissions.
- This is just an illustrative scenario imbedded in a multi-stage shock approach.
- Regarding hyBit & NRL we target a more sophisticated goal where we account for
  - the expansion of electrolysis & renewables capacities (*investment phase*),
  - the use of hydrogen & renewables as a substitute in industry (*operational phase*),
  - the productivity gain from technical advancements (*operational phase*).
- See also the HWWI publication in **Wirtschaftsdienst 2024, Nr. 6** (in German only), about potencial future H_2-price development in Northern Germany.

Thank you very much for your attention!

HWWI Hamburgisches WeltWirtschaftsInstitut

Hamburgisches WeltWirtschaftsInstitut (HWWI) gGmbH

PD Dr. Stephen Sacht

Deputy Head of the Method Center

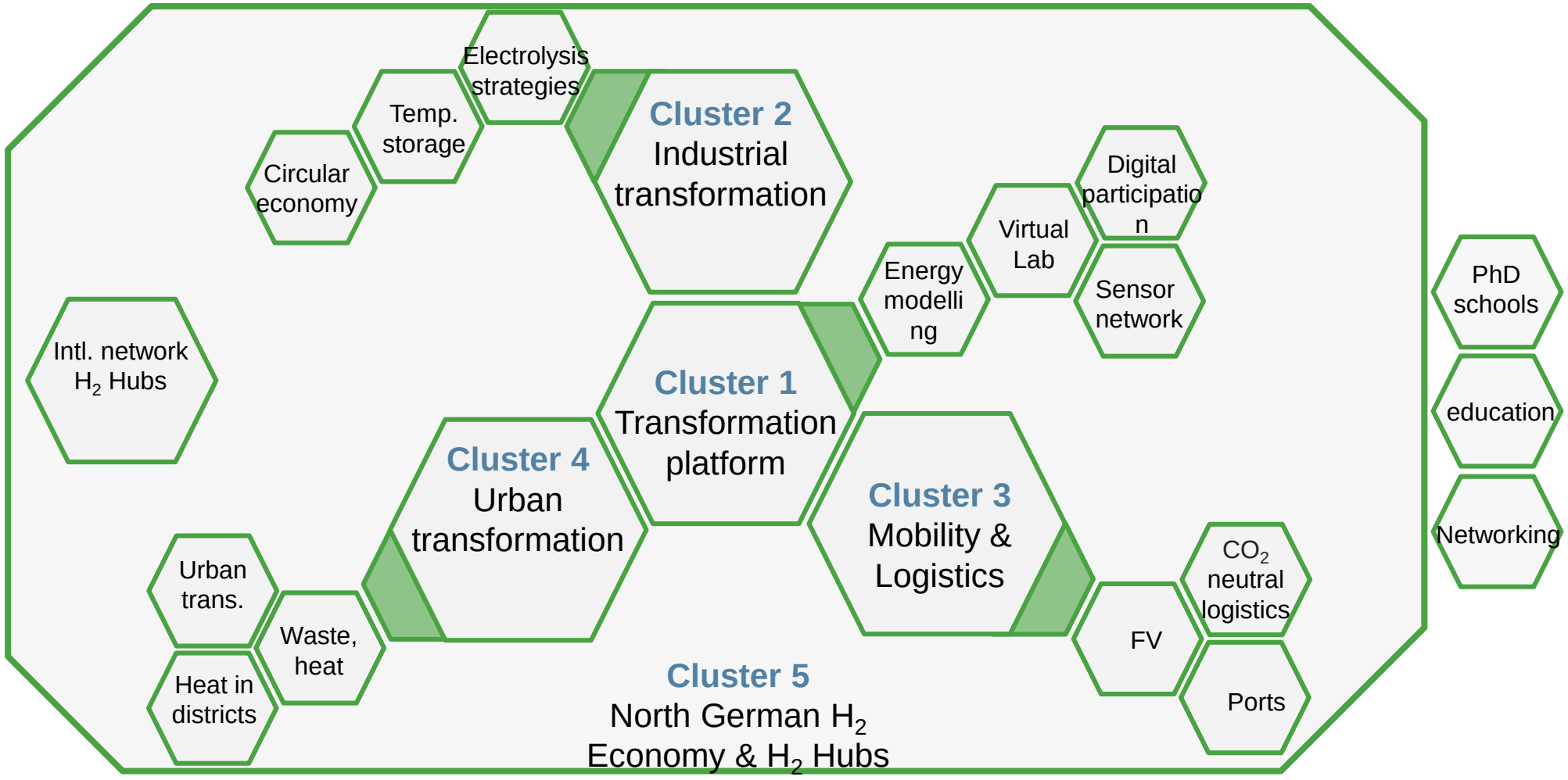
Mönkedamm 9 I 20457 Hamburg

Tel.: +49 40 340576-0 I info@hwwi.org

www.hwwi.org

Appendix

Project HyBit: Overview



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Wirtschaftsforschung seit über 100 Jahren
in der Welthandelsstadt Hamburg