

README File on Data and Codes for "Estimating Willingness-to-Pay for Emerging Technologies: A Study of Hydrogen Demand in the Ammonia Industry

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Initial Instructions

Before executing the provided Python script, please update file paths to match the folder on your computer and make sure the files:

1. [WB_AM_2026_Replicate.ipynb](#) and
 2. [Data_WB_AM_Feb_2026_Replicate.xlsx](#)
- are located there.

Data Availability Statement (DAS)

This replication package combines publicly available data and proprietary sources.

- **Ammonia capacity, demand, and production.** Ammonia production capacity (*Capacity_mmt*), production (*Yh_mmt*), exports, imports, and demand (all in million tonnes of ammonia, mmt) are sourced from GlobalData via the Refinitiv platform (*proprietary; institutional subscription required*).
- **Ammonia prices.** Country-level ammonia prices (*Price_y_USDt*) are compiled from GlobalData and FAO commodity statistics, accessed via the Refinitiv platform (*proprietary; institutional subscription required*).
- **Natural gas prices.** Country-level industrial natural gas price (p_{NGh}) data are sourced from the IEA Energy Prices database. Values for 2024–2026 are estimated and projected using Refinitiv country–exchange or corresponding hub futures price data (*IEA and Refinitiv data are proprietary; subscription access required*).
- **Carbon prices (EU ETS).** EU carbon allowance prices (p_{CO2EU}) are taken from the European Union Emissions Trading System, with recent years supplemented from the ICAP Allowance Price Explorer and projections for 2026 from Refinitiv.
- **Macroeconomic data.**

- GDP per capita (GDP_pop) and GDP growth (GDP_growth_imf): IMF *World Economic Outlook* (2025 release).
- Population (country and world, $PopH$ and $PopW$): IMF 2025 database.
- Arable land area ($Land_mha$) in hectors and million ha ($Land$): World Bank, *World Development Indicators* (indicator AG.LND.ARBL.HA).

For the macroeconomic indicators, values for 2024–2026 are constructed using the average annual growth rate over the last two available years.

Redistribution of proprietary data (IEA, Refinitiv, GlobalData) is not authorized under the public version of this package. Users must obtain the relevant subscriptions and licenses to access and reuse the underlying source data.

Other Core Variables

Key constructed variables include:

- $K_util = \frac{Production}{Capacity}$
- $Q_{hh} = \min(Production, Demand)$
- $Q_{wh} = \max(Demand - Production, 0)$
- $Trade_Percent = \frac{Demand - Production}{Demand}$
- $\gamma_t = global_efficiency(Year) = \gamma_{2000} \cdot improve^{year-2000}$ ($\gamma_{2000}=42$ for developing and 36 for developed countries)
- $\gamma_t^h = eff_h = if(Capacity_mt(Year) < Capacity_mt(Year - 1),$

$$\frac{\gamma_{t-1},}{\frac{Capacity(Year) - Capacity(Year-1)}{Capacity(Year)}} \cdot \gamma_t + \frac{Capacity(Year-1)}{Capacity(Year)} \cdot \gamma_{t-1}$$
- $peHeff = pNGh \cdot eff_h$
- $peWeff$ - average of peHeff for countries in other regions (see python script)
- $pCO2EU_eff = pCO2EU \cdot eff_h$
- $Cap_Limit = \max(Demand, Capacity)$
- $Land_pop = GDP_pop \cdot Land$
- $Lerner_AM = \frac{Price_y_USDt - peHeff}{Price_y_USDt}$
- $dPop, dQ, dK$ represent absolute change versus previous year, i.e. $v_t - v_{t-1}$

Global efficiency adjustments account for technological progress:

- Developing regions: efficiency improves from 42 (2000) to 30 (2025)
- Developed regions: efficiency improves from 36 (2000) to 30 (2025)

Software used

- Python 3.11.9
- VStudio Code
- Excel, MS Office 16

Furthermore, python script includes (at the begining) a list of required packages, including:

Package	Purpose
pandas	Data manipulation and analysis
numpy	Numerical computing
matplotlib, seaborn, plotly	Data visualization
statsmodels	Econometric modeling, time series (ARDL, VAR, unit roots)
scikit-learn	Machine learning (Ridge, clustering, preprocessing)
dowhy	Causal inference
sympy	Symbolic mathematics
linearmodels	Panel data econometrics
arch	Advanced time series unit roots
ruptures	Change point detection

Script and Notebook Structure

The primary workflow is contained in:

- `WB_AM.2026_Replicate.ipynb`

The notebook follows a strict sequential structure:

1. Data loading and cleaning
2. Construction of efficiency-adjusted prices
3. Data analysis and descriptive plotting
4. Stationarity testing (KPSS)
5. Country-level regressions (OLS, Ridge, ECM)
6. Extraction of structural parameters

7. Region-level regressions (OLS, FGLS)
8. Hydrogen willingness-to-pay (WTP) computation
9. Simulation and plotting

Naming: Script section and subsection names indicate the outputs with respect to their presentation in the text, e.g. Table N and Figure N.

Important: The order of sections in the notebook matters and must be preserved. Parameter estimation steps generate objects that are used in subsequent sections. Running sections out of order may lead to missing parameter values or inconsistent simulation outputs.

For theoretical derivations, model assumptions, structural identification strategy, and interpretation of the hydrogen WTP function, users should consult the associated paper. The paper provides the complete analytical framework underlying the empirical implementation.

Recommended Run Order

From the project root:

1. `Open WB_AM_2026_Replicate.ipynb`
2. Run all cells sequentially from top to bottom
3. Do not skip sections

Reproducibility Notes

Consistent with the Data Availability Statement, some inputs and generated data files cannot be redistributed publicly, but they may be included in the package for reproducibility verification.

- IEA and Refinitiv data require valid subscription access.
- Forecast values for 2025–2026 are preliminary.
- Structural parameter recovery depends on regression selection logic (OLS vs Ridge vs ECM).
- Simulation results are sensitive to the parameters as presented in "Sensitivity analysis".

Contact: For clarification regarding proprietary data access or structural modeling choices, please refer to the corresponding author *svetlana.ikonnikova@tum.de*.