Incorporating Hydrogen as an Energy Source: An extension of GDyn-E model

Ken Itakura*

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*Graduate School of Economics, Nagoya City University

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Outline

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3. GDyn-E Model Extension and Scenarios
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Introduction

Background

- Hydrogen emits no CO_2 when used as an energy source
- Hydrogen can be a better option for some industries where electrification is hard to adopt;
  e.g. aviation and maritime transport, iron and steel, chemicals
- Japanese government have set a target of carbon neutrality by 2050 and designed the Basic Hydrogen Strategy
- On February 2024, the government approved a new legislation to provide subsidies to suppliers of hydrogen and ammonia

Aim of this study

- to explore potential impact of subsidies on hydrogen supply (production, imports) in Japan,
- by incorporating hydrogen as a new energy subproduct into the GTAP-E database and the GDyn-E model.
- Policy scenario experiments hydrogen supply subsidy in Japan for 2030-2044

GTAP-E Data Extension for Hydrogen

Data Extension

- GTAP-E database
  - GTAP database v.10a (Aguiar et al., 2019), 2014 benchmark
  - 30 counties/regions and 16 industries
- Hydrogen Production
  - World hydrogen production (Brown, 2016), used as control total
  - Distribute the total to countries
- Hydrogen Trade
  - U.N. COMTRADE provides the information on hydrogen trade
  - Period coverage 2000–2022
- Divide chemical industry in GTAP-E database
  - Apply MSplitCom (Horridge, 2008)
  - Chemical -> Hydrogen + (other) Chemical
  - For use structure from the 2015 input-output table of Japan, basic sector classification of compressed gas and liquefied gas

World Hydrogen Production by Source, 2014

Source	Industry	Quantity (million metric tons)
Captive		**55.39**
	Ammonia	31.81
	Oil Refining	10.08
	Methanol	13.5
Byproduct		**40.93**
	Coke/Iron	15.63
	Oil Refining	17.08
	Ethylene	6.38
	Chloro-Alkali	1.84
Merchant	-	**6.16**
Total	-	**102.48**

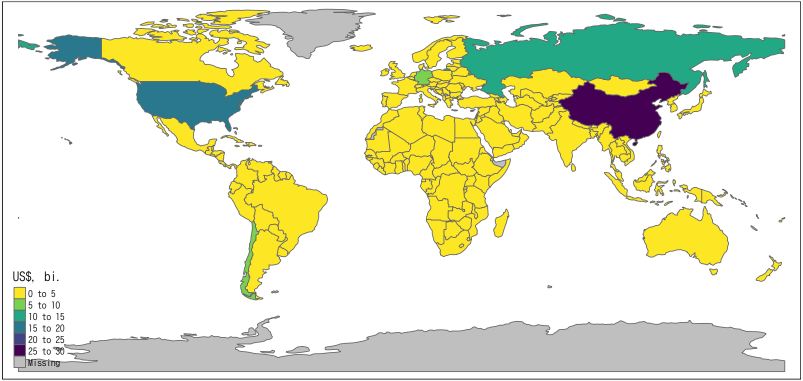
Source: Brown (2016)

Distribution Rates

We collect indicators for **industry** $\times$ **country** to compute the distribution rate by source from following institutions;
Hydrogen Analysis Resource Center; U.S. National Minerals Information Center; U.N. Industrial Commodity Production Statistics

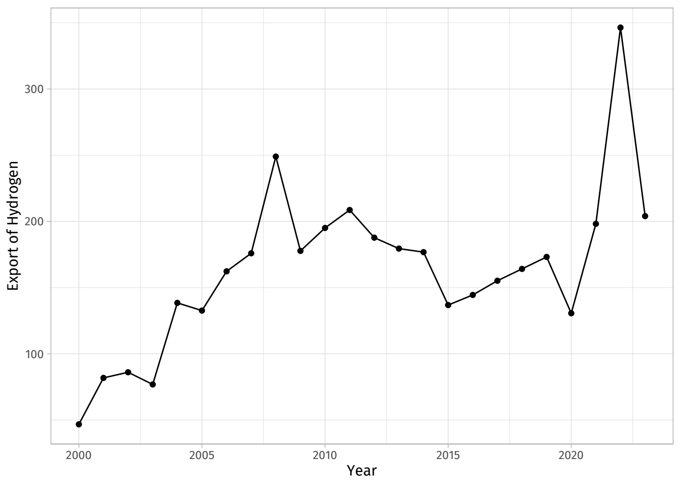
Source	Industry	Indicator
Captive, Byproduct	Ammonia	Ammonia production
	Oil Refining	Hydrogen production capacity
	Methanol	Methanol production
	Coke/Iron	Coke-oven gas
	Ethylene	Ethylene production capacity
	Chloro–Alkali	Caustic soda
Merchant	-	Hydrogen production capacity

Hydrogen Production in 2014 (US$, billion)



Note: World hydrogen production accounts for 0.07% in world total production.
Source: Author

World Hydrogen Trade, 2000–2022 (US$, million)



Note: Hydrogen trade accounts for 0.001% in total goods trade in the world.
Top 3 exporters: Belgium, Netherlands, Canada
Source: U.N. COMTRADE

Country / Region

No.	Country/Region	No.	Country/Region
1	UK	16	Indonesia
2	Germany	17	Malaysia
3	France	18	China
4	OtherEU	19	Korea
5	OtherEurope	20	Japan
6	EastEurope	21	CentralAsia
7	SouthAfrica	22	DvlpingAsia
8	OtherAfria	23	EmrgingAsia
9	Qatar	24	Oceania
10	UAE	25	Canada
11	SaudiArabia	26	USA
12	Gulf	27	Mexico
13	MiddleEast	28	Brazil
14	Russia	29	ChilArgentin
15	India	30	OtherAmerica

Source: Aguiar et al. (2019)

Sectors

No.	Sector	No.	Sector
1	AGR	9	RbbPlastics
2	Coal	10	Minerals
3	Oil	11	IronSteel
4	Gas	12	Automobiles
5	Oil_pcts	13	OthMnfcs
6	Electricity	14	Construction
7	Hydrogen	15	Transports
8	Chemicals	16	OthServices

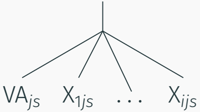
Source: Aguiar et al. (2019)

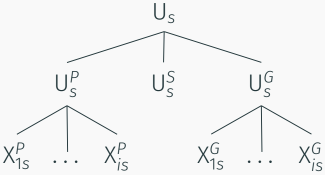
GDyn-E Model Extension and Scenarios

Model Structure of Production and Consumption

GTAP-E and GDyn-E model (Burniaux and Truong, 2002; McDougall and Golub, 2007; Corong et al., 2017; Golub, 2013)

$$O_{js} = \begin{cases} D_{js} & (dom.supply) \\ Q_{jrs} & (exports) \end{cases}$$





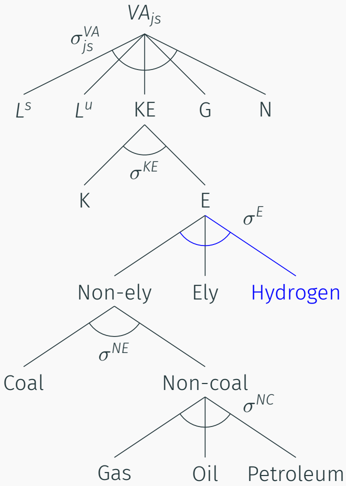
Production:

- O_{js} output of industry j in country s
- VA_{js} value-added composite used by j in s
- X_{ijs} composite good i used by j in s

Consumption:

- U_s per capita utility from aggregate household expenditure in s
- U_s^P, U_s^S, U_s^G sub-utility from private consumption, savings, gov't expenditure
- X_{is}^P composite good i for consumption
- X_{is}^G composite good i for gov't expenditure

Hydrogen as an Energy Subproduct in GTAP-E / GDyn-E



industry j in country s

Baseline / Experimental Scenario

Baseline is a hypothetical future state of the global economy for 2014–2050, constructed with the following data inputs:

- World Population Prospects, (U.N., 2022)
  Total and working age population
- Long-Term Baseline Projections (OECD, 2023)
  Real GDP
- Global Carbon Budget 2023 (Global Carbon Project, 2023)
  CO2 emission for 2014–2022

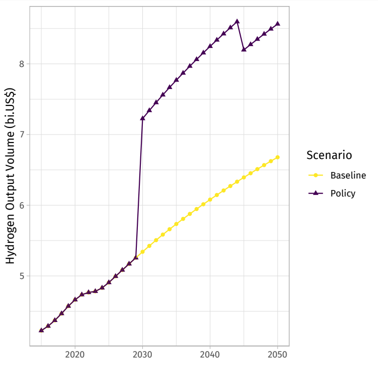
Experimental Scenario

- Japan provides subsidies on hydrogen supply (production and import) for 2030–2044
- For simplicity, no tax (cap & trade) on CO2 emissions, no tech change in this experiment

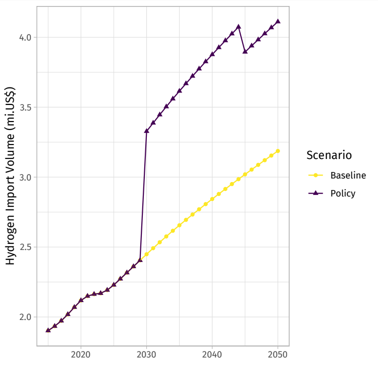
Results

Impact on Hydrogen Production and Import in Japan

(a) Hydrogen Production Volume (bi.US$)



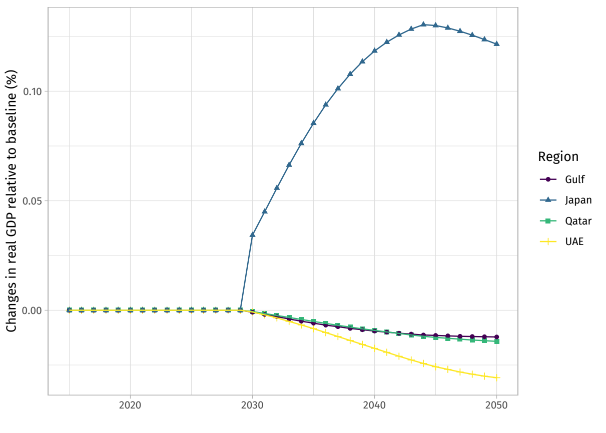
(b) Hydrogen Import Volume (mi.US$)



Note: Subsidies on hydrogen production and import for 2030-2044.

Impact on real GDP (%)

Change in real GDP relative to the baseline (%)
for Japan and three countries mostly affected in terms of %



Source: Author's simulation result

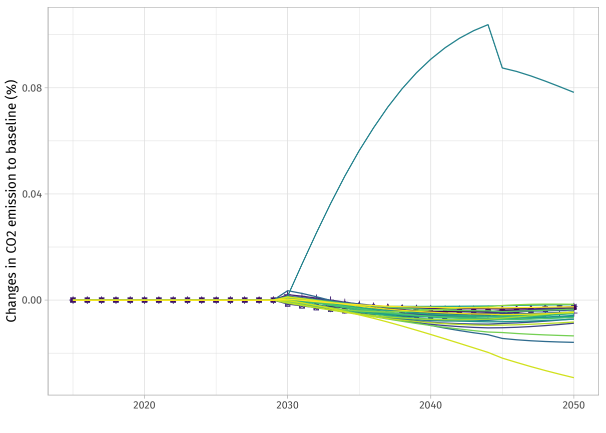
Impact on Real GDP in 2050

	US$, mi.	%		US$, mi.	%
UK	-140	-0.003	Indonesia	-71	-0.002
Germany	-127	-0.002	Malaysia	-35	-0.003
France	-111	-0.002	China	-388	-0.001
OtherEU	-839	-0.005	Korea	-9	-0.0003
OtherEurope	-58	-0.003	Japan	6622	0.122
EastEurope	-199	-0.006	CentralAsia	-16	-0.001
SouthAfrica	-25	-0.005	DvlpingAsia	-50	-0.001
OtherAfria	-220	-0.002	EmrgingAsia	-55	-0.002
Qatar	-75	-0.014	Oceania	-74	-0.002
UAE	-510	-0.031	Canada	-39	-0.001
SaudiArabia	-66	-0.003	USA	-438	-0.001
Gulf	-78	-0.012	Mexico	-100	-0.004
MiddleEast	-39	-0.001	Brazil	-86	-0.002
Russia	-3	-0.0001	ChilArgentin	-38	-0.002
India	-307	-0.002	OtherAmerica	-137	-0.002
			World	2285	0.001

Source: Author’s simulation result

Impact on CO2 emissions (%)

Change in CO2 emissions relative to the baseline (%)
Decrease globally except for Japan



Source: Author's simulation result

Sectoral Results for Japan in 2050

Sector	CO2 emissions (%)	Use of Hydrogen (%)
AGR	-0.17	30.55
Coal	0.23	0.23
Oil	0.03	0.03
Gas	0.05	0.05
Oil_pcts	0.09	0.09
Electricity	0.08	0.08
Hydrogen	3.29	3.29
Chemicals	0.29	31.16
RbbPlastics	0.17	31.00
Minerals	0.15	30.97
IronSteel	0.05	30.84
Automobiles	0.13	30.95
OthMnfcs	-0.12	30.62
Construction	-0.12	30.62
Transports	0.11	30.92
OthServices	0.08	30.89

Note: % change relative to baseline.
Source: Author's simulation result

Summary

This study attempts to

- to explore potential impact of subsidies on hydrogen supply (production, imports) in Japan for 2030-2044,
- by incorporating hydrogen as a new energy subproduct into the GTAP-E database and the GDyn-E model.

Results show that

- hydrogen supply rises over baseline, and the positive impact remains after 2045
- real GDP in Japan increases while others slightly decrease
- CO2 emissions in Japan become larger as compared baseline

Way forward

- Technological change in hydrogen production:
  reflect the rapid development in hydrogen industry,
  introduce sub-nest under hydrogen for “green,” “blue,” etc.
- Tax on CO2 emissions, cap and trade
- Target the recent data on hydrogen production and trade in baseline
- Improve the hydrogen data construction process

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Thank you for your attention.