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National Institute for Environmental Studies, Japan

3EID Project by the National Institute for Environmental Studies, Japan

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Outline of this presentation

- History of environmental input-output database in Japan
- Environmental input-output database by NIES (3EID)
- System boundary extension of 3EID
  - A global link input-output model (GLIO)
  - Consumption-based emission of Japan
  - Embodied intensity with global system boundary
  - Validity of domestic technology assumption (DTA)
  - Uncertainty of embodied global intensity
- Summary and future works

Wide use of environmental IOA in Japan

- An input-output analysis has been widely used in the filed of environmental systems study in Japan since the 1970s.
  - Life cycle assessment (e.g. Moriguchi et al., 1993, *Ind. Environ.*)
  - Material flow analysis (e.g. Murakami et al., 2004, *Mater. Trans*)
  - Waste management (e.g. Nakamura et al. 2002, *JIE*)
- Compilation of the various types of input-output tables with detail sector classification
  - National IOTs with more than 400 sectors
  - Intraregional and interregional IOTs
  - Linked IOT which links 3 IOTs of different year with a real price
- Continuous provision of publically available environmental database corresponding to IOTs

Open environmental database

- The first database
  - In 1971: The Input–Output Table for Environmental Pollution Analysis on the Kanto coastal region (1968 Table, SOx)
- The heyday: the 1990s
  - Keio University
  - Architectural Institute of Japan
  - Building Research Institute of the former Ministry of Construction
  - Central Research Institute of Electric Power Industry (CRIEPI)
  - National Institute for Environmental Studies (NIES)
  - The former National Research Institute for Metals (now NIMS)
  - Toshiba Corporation
- Update and WIO: after the 2000s
  - Keio Univ., CRIEPI and NIES
  - Waste Input–Output Table by Nakamura

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What is 3EID?

Environmental input-output database by NIES

The first

Kondo & Moriguchi (1997), *Carbon Dioxide Emission Intensity Based on the Input–Output Analysis*

Update as 3EID

Nansai, Moriguchi & Tohno (2002), *Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID)*

Extension to the web edition

http://www-cger.nies.go.jp/cger-j/db/enterprise/3eid/3eid_index_j.html

3EID for 2005 IOT: Energy and six GHGs for 400 sectors (based on the domestic supply chain only)

Importance of global supply chain

- New calculating and reporting standards considering supply chain emissions
  - ex: Scope 3 of the GHG Protocol Initiative, TR 14069 (organizational carbon footprint) in ISO14064-1.
  - In the U.S. Walmart has announced its intention to reduce the GHG emissions from its entire global supply chain by 20 million tonnes by the end of 2015.
- Conflicted concerns on GHG emission control between industrialized and industrializing countries
  - An opinion of an industrializing country: My emission is not mine, it should belong to the user of my product (an industrialized country)!
- Increased resource nationalism
  - Essential resources for green tech. eccentrically distributed throughout the world

System boundary extension of 3EID

Requirements

Applicable to LCI data on Japanese products with global system boundary (embodied global emission intensity)

Inclusion of many Japanese products (i.e. 400 sectors for Japan)

Inclusion of many countries (for various env. impact and material issues)

Lower burden on time and cost for data compilation (easy to update)

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Global link input-output model

Economic Systems Research, 2009, Vol. 21(3), September, pp. 267–290 Routledge Taylor & Francis Group

IMPROVING THE COMPLETENESS OF PRODUCT CARBON FOOTPRINTS USING A GLOBAL LINK INPUT–OUTPUT MODEL: THE CASE OF JAPAN

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Development of a global link input-output (GLIO) model, which enables an environmental input-output model to define global system boundary with lower burdens on time and cost for data compilation.

Nansai et al. (2009), Improving the completeness of product carbon footprints using a global link input-output model: the case of Japan, *Econ. Syst. Res.*, 21(3), 267-290.

Sir Richard Stone Prize (the best paper in *Econ. Syst. Res.* in 2009 and 2010) awarded by the International Input-Output Association (IIOA)

Environmental Science & Technology POLICY ANALYSIS pubs.acs.org/est

Characterization of Economic Requirements for a "Carbon-Debt-Free Country"

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Application of GLIO model to calculation of the consumption-based GHG emissions in Japan in 2005 and its structural analysis

Nansai et al. (2012) Characterization of economic requirements for a "carbon-debt-free country", *Environ. Sci. Technol*, 46(1), 155-163.

Footprint analysis with GLIO

	Japan Domestic commodity $(j_1=1\cdots406)$	Japan Imports to FD $(j_2=1\cdots406)$	Overseas Country $(q=1\cdots230)$	Final demand	Total
Japan Domestic commodity $(i_1=1\cdots406)$	$\mathbf{X}^{\mathrm{I}}$	$\mathbf{0}$	$\mathbf{X}^{\mathrm{III}}$	$\mathbf{f}^{JD}$	$\mathbf{x}^{JD}$
Japan Imports to FD $(i_2=1\cdots406)$	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{0}$	$\mathbf{f}^{JI}$	$\mathbf{x}^{JI}$
Overseas Country $(p=1\cdots230)$	$\sum_{k=1}^{l}\tilde{\mathbf{Y}}^{\mathrm{I}(k)}$	$\sum_{k=1}^{l}\tilde{\mathbf{Y}}^{\mathrm{II}(k)}$	$\sum_{k=1}^{l}\tilde{\mathbf{Y}}^{\mathrm{III}(k)}$	$\tilde{\mathbf{f}}^{G}$	$\tilde{\mathbf{x}}^{G}$

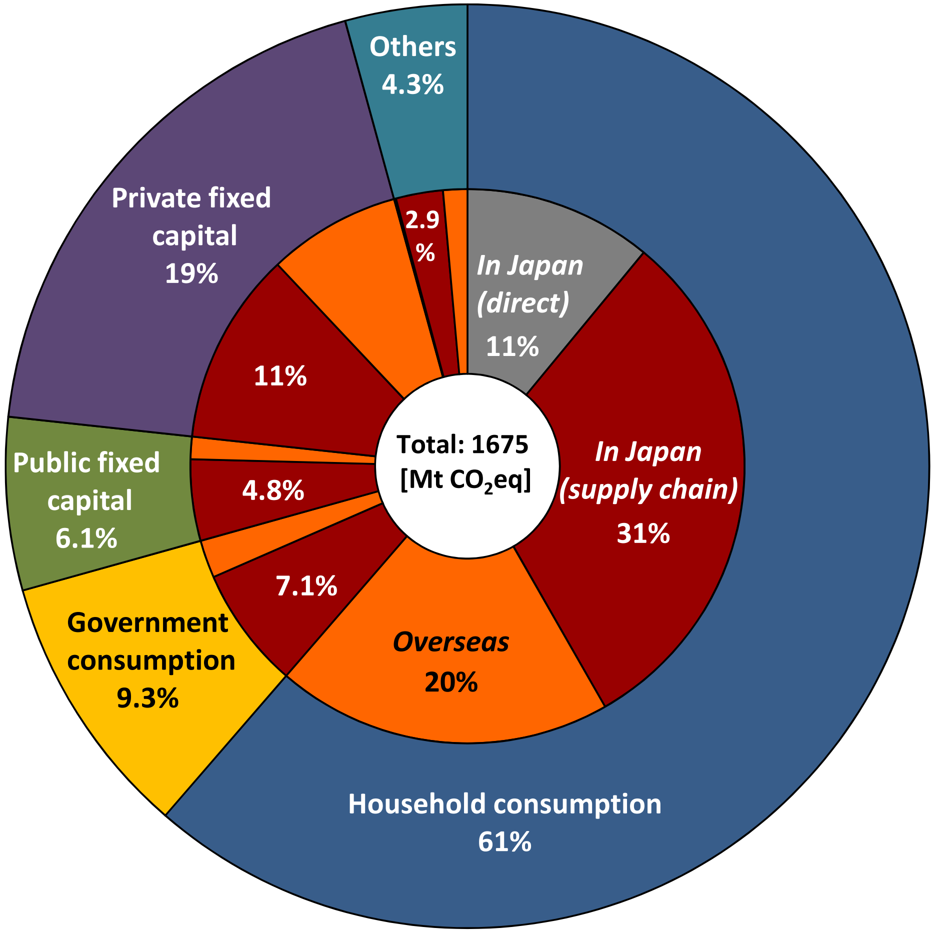
Japanese domestic commodity flow

Overseas footprint basis flow

Commodity type *k*
(*k*=1, …112)

- Vegetable (*k*=1)
- Crude oil (*k*=2)
- ⋮
- Commodity (*k*=*l*)

Consumption-based emissions



Emissions outside Japan:

541 Mt CO_2eq (33%)

c.f.) 560 Mt CO_2eq in 2001 (Hertwich and Peters, 2009)

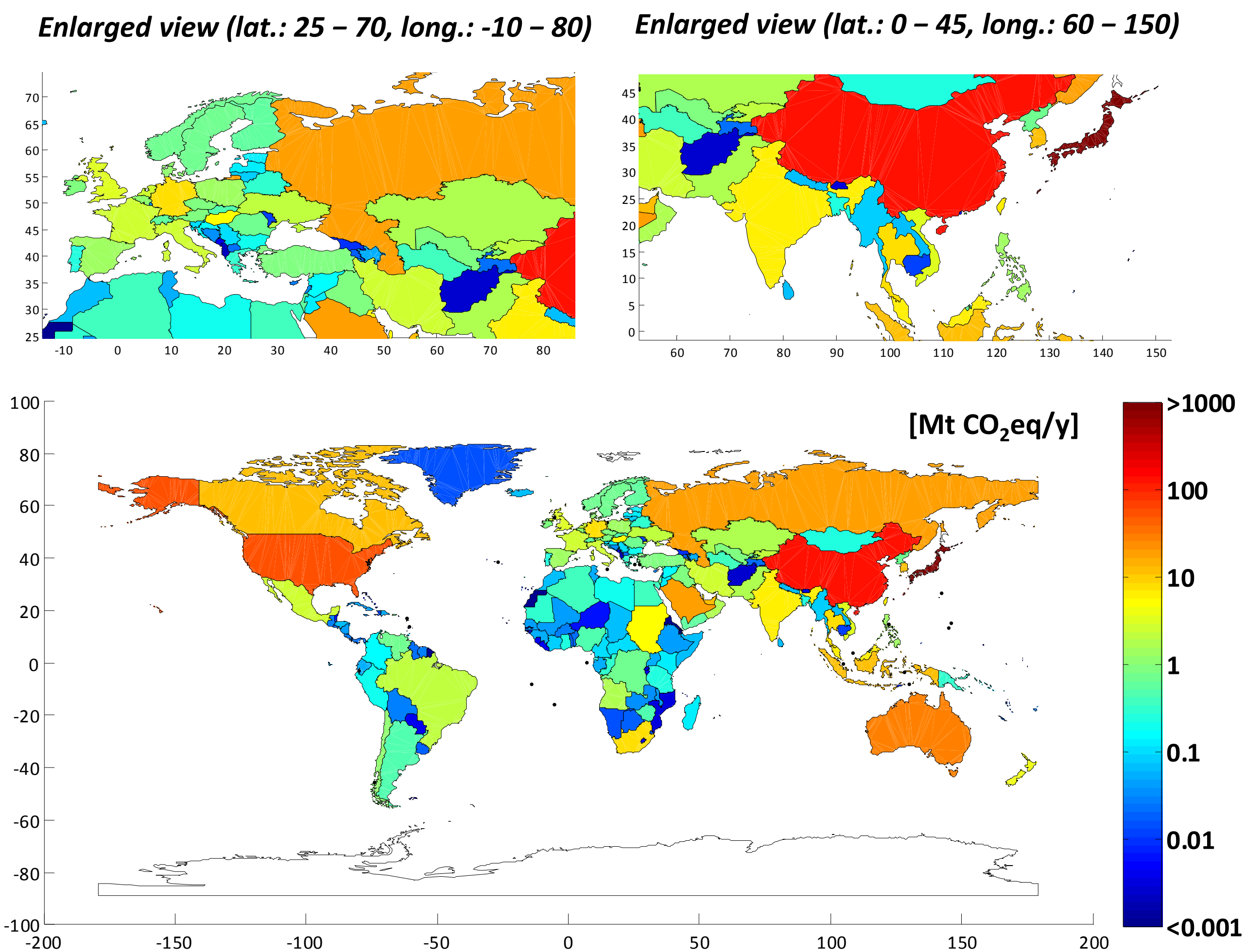
468 Mt CO_2 in 2004 (Davis and Caldeira, 2010)

Difference between the production-based and consumption-based emissions of Japan:

- 256 Mt CO_2eq

Figure: Contributions of five final demand categories to Japanese consumption-based GHG emissions in 2005 and composition of each category's emission locations: in Japan (direct), in Japan (supply chain) or overseas

Global distribution of Japan's GHG



Top 10 counties of the overseas emissions by Japan (541 $MtCO_2eq$)

1. **China: 30%**
2. **USA: 12%**
3. **Australia: 6.5%**
4. **Saudi Arabia: 4.8%**
5. **Russia: 4.2%**
6. **U.A.E.: 2.7%**
7. **Canada: 2.6%**
8. **South Korea: 2.5%**
9. **Thailand: 1.8%**
10. **Germany: 1.7%**

Figure: Global distribution of Japanese consumption-based GHG emissions in 2005.

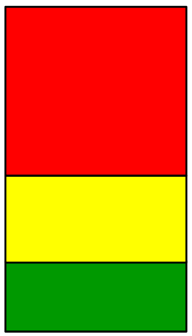
LCI data with global system boundary

Formulation of LCI data with global system boundary

$$\begin{pmatrix} \mathbf{e}^{JD} \\ 0 \\ 0 \end{pmatrix}^{trans} = \begin{pmatrix} \mathbf{d}^{JD} \\ 0 \\ \mathbf{i}^{G} \end{pmatrix}^{trans} \left\{ \mathbf{I} - \begin{pmatrix} \mathbf{A}_{11} & 0 & \tilde{\mathbf{A}}_{13} \\ 0 & 0 & 0 \\ \sum_{k=1}^{l} \tilde{\mathbf{A}}_{31}^{(k)} & \sum_{k=1}^{l} \tilde{\mathbf{A}}_{32}^{(k)} & \sum_{k=1}^{l} \tilde{\mathbf{A}}_{33}^{(k)} \end{pmatrix} \right\}^{-1} \mathrm{diag} \begin{pmatrix} \mathbf{i}^{JD} \\ 0 \\ 0 \end{pmatrix}$$

Elements of e^{JD} are embodied global GHG emission intensities of Japanese domestic products (tCO_2eq/million yen).

Ex. 100 [t-CO_2eq/M-JPY]



50: Induced emission within **foreign** supply chain

30: Induced emission within domestic supply chain

20: Direct emission of the sector

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LCI data with global system boundary

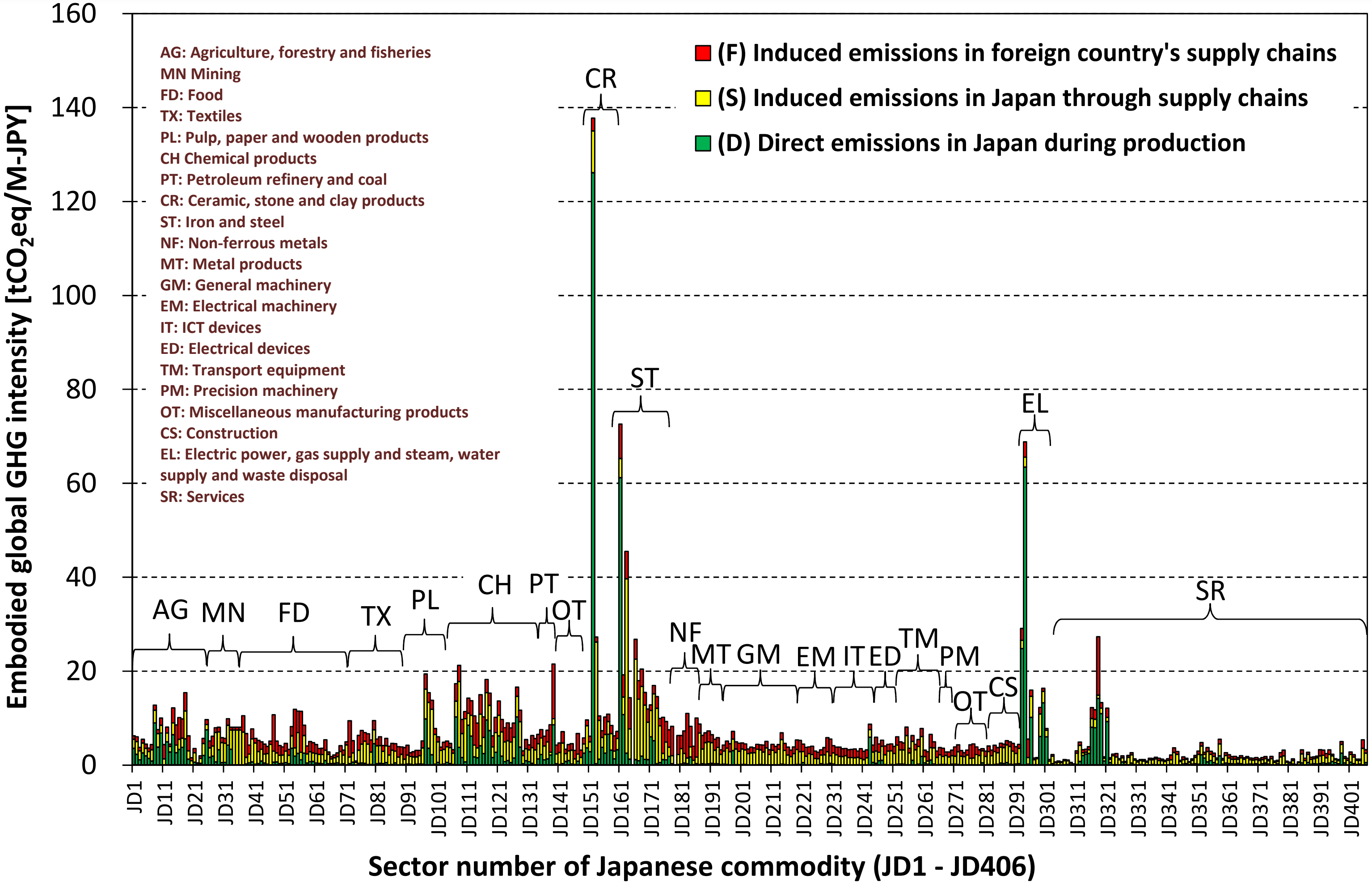

Figure: Embodied global GHG intensity of goods and services produced in Japan in 2005 and breakdown by emission category (direct emissions, induced emissions in Japan, induced emissions abroad)

LCI data with global system boundary

Table: The 10 Japanese domestic products with **the greatest embodied global GHG emission intensities** and the shares of direct emissions, induced emissions in Japan and induced emissions in foreign countries.

Rank	Sector number and name	Embodied global GHG intensity	(D) Share of direct emissions in Japan	(S) Share of induced emissions in Japan	(F) Share of induced emissions in foreign country
		[t-CO_2eq/M-JPY]	[%]	[%]	[%]
1	JD152: Cement	138	92	6	2
2	JD161: Pig iron	72.6	84	6	10
3	JD294: On-site power generation	68.8	92	3	5
4	JD163: Crude steel (converters)	45.5	6	82	13
5	JD293: Electricity	29.1	85	6	9
6	JD318: Ocean transport	27.3	52	2	46
7	JD153: Ready-mixed concrete	27.3	1	95	4
8	JD166: Hot rolled steel	26.8	4	80	16
9	JD139: Coal products	21.5	40	6	54
10	JD108: Industrial soda chemicals	21.2	18	66	16

LCI data with global system boundary

Table: The 10 Japanese domestic products with **the greatest share of induced foreign emissions** in their embodied global GHG emission intensity.

Rank	Sector number and name	Share of foreign emissions in embodied global GHG intensity [%]
1	JD183: Rolled and drawn aluminum	86
2	JD186: Other non-ferrous metal products	83
3	JD72: Feeds	82
4	JD56: Vegetable oils and meal	76
5	JD178: Other non-ferrous metals	76
6	JD175: Copper	75
7	JD38: Processed meat products	75
8	JD185: Nuclear fuels	75
9	JD47: Flour and other grain milled products	72
10	JD295: Gas supply	71

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Comparison with an embodied intensity under DTA

- Domestic technology assumption (DTA) : the emissions associated with imports are assumed to be the same as those of equivalent domestic products.
- DTA is the easiest approach to define global supply chain in an environmental input-output model, but how much of underestimate or overestimate dose an embodied intensity with DTA cause?

$$\mathbf{e}^{DTA} = \mathbf{d}\left(\mathbf{I} - \mathbf{A}\right)^{-1}$$

$$\Delta_i\left(\%\right) = \frac{\left(e_i^{DTA} - e_i^{GLIO}\right)}{e_i^{GLIO}} \times 100$$

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Comparison with an embodied intensity under DTA

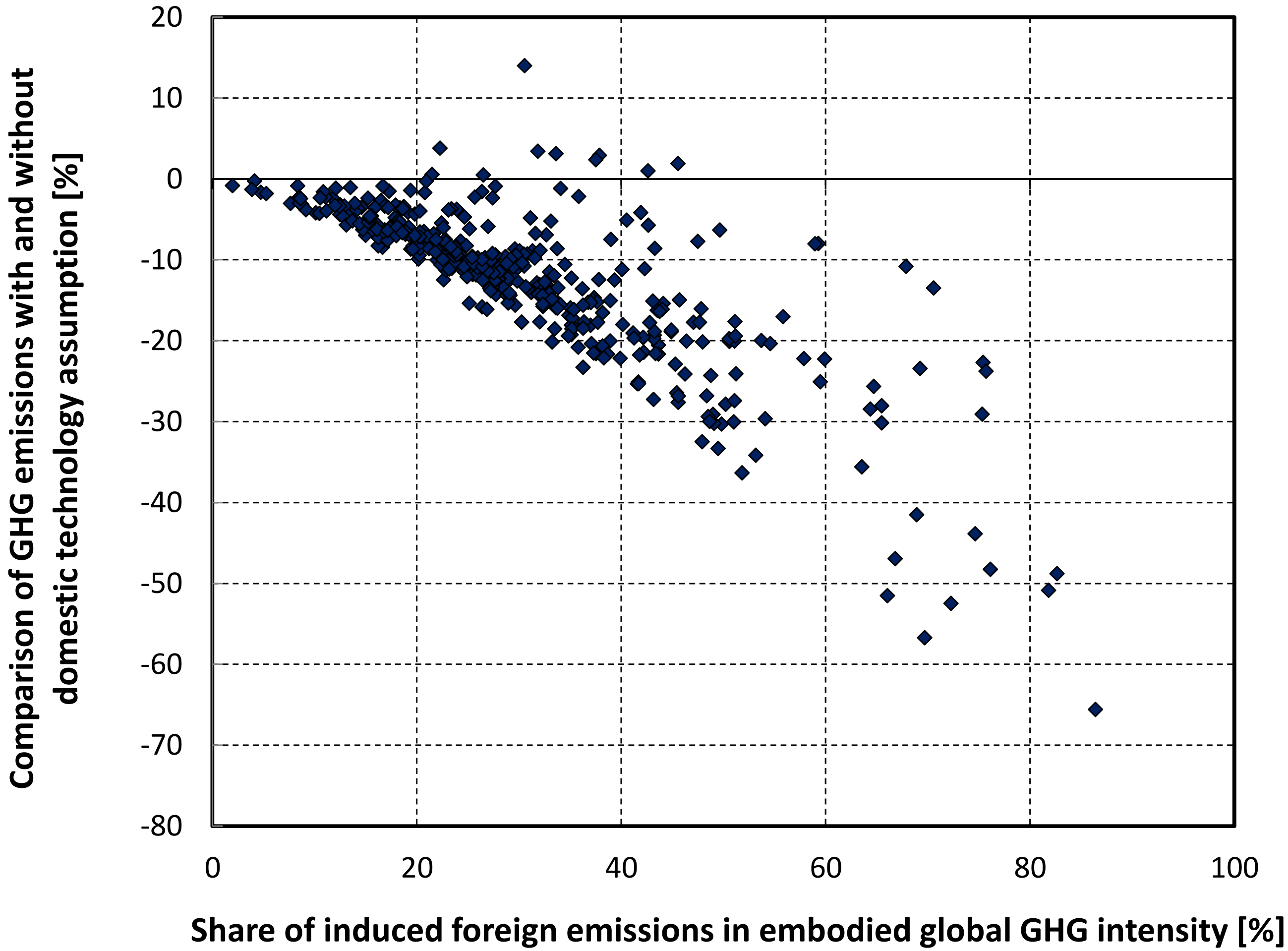

Figure: Relation between share of induced foreign emissions in embodied global GHG intensity and comparison of GHG emissions with and without domestic technology assumption

Comparison with an embodied intensity under DTA

Table: The 10 Japanese domestic products with **the greatest difference between the embodied global GHG emission** intensity by GLIO and that calculated under the domestic technology assumption.

Rank	Sector number and name	Difference of GHG emissions with use of the domestic technology assumption [%]
1	JD183: Rolled and drawn aluminum	-66
2	JD11: Seeds and seedlings	-57
3	JD47: Flour and other grain mill products	-52
4	JD90: Timber	-52
5	JD72: Feeds	-51
6	JD186: Other non-ferrous metal products	-49
7	JD56: Vegetable oils and meal	-48
8	JD277: "Tatami" (straw matting) and straw products	-47
9	JD185: Nuclear fuels	-44
10	JD54: Starch	-42

Uncertainty of an embodied global intensity

Formulation of LCI data with global system boundary

$$\begin{pmatrix} \mathbf{e}^{JD} \\ 0 \\ 0 \end{pmatrix}^{trans} = \begin{pmatrix} \mathbf{d}^{JD} \\ 0 \\ \mathbf{i}^{G} \end{pmatrix}^{trans} \left\{ \mathbf{I} - \begin{pmatrix} \mathbf{A}_{11} & 0 & \tilde{\mathbf{A}}_{13} \\ 0 & 0 & 0 \\ \sum_{k=1}^{l} \tilde{\mathbf{A}}_{31}^{(k)} & \sum_{k=1}^{l} \tilde{\mathbf{A}}_{32}^{(k)} & \sum_{k=1}^{l} \tilde{\mathbf{A}}_{33}^{(k)} \end{pmatrix} \right\}^{-1} \mathrm{diag} \begin{pmatrix} \mathbf{i}^{JD} \\ 0 \\ 0 \end{pmatrix}$$

How much is an uncertainty of e^{JD} associated with the simplified input structure of overseas countries?

⬇

Giving variation to elements of A^{13} and A^{33} with Monte Carlo Simulation, coefficients of variation of elements of e^{JD} are estimated

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Uncertainty of an embodied global intensity

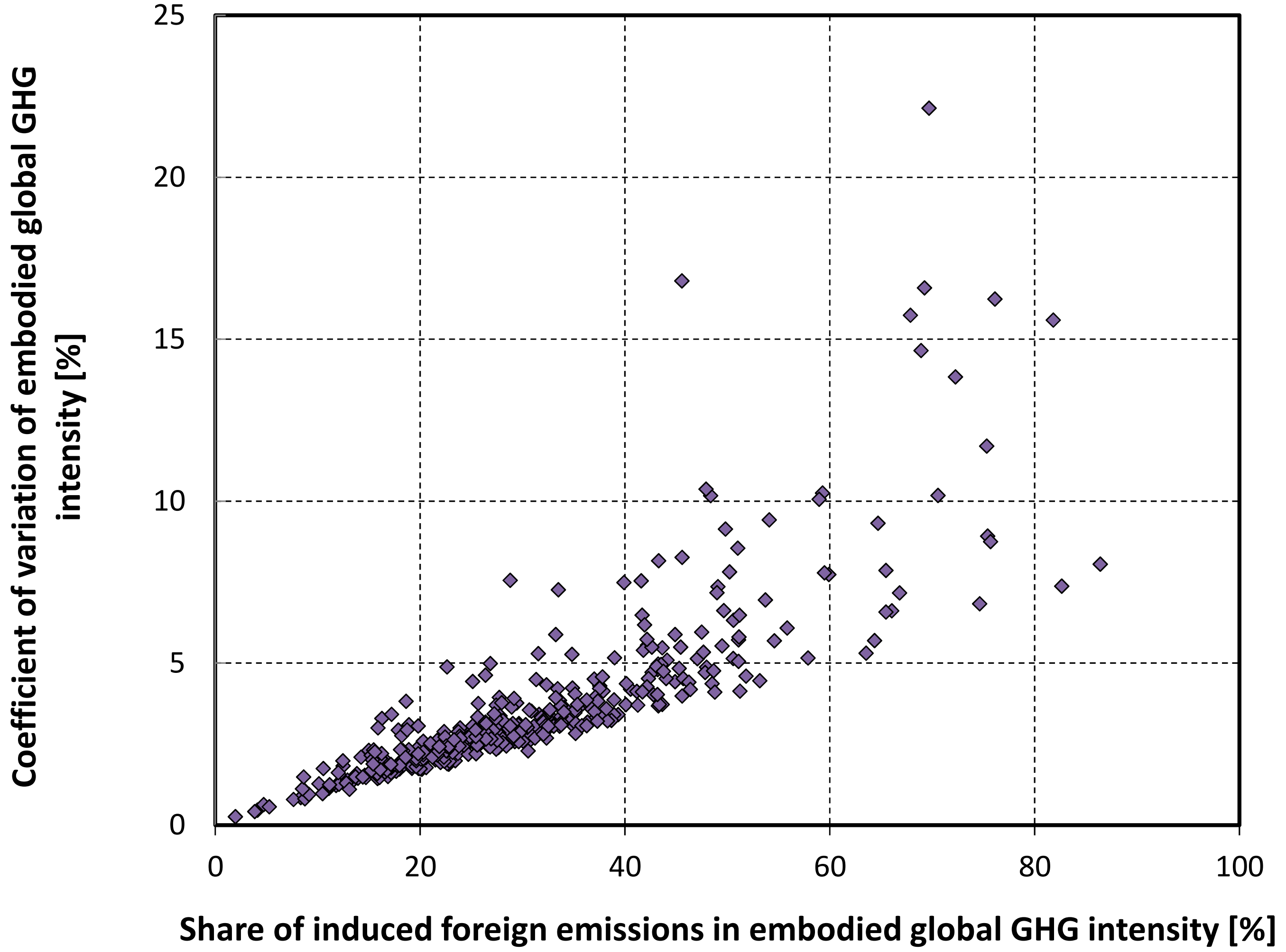

Figure: Relation between share of induced foreign emissions in embodied global GHG intensity and coefficient of variation of embodied global GHG intensity

Uncertainty of an embodied global intensity

Table: The 10 Japanese domestic products with the greatest coefficient of variation of their embodied global GHG emission intensity.

Rank	Sector number and name	Coefficient of variation of embodied global GHG intensity [%]
1	JD11: Seeds and seedlings	22.1
2	JD318: Ocean transport	16.8
3	JD262: Aircraft repair	16.6
4	JD56: Vegetable oils and meal	16.2
5	JD138: Petroleum refinery products (incl. greases)	15.7
6	JD72: Feeds	15.6
7	JD54: Starch	14.6
8	JD47: Flour and other grain mill products	13.8
9	JD38: Processed meat products	11.7
10	JD342: Image information production and distribution	10.4

Summary and future work

- Embodied global intensities for 406 Japanese products with GLIO is applicable to LCI data with global system boundary.
- The largest difference between embodied intensity with DTA and that by GLIO is - 66% for the rolled and drawn aluminum sector.
- The largest coefficient of variation of embodied global GHG intensity is 22.1 % for the seeds and seedlings sector.
- Embodied global energy and emissions (GHGs, air pollutants) intensities with GLIO will be available on the 3EID web.
- GLIO will be further applied to the international material flow analysis on natural resources.

Thank you for kind attention.

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