Factor Decomposition Analysis of Changes in CO_2 Emissions from Container Operating Companies

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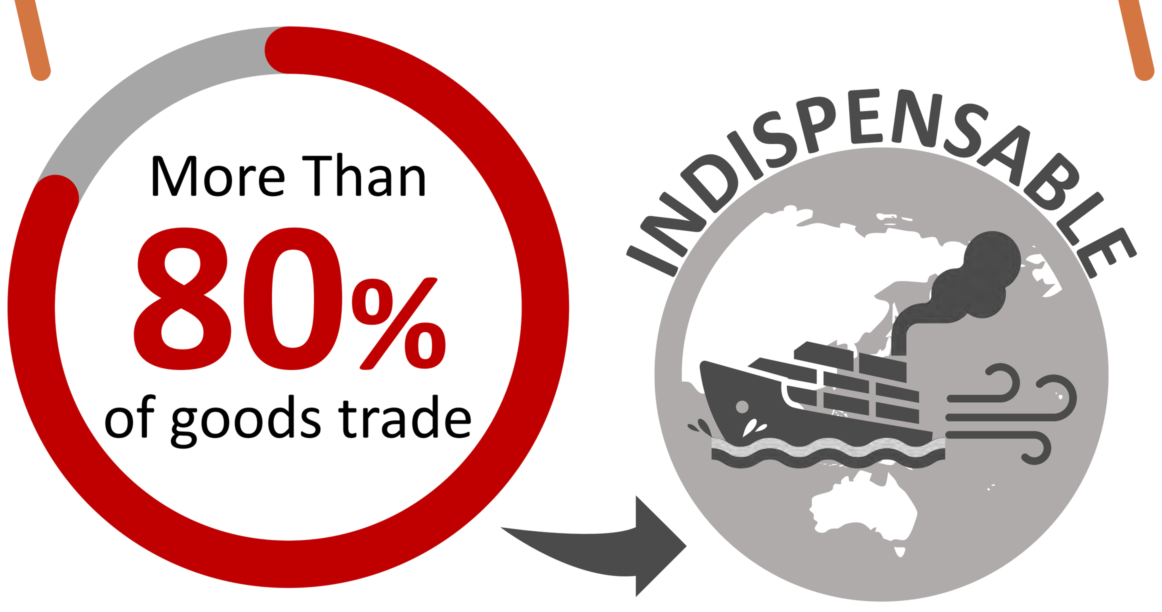
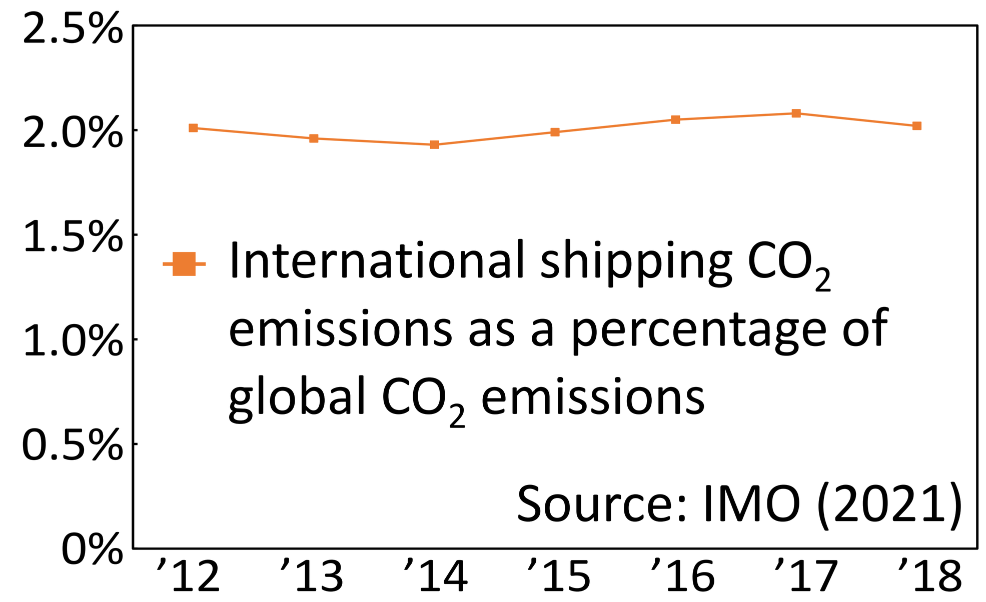
1 INTRODUCTION

1 Importance of maritime transport



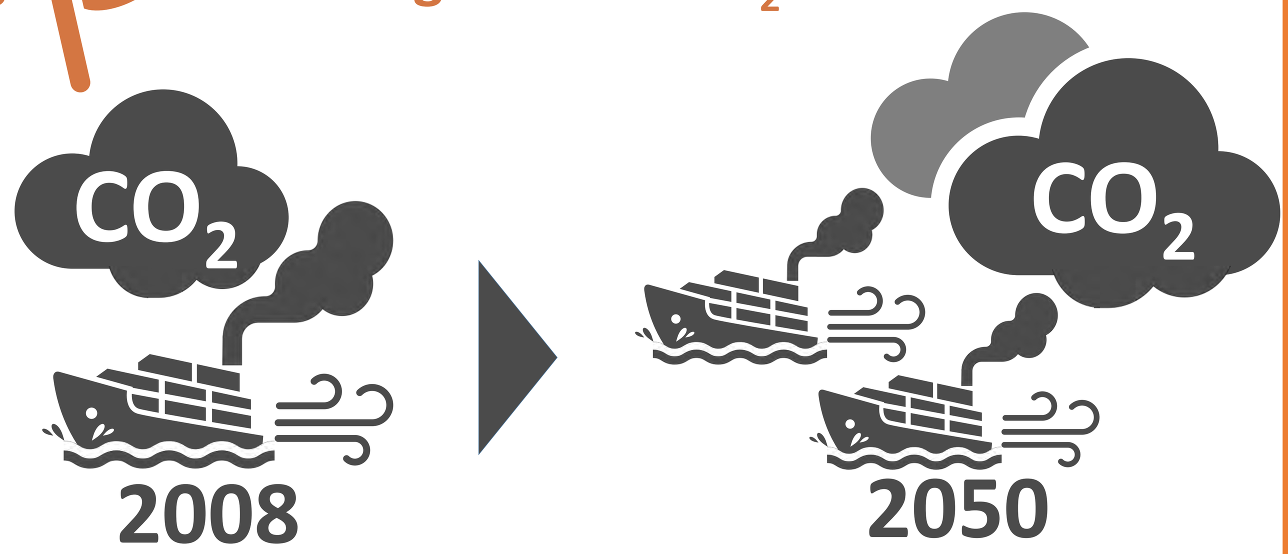
conducted through the sea; thus maritime transport is indispensable for world trade.

2 CO_2 emission share of international shipping



CO_2 emissions from international shipping accounted for 2% of the global CO_2 emissions.

3 Increasing trend of CO_2 emissions



CO_2 emissions from international shipping were predicted to increase by 130% in 2050 compared with 2008 levels (IMO, 2021).

- Reducing CO_2 emissions of container shipping is necessary because **container ships are the largest source of CO_2 of all types of ships**.
- We considered the behavior of **container ship operators**, who decide the destination and routes of ships, as key factors for policymaking, and analyzed the CO_2 emissions based on detailed operator companies.

4 Purpose of this study

1. To estimate CO_2 emissions and identify drivers of changes in CO_2 emissions. for each company.
2. To discuss policies for decarbonization based on the factors.

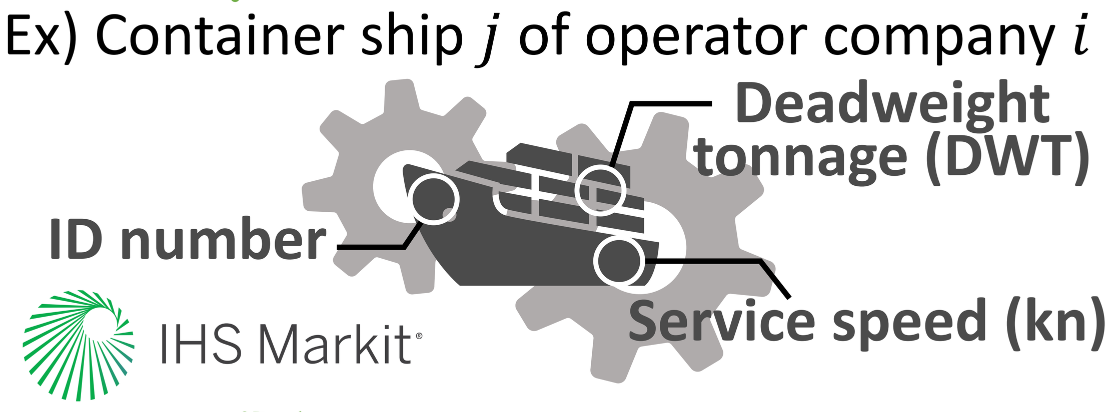
5 Contributions of this study

- We pointed out the importance of analysis from the perspective of operating companies to discuss the decarbonization policies of maritime transport.
- This research framework is able to apply to all vessels used in international shipping and has a high academic spillover effect because it leads to the decarbonization of international shipping as a whole (SDGs 13, 14).
- This study can promote decarbonization of all supply chains that use maritime transport (SDGs 9, 12, 13).

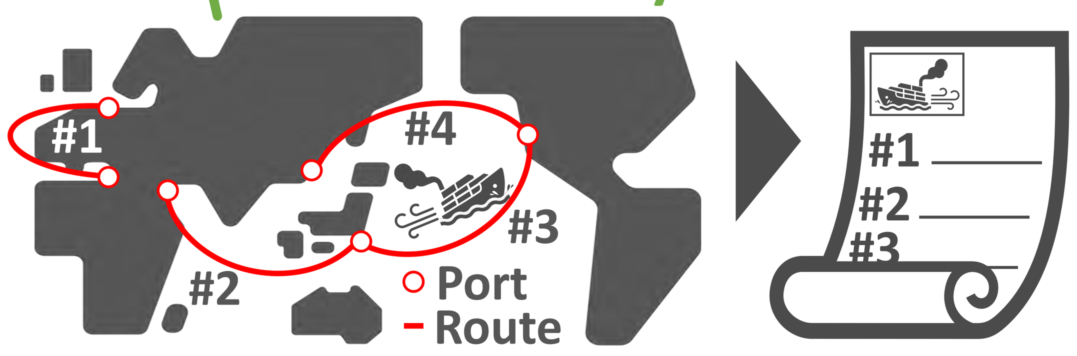
2 DATA AND METHODOLOGY

Basic ship information

Ex) Container ship j of operator company i



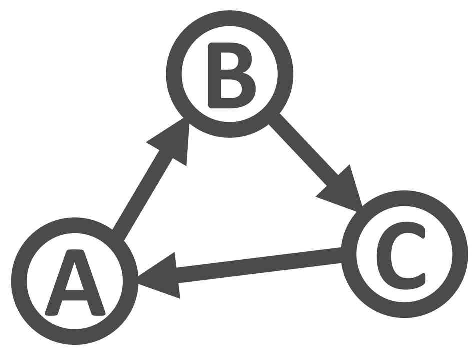
Port call history data



Companies considered in this study

Company (abbreviation)	TEU	Share
Maersk Line (Maersk)	4,128,985	16.9%
Mediterranean Shipping Company (MSC)	3,902,661	15.9%
COSCO SHIPPING Lines (COSCO)	3,022,125	12.3%
CMA CGM (CMA)	3,016,687	12.3%
Hapag-Lloyd (Hapag)	1,774,132	7.2%
Ocean Network Express (ONE)	1,609,453	6.6%
Evergreen Marine Corporation (EMC)	1,327,918	5.4%
World	24,479,057	100.0%

Definition of adjacency matrix



Example Network

Arrival: q; Departure: p

	A	B	C
A	0	1	0
B	0	0	1
C	1	0	0

Adjacency matrix (g^{ji}_{pq})

"Weighted" adjacency matrix

$$D^{ji}_{pq} = \underline{distance_{pq}} \times g^{ji}_{pq}$$

$$K^{ji}_{pq} = \underline{DWT^{ji}} \times D^{ji}_{pq} \qquad Q^{ji}_{pq} = \underline{EF \times F^{ji}} \times D^{ji}_{pq}$$

↳ Transport activity ↳ CO_2 emissions

EF: Emission factor, F: Fuel efficiency

CO_2 emissions of each company

- Route-specific

$$Q^i_{pq} = \sum_{j=1}^{m_i} Q^{ji}_{pq}$$

- Aggregated

$$Q^i = \sum_{p=1}^{N} \sum_{q=1}^{N} Q^i_{pq}$$

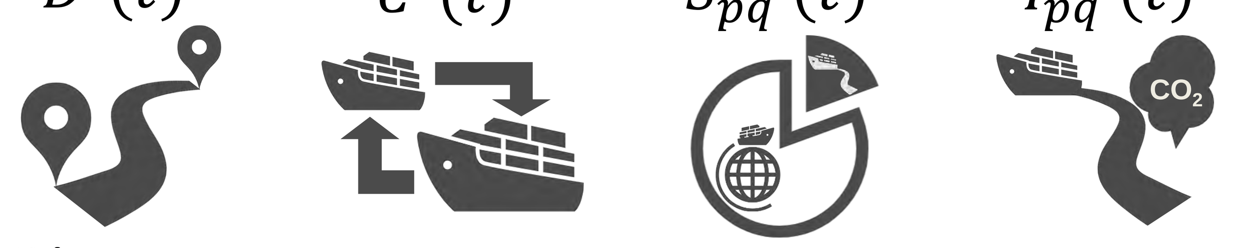
$[j = 1,2,\cdots,m_i \quad p = 1,2,\cdots,N \quad q = 1,2,\cdots,N]$

Factor decomposition analysis (LMDI)

We decomposed the CO_2 emissions of operator company i in year t into four factors.

$$Q^i(t) = \sum_{p=1}^{N} \sum_{q=1}^{N} D^i(t) \times \frac{K^i(t)}{D^i(t)} \times \frac{K^i_{pq}(t)}{K^i(t)} \times \frac{Q^i_{pq}(t)}{K^i_{pq}(t)}$$

$D^i(t)$ Distance; $C^i(t)$ Capacity; $S^i_{pq}(t)$ Structure; $I^i_{pq}(t)$ Intensity



Applying Logarithmic Mean Divisia Index (LMDI) method by Ang (2005), we quantified the contributions of the four factors to the changes in CO_2 emissions.

3 RESULTS

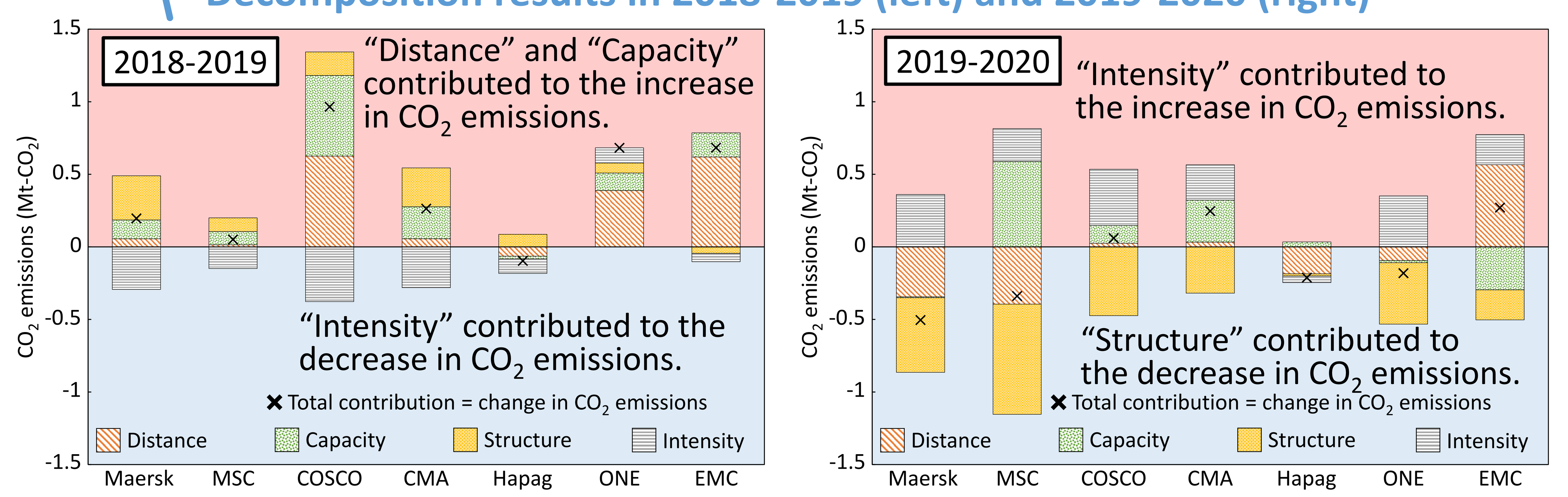
CO_2 emissions of each company

Company	2018		2019		2020	
Maersk	21.2	(24%)	21.4	(23%)	20.9	(23%)
MSC	21.4	(24%)	21.5	(23%)	21.1	(23%)
COSCO	11.3	(13%)	12.3	(13%)	12.4	(14%)
CMA CGM	11.6	(13%)	11.8	(13%)	12.1	(13%)
Hapag-Lloyd	9.2	(10%)	9.1	(10%)	8.9	(10%)
ONE	8.6	(10%)	9.2	(10%)	9.1	(10%)
Evergreen	6.2	(7%)	6.9	(7%)	7.2	(8%)
Total	89.6	(100%)	92.3	(100%)	91.6	(100%)

- Overall, CO_2 emissions of these companies increased by 2 Mt-CO_2 (about 2% increase) during 2018-2020.
- A company with a larger share of shipping capacity emitted more CO_2.

► **This result indicated that it needed further efforts to decarbonize the container shipping.**

Decomposition results in 2018-2019 (left) and 2019-2020 (right)



- The contribution of "Structure" offset the contribution of "Intensity" to the decrease in CO_2 emissions for the three companies in 2018-2019 (left results).
- "Structure" contributed the most to the decrease in CO_2 emissions of the five companies in 2019-2020 (right results).

► **These results indicated that policies for shipping network structure can be effective.**