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Computational General Equilibrium Model with Maritime Route Choice

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1. Introduction

- Maritime transport carries more than eighty percent of world merchandise trade by volume
- The main container trade flows are among three economic centers – North America, Europe, and Asia
- Potential of Artic Shipping due to sea ice retreat, competing with other maritime trading routes
    - Suez Canal
    - Panama Canal
    - Cape of Good Hope or Cape Horn
- Require a model to evaluate the impact of route-specific shocks on global trade and economy

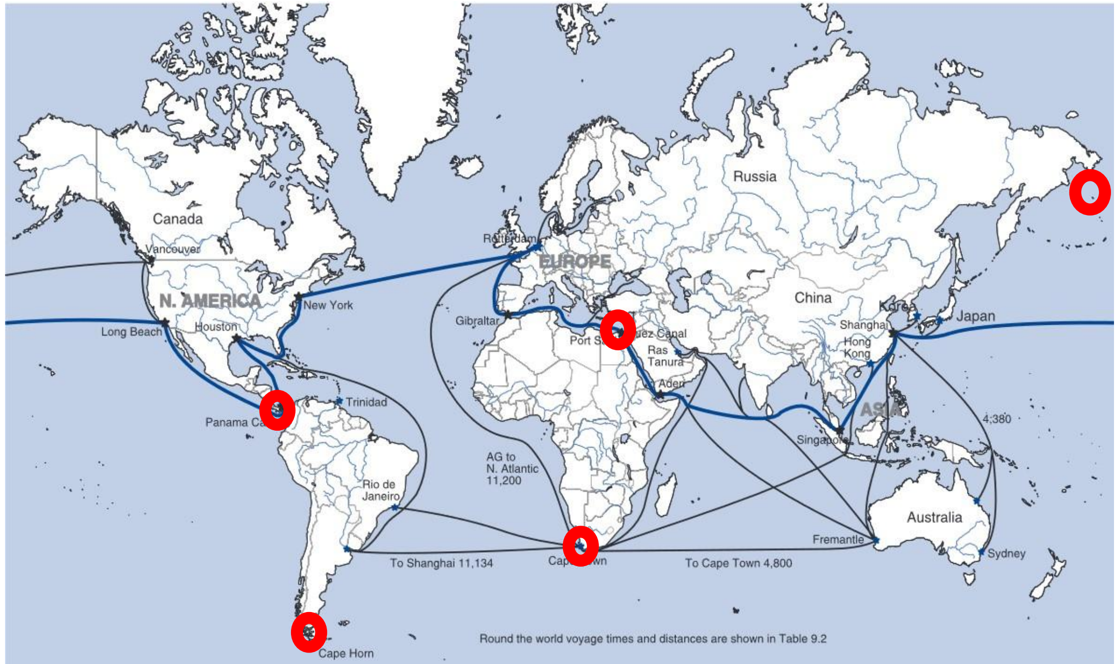


Figure 1. Maritime Trade Routes
Source: Figure 9.1 in Stopford (2009)

Literature on Arctic Shipping

- feasibility of Arctic Shipping:
  - **ice-breaking or escorting fees** (Liu and Kronbak, 2010; Faury and Cariou, 2016; Xu, Yang, and Weng, 2018; Xu et al., 2011; Faury, Cheaitou, and Givry, 2020; Theocharis et al., 2021),
  - **navigation period** (Schøyen and Brathen, 2011; Zhao, Hu, and Lin, 2016; Sibul and Jin, 2021),
  - **fuel cost** (Verny and Grigentin, 2009; Lasserre, 2014; Sibul and Jin, 2021; Theocharis et al., 2021)

- economic impacts of Arctic Shipping
  - **on transportation cost** (Xu et al., 2011; Rajagopal and Zhang, 2021; Schøyen and Brathen, 2011; Shibasaki et al., 2018; Bekkers, Francois, and Rojas-Romagosa, 2018)
  - **on trade** (Shibasaki et al., 2018; Bekkers, Francois, and Rojas-Romagosa, 2018)
  - **environment** (Yumashev et al., 2017)

This paper focus on the second literature.

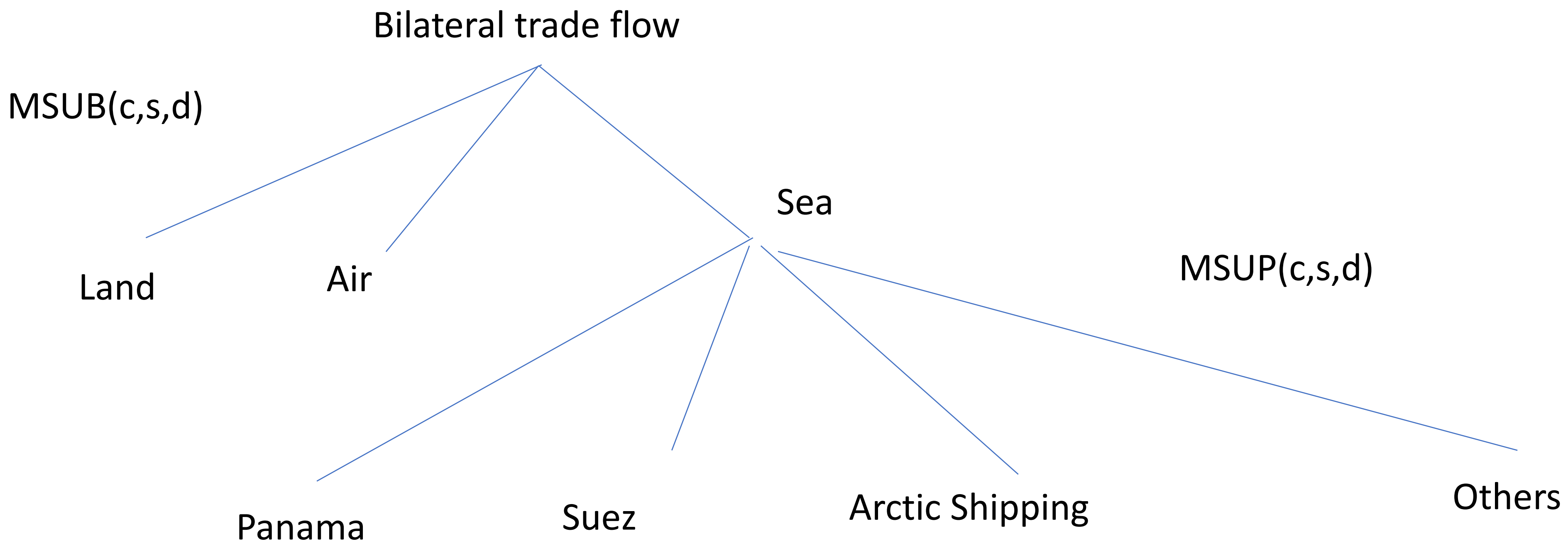
Literature on global trade model

- CGE model:
  - Transport in CGE: reviewed in (Robson, Wijayaratna, and Dixit 2018) (2018)
  - GTAP:
    - Standard GTAP: Corong et al (2017)
    - GTAP with transport modes: Avetisyan (2018)
    - Application of GTAP in transport evaluation: Shibasaki et al. (2018)
- Trade model with transport sector: Lux (2011), Hummels and Schaur (2013), Heiland et al. (2019), Brancaccio, Kalouptsidi, and Papageorgiou (2020), Fajgelbaum and Schaal (2020)
- Route Choice: Shibasaki et al (2018), Shibasaki, Kato, and Ducruet (2020), Kanamoto et al. (2021)

This paper is the combination of CGE and route choice model approach.

3. Modifying GTAP model: general framework

- Mode choice: in the standard GTAP
- Adding Route choice among Sea transport



3. Calibration

- Elasticity of substitution among routes:
  - Quantity of transport for each region pair and route
  - Unit costs (prices) for each region pair and route
- Transport margin for each routes:
  - Total transportation costs for each region pair and route
- Trade in transport services for each routes:
  - Assumptions: proportional to transport quantity of region pair-route

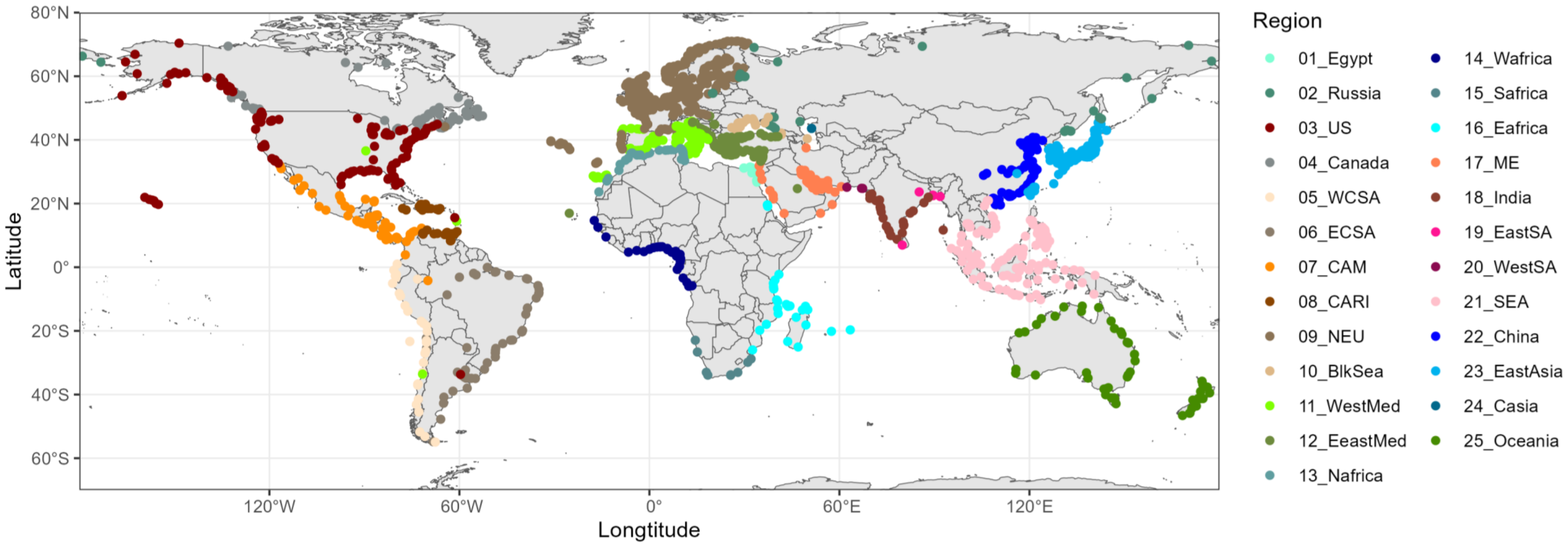
Data Source

- Margin for sea transport: VTWR from GTAP 11 database
- Voyage or service intakes/capacity, durations, speeds, vessel type on each commodity-source-destination:
    - Container: MDS data
    - Dry Bulk: AXS Dry
    - Liquid Bulk: Alpha tanker
- Fuel price, charter costs: Clarkson Shipping Intelligence
- Fuel consumption: IMO (2020), IHS ship database
- Arctic shipping related costs: Furuichi & Otsuka (2013)

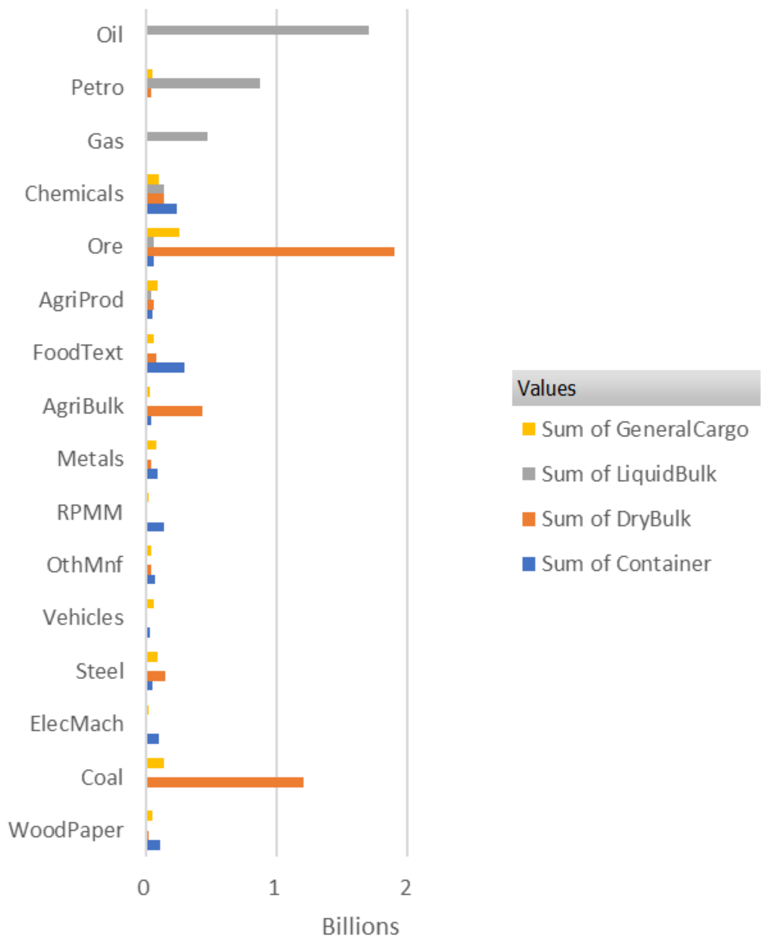
Maritime Unit Cost on Each Route

- Weighted Average Unit Cost for each OD
  - Dry bulk and liquid bulk: all voyages on each OD in 2017, estimated voyage intakes as weights
  - Container: all services passing through each OD in 2017, services capacity as weights
- Unit cost for each OD
  - fuel costs, operating costs, capital costs, port dues, insurance cost, canal tolls.
    - daily fuel consumption is the product of specific fuel consumption (SFC) and engine power.
      - SFC values are taken from the IMO's report (IMO, 2020) for different fuel types (heavy fuel, marine gas, or LNG) and SSD engine type.
      - Engine powers are taken from IHS ship database. When engine powers are not available, they are filled based on a regression between known value and vessels' length, speed, and DWT).
    - fuel prices (HSFO, MGO, and LNG) are taken from Clarkson Intelligence
    - operating costs and capital costs are estimated using time-charter costs from Clarkson Intelligence
    - port dues: 0.428 USD/GT/call
    - insurance free: 0.343 percent of building price per year
  - Artic shipping includes additional costs:
    - icebreakers (5 USD/GT),
    - ice-pilot (673 USD/day),
    - insurance premium (10 USD/GT/year),
    - specific fuel coefficient premium (10% on top of SFC for normal vessels),
    - shipping building cost premium (10% on top of building cost for normal vessels) (Furuichi & Otsuka, 2013)

Matching GTAP regions with Shipping Ports



Matching Commodity with Ship Types



Source: GTA forcasting
Note: GTAP commodities are matched with GTA commodities using the description in corresponding ISIC rev 4 and CPC v2.1.
Most matches are 1:1 with the exception of live animal and animal products (ctl + oap), meat (omt + cmt), petroleum products and coal (p_c + coa).

No	ACOMM	Description
1	AgriProd	Agricultural Products (Container, General Cargo)
2	AgriBulk	Wheat, Grains, Paddy Rice, Oil Seeds, Sugar
3	Oil	Oil
4	Gas	Gas
5	Petro	Petroleum Products
6	Coal	Coal and Coke
7	Ore	Ore
8	Chemicals	Chemical Products
9	Steel	Crude Steel
10	Metals	Metals nec, Metal Products,
11	FoodText	Food and Beverages, Textiles and Wearing Apparel,
12	WoodPaper	Wood and Paper,
13	RPMM	Rubber, plastic products, Basic pharmaceutical products, Mineral products nec,
14	ElecMach	Electrical and Machinery, Transport Equipment, Other manufacturing
15	Vehicles	Vehicles
16	OthMnf	Other Manufacturing
17	Tsea	Water Transport Services
18	Tland	Land Transport Services
19	Tair	Air Transport Services
20	Services	Other Services

Route Elasticity of Substitution

$$\ln \frac{Q_{g,ijs}}{Q_{g=Other,ijs}} = -\sigma_s^g \ln \frac{UC_{g,ijs}}{UC_{g=Other,ijs}} + d_{it} + d_{jt} + d_g + \epsilon_{g,ijst}, \qquad (16)$$

- $Q_{g,irs}$ is the quantity of goods or services,
- σ_{gs} is the elasticity of substitution for commodity s
- $P_{g,irs}$ is price of each route,
- $d_{v=i,j,g,t}$ are fixed effects capturing specific influences for origin i, destination j, route g and time t.

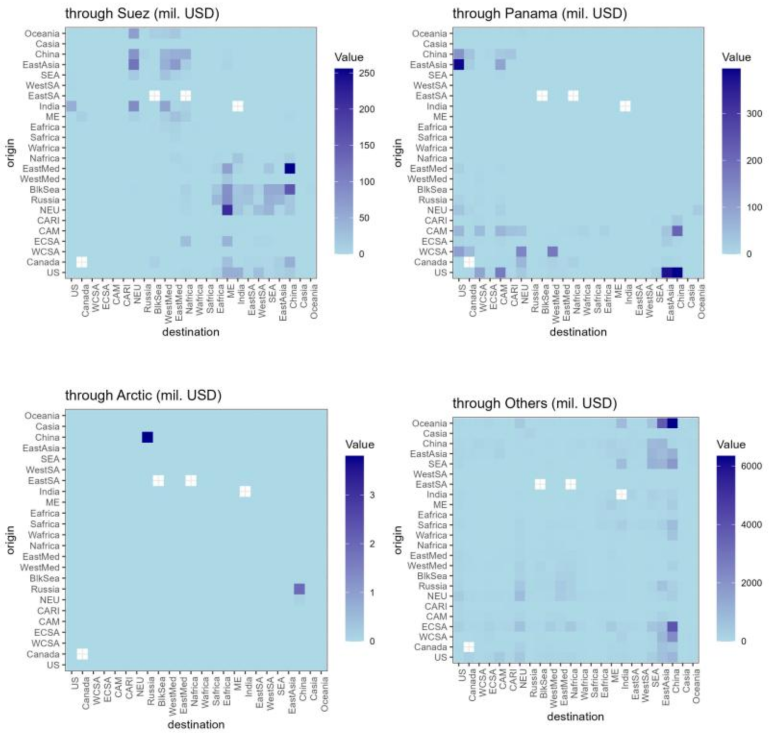
Estimation Results

Commodity	Estimate	Std. Error	Sigma
Container	0.46	0.42	1.00
Agribulk	-1.80	0.35	1.80
Coal	-1.55	0.26	1.55
Ore	-1.23	0.09	1.23
Steel	-1.00	0.58	1.00
Chemicals	-0.01	1.54	1.00
Gas	-1.26	0.33	1.26
Oil	-1.49	0.29	1.49
Products	-1.75	0.36	1.75
Other	-1.26	0.03	1.26

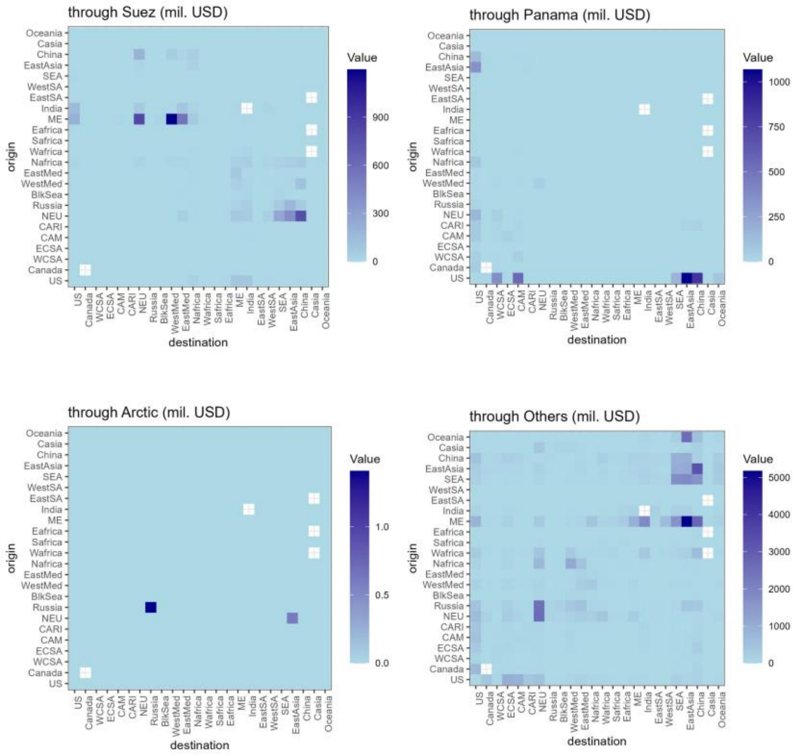
Source: Authors' estimations based on Alpha Tanker, AXS Dry, and MDS data.

Maritime Transport Margin on Each Route

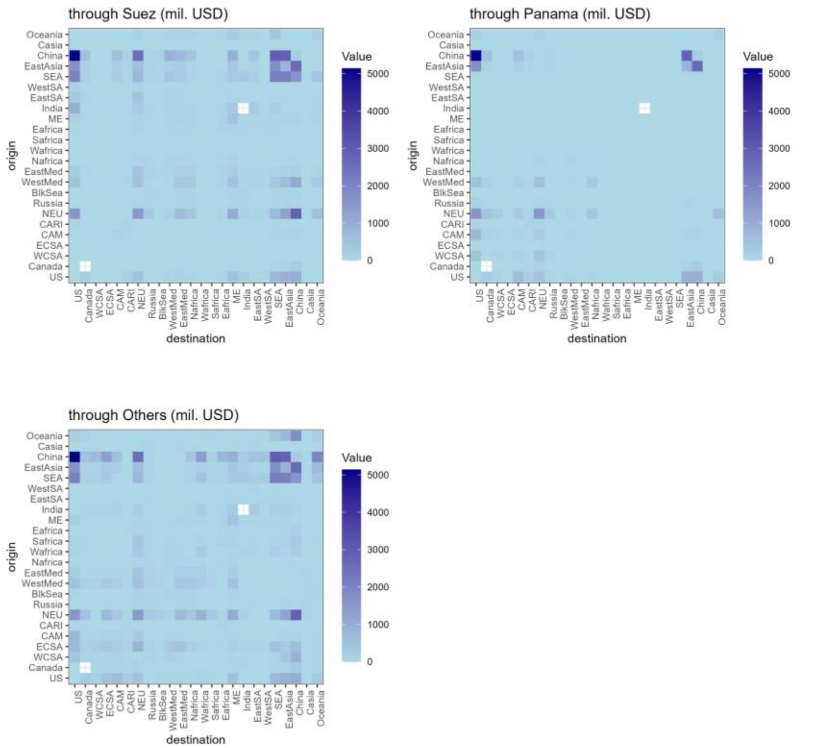
- Container trade flows are more dispersed than dry bulk and liquid bulk
- Each route:
    - Most cargo flows are in neighboring trade partner
    - Suez Canal are mostly between Asia and Europe for container, Oceania and Europe for dry bulk, and Middle East and Europe for liquid bulk
    - Panama Canal are mostly between North America and East Asia, and between North America (on the West Coast) and Europe for container, between the US and East Asia for liquid bulk.
    - Arctic Routes are mostly between East Asia and Europe and in Russia for liquid bulk.



DRY BULK



LIQUID BULK

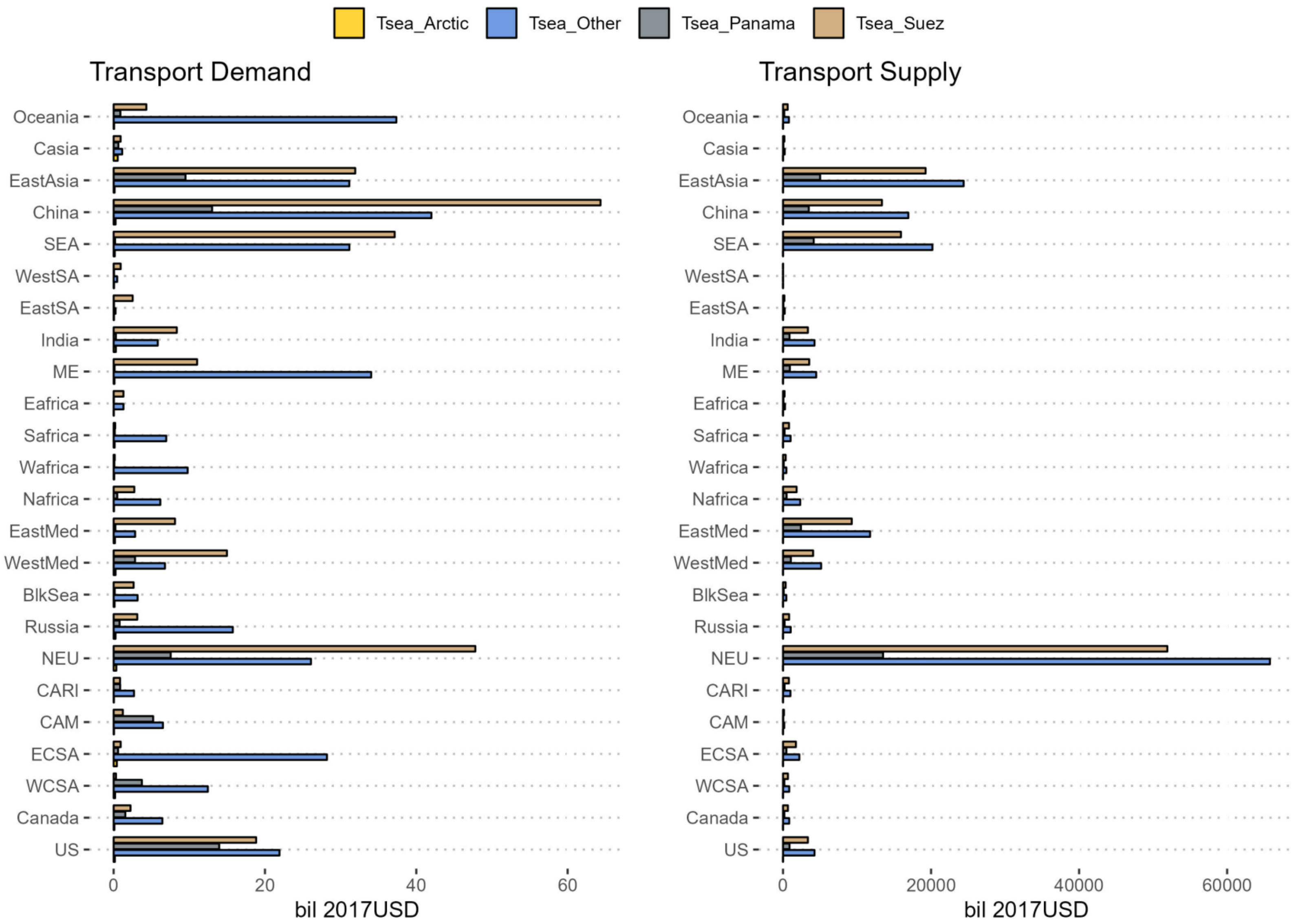


CONTAINER

Splitting Sea Transport Margin

- **Industry costs = sales of locally made goods:**
  - **Industry costs:** sum of expenditures in the NATIONAL arrays over all inputs, sources at basic prices plus taxes
  - **sales of locally made goods:** sum of domestic sales over all intermediate producers and final demand and export sales over all destinations
- **Supply = demand for imports:**
  - **Supply:** sum of trade over all origins
  - **Demand:** sum of imports over all intermediate producers and final demand
- **<u>Margin supply = margin demand</u>**
  - <u>**VST:** sum of margin exports -> assuming all regions have same route share</u>
  - <u>**VTWR**: transport costs for each region pair and route specific</u>

Splitting Results

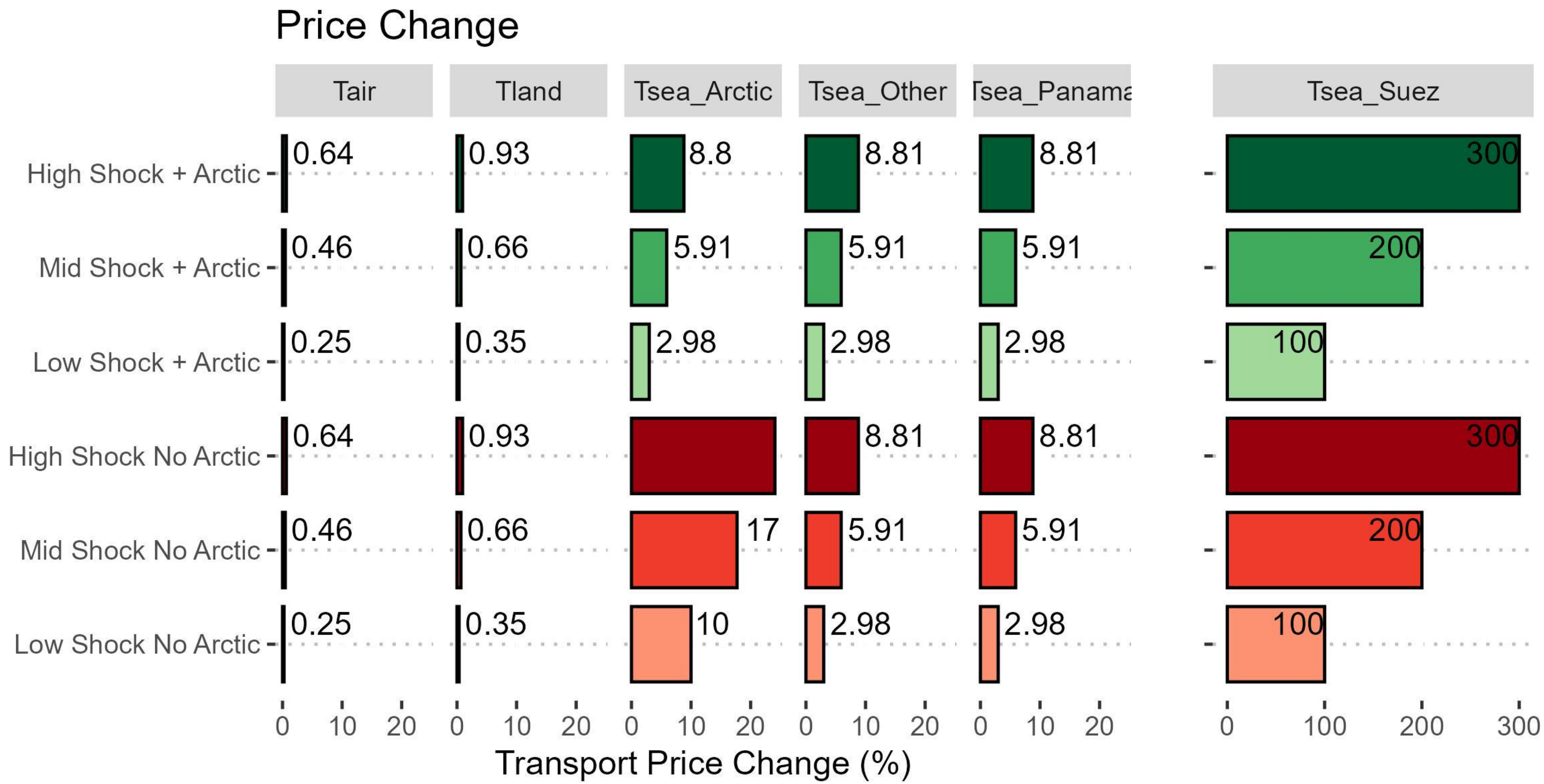


5. Simulation

- Baseline:
  - 2017 to 2025: GDP growth, balance account from IMF's World Economic Outlook
  - 2025 to 2030: GDP growth from Shared Social Economic Pathway Middle of Road (SSP2), Population and labor growth from UN Prospect Database

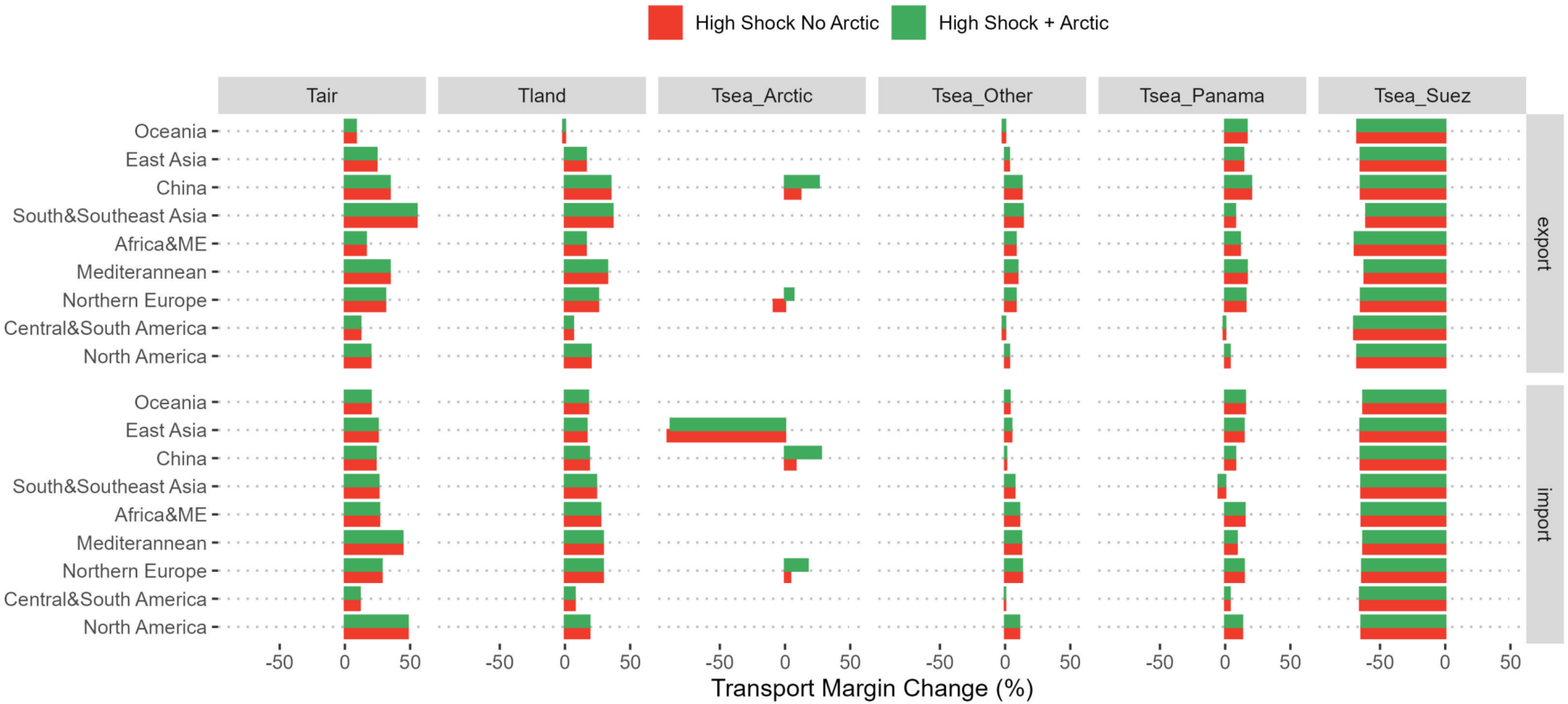
- Policy scenarios: combination of two elements in 2030
  - Increase in Suez Canal route price by 100, 200, 300%
  - Keep supply for Arctic route unchanged or not

Simulation Results: Transport Price

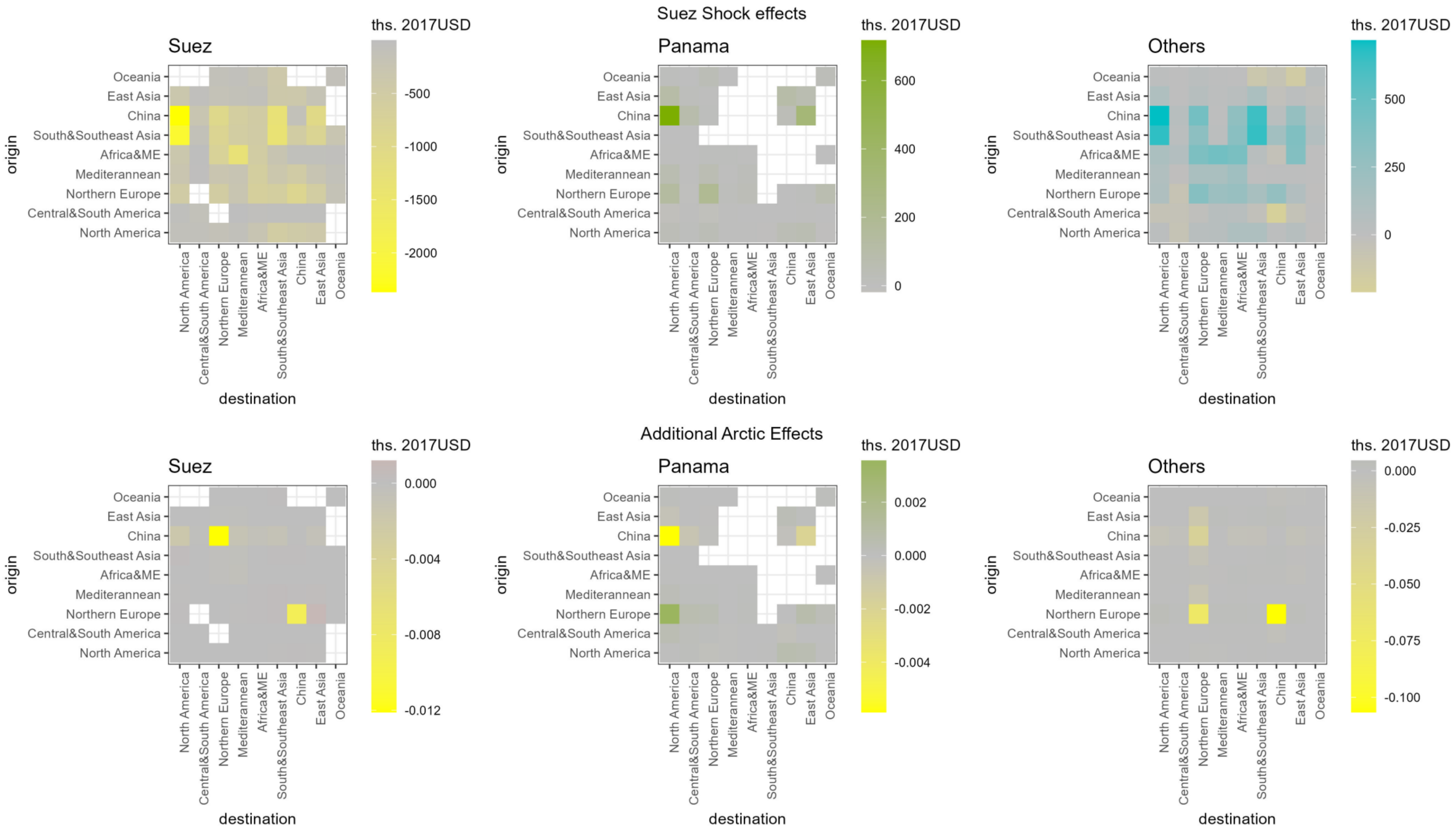


Simulation Results: Transport Price Index

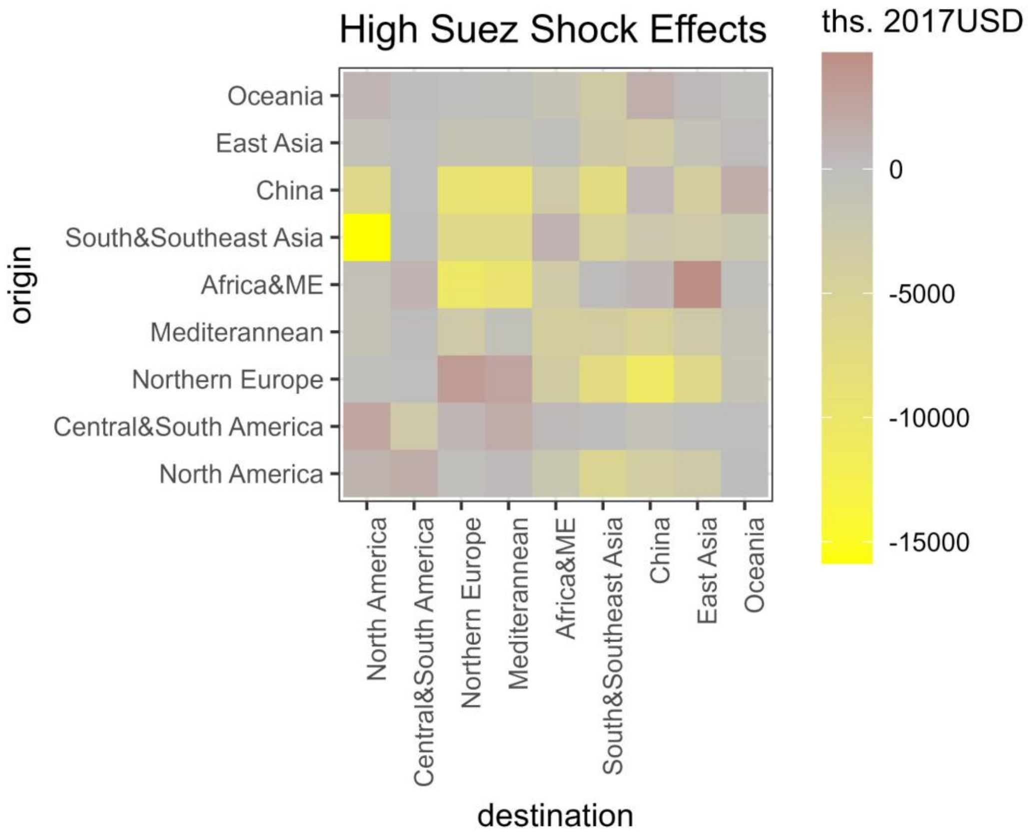
Simulation Results: Transport Margins

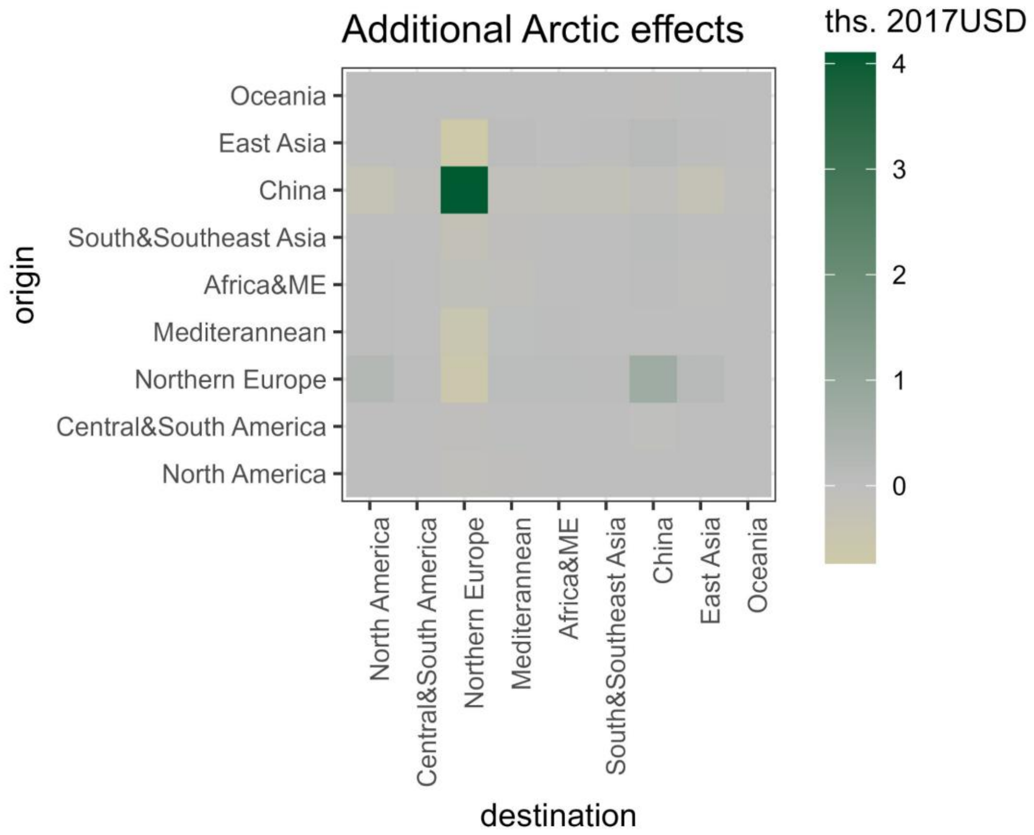


Simulation Results: Transport Margins

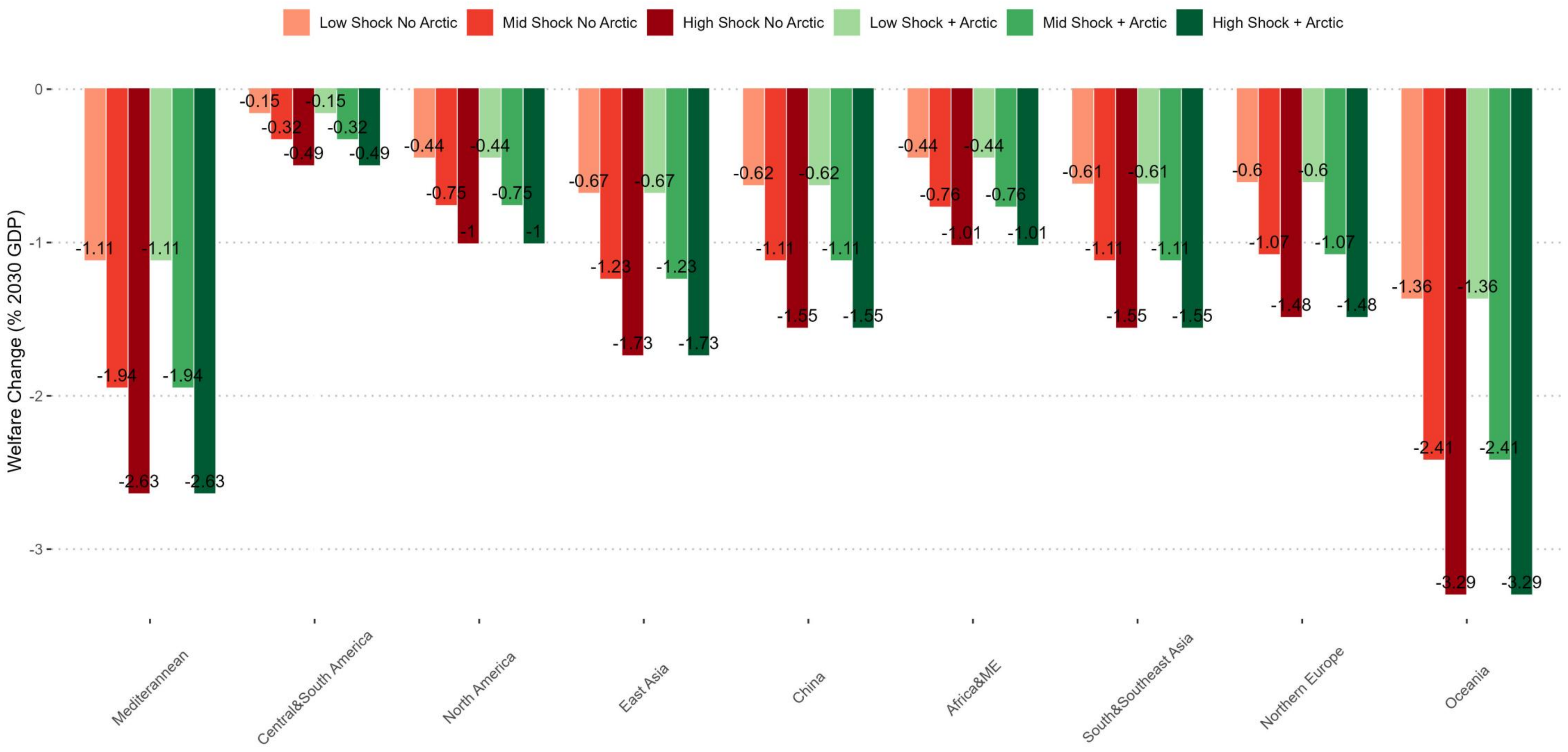


Simulation Results: Trade





Simulation Results: Welfare



Discussion

- Including route choice in the standard GTAP model has significant implications:
  - route-specific shocks result in a transport demand shift from one route to another but also increase demand of other route through change in total demand
  - a uniform shock could result in heterogenous impacts on commodities and exporters/importers due to different voyage cost structures and trading patterns.
- The role of Arctic shipping
  - allow more adjustment in price of not only itself but other routes and modes, although with very small magnitude

6.Conclusion

- Introduced a route choice structure into a standard GTAP model
- Conducted a simulation for a change in Suez Canal route with and without Arctic supply adjustment
- Future work includes sensitivity analysis

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