Shock Risks and Chokepoint Overreliance

Empirical Evidence from the Ever Given Incident

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Background

On March 23, 2021, the Ever Given got stranded in the Suez Canal

It was 6 days before the rescue crew freed the ship

During the blockage, all trade through the canal was stopped

Chokepoints

The Suez Canal is a chokepoint in the maritime trade network

Most maritime trade travels through just a handful of chokepoints

- 80% of oil imports (EIA 2017)
- 55% of food imports (Bailey and Wellesley 2017)

Transport shocks to these chokepoints have been theorized to have major ramifications on the global economy (Pratson 2023; Wang, Du, and Peng 2024; Xiao et al. 2022)

However, since chokepoint shocks have been rare, there are very few empirical studies on the topic

Questions

How do shocks to chokepoints affect the global economy?

Where are these effects concentrated?

What can countries do to insure against the effects of these shocks?

Empirical Strategy

The effects of chokepoint shocks come from two places:

1. **Direct Effects:** Shocks stop ships carrying goods, which means they don't get to their destination (Kosowska-Stamirowska 2020)
2. **Propagation Effects:** Shocks affect the transport of intermediate goods, which affects future production and exports (Elliott and Jackson 2023; Boehm, Flaaen, and Pandalai-Nayar 2019; Célian Colon 2019)

The Suez Canal blockage is thought to have caused both of these (Lee and Wong 2021; Özkanlisoy and Akkartal 2022; Wan et al. 2023)

Direct Effects (1/3)

Theory: For a port/country j, we expect

$$M_{j,t+t_{s,j}} \approx (1 - s_j \times c_t)\overline{M}_j$$

where

$$\begin{aligned} M_{j,t} &= \text{imports into } j \text{ at time } t \\ \overline{M}_j &= j\text{'s average imports} \\ s_j &= \text{percent of } j\text{'s imports that go through the canal} \\ c_t &= \text{indicator for canal blockage at time } t \\ t_{s,j} &= \text{time ships take to get from the Suez Canal to } j \end{aligned}$$

Direct Effects (2/3)

Taking logs

$$\log M_{j,t+t_{s,j}} \approx \log(1 - s_j \times c_t) + \log \overline{M}_j$$

Two changes:

1. s_j is usually small → Take it out of the log
2. $\log \overline{M}_j$ gets lumped into fixed effects

Direct Effects (3/3)

Estimating Equation: Therefore, the estimating equation is

$$\log M_{j,t+t_{s,j}} = \alpha_1 c_t + \alpha_2(s_j \times c_t) + \beta_j + \varepsilon_{j,t}$$

for ports and countries j and time t where

Variable	Interpretation	Expected Sign
α_1	Global trends during the blockage	0
α_2	Blockage effect on exposed ports	-
β_j	"Normal" imports for j (FE)	
$\varepsilon_{j,t}$	Error term	

Propagation Effects (1/3)

We use Input-Output analysis from Leontief 1951

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{F}$$
$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}$$

where

$$\mathbf{x} = \text{vector of output by good type}$$
$$\mathbf{A} = \text{Leontief input-output matrix}$$
$$\mathbf{F} = \text{final use by good type}$$

Propagation Effects (2/3)

From Los, Timmer, and Vries 2015, using industry-country as the good types, we know

$$\mathbf{V} = \hat{\mathbf{w}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}$$

where

$\hat{\mathbf{w}}$ = diagnal matrix of value added per unit of output by type
$\mathbf{V}$ = value added to the final use from each type

This holds for any $\mathbf{F}$, not just aggregate final use

Empirical Strategy: Examine how much value added to final used in each country comes from across the canal

Most trade is maritime → Assume this most likely crosses through the canal (EIA 2017)

Leontief analysis uses linear functions → Multiply by $\frac{6}{365}$

Result is a lower bound for blockage propagation effects

Data

Data

We’ll use three types of data

1. A maritime trade network
2. Imports right after the shock
3. Intercountry input-output tables

Trade Network (1/4)

Use the trade network constructed in Verschuur, Koks, and Hall 2022

This network includes information about common maritime routes, like location, distance, trade flow, and trade flow that's been through the Suez Canal

It also includes locations and flows for the ports connected to the network

Trade Network (2/4)

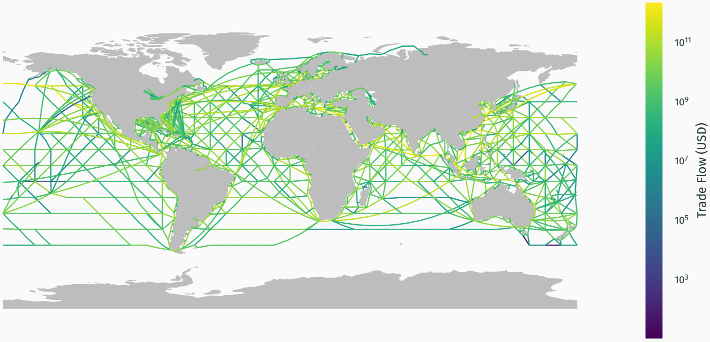


Figure 3.1: Trade flows along routes in the network

Trade Network (3/4)

Calculate exposure score using

$$\text{Exposure} = \frac{\text{Flow Through Canal}}{\text{Flow Along Route}}$$

for the routes going into a port/country

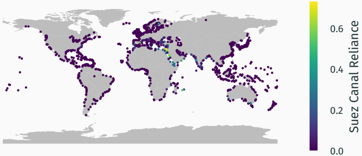


Figure 3.2: Suez Canal exposure for ports

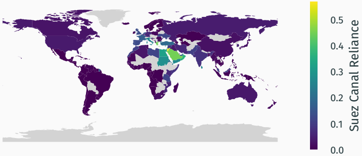


Figure 3.3: Suez Canal exposure for countries

Trade Network (4/4)

Calculate the travel time from the Suez Canal using

$$\text{Travel Time} = \frac{\text{Distance from Canal Along Network}}{\text{Average Ship Speed}}$$

for each port

Country distance is the average for all ports weighted by flow into the ports

Figure 3.4: Port distances from the Suez Canal

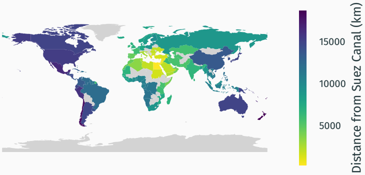


Figure 3.5: Country distances from the Suez Canal

Imports (1/3)

Use country import data from Cerdeiro et al. 2020 and port import data from Arslanalp, Koepke, and Verschuur 2021

Use AIS data to estimate maritime imports into a country or port at a daily frequency

The estimates are updated weekly and published by the IMF

The frequency lets us isolate direct effects before propagation effects cause endogeneity concerns

Imports (2/3)

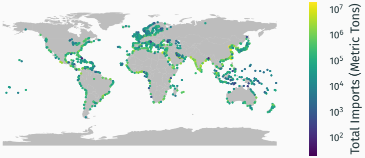


Figure 3.6: Total port imports between 3/1/21 and 5/31/21

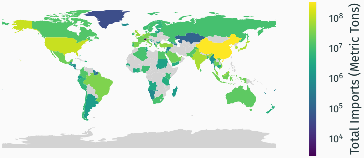


Figure 3.7: Total country imports between 3/1/21 and 5/31/21

Imports (3/3)

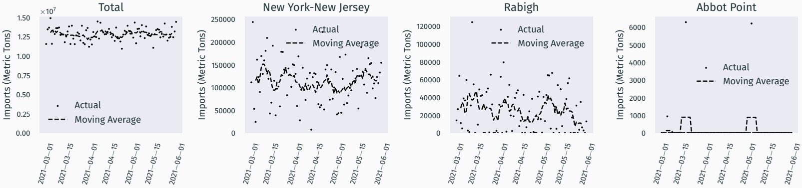


Figure 3.8: Imports in various ports from 3/1/21 to 5/31/21

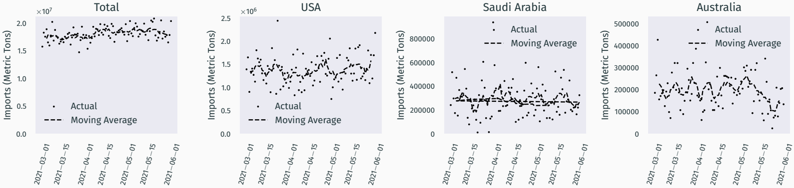


Figure 3.9: Imports in various countries from 3/1/21 to 5/31/21

Input-Output Tables (1/2)

We use input-output tables from the OECD, Inter-Country Input-Output Database

Maps inputs from

- 77 Countries (76 actual + Rest of World)
- 45 Industries
- 6 Final Uses
- 2 Value Added Types

Spans 2016-2020

$$
\begin{array}{cccc}
 & \text{Outputs} & \text{Final Demand} & \text{Total Output} \\
\text{Inputs} & \begin{pmatrix} \mathbf{Z}_{11} & \cdots & \mathbf{Z}_{n1} \\ \vdots & \ddots & \vdots \\ \mathbf{Z}_{n1} & \cdots & \mathbf{Z}_{nn} \end{pmatrix} & \begin{pmatrix} \mathbf{F}_{11} & \cdots & \mathbf{F}_{n1} \\ \vdots & \ddots & \vdots \\ \mathbf{F}_{n1} & \cdots & \mathbf{F}_{nn} \end{pmatrix} & \begin{pmatrix} \mathbf{X}_{1} \\ \vdots \\ \mathbf{X}_{n} \end{pmatrix} \\
\text{Value Added} & \begin{pmatrix} \mathbf{V}_1^\top & \cdots & \mathbf{V}_n^\top \end{pmatrix} & & \\
\text{Total Output} & \begin{pmatrix} \mathbf{X}_1^\top & \cdots & \mathbf{X}_n^\top \end{pmatrix} & &
\end{array}
$$

Figure 3.10: Example World Input-Output Table

First Order Effects

Port Model (1/2)

	Total		Cargo		Tanker	
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure × Crash	-0.999**	-1.171***	-0.686**	-1.237***	-0.999**	-0.733**
	(0.426)	(0.448)	(0.314)	(0.405)	(0.426)	(0.326)
Crash		0.045		0.011		0.012
		(0.036)		(0.034)		(0.028)
Port FE	Yes	Yes	Yes	Yes	Yes	Yes
Speed (km/h)	40	40	40	40	20	20
Observations	48,744	48,744	48,744	48,744	48,744	48,744
No. of Ports	1,354	1,354	1,354	1,354	1,354	1,354
R^2	0.519	0.519	0.530	0.530	0.408	0.408

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.1: Port Regression Results

Port Model (2/2)

We find a large, statistically significant decrease in port imports during the blockage

Based on Model 2, import effects for

- Fully Exposed Port: 67.6% decrease
- 10% Exposed Port: 7.0% decrease (47 in Dataset)

Country Model (1/2)

	Total		Cargo		Tanker	
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure × Crash	-1.821**	-2.438**	-1.210	-1.867	0.312	0.526
	(0.846)	(1.107)	(1.045)	(1.245)	(1.100)	(1.325)
Crash		0.163		0.173		-0.056
		(0.192)		(0.166)		(0.202)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Speed (km/h)	40	40	40	40	20	20
Observations	3,100	3,100	3,100	3,100	3,089	3,089
No. of Countries	90	90	90	90	90	90
R^2	0.515	0.515	0.511	0.511	0.522	0.522

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.2: Country Regression Results

Country Model (2/2)

We find an even larger, but less statistically significant decrease in country imports during the blockage

Based on Model 2, import effects for

- Fully Exposed Country: 90.0% decrease
- 10% Exposed Country: 7.7% decrease (10 in Dataset)

Propagation Effects

Predict the percent of value added for final use in each country that would have been blocked

Use paths between ports to figure out whether value would have gone through the canal

Assume no trade from the rest of the world goes through the Canal

	Count	Mean	St. Dev	Min	25%	50%	75%	Max
Total Effects	68	0.098	0.122	0.002	0.053	0.081	0.110	0.812

Notes: 100% is the maximum possible, not 1.

Table 5.1: Estimated Propagation Effects, Summary Statistics

Propagation Effects Estimates (2/3)

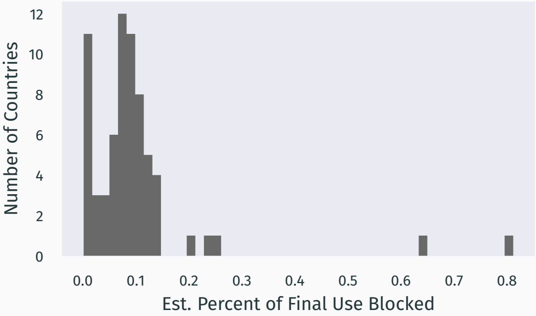


Figure 5.1: Estimated Propagation Effects, Histogram

Propagation Effects Estimates (3/3)

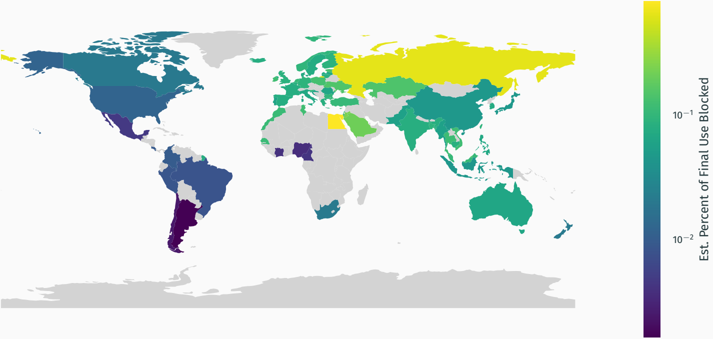


Figure 5.2: Estimated Propagation Effects, Locations

Propagation Effects Spread

Propagation effects from transport shocks spread and affect groups that would otherwise be unaffected (Célian Colon 2019)

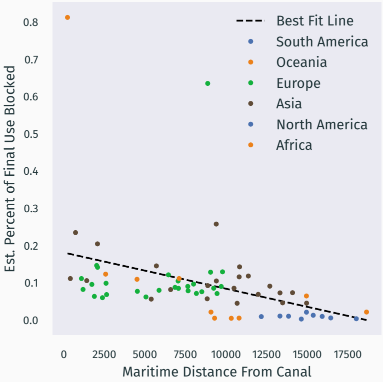


Figure 5.3: Estimated Propagation Effects by Distance

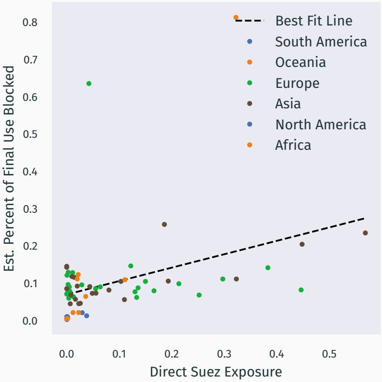


Figure 5.4: Estimated Propagation Effects by Direct Exposure

Conclusions

Main Takeaways

We found

- Ports/countries that route significant amount of trade through the canal are more exposed to chokepoint shocks
- Propagation effects spread to would-be-unaffected countries, but are more concentrated near the event and in more directly exposed areas

Importance

Chokepoints are often located in geopolitically or climatologically unstable areas (Xiao et al. 2022)

- Shipping through the Panama Canal is down substantially due to climate change (Arslanalp et al. 2023)
- Houthi rebels are attacking ships entering the Red Sea, which leads into the Suez Canal (Bigg, Shankar, and Fuller 2024; CRS 2024)

Understanding how these are going to affect different regions economies is essential

Limitations

There were many assumptions that lead the results

- Ships travel at a consistent speed accross the shortest route
- Production can be estimated with a linear matrix
- Data accuracy

Future Work

Using AIS data could fix many of these limitations, since it wouldn’t require the same assumptions

Exploring the effects of weaker but longer term shocks

Questions?

Quanity Effects (1/3)

Create a new Suez Canal Exposure measure based on the ratio of quantity of trade through the canal instead of value

These measures are similar, but not identical

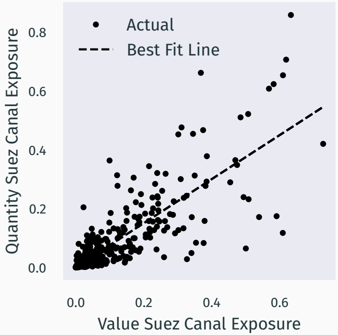


Figure 6.1: Port value vs quantity exposures

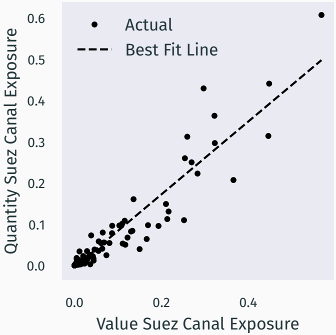


Figure 6.2: Port value vs quantity exposures

Quanity Effects (2/3)

	Total		Cargo		Tanker	
	(1)	(2)	(3)	(4)	(5)	(6)
Q Exposure × Crash	-1.467***	-1.655***	-1.711***	-1.768***	-0.795**	-0.830**
	(0.494)	(0.508)	(0.437)	(0.447)	(0.362)	(0.373)
Crash		0.048		0.015		0.009
		(0.036)		(0.033)		(0.027)
Port FE	Yes	Yes	Yes	Yes	Yes	Yes
Speed (km/h)	40	40	40	40	20	20
Observations	48,744	48,744	48,744	48,744	48,744	48,744
No. of Ports	1,354	1,354	1,354	1,354	1,354	1,354
R^2	0.519	0.519	0.530	0.530	0.408	0.408

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.1: Port Regression Results Using Quantity Exposure

Quanity Effects (3/3)

	Total		Cargo		Tanker	
	(1)	(2)	(3)	(4)	(5)	(6)
Q Exposure × Crash	-2.070**	-2.582**	-1.463	-2.045*	1.235	1.667
	(0.832)	(1.013)	(1.090)	(1.211)	(1.135)	(1.305)
Crash		0.142		0.162		-0.120
		(0.179)		(0.154)		(0.191)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Speed (km/h)	40	40	40	40	20	20
Observations	3,100	3,100	3,100	3,100	3,089	3,089
No. of Countries	90	90	90	90	90	90
R^2	0.515	0.515	0.511	0.511	0.522	0.522

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.2: Country Regression Results Using Quantity Exposure

Dynamic Model (1/3)

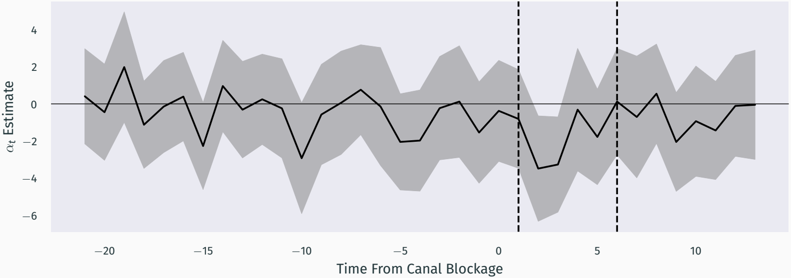
Effects could change differently at specific times near and durring the blockage

Estimate

$$\log M_{j,t+t_{sj}} = \alpha_t s_j + \beta_j + \varepsilon_{j,t}$$

with different α_t for each t

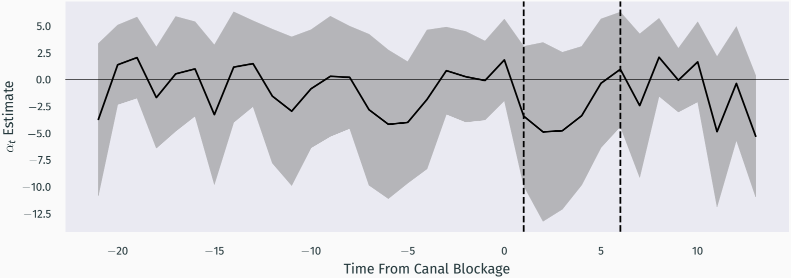
Dynamic Model (2/3)



Notes: Model ran from March 1, 2021 (-21 on the x-axis) to April 5, 2021 (13 on the x-axis). Gray region denotes the 95% confidence interval. Vertical bars denote the start and end of the blockage.

Figure 6.3: Port Dynamic Model Regression Results

Dynamic Model (3/3)



Notes: Model ran from March 1, 2021 (-21 on the x-axis) to April 5, 2021 (13 on the x-axis). Gray region denotes the 95% confidence interval. Vertical bars denote the start and end of the blockage.

Figure 6.4: Country Dynamic Model Regression Results

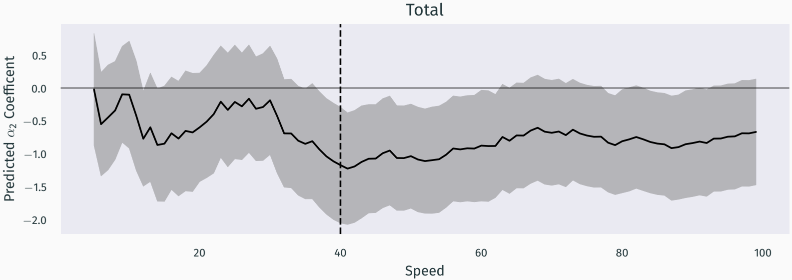
Speed Choice (1/7)

The assumed speed was an informed choice based on Sirimanne et al. 2022, but wasn't the only possible option

Run the regression with other speeds, see how the result changes

Tested all whole number speeds from 5-100 km/h

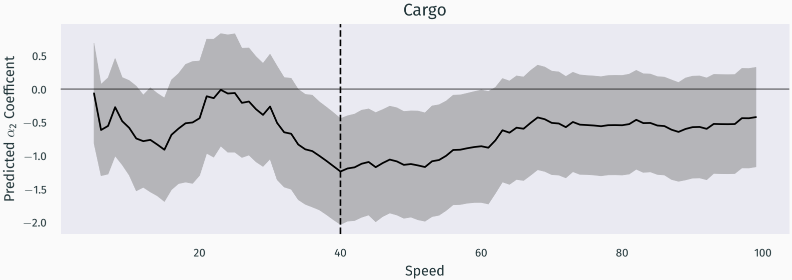
Speed Choice (2/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.5: Port Regression α_2 Estimates by Assumed Speed

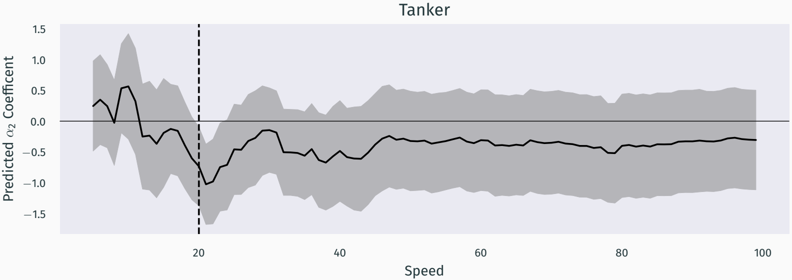
Speed Choice (3/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.6: Cargo Port Regression α_2 Estimates by Assumed Speed

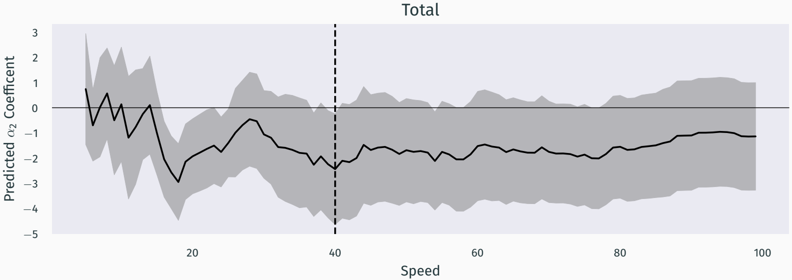
Speed Choice (4/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.7: Tanker Port Regression α_2 Estimates by Assumed Speed

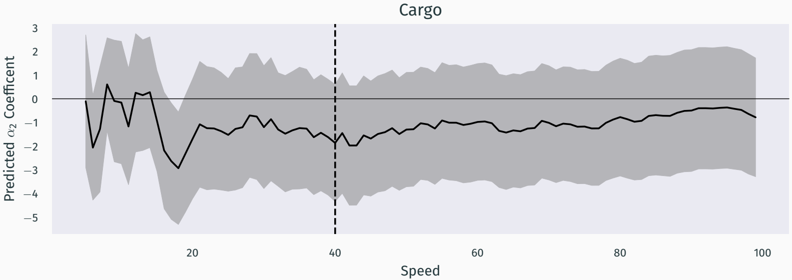
Speed Choice (5/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.8: Country Regression α_2 Estimates by Assumed Speed

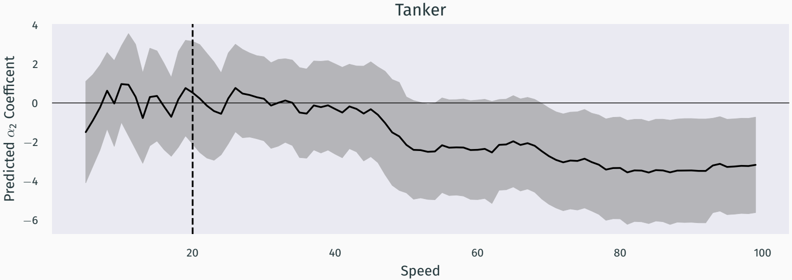
Speed Choice (6/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.9: Cargo Country Regression α_2 Estimates by Assumed Speed

Speed Choice (7/7)



Notes: Gray region denotes the 95% confidence interval. Vertical bar denotes the speed used in the main results.

Figure 6.10: Tanker Port Regression α_2 Estimates by Assumed Speed

Time Trend (1/2)

The model had no time fixed effects

Estimate

$$\log M_{j,t+\hat{t}_{sj}} = \alpha_2 \left(c_t \times s_j\right) + \beta_j + \gamma_t + \delta_{t+\hat{t}_{sj}}$$

which has reference time fixed effects (γ_t) and time fixed effects ($\delta_{t+\hat{t}_{sj}}$)

Time Trend (2/2)

	Port			Country		
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure × Crash	-0.921**	-1.171***	-1.067**	-2.042**	-2.435**	-3.690***
	(0.435)	(0.448)	(0.459)	(0.982)	(1.108)	(1.321)
Port FE	Yes	Yes	Yes			
Country FE				Yes	Yes	Yes
Time FE	Yes	No	Yes	Yes	No	Yes
Ref. Time FE	No	Yes	Yes	No	Yes	Yes
Speed (km/h)	40	40	40	40	40	40
Observations	48,744	48,744	48,744	3,100	3,100	3,100
No. of Geo Effects	1,354	1,354	1,354	90	90	90
R^2	0.520	0.519	0.521	0.524	0.519	0.529

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.3: Time Fixed Effects Regression Results

Distance Heterogeneity (1/2)

Effects could be different at different distances from the canal due to

- Dispersion
- Rerouting
- Other factors

Estimate the model for ports at three distances from the canal

- Under 2,500 km
- 2,500 - 10,000 km
- Over 10,000 km

Only do this for ports (For now)

Distance Heterogeneity (2/2)

	Under 2,500 km		2,500-10,000 km		Over 10,000 km	
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure × Crash	-1.582**	-1.744***	-0.405	0.022	-0.290	-1.335
	(0.587)	(0.775)	(0.632)	(0.662)	(1.299)	(1.372)
Crash		0.055		-0.104*		0.130***
		(0.180)		(0.062)		(0.047)
Port FE	Yes	Yes	Yes	Yes	Yes	Yes
Speed (km/h)	40	40	40	40	40	40
Observations	3,924	3,924	16,308	16,308	16,200	16,200
No. of Ports	109	109	453	453	450	450
R^2	0.471	0.471	0.481	0.481	0.545	0.545

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.4: Banded Port Regression Results

Placebo Regressions (1/3)

To eliminate the possibility of structural effects from canals causing the results, not the blockage, estimate the model using

- Panama Canal exposure
- the same days in 2019 where there was no blockage

Placebo Regressions (2/3)

	Port		Country	
	(1)	(2)	(3)	(4)
Panama Exposure × Crash	0.123	0.226	-0.242	-0.217
	(0.361)	(0.374)	(0.840)	(0.979)
Crash		-0.041		-0.008
		(0.035)		(0.162)
Port FE	Yes	Yes		
Country FE			Yes	Yes
Speed (km/h)	40	40	40	40
Observations	48,744	48,744	3,085	3,085
No. of Geo Effects	1,354	1,354	90	90
R^2	0.518	0.518	0.513	0.513

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.5: Regression Results Using Panama Exposure

Placebo Regressions (3/3)

	Port		Country	
	(1)	(2)	(3)	(4)
Exposure × Crash	0.179	0.024	0.157	-0.397
	(0.373)	(0.396)	(0.913)	(0.991)
Crash		0.041		0.146
		(0.036)		(0.097)
Port FE	Yes	Yes		
Country FE			Yes	Yes
Speed (km/h)	40	40	40	40
Observations	48,780	48,780	3,113	3,113
No. of Geo Effects	1,355	1,355	90	90
R^2	0.509	0.509	0.510	0.510

Notes: Dependent variable: Log Imports. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6.6: Regression Results in 2019

Continent Heterogeneity (1/2)

Separate propagation effects by continent

	Count	Mean	St. Dev	Min	25%	50%	75%	Max
Africa	8	0.148	0.273	0.004	0.004	0.064	0.113	0.812
Asia	23	0.106	0.059	0.044	0.069	0.091	0.117	0.257
Europe	27	0.112	0.107	0.059	0.076	0.087	0.107	0.635
North America	4	0.011	0.005	0.008	0.008	0.010	0.014	0.020
Oceania	2	0.042	0.031	0.020	0.031	0.042	0.053	0.064
South America	5	0.006	0.004	0.002	0.002	0.008	0.009	0.010
Total	68	0.098	0.122	0.002	0.053	0.081	0.110	0.812

Table 6.7: Estimated Propagation Effects by Continent, Summary Statistics

Continent Heterogeneity (2/2)

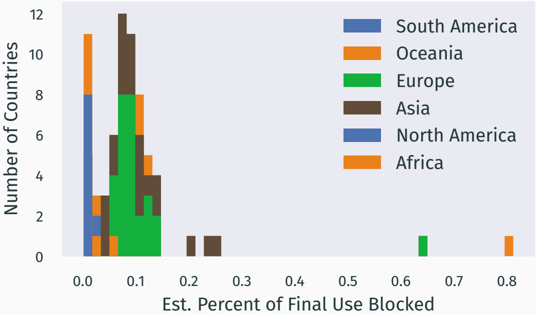


Figure 6.11: Estimated Propagation Effects by Continent, Histogram

Rest of World Effects

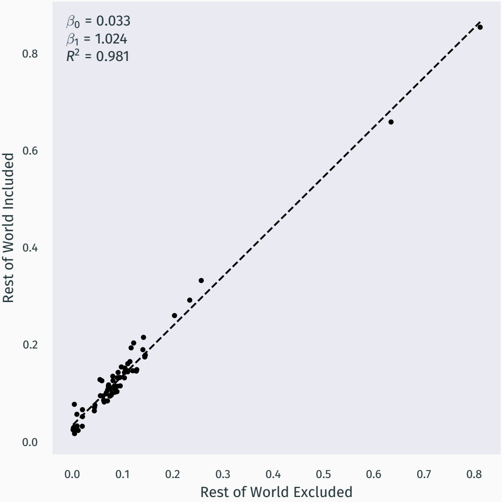


Figure 6.12: Estimated Propagation Effects With Versus Without the Rest of the World

Time of Estimation

Figure 6.13: Estimated Propagation Effects in Different Years

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