Maritime Trade Disruptions in Global Food Supply Chains: Effects on Caloric Availability
Risk and Profit Conference 2025

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Overview

- Background
- Methods and Data
- Results
- Limitations and Further Research
- Conclusions

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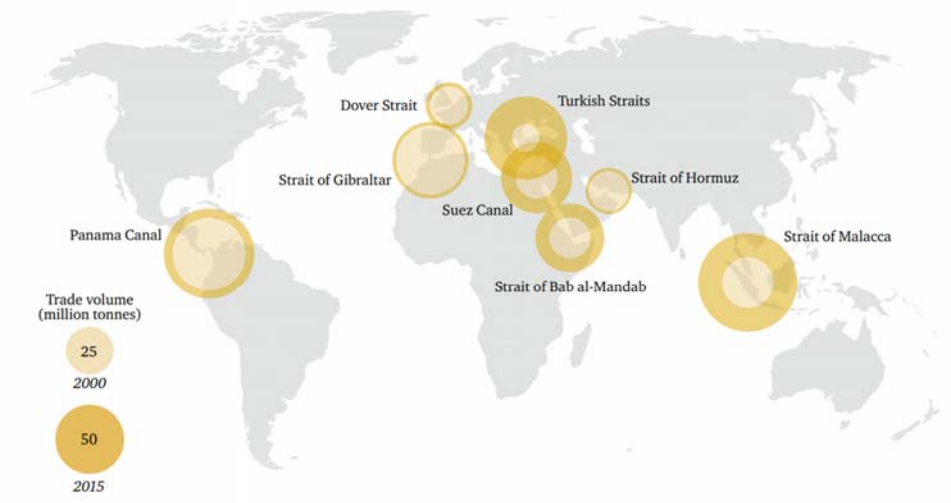
Background

- For the vast majority of countries, food security cannot be guaranteed by domestic production alone (Brenton et al., 2022)
- World trade allows for food to move from countries with abundant food sources to countries that do not have enough supplies (Runge, et al., 2003)
- 93,000 merchant ships and 1.25 million seafarers transport 6 billion tons of cargo globally (Brancaccio, et al., 2020; He et al. 2023)
  - More than 80% of total world trade VOLUME
  - 70% of total world trade VALUE
- Chokepoint:
  - An area of congestion along a trade route
  - Bailey and Wellesley. 2017. *Chokepoints and Vulnerabilities in Global Food Trade*

Source: Rodrigue, J-P., Notteboom, T., Pallis, A. (2022), *Port Economics, Management and Policy,* New York: Routledge

Annual Maritime chokepoint throughput of maize, wheat, rice, and soybean, 2000 and 2015



Sources: Chatham House Maritime Analysis Tool; Chatham House (2017), resourcetrade.earth, http://resourcetrade.earth (2015 data).

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Hazards to chokepoints

- Weather and climate
  - Slow onset of climate impacts (rising sea levels)
  - Extreme weather events (hurricanes, drought, etc.)
- Security and conflict
  - Physical attacks
  - Cyber attacks
- Political and institutional
  - Corruption
  - Worker strikes

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Why is it important?

- Supply chain disruptions becoming more frequent and larger in magnitude:
  - COVID-19 (2020)
    - World trade decreased by 7.0-7.4% in 2020 relative to 2019
    - In 2020, global trade fell by 8.9%, the steepest drop since the global financial crisis
  - *Ever Given* lodged in Suez Canal (2021)
    - Closed for 6 days
    - Affecting 15% of world's container capacity
    - Late fees for cargo ranged from $15,000-$30,000 per day

Why is it important?

- Russia-Ukraine Crisis (2021)
  - Low-income and lower-middle-income countries received 20% less grain exports from Ukraine as of Jan. 2023
  - Reduced exports from Ukraine by 47.3% until Aug. 2022
- Drought in Panama from El Niño (2022-present)
  - 5-6% of world trade passes through
  - Limits imposed on number of ships allowed passage
  - Auction system for companies to bid on priority passage (very expensive)
- Pirates (ongoing)
  - 50% drop in traffic (Suez Canal Authority)
  - Somali piracy reduced bilateral trade passing through the Gulf of Aden by 1.7-1.9% per year over a period of 10 years (2000-2010)
- Others!

No country left out

- Low-income food-deficit countries are most vulnerable BUT there are a few high-income food-deficit countries that are most exposed to disruptions (Bailey and Wellesley, 2017)
  - Japan and South Korea
- Import dependence doesn't necessarily mean high risk but can be indirect risk (Bailey and Wellesley, 2017)
  - Through compounding effect of a country's trading partners experiencing a shock

Research Question

- Which countries face the greatest risks to their food supply when ships can no longer utilize the Panama Canal, the Suez Canal or the Malacca Strait
  - Just under 18% of annual global grain exports travel through the Strait of Malacca (Bailey and Wellesley, 2017)
  - 15% of annual global grain exports travel through the Panama Canal
  - 7% of annual global grain exports travel through the Suez Canal

This paper

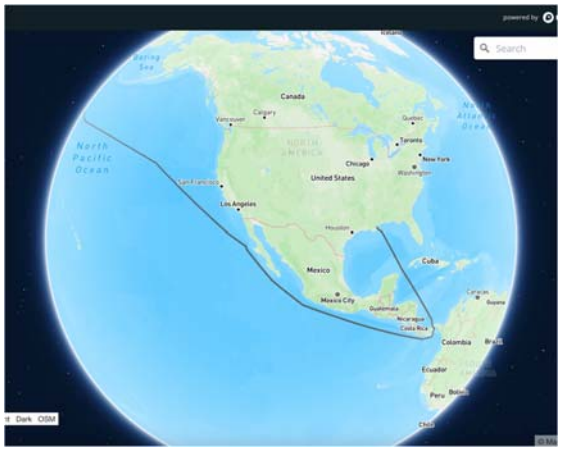
- Find the impact distance has on trade between two countries
- Three scenarios interchanging data in distance variable:
  - Alternative distance without the Panama Canal on a trade route
  - Alternative distance without the Suez Canal on a trade route
  - Alternative distance without the Malacca Strait on a trade route
- Find baseline scenario
- Predicted values of imported calories using counterfactual distances
- Find individual country changes
  - Relative percentage change in imported calories

Distance dataset

- Selected largest port per country
  - Two ports were selected if a country bordered two oceans (eight countries)
- World Port Index → port information
  - Individual port coordinates
- Input port coordinates into computation tool Searoute developed by (Gaffuri, 2024) to compute the shortest maritime route of the most used shipping routes
  - Alternative routes also computed
- Countries with 2 ports → selected the port that results in the minimum distance in the trading country pair

USA to CHN – shortest distance

18,898.44 miles (using the Panama Canal)



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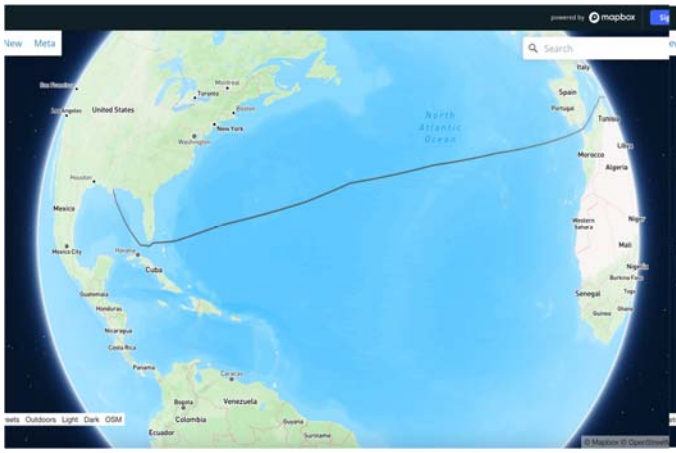
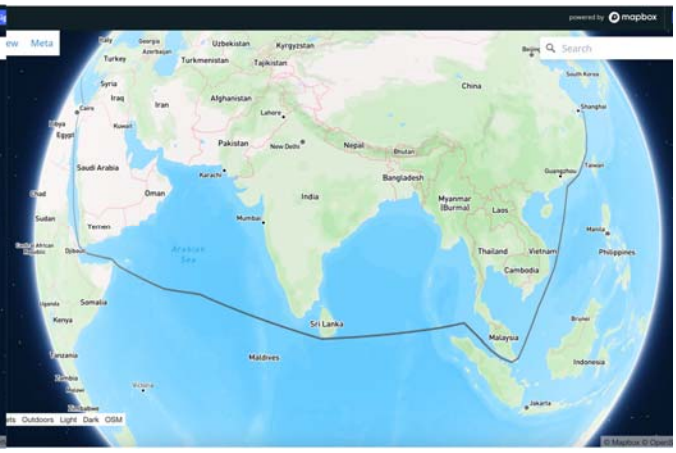
Source: Gaffuri, J. *Searoute*. 2024 using WPI data

USA to CHN – without the Panama Canal

25,501.88 miles (adds 6,603.44 miles without the Panama Canal)





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Source: Gaffuri, J. *Searoute*. 2024 using WPI data

Data

- Bilateral trade values: FAOSTAT
  - Maize, wheat, and rice
  - 12 years (2010-2022)
- Convert MT to calories (use FAO calorie estimates)
- Dyadic characteristics:
  - CEPII → contiguity, common languages, free trade agreements
  - USITC Dynamic Gravity Database → joint membership of WTO and/or EU
  - *Most current year values were applied to years with missing data
- 140 countries with port and trade data
  - 5 countries do not export the grains evaluated
- *Bilateral trade costs are assumed to be the same roundtrip

Table 5.1 Regression Comparison

	Dependent variable:			
	log (Total Import Qty Calories)			
	Dist. Only	Cont. added	FTA added	All others
	(1)	(2)	(3)	(4)
Year	-0.094***	-0.093***	-0.102***	-0.100***
	(0.006)	(0.006)	(0.006)	(0.006)
log(distKM$_{ij}$)	-1.760***	-1.570***	-1.404***	-1.200***
	(0.025)	(0.028)	(0.030)	(0.031)
contig$_{ij}$		1.552***	1.469***	1.507***
		(0.092)	(0.092)	(0.091)
fta_wto$_{ij}$			0.895***	0.710***
			(0.062)	(0.062)
comlang_off$_{ij}$				0.417***
				(0.066)
member_wto_joint$_{ij}$				0.651***
				(0.250)
member_eu_joint$_{ij}$				2.579***
				(0.107)
Constant	226.786***	223.097***	238.735***	232.706***
	(11.799)	(11.742)	(11.748)	(11.686)
Observations	28,235	28,235	28,235	28,235
R^2	0.553	0.557	0.56	0.57
Adjusted R^2	0.548	0.553	0.556	0.566
Residual Std. Error	3.429	3.412	3.399	3.363
F Statistic	125.591***	127.437***	128.672***	132.278***
Note:				*p<0.1; **p<0.05; ***p<0.01

Distance Impact

- For every 1% increase in distance traveled between two countries, the number of imported calories decreases 1.2%

- Expected
  - The further apart a country pair is the less likely they will trade with one another
  - Sharing common traits between trade partners increases trade between countries

Dyadic Characteristics Impact

Characteristic	Impact on Calories traded between Countries
Sharing a border	351.77%
Common language	50.98%
Member of Free Trade Agreement	103.20%
Member of WTO	124.11%
Member of EU	1,219.71%

Counterfactual Results

Top 10 Countries – Panama Canal

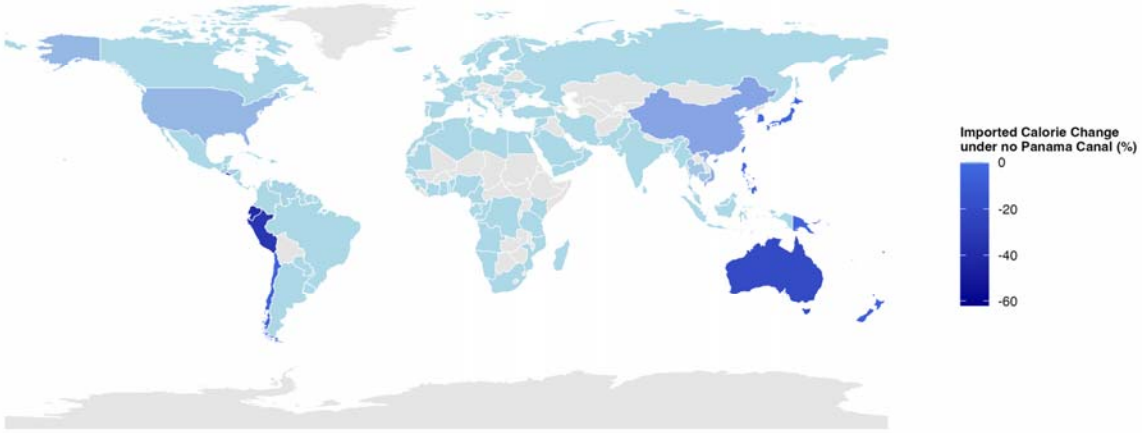
Rank	Country	% change in imported calories	GDP Ranking (out of 209 countries)	Country Population
1	El Salvador	-62.08	104	6,309,624
2	Ecuador	-40.55	63	17,980,083
3	Peru	-32.90	49	33,845,617
4	Samoa	-32.23	198	216,663
5	French Polynesia	-28.19	164	281,118
6	Tonga	-24.83	203	104,597
7	Australia	-20.05	13	26,658,948
8	Fiji	-12.10	165	924,145
9	China, Macao SAR	-7.37	94	678,800
10	New Zealand	-7.11	51	5,223,100

Note: A total of 80 countries experienced a change in imported calories

Panama Canal Map

Percentage Change in Imported Calories by Country with no Panama Canal

Darker colors indicate higher percentage changes



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Source: FAOSTAT and World Port Index

Top 10 Countries – Suez Canal

Rank	Country	% change in imported calories	GDP Rank (out of 209 countries)	Country Population
1	Jordan	-81.37	89	11,439,213
2	Djibouti	-75.04	169	1,152,944
3	Yemen	-70.44	-	39,390,799
4	Iran	-54.03	36	90,608,707
5	United Arab Emirates	-50.46	27	10,483,751
6	Oman	-45.35	66	5,049,269
7	Sri Lanka	-45.30	75	22,037,000
8	Qatar	-44.71	55	2,656,032
9	India	-37.84	5	1,438,069,596
10	Saudi Arabia	-37.56	19	33,264,292

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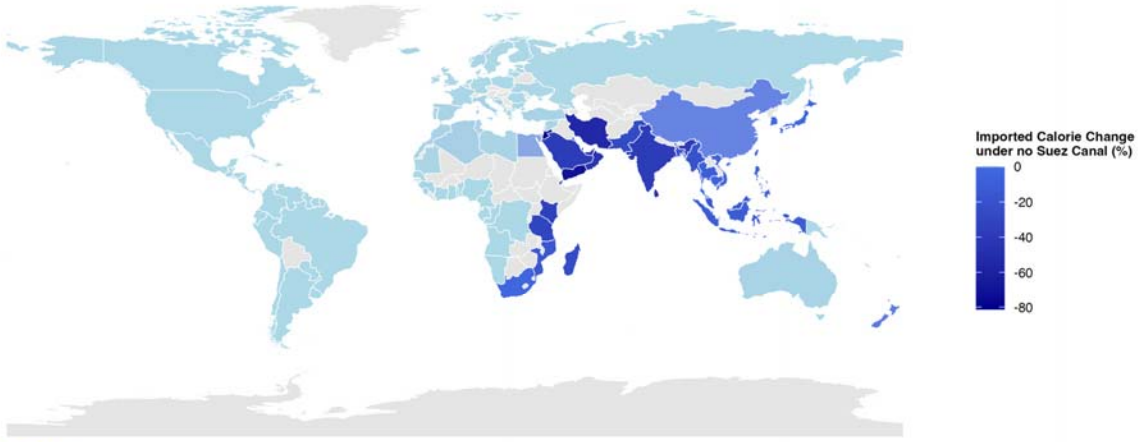
Note: A total of 111 countries experienced a change in imported calories

Suez Canal Map

Percentage Change in Imported Calories by Country with no Suez Canal

Darker colors indicate higher percentage changes



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Source: FAOSTAT and World Port Index

Top 10 Countries – Malacca Strait

Rank	Country	% change in imported calories	GDP Rank (out of 209 countries)	Country Population
1	Malaysia	-19.87	37	35,126,298
2	Bangladesh	-7.10	32	171,466,990
3	Myanmar	-5.09	86	54,133,798
4	Singapore	-3.32	30	5,917,648
5	Thailand	-2.56	26	71,702,435
6	Viet Nam	-1.69	34	100,352,192
7	China, Taiwan Province of	-1.23	-	23,396,049
8	Brunei Darussalam	-0.99	138	458,949
9	Cambodia	-0.95	98	17,423,880
10	Philippines	-0.94	33	114,891,199

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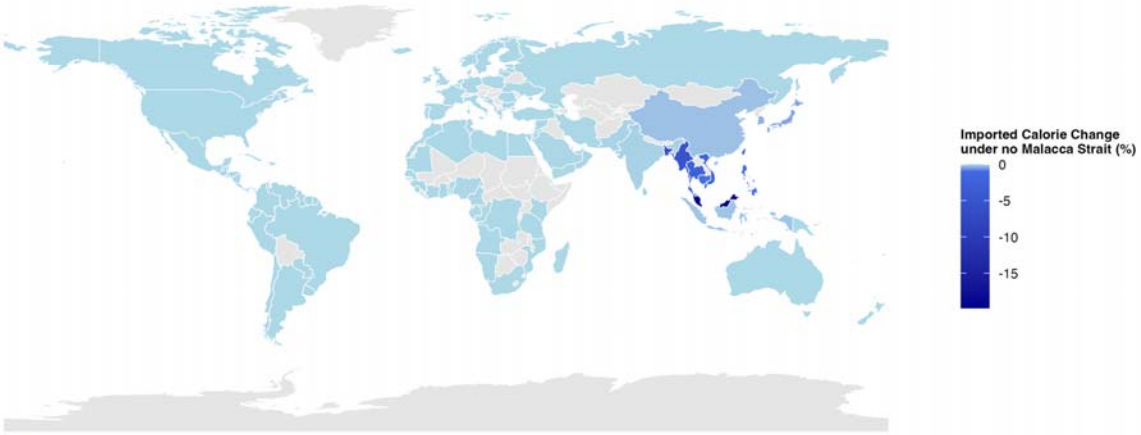
Note: A total of 90 countries experienced a change in imported calories

Malacca Strait Map

Percentage Change in Imported Calories by Country with no Malacca Strait

Darker colors indicate higher percentage changes



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Source: FAOSTAT and World Port Index

U.S. Top Importers under Counterfactuals

(Countries that the U.S. Exports to)

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U.S. Exports – Panama Canal

Rank	Country	% change in imported calories
1	El Salvador	-86.18
2	Ecuador	-84.43
3	Peru	-78.23
4	Chile	-60.21
5	French Polynesia	-56.00
6	Japan	-41.93
7	New Zealand	-39.28
8	Republic of Korea	-35.56
9	Australia	-31.83
10	China, Mainland	-30.21

Note: A total of 18 countries in this group

U.S. Exports – Suez Canal

Rank	Country	% change in imported calories
1	Jordan	-51.73
2	Yemen	-39.46
3	Djibouti	-36.36
4	Oman	-27.50
5	Pakistan	-26.09
6	United Arab Emirates	-25.77
7	Qatar	-25.66
8	Bahrain	-25.30
9	Saudi Arabia	-23.87
10	Kuwait	-17.79

Note: A total of 19 countries in this group

U.S. Exports – Malacca Strait

Rank	Country	% change in imported calories
1	Singapore	-4.87

Note: A total of 1 countries in this group

Limitations

- Exclusion of landlocked countries
- Exclusion of domestic supply of grains
- Exclusion of zero trade flow countries

Further Research

- Inclusion of landlocked countries
- Inclusion of other food products (protein, fruits, and vegetables)
- Change in GHG emissions with longer distances from alternative routes
- Countries indirectly affected and their chokepoint dependency

Conclusions

- Aligns with and supports previous literature (Bailey and Wellesley, 2017)
- Countries of all economic sizes are affected by maritime trade disruptions

- To be aware of for trade negotiations and for other export products outside of these grains (protein, soybeans, fuel, etc.)
- On the flip side for import products outside of agriculture (medicine, technology, etc.)
- Knowing where we (the U.S.) stand risk wise so we can be better prepared for unexpected events

Thank you!

Questions?

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4. Bailey, R., and L. Wellesley. 2017. *Chokepoints and vulnerabilities in global food trade*. London: Chatham House.

Countries bordering two oceans

Atlantic	Pacific	Country
Montreal	Vancouver	Canada
Barranquilla	Buenaventura	Colombia
Puerto Limon	Golfito	Costa Rica
Santo Tomas De Castillo	Puerto Quetzal	Guatemala
Veracruz	Manzanillo	Mexico
Bluefields	Corinto	Nicaragua
Puerto Cristobal	Balboa	Panama
Novorossiysk	Vladivostok	Russia

5 Countries that import only

1. Comoros
2. Cabo Verde
3. Faroe Islands
4. The Solomon Islands
5. Samoa

Method for measuring binary variable impact

- Exponential of the variable coefficient
- Subtract 1
- Multiply by 100 (to get in % terms)

- Ex) sharing a common language between country i and j ($commlang\_off_{ij}$): 0.417
- Exponential of 0.417 = 1.5174
- 1.5174 – 1 = 0.5174
- 0.5174*100 = 51.74%

Binary variable impact on dependent variable

Variable	Coefficient	Impact on dependent Var. (imported calories)
year	-0.100	-9.52%
$contig_{ij}$	1.507	351.32%
fta_wto_{ij}	0.710	103.40%
$commlang\_off_{ij}$	0.417	51.74%
$member\_wto\_joint_{ij}$	0.651	91.75%
$member\_eu\_joint_{ij}$	2.579	1218.40%

We've seen them

- Recent supply chain disruptions:
  - Ever Given lodged in Suez Canal (2021)
    - Political and institutional
  - Russia-Ukraine Crisis (2021)
    - Security and conflict
  - Drought in Panama from El Niño (2022-present)
    - Weather and climate
  - Pirates (ongoing)
    - Security and conflict
  - Others!

Gravity Model

- Study the effects of bilateral trade costs on bilateral trade flows
- Reasons why it's popular and successful:
  - Very intuitive to understand (modeled after Newton's law of gravity)
  - Structural model with strong theoretical foundations (can be used for counterfactual analysis)
  - Represent a realistic equilibrium environment that can simultaneously accommodate multiple sectors, firms, and countries
  - Flexible structure that can be integrated into broader models to study links within a country
  - *Ability to predict bilateral trade flows
    - Easy to use to isolate the impact of transportation trade costs between countries on food security

Gravity Model

- Newton's Gravity: $F = G\frac{(m_1 m_2)}{r^2}$
- Tinberger's Gravity Model: $X_{ij} = \lambda\frac{(GDP_i)^{\alpha}(GDP_j)^{\beta}}{dist_{ij}^{\gamma}}$
- $\ln(X_{ijt}) = \ln(\lambda) + \alpha\ln(GDP_{it}) + \beta\ln(GDP_{jt}) - \gamma(dist_{ij}) + \varepsilon_{ijt}$
- Add in other trade characteristics
  - Shared borders, common language, trade relations, etc.

This paper

- Find the beta on the distance variable through regression analysis
  - Shortest distance between two countries in distance variable
- Three scenarios interchanging data in distance variable:
  - Counterfactual: Alternative distance without the Panama Canal on a trade route
  - Counterfactual: Alternative distance without the Suez Canal on a trade route
  - Counterfactual: Alternative distance without the Malacca Strait on a trade route
- Fitted regression values for the baseline scenario of the imported calories
- Predicted values of imported calories using counterfactual distances
- Exponential values to find individual country changes
- Relative percentage change in imported calories

This paper

- Find the impact distance has on trade between two countries
- Three scenarios interchanging data in distance variable:
  - Counterfactual: Alternative distance without the Panama Canal on a trade route
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- Find baseline scenario of the imported calories between two countries
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Landlocked Countries

- Took the capital city in each country and calculated the driving distance between the cities
  - Often, the capital is also the most populated city
- CEPII:
  - Coordinates of the capital cities of landlocked countries
- Google Maps to calculate the driving distance between city coordinates
- Added the driving distance to the sea distance
  - Ex) Paraguay → China:
    - driving distance between Asuncion, Paraguay (landlocked) to Buenos Aires, Argentina (1,236 KM)
    - PLUS the sea distance between Buenos Aires, Argentina to Shanghai, China (x KM)

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Gravity Equation

- $\log(C_{ijt}) = \beta_1 t + \beta_2 P\_ISO_i + \beta_3 R\_ISO_j + \beta_4 \log(distKM_{ij}) + \beta_5 contig_{ij} + \beta_6 fta\_WTO_{ijt} + \beta_7 commlang\_off_{ij} + \beta_8 member\_joint\_WTO_{ijt} + \beta_9 member\_joint\_EU_{ijt} + \varepsilon_{ijt}$
  - C = imported calories
  - i = exporting country (Partner)
  - j = importing country (Reporter)
  - t = year
  - $distKM_{ij}$ = distance between i and j ports (from each country) in KM
  - $contig_{ij}$ = countries i and j share a common border
  - fta_WTO_{ij} = countries i and j both participate in a free trade agreement according to the WTO
  - $member\_joint\_WTO_{ij}$ = countries i and j both belong to the WTO
  - $Member\_joint\_EU_{ij}$ = countries i and j both belong to the EU
- Fixed Effects for importer and exporter
  - P_ISO_i = A country is the exporting country within a trading country pair
  - R_ISO_i = A country is the importing country within a trading country pair

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Expectations

- Signs of coefficients:
  - Distance (-)
  - Binary variables (+)

Dyadic Characteristics Impact

- Sharing a border:
  - Calories traded between countries to increase 351.77%
- Common language:
  - Calories traded between countries increase 50.98%
- Member of WTO:
  - Calories traded between countries increase 124.11%
- Member of EU:
  - Calories traded between countries increase 1,219.71%
- Belonging to a Free Trade Agreement:
  - Calories traded between countries increase 103.20%

Supplemental material