ECO412 Presentation

THE IMPACT OF U.S. CHINA TRADE WAR – A GRAVITY APPROACH

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November 8, 2024

The U.S.-China Trade War: An Economic Conflict Reshaping Global Trade

- **A Long-standing Rivalry**: Over the past few decades, China's rapid industrialization has challenged the U.S.'s position as a dominant economic power. Concerns over intellectual property, trade imbalances, and state-supported Chinese industries fueled mounting tensions.
- **The Trade War Begins**: In 2018, the U.S. imposed tariffs on Chinese goods to address what it saw as unfair trade practices and to curb the trade deficit. China retaliated, leading to an escalating cycle of tariffs on products ranging from electronics to agricultural goods, worth hundreds of billions of dollars.
- **Global Economic Disruptions**: The ripple effects of this trade war extended well beyond the U.S. and China. Countries like Vietnam, Mexico, and India began to experience shifts in trade patterns as companies and supply chains adapted to avoid tariffs. Global trade flows became more complex, redirecting goods through third-party countries.

Problem Statement: Addressing Trade Disruptions from the U.S.-China Tariff War

- **Limitations of Traditional Models**: Standard gravity models in trade analysis struggle to account for the complexities of tariffs and non-tariff barriers (NTBs), particularly under a trade war scenario. They fall short in capturing trade diversions, welfare impacts, and shifts in global supply chains.
- **Research Gap**: There is a need for a more robust model that can incorporate these complex variables to accurately predict trade flows and economic impacts under tariff scenarios. This research aims to bridge that gap.
- **Objective of the Analysis**: Using a structural gravity model, this study will assess how tariffs and NTBs between the U.S. and China influence bilateral trade, divert trade to other nations, and impact GDP and welfare in multiple economies. The analysis will provide a more comprehensive view of the trade war's ripple effects on the global economy.

Why Gravity Model ?

- **Capturing Trade Flow Patterns**: The gravity model is a well-established tool in international trade analysis. It effectively captures trade flow patterns by linking bilateral trade volumes to economic size and distance, making it ideal for understanding the foundational dynamics between two large economies like the U.S. and China.
- **Incorporating Economic Variables**: The model allows for the inclusion of key economic variables such as GDP, distance, tariffs, and non-tariff barriers (NTBs), providing a comprehensive view of the factors influencing trade. This flexibility is critical in evaluating the complex interactions of tariffs in a trade war.
- **Adapting to Policy Changes**: The structural gravity model extends the traditional model by incorporating multilateral trade resistance terms, trade diversion effects, and tariff scenarios, allowing for an adaptable framework that can simulate different policy impacts under various trade war conditions.
- **Predictive Power with Counterfactual Scenarios**: The model supports counterfactual analysis, enabling predictions of trade flows under hypothetical scenarios (e.g., one-way vs. two-way tariffs). This capability is invaluable in assessing the potential outcomes of policy decisions made during the U.S.-China trade war.

Evolution of Gravity Model

- **McCallum's Border Puzzle (1995)**: McCallum examined trade between Canadian provinces and U.S. states and found that Canadian provinces traded significantly more with each other than with U.S. states, even after accounting for distance and economic size. This phenomenon became known as the "Border Puzzle."
- **Equation Used**: McCallum used a simple gravity model to analyze trade flows:

$$X_{ij} = \alpha \frac{GDP_i \cdot GDP_j}{D_{ij}}$$

  where:
  - X_{ij}: Trade flow from region i to region j
  - GDP_i, GDP_j: Gross Domestic Products of regions i and j
  - D_{ij}: Distance between i and j
  - α: A constant
- **Insight**: This model showed that internal trade (within Canada) was 22 times higher than cross-border trade with the U.S., highlighting the limitations of traditional gravity models in accounting for border-related trade barriers.

Evolution of Gravity Model

- **Anderson and van Wincoop's Structural Gravity Model (2003)**: Anderson and van Wincoop addressed McCallum's Border Puzzle by introducing multilateral resistance terms, which account for both bilateral trade costs and the overall trade resistance each country faces globally.
- **Equation**: The structural gravity model they proposed is:

$$X_{ij} = \frac{Y_i Y_j}{Y_W} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma}$$

  where:
  - X_{ij}: Trade flow from country i to country j
  - Y_i, Y_j: Economic sizes (GDPs) of countries i and j
  - Y_W: World GDP
  - t_{ij}: Trade cost between i and j
  - P_i, P_j: Multilateral resistance terms for i and j
  - σ: Elasticity of substitution
- **Significance**: By incorporating multilateral resistance, this model more accurately reflects trade flows, resolving some of the limitations highlighted by McCallum's findings.

Evolution of Gravity Model

- **Baldwin and Taglioni's Methodological Improvements (2006)**: Baldwin and Taglioni identified common estimation errors in gravity models, particularly the omission of multilateral resistance terms and improper handling of time-invariant variables.
- **Improved Equation**: They proposed including time-varying country fixed effects to control for multilateral resistance terms more effectively:

$$X_{ijt} = \exp(\delta_{it} + \delta_{jt} + \beta Z_{ijt}) + \epsilon_{ijt}$$

  where:
  - X_{ijt}: Trade flow from country i to country j at time t
  - δ_{it}, δ_{jt}: Time-varying fixed effects for countries i and j
  - Z_{ijt}: Vector of explanatory variables (e.g., distance, tariffs)
  - ϵ_{ijt}: Error term
- **Impact**: These methodological improvements reduce bias and enhance the accuracy of gravity model estimations, making them more reliable for complex trade analyses.

Literature Review

- **Foundational Studies on the Gravity Model**: Anderson and van Wincoop (2003) and Baldwin (2007) laid the groundwork for understanding how trade resistance—including tariffs and non-tariff barriers (NTBs)—affects international trade flows. Their work emphasized the importance of accounting for multilateral trade resistance, making the gravity model a reliable tool for analyzing bilateral trade patterns.
- **Focus on Trade Wars and Tariff Impacts**: Recent studies have increasingly applied the gravity model to analyze trade conflicts, such as the U.S.-China tariff war. These studies underscore the importance of incorporating tariff changes and NTBs to capture the trade diversion effects seen when trade shifts to third-party countries like Vietnam and Mexico due to increased U.S.-China tariffs.
- **Advanced Econometric Techniques**: Techniques like Poisson Pseudo Maximum Likelihood (PPML) have become crucial for estimating trade flows, especially under conditions with zero-trade observations and heteroscedasticity. PPML is particularly useful for addressing the complex, asymmetrical patterns that arise in trade wars.
- **Contribution of This Study**: To address the gaps in traditional models, this research employs a structural gravity model enhanced with Non-Tariff Measure (NTM) indices—Prevalence Score. This approach allows a comprehensive assessment of how the U.S.-China trade war has reshaped global trade flows and affected welfare in various economies.

Data Collection and Sources

- **Data Coverage**:
  - **Time Frame**: 2017 to 2021
  - **Countries Analyzed**:
    - United States, China, Canada, Mexico, Germany, Japan, South Korea, India and Vietnam.
  - **Sectors (HS Codes)**:
    - **HS 0-24 (Agriculture)**: Live animals; animal products; vegetable products; animal or vegetable fats and oils; prepared foodstuffs; beverages, spirits, and vinegar; tobacco and manufactured tobacco substitutes.
    - **HS 72-76 (Metals)**: Iron and steel; articles of iron or steel; copper and articles thereof; nickel and articles thereof; aluminum and articles thereof.
    - **HS 85 (Technology)**: Electrical machinery and equipment; sound recorders and reproducers; television image and sound recorders and reproducers; parts and accessories thereof.
    - **HS 87 (Automobiles)**: Vehicles other than railway or tramway rolling stock, and parts and accessories thereof.
- **Primary Data Sources**:
  - **United Nations Comtrade Database**: Comprehensive international trade statistics.
  - **World Bank**: GDP and economic indicators.
  - **CEPII's GeoDist Database**: Geographical distances between countries.
  - **World Integrated Trade Solution (WITS)**: Tariff and non-tariff measures data.

Dataset Preview

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Imp. Value (1000$)	Importer	Exporter	HS	Product Name	Year	GDP (Imp) (mn $)	GDP (Exp) (mn $)	Distance	Duty Type	Avg. Tariff	NTB (Imp)	NTB(Exp)	COB	TC	TD1	TD2	IMP_1
2	9,587.46	Canada	China	1	LIVE ANIMALS	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0	95.14	55.47	0	1	0	1	1
3	830.13	Canada	China	2	MEAT AND EDIBLE MEAT OFFAL	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	23.54	95.14	55.47	0	1	0	1	1
4	3,63,963.52	Canada	China	3	FISH AND CRUSTACEANS, MOLLUSCS AND OTHER AQUATIC I	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.64	95.14	55.47	0	1	0	1	1
5	4,314.42	Canada	China	4	DAIRY PRODUCE; BIRDS' EGGS; NATURAL HONEY; EDIBLE	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	71.96	95.14	55.47	0	1	0	1	1
6	10,882.37	Canada	China	5	PRODUCTS OF ANIMAL ORIGIN, NOT ELSEWHERE SPECIFIED	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0	95.14	55.47	0	1	0	1	1
7	3,364.05	Canada	China	6	LIVE TREES AND OTHER PLANTS; BULBS, ROOTS AND THE	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	5.12	95.14	55.47	0	1	0	1	1
8	1,54,824.20	Canada	China	7	EDIBLE VEGETABLES AND CERTAIN ROOTS AND TUBERS	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	1.63	95.14	55.47	0	1	0	1	1
9	75,726.91	Canada	China	8	EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MEL	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.67	95.14	55.47	0	1	0	1	1
10	56,862.64	Canada	China	9	COFFEE, TEA, MATÉ AND SPICES	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.04	95.14	55.47	0	1	0	1	1
11	4,551.92	Canada	China	10	CEREALS	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	5.1	95.14	55.47	0	1	0	1	1
12	9,925.37	Canada	China	11	PRODUCTS OF THE MILLING INDUSTRY; MALT; STARCHES;	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	5.54	95.14	55.47	0	1	0	1	1
13	83,173.92	Canada	China	12	OIL SEEDS AND OLEAGINOUS FRUITS; MISCELLANEOUS GRA	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.54	95.14	55.47	0	1	0	1	1
14	28,330.26	Canada	China	13	LAC; GUMS, RESINS AND OTHER VEGETABLE SAPS AND EXT	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0	95.14	55.47	0	1	0	1	1
15	3,839.14	Canada	China	14	VEGETABLE PLAITING MATERIALS; VEGETABLE PRODUCTS N	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0	95.14	55.47	0	1	0	1	1
16	14,772.63	Canada	China	15	ANIMAL OR VEGETABLE FATS AND OILS AND THEIR CLEAVA	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	4.24	95.14	55.47	0	1	0	1	1
17	55,694.06	Canada	China	16	PREPARATIONS OF MEAT, OF FISH OR OF CRUSTACEANS, M	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	9.45	95.14	55.47	0	1	0	1	1
18	32,574.50	Canada	China	17	SUGARS AND SUGAR CONFECTIONERY	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	3.66	95.14	55.47	0	1	0	1	1
19	3,956.88	Canada	China	18	COCOA AND COCOA PREPARATIONS	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	22.19	95.14	55.47	0	1	0	1	1
20	59,763.60	Canada	China	19	PREPARATIONS OF CEREALS, FLOUR, STARCH OR MILK; PA	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	11.82	95.14	55.47	0	1	0	1	1
21	1,36,750.35	Canada	China	20	PREPARATIONS OF VEGETABLES, FRUIT, NUTS OR OTHER P	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	5.92	95.14	55.47	0	1	0	1	1
22	55,570.30	Canada	China	21	MISCELLANEOUS EDIBLE PREPARATIONS	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	12.48	95.14	55.47	0	1	0	1	1
23	12,683.08	Canada	China	22	BEVERAGES, SPIRITS AND VINEGAR	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	4.13	95.14	55.47	0	1	0	1	1
24	34,557.70	Canada	China	23	RESIDUES AND WASTE FROM THE FOOD INDUSTRIES; PREPA	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	3.61	95.14	55.47	0	1	0	1	1
25	3,831.76	Canada	China	24	TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	6.95	95.14	55.47	0	1	0	1	1
26	5,35,915.75	Canada	China	72	IRON AND STEEL	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0	95.14	55.47	0	1	0	1	1
27	19,27,341.07	Canada	China	73	ARTICLES OF IRON OR STEEL	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	1.45	95.14	55.47	0	1	0	1	1
28	80,763.43	Canada	China	74	COPPER AND ARTICLES THEREOF	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.3	95.14	55.47	0	1	0	1	1
29	5,522.62	Canada	China	75	NICKEL AND ARTICLES THEREOF	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.1	95.14	55.47	0	1	0	1	1
30	5,69,430.68	Canada	China	76	ALUMINIUM AND ARTICLES THEREOF	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	1.24	95.14	55.47	0	1	0	1	1
31	1,39,89,250.10	Canada	China	85	ELECTRICAL MACHINERY AND EQUIPMENT AND PARTS THERE	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	0.97	95.14	55.47	0	1	0	1	1
32	19,01,989.29	Canada	China	87	VEHICLES OTHER THAN RAILWAY OR TRAMWAY ROLLING STO	2017	16,49,265.64	1,23,10,491.33	10300.58	MFN	3.28	95.14	55.47	0	1	0	1	1
33	8,131.46	Canada	Germany	1	LIVE ANIMALS	2017	16,49,265.64	36,90,849.15	6454.213	MFN	6.76	95.14	43.85	0	1	0	0	1
34	14,214.98	Canada	Germany	2	MEAT AND EDIBLE MEAT OFFAL	2017	16,49,265.64	36,90,849.15	6454.213	MFN	23.39	95.14	43.85	0	1	0	0	1

Variable Descriptions

Variable Name	Description
Imp. Value (1000$)	Import value in thousands of U.S. dollars
Importer	Country importing the product
Exporter	Country exporting the product
HS	Harmonized System (HS) code for product classification
Product Name	Name or type of the product being traded
Year	Year of the trade data record
GDP (Imp) (mn $)	Gross Domestic Product of the importer in million U.S. dollars
GDP (Exp) (mn $)	Gross Domestic Product of the exporter in million U.S. dollars
Distance	Geographical distance between importer and exporter
Duty Type	Type of duty or tariff applied to the product
Avg. Tariff	Average tariff rate applied on the traded product
NTB (Imp)	Non-tariff barriers in the importing country
NTB (Exp)	Non-tariff barriers in the exporting country
COB	Dummy variable indicating if countries share a common border
TC	Trade costs associated with the transaction
TD1	Trade diversion dummy variable 1
TD2	Trade diversion dummy variable 2
IMP_x	Importer-specific dummy variables
EXP_x	Exporter-specific dummy variables
USMCA	Indicator variable for the United States-Mexico-Canada Agreement membership
RCEP	Indicator variable for Regional Comprehensive Economic Partnership membership
ASEAN+	Indicator variable for ASEAN Plus agreement membership
PPI	Producer Price Index, indicating the average change over time in the selling prices received by domestic producers

Model Specification

The functional form of our model, where the dependent variable is represented as a function of independent variables, is given by:

$$X_{ij} = F\left(d_{ij}, Y_i, Y_j, NTB_i, NTB_j, IMP_1 \ldots IMP_9, EXP_1 \ldots EXP_9, TD_1, TD_2, COB_{ij}, 1 + \Delta t_{ij}\right)$$

where,

- X_{ij} : Import value in Country i from Country j (in thousands of USD)
- Y_i : GDP of the importing country i (in million USD)
- Y_j : GDP of the exporting country j (in million USD)
- d_{ij} : Bilateral distance between countries i and j
- NTB_i : Non-Tariff Barrier in the importing country i (Prevalence Score)
- NTB_j : Non-Tariff Barrier in the exporting country j
- IMP_k : Importer dummy variables (for each of the 9 importing countries)
- EXP_k : Exporter dummy variables (for each of the 9 exporting countries)
- TC : Trade creation dummy variable
- TD_1 : Trade diversion dummy variable 1
- TD_2 : Trade diversion dummy variable 2
- COB_{ij} : Dummy variable indicating if countries i and j share a common border
- $1 + \Delta t_{ij}$: Change in tariffs between countries i and j

Baseline Estimation

The model is estimated using two approaches: **Two-Way Fixed Effects (TWFE)** and **Poisson Pseudo Maximum Likelihood (PPML)**.

- **Two-Way Fixed Effects (TWFE)**:

$$\log(\text{Imp. Value}_{ij}) = \alpha + \beta_1 \log(\text{GDP (Exp)}_j) + \beta_2 \log(\text{GDP (Imp)}_i) + \beta_3 \log(\text{Distance}_{ij}) + \beta_4 \log(\text{ATE})$$

$$+\beta_5 \log(\text{NTB (Exp)}_j) + \beta_6 \log(\text{NTB (Imp)}_i) + \sum_{k=1}^{9} \gamma_k \text{IMP}_k + \sum_{k=1}^{9} \delta_k \text{EXP}_k + \theta_1 \text{TD}_1 + \theta_2 \text{TD}_2 + \rho \text{COB}_{ij} + \sigma \text{TC} + \epsilon_{ij}$$

- **Poisson Pseudo Maximum Likelihood (PPML)**:

$$\text{Imp. Value}_{ij} = \exp(\alpha + \beta_1 \text{GDP (Exp)}_j + \beta_2 \text{GDP (Imp)}_i + \beta_3 \text{Distance}_{ij} + \beta_4 \text{ATE} + \beta_5 \text{NTB (Exp)}_j + \beta_6 \text{NTB (Imp)}_i$$

$$+ \sum_{k=1}^{9} \gamma_k \text{IMP}_k + \sum_{k=1}^{9} \delta_k \text{EXP}_k + \theta_1 \text{TD}_1 + \theta_2 \text{TD}_2 + \rho \text{COB}_{ij} + \sigma \text{TC}) + \epsilon_{ij}$$

Baseline Estimation Codes

Simulation of TWFE :

```python
X = data[['log_GDP_Exporter', 'log_GDP_Importer', 'log_Distance', 'log_ATE', 'log_NTB_Exporter', 'log_NTB_Importer', 'COB','TC', 'TD1', 'TD2',
        'IMP_1', 'IMP_2', 'IMP_3', 'IMP_4', 'IMP_5', 'IMP_6', 'IMP_7', 'IMP_8', 'IMP_9', 'EXP_1', 'EXP_2', 'EXP_3', 'EXP_4', 'EXP_5', 'EXP_6', 'EXP_7', 'EXP_8', 'EXP_9']]

y = np.log(data['Imp. Value (1000$)'] + 1)
X = sm.add_constant(X)

twfe_model = sm.OLS(y, X).fit()

print(twfe_model.summary())
```

Python

This code snippet shows the implementation of the Two-Way Fixed Effects (TWFE) methodology for estimating the impact of various factors on trade flows between countries.

Standard PPML Methodology :

```python
X_standard = data[['GDP_Exp', 'GDP_Imp', 'Dist', 'ATE', 'NTB_Exp', 'NTB_Imp', 'COB','TC', 'TD1', 'TD2','IMP_1', 'IMP_2', 'IMP_3', 'IMP_4', 'IMP_5', 'IMP_6', 'IMP_7', 'IMP_8',
            'IMP_9', 'EXP_1', 'EXP_2', 'EXP_3', 'EXP_4', 'EXP_5', 'EXP_6', 'EXP_7','EXP_8', 'EXP_9']]

y_standard = data['Imp. Value (1000$)']

X_standard = sm.add_constant(X_standard)

ppml_standard_model = sm.GLM(y_standard, X_standard, family=sm.families.Poisson()).fit()

print(ppml_standard_model.summary())
```

✓ 0.2s Python

This code snippet shows the implementation of the Poisson Pseudo Maximum Likelihood (PPML) methodology, which handles zero trade flows and addresses heteroscedasticity issues in trade data.

Two-Way Fixed Effects (TWFE) - Results

OLS Regression Results

Dep. Variable:	Imp. Value (1000$)	R-squared:	0.275
Model:	OLS	Adj. R-squared:	0.274
Method:	Least Squares	F-statistic:	166.5
Date:	Wed, 06 Nov 2024	Prob (F-statistic):	0.00
Time:	01:32:18	Log-Likelihood:	-23828.
No. Observations:	9662	AIC:	4.770e+04
Df Residuals:	9639	BIC:	4.787e+04
Df Model:	22		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-1.7977	4.817	-0.373	0.709	-11.239	7.644
log_GDP_Exporter	0.4979	0.547	0.910	0.363	-0.575	1.571
log_GDP_Importer	0.9716	0.551	1.763	0.078	-0.109	2.052
log_Distance	-0.9779	0.050	-19.700	0.000	-1.075	-0.881
log_ATE	-0.4423	0.027	-16.098	0.000	-0.496	-0.388
log_NTB_Exporter	-0.1257	0.288	-0.437	0.662	-0.690	0.438
log_NTB_Importer	-0.5767	0.199	-2.905	0.004	-0.966	-0.188
COB	-0.0017	0.131	-0.013	0.989	-0.258	0.255
TC	-0.8713	1.273	-0.684	0.494	-3.367	1.624
TD1	0.8507	0.611	1.392	0.164	-0.347	2.049
TD2	0.1408	0.670	0.210	0.834	-1.172	1.454

The table presents the OLS regression results for the TWFE model, showing coefficients, standard errors, t-values, and significance levels.

Interpretation of Key TWFE Results

Key Findings and Economic Implications:

- **log_GDP_Exporter (0.497) and log_GDP_Importer (0.971)**: Both positive coefficients indicate that as the economic size of either trading partner increases, trade volume also increases. This supports the gravity model, suggesting that larger economies tend to engage in more trade.
- **log_Distance (-0.977)**: The negative coefficient shows that distance acts as a trade deterrent. For every 1% increase in distance, trade decreases by 0.977%, aligning with theory that geographic raises transportation costs & reduces trade.
- **log_ATE (-0.4423)**: The negative coefficient on average tariffs indicates that higher tariffs are associated with reduced trade flows, as tariffs increase import costs and reduce the competitiveness of foreign goods.
- **log_NTB_Exporter (-0.1257) and log_NTB_Importer (-0.5767)**: The negative coefficients for non-tariff barriers confirm their role as obstacles to trade, with the NTB impact being stronger on the importer side. Non-tariff barriers add compliance costs, making trade less attractive.
- **Trade Diversion Dummies (TD1: 0.8507, TD2: 0.1408)**: The positive coefficients for TD1 and TD2 suggest that trade may be diverted to alternative markets, supporting the concept of trade redirection due to high tariffs.

Conclusion: The TWFE results support classical trade theories and the gravity model, showing that larger economies trade more, and trade barriers (distance, tariffs, and NTBs) reduce trade flows.

```
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:      Imp. Value (1000$)   No. Observations:                 9662
Model:                             GLM   Df Residuals:                     9639
Model Family:                  Poisson   Df Model:                           22
Link Function:                     Log   Scale:                          1.0000
Method:                           IRLS   Log-Likelihood:            -1.6406e+10
Date:                 Wed, 06 Nov 2024   Deviance:                   3.2811e+10
Time:                         01:32:25   Pearson chi2:                 1.03e+11
No. Iterations:                     10   Pseudo R-squ. (CS):              1.000
Covariance Type:             nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          3.7511      0.002   2290.944      0.000       3.748       3.754
GDP_Exp        0.1181      0.000    651.757      0.000       0.118       0.118
GDP_Imp        0.7861      0.000   4152.121      0.000       0.786       0.786
Dist          -0.5732   2.24e-05  -2.56e+04      0.000      -0.573      -0.573
ATE           -0.5345   1.34e-05     -4e+04      0.000      -0.535      -0.535
NTB_Exp       -0.3002      0.000  -2996.685      0.000      -0.300      -0.300
NTB_Imp       -0.0346    7.2e-05   -480.829      0.000      -0.035      -0.034
COB            0.3188   5.63e-05   5659.091      0.000       0.319       0.319
TC             0.9012      0.000   2085.416      0.000       0.900       0.902
TD1           -0.4749      0.000  -2275.802      0.000      -0.475      -0.474
TD2           -0.2889      0.000  -1266.450      0.000      -0.289      -0.288
...
EXP_7          0.3961      0.000   2320.079      0.000       0.396       0.396
EXP_8          1.6805      0.001   2909.912      0.000       1.679       1.682
EXP_9          0.1685      0.000    448.312      0.000       0.168       0.169
==============================================================================
```

The table presents the GLM regression results using the PPML method, including coefficients, standard errors, z-values, and significance levels.

Interpretation of Key PPML Results

Key Findings and Economic Implications:

- **GDP_Exp (0.1181) and GDP_Imp (0.7861)**: Positive coefficients reinforce the gravity model, suggesting that countries with larger GDPs trade more. A 1-unit increase in the exporter's GDP is associated with an 11.81% increase in trade, while the importer's GDP has an even more substantial impact at 78.61
- **Distance (-0.5732)**: The negative coefficient indicates that geographical distance significantly reduces trade, with every 1-unit increase in distance leading to a 57.32% decrease in trade flow, consistent with the idea that longer distances raise transportation costs.
- **ATE (-0.5345)**: This negative coefficient on tariffs suggests a 53.45% reduction in trade flow for every 1-unit increase in the average tariff rate, highlighting tariffs' strong deterrent effect on trade volumes.
- **NTB_Exp (-0.3002) and NTB_Imp (-0.0346)**: Both coefficients for non-tariff barriers are negative, with the exporter's NTB having a more substantial impact on trade reduction. This aligns with the notion that non-tariff barriers limit market access and increase trade compliance costs.

Conclusion: The PPML results provide further evidence in support of trade theory, highlighting the importance of GDP, distance, and tariffs. The negative impact of non-tariff barriers variables underscores the complexity of trade barriers, with both tariffs and non-tariff measures acting as significant trade deterrents.

GE-PPML Estimation

General Equilibrium Poisson Pseudo Maximum Likelihood (GE-PPML):

- GE-PPML is a robust estimator widely used in international trade for general equilibrium analysis.
- The method allows for zero trade values by using a Poisson model, making it suitable for trade data with sparsity or heteroscedasticity issues.
- It includes fixed effects to control for unobserved characteristics between pairs of trading partners (Exporter and Importer fixed effects).
- In a GE framework, GE-PPML enables the evaluation of general equilibrium effects, such as changes in welfare, GDP, and trade impacts due to policy changes.
- The model is effective in measuring the effects of trade agreements, tariffs, and non-tariff barriers, linking to economic theory by accounting for comparative advantage and trade costs.

```
#Fixed Effects Poisson (GE-Model)

model <- fepois(log_Imp_Value ~ log_GDP_Imp + log_GDP_Exp + log_ATE + log_NTB_Imp + log_NTB_Exp + Distance + COB | Exporter + Importer, data = data)
summary(model)
```

Importer and Exporter Fixed Effects

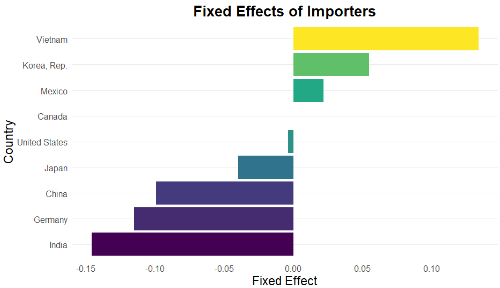
Overview:

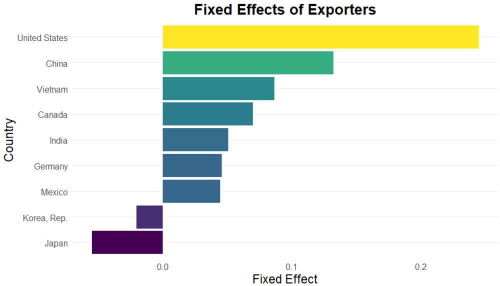
- Fixed effects capture unobserved, country-specific characteristics that influence trade independently of observable variables like GDP or distance.
- In trade theory, these fixed effects help identify inherent advantages or barriers in certain countries, reflecting factors like infrastructure, regulatory environment, and cultural factors.
- High positive fixed effects suggest countries with favorable conditions for trade, while negative fixed effects indicate potential trade barriers or limitations.

```
#Fixed Effects Data frames of Importers and Exporters

exporter_fe <- fixef(model)$Exporter
importer_fe <- fixef(model)$Importer

exporter_fe_df <- data.frame(Country = names(exporter_fe), Fixed_Effect = exporter_fe)
importer_fe_df <- data.frame(Country = names(importer_fe), Fixed_Effect = importer_fe)

print(exporter_fe_df)
print(importer_fe_df)
```

Fixed Effects for Exporters and Importers

Country	Exp. F.E	Imp. F.E
United States	0.245	-0.004
China	0.132	-0.099
Vietnam	0.086	0.134
Canada	0.070	0.002
India	0.051	-0.146
Germany	0.046	-0.115
Mexico	0.045	0.022
Korea, Rep.	-0.020	0.055
Japan	-0.055	-0.040





Interpretation of Importer and Exporter Fixed Effects

Detailed Interpretation of Key Results:

- **Exporter Fixed Effects**: Vietnam's positive exporter effect (0.086) suggests it has benefited as an alternative manufacturing hub, with some trade diverted from China due to the tariffs.
- **Importer Fixed Effects**: Vietnam's high positive importer effect (0.134) indicates that it has become a key destination for imports, possibly due to shifts in supply chains away from China as companies look to avoid tariffs. This shift benefits Vietnam's domestic industries, which now import more raw materials and components. Korea (0.055) and Mexico (0.022) also show positive importer effects, likely reflecting similar supply chain adjustments where these countries have absorbed trade flows redirected from China.

Conclusion: These fixed effects provide empirical insights into each country's trade dynamics:

- High positive exporter fixed effects align with comparative advantage and competitive export sectors.
- Positive importer fixed effects indicate openness to imports, while negative effects suggest protectionist policies or trade barriers.
- The findings highlight the diversity in trade policies and economic structures across countries, supporting theories of comparative advantage, protectionism, and intra-industry trade.

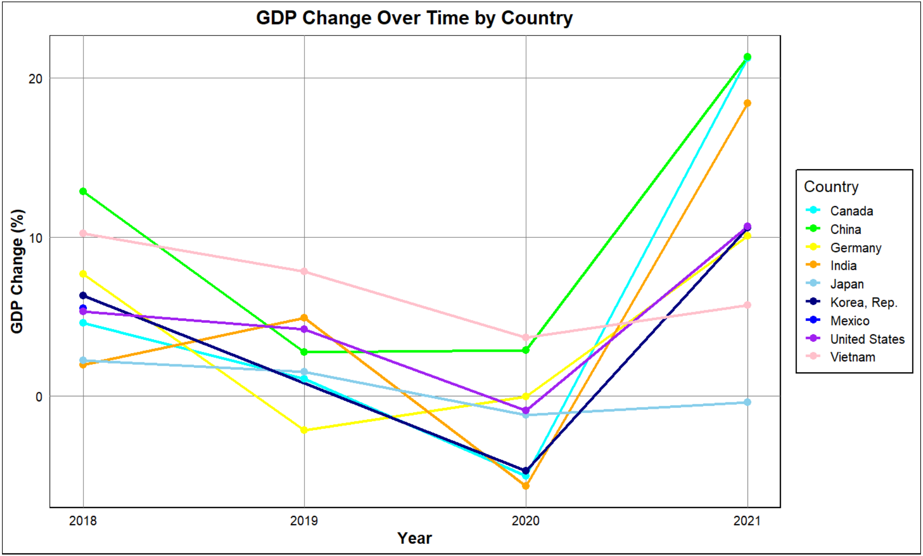
GDP Change

Overview:

- GDP changes reflect the economic health of a country, influenced by factors like trade flows, investment, and production.
- In the context of the U.S.-China tariff war, GDP growth patterns can indicate economic resilience or vulnerability due to shifts in trade policies and supply chain adjustments.
- Countries closely tied to the U.S. or China may experience economic impacts, either positive or negative, depending on their role in redirected trade flows and supply chain restructuring.

```r
#GDP Change

gdp_changes <- data %>%
  group_by(Country = Importer, Year) %>%
  summarize(GDP = mean(GDP_Imp, na.rm = TRUE)) %>%
  arrange(Country, Year) %>%
  mutate(GDP_Change = (GDP - lag(GDP)) / lag(GDP) * 100) %>%
  filter(Year >= 2018) %>%
  ungroup()

print(gdp_changes)
```

GDP Change


GDP Change Over Time by Country
GDP Change (%)
20
10
0
2018
2019
2020
2021
Year
Country
Canada
China
Germany
India
Japan
Korea, Rep.
Mexico
United States
Vietnam

GDP Change

Interpretation of the Graph:

- In 2020, most countries saw a decline in GDP growth, likely due to combined effects of the tariff war and global economic challenges, such as the COVID-19 pandemic.
- By 2021, countries like **Canada** and **India** exhibited significant GDP growth (over 20%), likely benefiting from trade redirection away from China.
- **China** and the **United States** showed moderate growth recovery in 2021, reflecting their ability to adapt, though impacted by ongoing tariffs.

Conclusion:

- The U.S.-China tariff war led to shifts in global trade flows, with some countries benefiting from redirected trade, as reflected in positive GDP growth changes.
- Emerging economies like Vietnam experienced substantial GDP growth as they absorbed supply chain shifts, while countries heavily reliant on the U.S. or China faced mixed impacts.
- The GDP fluctuations provide insights into the broader economic adjustments caused by the tariff war, highlighting the resilience and adaptability of certain economies in the face of trade policy shifts.

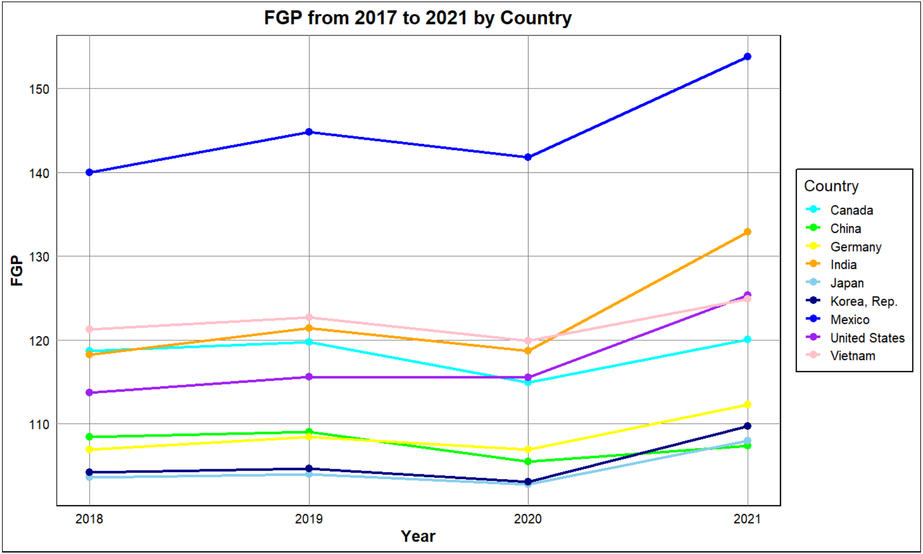
FGP Change

Overview:

- The Foreign Goods Price (FGP) measures the relative price changes of imported goods, reflecting the effects of tariffs, trade policies, and global supply chain adjustments.
- In the context of the U.S.-China tariff war, FGP changes can indicate shifts in import costs due to tariffs imposed on goods, leading countries to seek alternative suppliers or adjust to higher prices on imports.
- Countries that act as alternative suppliers or are affected by redirected demand may experience distinct FGP trends.

```
#FGP Change

fgp_data <- read_excel(file_path, sheet = "GE-Data")

fgp_changes <- fgp_data %>%
  arrange(Country, Year) %>%
  group_by(Country) %>%
  mutate(PPI_Change = (PPI - lag(PPI)) / lag(PPI) * 100) %>%
  filter(Year >= 2018) %>%
  ungroup()

print(fgp_changes)
```

FGP Change



FGP from 2017 to 2021 by Country
150
140
130
120
110
FGP
2018
2019
2020
2021
Year
Country
Canada
China
Germany
India
Japan
Korea, Rep.
Mexico
United States
Vietnam

FGP Change

Interpretation of the Graph:

- From 2018 to 2021, FGP trends reveal a mixed impact across countries. Notably, **the United States** and **India** show a consistent increase in FGP, indicating higher import prices, possibly due to redirected trade flows and increased reliance on non-Chinese suppliers.
- **China** shows a stable FGP until 2021, reflecting controlled import price growth despite the tariffs, potentially due to maintaining domestic production capabilities.
- Emerging economies like **Vietnam** and **Korea, Rep.** show more gradual FGP increases, suggesting they absorbed some redirected trade flows and supply chain adjustments with moderate pricing impacts.
- **Japan** and **Germany** exhibit stable or declining FGP changes over time, potentially indicating diversified supply chains or less dependency on affected goods.

Conclusion:

- The U.S.-China tariff war led to shifts in import costs for many countries, with alternative suppliers experiencing moderate FGP increases as they absorbed redirected demand.
- Countries with higher FGP growth likely faced higher import prices as they shifted away from Chinese goods due to tariffs, while countries with stable FGP trends maintained diversified supply chains to mitigate price volatility.
- These changes illustrate how trade policies impact foreign goods prices, shaping economic resilience and adaptability in international markets.

World and Country-Level Welfare Impact

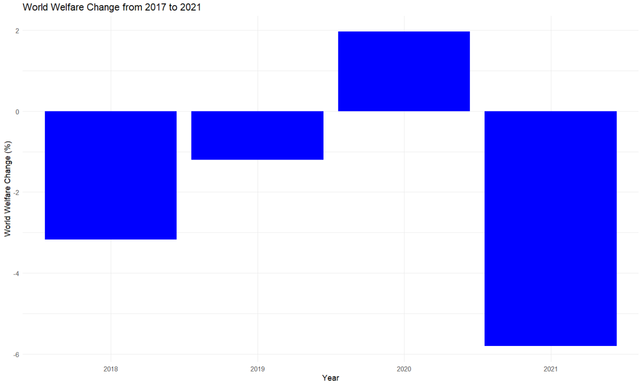
Overview:

- Welfare changes reflect economic well-being, often impacted by trade policies, shifts in global demand, and cost of goods.
- The U.S.-China tariff war has influenced welfare by disrupting trade flows, altering import and export costs, and prompting countries to re-evaluate trade partners.
- Examining welfare on a world and country level allows us to assess the relative economic gains or losses from these shifts.

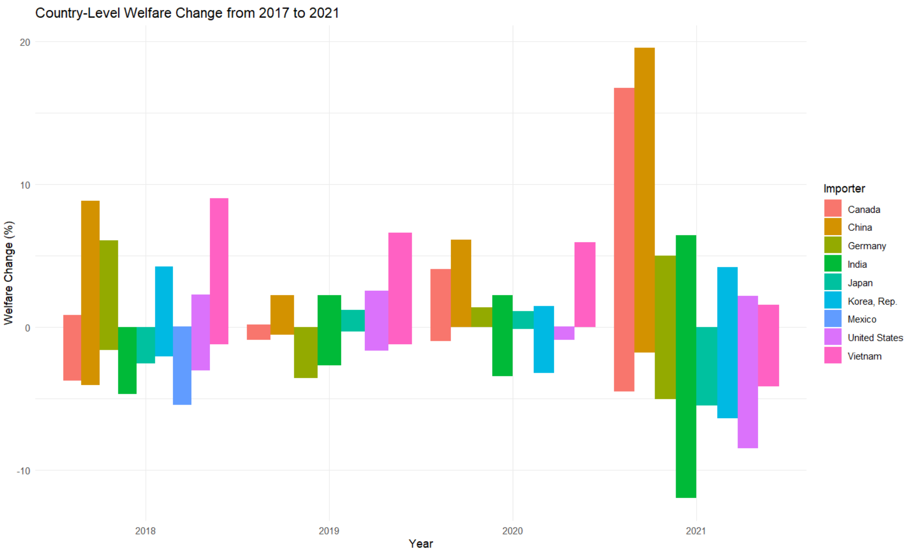
```r
#Overall Welfare Change

welfare_data <- data %>%
  left_join(fgp_changes, by = c("Importer" = "Country", "Year" = "Year")) %>%
  arrange(Importer, Year) %>%
  group_by(Importer) %>%
  mutate(
    GDP_Growth = (GDP_Imp - lag(GDP_Imp)) / lag(GDP_Imp) * 100,
    Welfare_Change = GDP_Growth - PPI_Change
  ) %>%
  ungroup()

# World Welfare (Taking these 9 countries as a Mini World)

world_welfare <- welfare_data %>%
  group_by(Year) %>%
  summarize(World_Welfare = mean(Welfare_Change, na.rm = TRUE)) %>%
  filter(Year >= 2018)

print(world_welfare)
```

World and Country-Level Welfare Impact

```r
# Unique Relative Welfare for Each Country

welfare_data_relative <- welfare_data %>%
  left_join(world_welfare, by = "Year") %>%
  mutate(Relative_Welfare = Welfare_Change / World_Welfare) %>%
  select(Importer, Year, Welfare_Change, World_Welfare, Relative_Welfare)

welfare_stats_table <- welfare_data_relative %>%
  filter(Year >= 2018) %>%
  select(Country = Importer, Year, Welfare_Statistic = Relative_Welfare) %>%
  arrange(Year, desc(Welfare_Statistic)) %>%
  distinct(Country, Year, .keep_all = TRUE)

print(welfare_stats_table)
```



World and Country-Level Welfare Impact



World and Country-Level Welfare Impact

Interpretation of Graphs:

- **World Welfare Change (Graph 1)**: - In 2018 and 2019, world welfare saw negative growth, likely due to early trade tensions and increased import costs from tariffs. - A slight recovery is visible in 2020, perhaps reflecting temporary trade adjustments or relaxed tariffs, but 2021 shows a further decline as trade impacts persisted due to Covid-19.
- **Country-Level Welfare Change (Graph 2)**: - Countries like **Vietnam** (2018) and **Canada** (2020, 2021) experienced higher welfare changes, potentially benefiting from redirected trade as the tariff war encouraged diversifying supply sources. - **China** and the **United States** experienced fluctuating welfare changes mostly negative imapct, reflecting the direct economic impacts of tariffs and shifting trade dynamics. - **Germany** and **Japan** showed relatively stable welfare changes, possibly due to diversified trade networks that mitigated the impact of the tariff war.

Conclusion:

- The U.S.-China tariff war had a mixed impact on welfare, with countries like Mexico and Vietnam benefitting from increased demand as alternative suppliers.
- World welfare fluctuated, reflecting global economic uncertainty and adjustments in trade policies.
- Overall, welfare changes illustrate the resilience of economies able to adjust to new trade dynamics and the challenges faced by countries more directly impacted by tariffs.

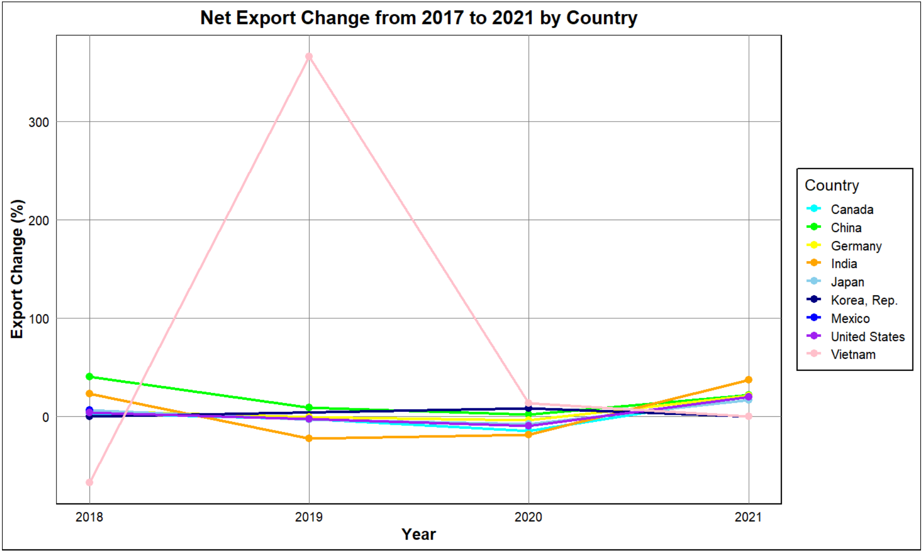
Net Export Change

Overview:

- Net export change captures fluctuations in a country's exports, which can be influenced by external trade policies, economic demand, and competitive market adjustments.
- The U.S.-China tariff war disrupted traditional trade routes, forcing countries to seek alternative markets or suppliers, affecting export values.
- Analyzing the net export change offers insights into how countries adjusted their export strategies and trade partnerships during the trade conflict.

```r
# Net Foreign Export Change

annual_exports <- data %>%
  group_by(Exporter = Importer, Year) %>%
  summarize(Annual_Exp_Value = sum(Imp_Value, na.rm = TRUE)) %>%
  ungroup()

annual_exports <- annual_exports %>%
  arrange(Exporter, Year) %>%
  group_by(Exporter) %>%
  mutate(
    Exp_Value_Change_Pct = (Annual_Exp_Value - lag(Annual_Exp_Value)) / lag(Annual_Exp_Value) * 100
  ) %>%
  filter(Year >= 2018) %>%
  ungroup()

print(annual_exports)
```

Net Export Change



Net Export Change

Interpretation of the Graph:

- **Vietnam** shows a substantial spike in 2019, reflecting an increase in exports potentially due to diverted trade demand as companies shifted away from China.
- **China** and the **United States** experienced relatively stable export changes, indicating adjustments in their export volumes despite the tariff war.
- Countries like **India** and **Germany** maintained a steady export trend, potentially benefiting from demand as alternative suppliers without major surges or declines.
- The overall trends show moderate adjustments for most countries, reflecting the redistribution of trade flows and adjustments in global supply chains.

Conclusion:

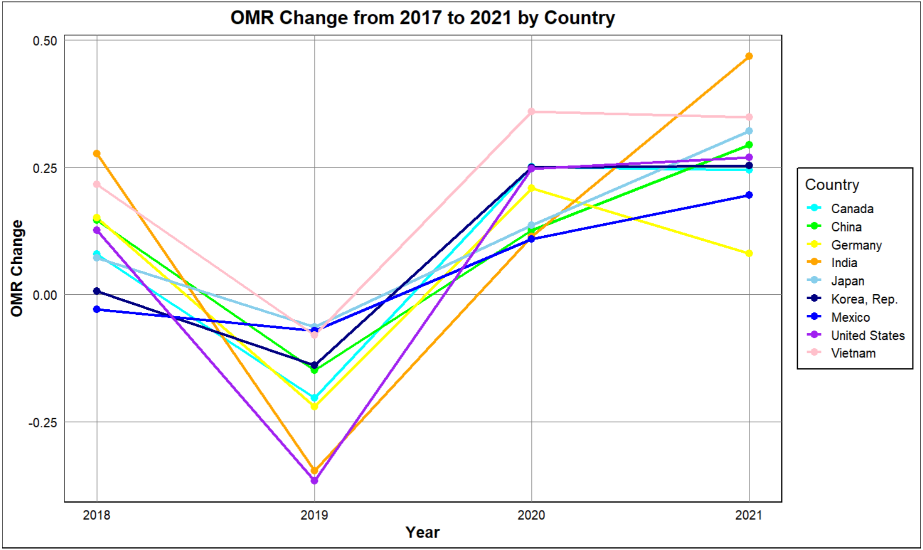
- The U.S.-China tariff war caused shifts in export volumes, with countries like Vietnam benefiting significantly due to redirected demand.
- This disruption reflects how trade conflicts can lead to temporary economic gains for countries that adapt quickly to shifting trade patterns.
- These export changes underscore the adaptability of global trade networks and the ripple effects of major economic policy shifts on international trade dynamics.

Overview:

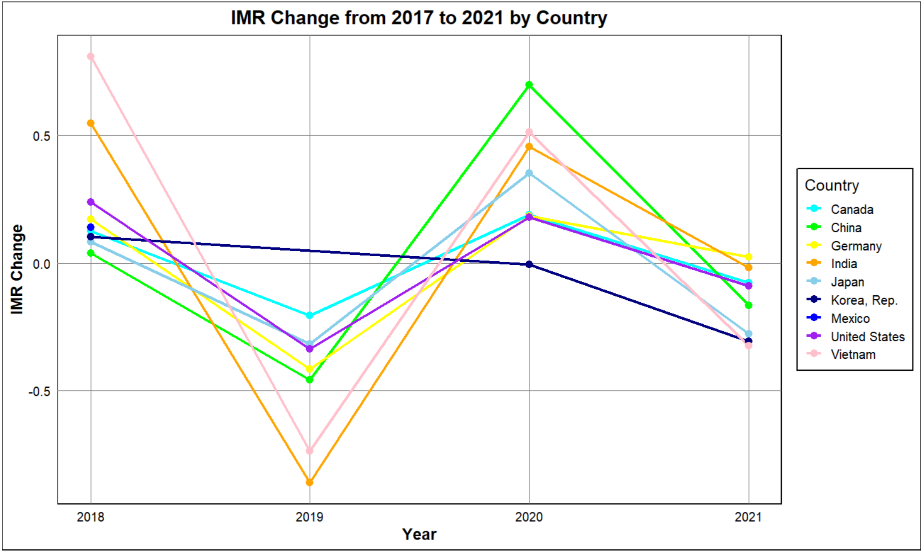
- **Outward Multilateral Resistance (OMR)** and **Inward Multilateral Resistance (IMR)** quantify the global "resistance" faced by countries in exporting and importing goods.
- In the tariff war context, these metrics reveal how policies like tariffs and NTBs (Non-Tariff Barriers) impact a country's trade accessibility and competitiveness.
- **OMR** reflects export resistance influenced by international demand and trade barriers, while **IMR** reflects import resistance influenced by trade policies and agreements.

```r
# OMR and IMR Change

omr_yearly <- list()
imr_yearly <- list()

for (year in unique(data$Year)) {

  data_year <- data %>% filter(Year == year)

  model_ols <- feols(
    log_Imp_Value ~ log_GDP_Imp + log_GDP_Exp + log_ATE + log_NTB_Imp + log_NTB_Exp + Distance |
      Exporter + Importer,
    data = data_year
  )

  omr <- fixef(model_ols)$Exporter
  imr <- fixef(model_ols)$Importer

  imr <- imr + mean(imr, na.rm = TRUE)

  omr_yearly[[as.character(year)]] <- data.frame(Country = names(omr), Year = year, OMR = omr)
  imr_yearly[[as.character(year)]] <- data.frame(Country = names(imr), Year = year, IMR = imr)
}

omr_df <- bind_rows(omr_yearly)
imr_df <- bind_rows(imr_yearly)

omr_changes <- omr_df %>%
  arrange(Country, Year) %>%
  group_by(Country) %>%
  mutate(OMR_Change = OMR - lag(OMR)) %>%
  filter(Year >= 2018) %>%
  ungroup()
```

OMR


OMR Change from 2017 to 2021 by Country
OMR Change
0.50
0.25
0.00
-0.25
2018
2019
2020
2021
Year
Country
Canada
China
Germany
India
Japan
Korea, Rep.
Mexico
United States
Vietnam

IMR


IMR Change from 2017 to 2021 by Country
IMR Change
0.5
0.0
-0.5
2018
2019
2020
2021
Year
Country
Canada
China
Germany
India
Japan
Korea, Rep.
Mexico
United States
Vietnam

OMR and IMR

- **OMR (Outward Multilateral Resistance):**
  - The OMR graph shows a significant dip in 2019 across multiple countries, indicating increased trade resistance at the height of the tariff war.
  - Countries like the United States, China, and Germany show fluctuating OMR levels, reflecting increased trade barriers and market access challenges due to tariffs.
  - By 2020-2021, most countries demonstrate a recovery in OMR, with India and Vietnam showing strong rebounds, likely benefiting from redirected demand as global buyers seek alternatives to the U.S.-China trade corridor.
- **IMR (Inward Multilateral Resistance):**
  - The IMR graph reveals similar trends to OMR, with notable increases in trade resistance in 2019 as countries implement protective tariffs and NTBs.
  - The United States, as a key initiator of the trade war, shows fluctuations in IMR, suggesting shifts in import policy.
  - For countries like China and Vietnam, variations in IMR reflect changes in trade dynamics and the global reorientation of supply chains.
  - By 2021, IMR stabilizes for most countries, indicating an adjustment to the new trade landscape, though higher levels for some nations suggest lasting trade war effects.
- **Conclusion:**
  - The analysis underscores the direct impact of the U.S.-China trade war on global trade resistance. Fluctuations in both metrics during the peak of the tariff war illustrate the economic friction and market access limitations caused by policies.
  - **OMR Trends:** Countries that adapted quickly, such as Vietnam and India, benefited from redirected demand, reducing OMR in later years.
  - **IMR Trends:** Persistent IMR levels in countries like China and the U.S. indicate that the trade war's effects may have long-term implications on their import landscape, affecting future trade agreements and strategic alliances.

Counterfactual Analysis

Scenario 1: Two-Way Tariff Imposition
In this scenario, both the US and China impose tariffs on each other's goods, reflecting mutual tariff actions. We modify the model by adjusting Δt_{ij} to represent existing tariff changes. This scenario evaluates:

- The effects of higher two-way tariffs on trade diversion to third-party countries such as **Vietnam** and **Mexico**.
- The impact on **GDP** and **welfare** for both the US, China, and third-party countries.
- The consequences for **consumer welfare** due to increased goods prices.

Scenario 2: One-Way Tariff Imposition
In this scenario, only the **US** imposes tariffs on Chinese imports, without reciprocal tariffs from China. We adjust Δt_{ij} accordingly to reflect this one-sided tariff imposition. This scenario examines:

- How US tariffs lead to trade diversion to countries like **Vietnam** and **India**.
- Potential for **increased Chinese exports** to the US in the absence of retaliatory tariffs.
- Effects on **consumer** and **producer welfare** in the US and China.

Empirical Results

Exporter	Year	Trade Inflows (Scenario 1)	Trade Inflows (Scenario 2)
China	2017	34,361,200	36,256,583
China	2018	37,498,354	39,756,225
China	2019	32,552,173	35,350,435
China	2020	39,946,464	42,349,826
China	2021	47,408,804	50,857,830
United States	2017	67,142,168	68,652,184
United States	2018	74,830,212	76,488,607
United States	2019	60,820,817	62,034,908
United States	2020	62,472,577	63,549,691
United States	2021	81,794,548	83,409,851

Interpretation of Results:

- **Trade Inflows Under Scenario 1:** The reduction in trade inflows for both China and the US in 2019 demonstrates the impact of mutual tariffs, with diverted trade flows enhancing third-party nations' trade shares.
- **Trade Inflows Under Scenario 2:** The one-way tariff scenario shows marginally higher trade inflows for both the US and China in comparison to Scenario 1, as China benefits from continued access to the US market. This result aligns with **market substitution effects** where consumers substitute higher-cost domestic products for imported goods.
- **Long-Term Impact:** The consistently increasing trend in Chinese trade inflows in Scenario 2 highlights the resilience of Chinese exports when there is no reciprocal tariff, reflecting China's **competitive pricing** and **production efficiency**.

These results underscore the importance of strategic tariff policies, demonstrating that while mutual tariffs can suppress bilateral trade significantly, one-sided tariffs have differential impacts, benefiting the un-tariffed country through persistent demand in foreign markets.

Explanation of Trade Impact Indicators:

- **PTI (Partial Trade Impact):** Measures the immediate impact of a trade agreement on trade flows between member countries without considering broader economic adjustments.
- **MTI (Modular Trade Impact):** Evaluates the trade impact by segmenting the effects of trade agreements on countries that are members (**Yes**) versus non-members (**No**), capturing differential gains.
- **GETI (General Equilibrium Trade Impact):** Assesses the overall impact of trade agreements within a general equilibrium framework, accounting for indirect effects across the economy, including changes in prices and output in response to the agreement.

Members	Coefficient	PTI	MTI		GETI	
			Yes	No	Yes	No
USMCA	1.13	3.11	2.99	2.73	3.95	3.86
RCEP	1.65	5.23	1.63	1.55	2.26	2.07
ASEAN+	-1.73	0.18	0.49	0.41	0.27	0.20
Common Border	-0.21	0.81	0.89	0.79	0.96	0.88

- **USMCA:** United States-Mexico-Canada Agreement
- **RCEP:** Regional Comprehensive Economic Partnership
- **ASEAN+:** Association of Southeast Asian Nations Plus

Conclusion

- The analysis underscores the **profound impact** of the **US-China trade war** on global trade dynamics, illustrating how **bilateral tariffs disrupt traditional trade flows** and create **new opportunities for third-party nations**. The imposition of **two-way tariffs** has not only curtailed trade between the US and China but has also catalyzed a **reconfiguration of global trade patterns**, benefiting economies like **Vietnam** and **Mexico** that emerged as **alternative sources** for goods previously exchanged between the two superpowers.
- This study's **counterfactual analysis** and **coefficient estimations** reveal that **strategic trade agreements**, such as **USMCA** and **RCEP**, play a **pivotal role in buffering member nations** against trade shocks and **fostering resilience**. The ripple effect on **GDP, welfare,** and **multilateral trade costs** (as evidenced by **OMR** and **IMR**) highlights the importance of **adaptive trade policies** to maintain **economic stability**.
- Overall, the findings emphasize the importance of a **multilateral approach** in trade policy, where countries actively engage in **agreements that enhance economic resilience**. The observed **trade diversions** and **welfare impacts** underscore the need for **cooperation** and **flexible policy frameworks** to navigate **future trade disruptions** and promote **sustainable growth**.

Thank You!

Alok Kumar - 210101