TILBURG UNIVERSITY

MASTER'S THESIS MSC ECONOMICS

The Evolution of the Distance Effect on Bilateral Trade

EVIDENCE FROM THE GRAVITY MODEL OF INTERNATIONAL TRADE

June 2021

Author

MIQUEL SOLER

Student number

SNR: 2064021

Supervisor

PROF. DR. HARRY VAN DALEN

Second Reader

DR. MALIK ÇÜRÜK

ABSTRACT

This paper analyzes the elasticity of bilateral trade with respect to geographical distance between two countries. Distance can be seen as a natural barrier to trade as longer distances generate higher trading costs. The questions asked are what is the impact to bilateral when distance increases? And how has this effect evolved since 1949? This effect was quantified through an implementation of the Gravity Model of International Trade. These questions are answered by first by measuring the global effect by using data on all sovereign states for each year and then dividing our sample into twenty different subregions. Following the trend established by previous literature, we observe that the effect of distance on bilateral trade continues to increase over time. However, we also find subregion-specific trends which diverge from the established global direction such as the case for Southeast Asia, who's current trend is declining or the case of Eastern Europe, which is mostly characterized by the collapse of the Soviet Union.

ACKNOWLEDGEMENTS

First and foremost, I would like to sincerely thank my supervisor, Harry van Dalen, for guiding me through this process while always showing great interest throughout the development of my research.

I would also like to thank Dr. Malik Çürük for suggesting the CEPII database on gravity estimations.

Finally, I would like to thank the Stack Overflow community for helping me troubleshoot a multitude of issues within my code.

CONTENTS

1. INTRODUCTION

Shortly after World War II the world's nations have been focused on the reduction of man-made barriers to trade. The General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO) were built with the objective of regulating and reducing tariffs and quotas on international trade. Other international economic institutions such as the World Bank (WB) and the International Monetary Fund (IMF) tackled the income and currency barriers to trade respectively. Consequently, international trade started to surge.

Additionally, countries started creating bilateral free trade agreements in order to eliminate tariffs between each other. In the case of the European Union, this was a multilateral agreement with a deeper level of economic integration. Therefore, there is no doubt that the world economy has become increasingly interdependent over the last century. Economic growth has been accelerated thanks to this economic globalization process, however, while countries can reject protectionist policies and keep participating in new broader trade agreements, they will always need to face the obstacle of distance. Even after continuing to combat trade barriers with deeper trade agreements such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), there will always be natural barriers to trade which cannot be eradicated.

Therefore, as the world keeps globalizing and our economies become increasingly interdependent, the effect of natural barriers becomes a predominant force which overshadow the effect of tariffs, quotas, and other government-set barriers to trade. Thus, it has become increasingly important to analyze and measure the effects of geographical distance over trade in order to properly quantify trading costs and be able to forecast future international trade.

During our research, we will quantify the effect of the main natural barrier, distance between countries, in order to answer the principal question of the paper: How has the effect of distance between nations affected international trade over time? In order to reveal this, we will plot the effect of distance on international trade over time in order to observe if, with the help of new technologies, we have mitigated the magnitude of its effect.

Additionally, as it would be naïve to assume that all regions have followed the same course, we will branch out our research by analyzing twenty different subregions. Therefore, we will be able to illustrate how different economies have followed different paths and are retain various distinct trends. Therefore, on top of our main research question, we will also attempt to reveal how this effect has diverged between different subregions.

The structure of this paper is as follows. In section 2 we will provide an examination of existing literature which deal with the subjects of the gravity model of international trade and measure the effect of distance on bilateral trade. In section 3 we layout the different datasets that are used throughout our research and discuss the models which will be used to answer the research questions. In section 4 we will present the results of the study by illustrating the coefficients of our models and interpreting its implications. In section 5 we will undergo a process of data validation to explore if our results are consistent. Finally, in section 6 we will present our concluding remarks and discuss any issues which may have hindered our model's precision.

2. LITERATURE REVIEW

As international trade significantly increases after World War II and as new technologies improve the efficiency of the transportation industry and infrastructure, one would assume that the effect of distance on bilateral trade has been diminishing over time.

Figure 1: Value of exported goods as share of GDP, 1827 to 2014

Source: Foquin and Hugot (CEPII 2016)

However, our review of the literature seems to suggest that the opposite effect is true. The literature which we explore for this paper is based on the gravity model for international trade. As stated by Head and Mayer (2014), there are several estimation approaches to this model. Head and Mayer (2014) provides several theory-consistent econometrical methodologies with a strong microeconomic foundation. Additionally, the authors cover the history of the gravity model and warns us about the biased and potentially misinterpreted results that come from naïve approaches.

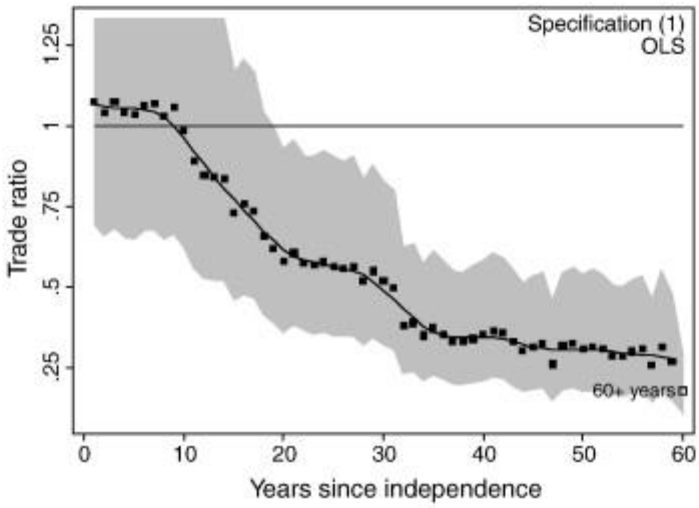
Head et al (2010) makes use of the standard estimating procedure as described in Head and Mayer (2014) for a fixed effects estimation. We will focus on this approach as the authors affirm that it does not contain strong structural assumptions on the underlying model, is recommended by major empirical trade economists, and provides consistent estimates of the dyadic effects (variables describing the interaction between two countries), which include distance.

Head et al (2010) uses the gravity model for international trade in order to determine the effect of a nation's independence on post-colonial trade. They represent the gravity equation through x_{ijt}, representing the exports from the exporting country *i* to the country *j* in year *t*.

$$lnx_{ijt} = lnG_t + lnM_{it}^{ex} + lnM_{jt}^{im} + \delta D_{ijt} + u_{ijt}$$

Where M_{it}^{ex} and M_{jt}^{im} (monadic effects) reflect the attributes of the exporter *i* and the importer *j* for the time period and D_{ijt} and u_{ijt} (dyadic effects) represent the observed and unobserved determinants for trade costs. The set of dyadic D_{ijt} are divided into two groups: time-variant control variables which represent the colonial status of the country and time-fixed effects such as distance, shared borders, language, currency, legal origins, trade agreements, and GATT/WTO membership. Heat et al, are then able to illustrate the effect of gaining independence on the new country's share of trade with its former metropole:

Figure 2: Non-parametric independence effects



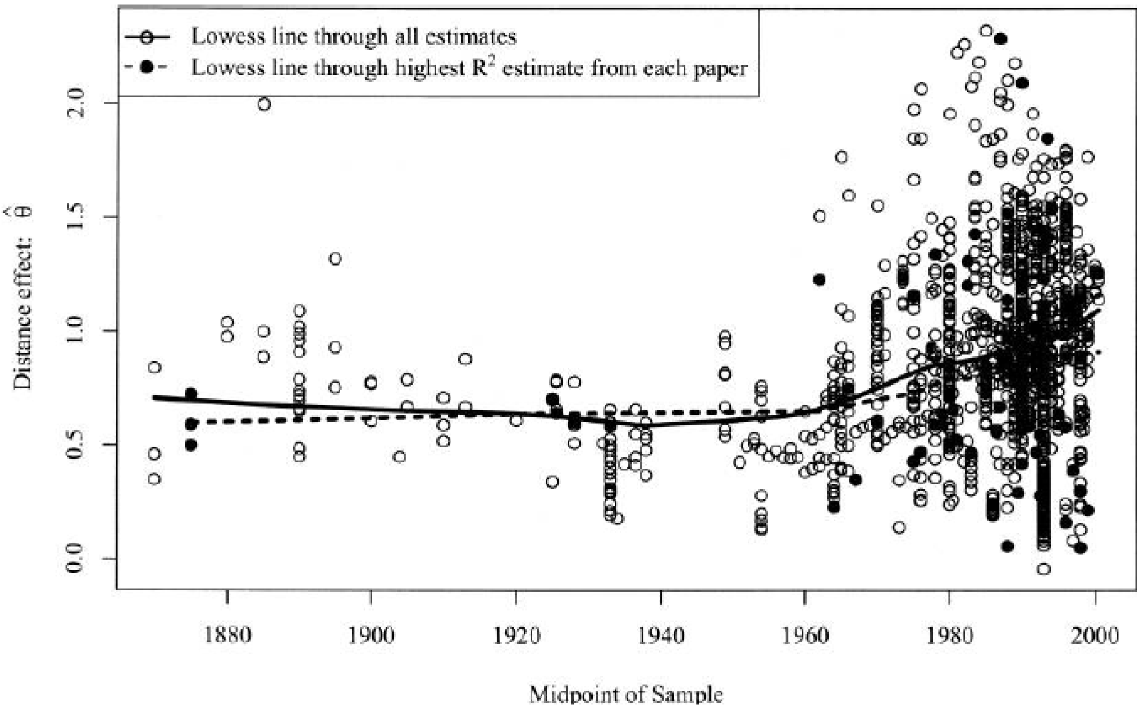
Source: Head et al (2010, p. 6)

As one might expect, the share of trade with their former metropoles rapidly declines as they stop depending on them and instead open to the rest of the world. The paper continues by comparing independence events and categorizing by amicable and hostile separations. While trade falls more rapidly during hostile separations, on the long-run, the paper finds that the deterioration of trade is equivalent in both cases.

While focused on a different topic, Head et al (2010) provides a well-structured methodology that can be assimilated in order to create our own design with a different focus in mind, using an up-to-date dataset in order to analyze different countries and sub-regions.

Finally, Disdier and Head (2008) analyze our main interest – the evolution of the impact of the effect of distance on bilateral trade. However, this paper is constructed under a distinct methodology. The authors collect 1467 estimates from 103 different papers in order to construct a meta-regression. The paper finds a slight decrease in estimated distance effects through 1870 and 1950, afterwards the estimated effect begins to rise.

Figure 3: The Variation of the Distance Effect Relative to the Midperiod of the Data Sample



Source: Disdier and Head (2008, p 45)

These findings, as stated by the authors “represent a challenge for those who believe that technological change has revolutionized the world economy, causing the impact of spatial separation to decline or disappear”.

Disdier and Head (2008) are able to show how closely correlated is distance with bilateral trade after estimating a mean elasticity of 0.9. Meaning that an increase of distance between two countries of 1% would decrease their trade flows by 0.9%. Leamer (2007) remark that this effect is “possibly the only important finding that has withstood the scrutiny of time and the onslaught of economic technique”. Therefore, it would be valuable to describe how the impact of this effect has changed over time in order to attempt to identify any possible trendlines which would allow us to predict if we are heading towards a world where distance is becoming decreasingly important or if this effect has already consolidated in a steady value. Disdier and Head (2008) found that the effect of distance increased between the periods of 1950 – 2000. This may seem counter-intuitive for those who believe that the new technologies of the modern world would allow us to better tackle the transportation costs of trade. Therefore, it is intriguing to check whether we arrive to a similar conclusion and check for any turning points after the year 2000. As the data ends at the year 2000, it would be reasonable to believe that this trend would once again decrease as the global internet usage drastically rose over the last 20 years.

As our approach will be focused on the effect of distance, the new covariates, unexplored by other models, will also be focusing on the other geographical conditions which may influence bilateral trade. As the effect of distance can be affected by the landscape of a country, we will include covariates which will categorize the different terrains and environments.

3. DATA & METHODOLOGY

In order to determine the effect of distance between countries on their international trade we will make us of the gravity model of international trade.

This model was first introduced by Jan Tinbergen (1962). He contrasted the patterns of bilateral trade flows between two countries with Newton's universal law of gravitation. In physics we can describe the force of gravity to be proportional to the mass of matter and inversely proportional to the distance between them. Similarly, in economics Jan Tinbergen describes trade flows between two countries as "proportional to the gross national products of those countries and inversely proportional to the distance between them."

$$T_{A,B} \propto \frac{(GDP_A)^{\alpha}\,(GDP_B)^{\beta}}{(Dist_{AB})^{\zeta}}$$

With α, β, ζ ≈ 1.

This model is used in international economics in order to predict trade flows between two countries after considering their economic size (GDP) and the distance between them. Chaney (2011) acknowledges that this model has been proven to be stable over time, across different countries, and using different econometric specifications. The theoretical model which we will use is based on the logit model as described by Head et al (2010):

$$lnBilateral\,Trade_{ijt} \;=\; lnGt + ln\beta_1 Distance_{it} + ln\beta_2 GDP^{ex}_{it} + ln\beta_3 GDP^{im}_{jt} + \delta D_{ijt} + u_{ijt}$$

Where G represents the model's constant, Distance represents the geographical distance between the origin and destination countries, GDP^{ex} and GDP^{im} represent the nominal level of GDP for that year for the exporter and importer countries respectively, *D* represents the observed time-variant control variables and time-fixed effects described in table 1, and *u* represents the error term.

Additional factors have also been considered. In papers such as in Disdier and Head (2008), where dummy variables are introduced in order to control for geographical features such as “Single Continent” (stating if both countries pertain to the same continent) and controls for common language and trade agreements. I will be controlling for these confounders as well as exploring additional geographical features by controlling for landlocked/island nations, estimating the roughness of their terrain through the terrain’s altitude changes and including the percentage of terrain which is considered tropical or a desert. I believe this helps control for the challenges faced by mountainous landlocked countries such as Austria and Switzerland as well as controlling for the challenges to trade caused by rough climates and terrains.

The primary database that is used is the CEPII database on gravity estimations. This dataset collects data from all country pairings between 1948 and 2019, including bilateral trade flows from both the databases from the IMF and the UN, trade facilitation measures (GATT/WTO membership and trade agreements), proxies for cultural proximity (language, religion, colonial ties), macroeconomic indicators (GDP), and geographical distance. Geographical distance reflects the distance between the coordinates of the geographical centroid of each country. However, this is done after considering the spatial distribution of economic activity within each country. Therefore, if we take Russia as an example, its geographical centroid will not be somewhere in Siberia, but will instead be much closer to Moscow. We use this database to create our dependent variable: *l_tradeflow_mean* by creating an average of the bilateral tradeflows reported by origin and destination countries. Our number of observations ultimately depend on the availability of this data. Due to the limited availability on tradeflow data, we choose to merge tradeflow data by using both the IMF and Comtrade as our tradeflow sources. While this could potentially be an issue, it is important to remark that, for observations where both sources have available data, their respective averages converge to the same value. Therefore, we are able to make use of 1159 observations for year 1949 and 24,399 observations for year 2019. This increase is not only explained by better data availability, but also since the number of countries has increased from 106 in 1949 to 195 in 2019, the maximum number of possible observations has increases from 11,130 to 37,830.

We also make use of the dataset of terrain ruggedness and other geographical characteristics from Nunn and Puga (2012). Their dataset includes a population-weighted ruggedness index which is constructed by calculating the differences in elevation between a grid of 30 by 30 arcsecond cells (≈0.8km^2). This is then weighted by the population in each cell using the LandScan dataset (Oak

Ridge National Laboratory, 2001). Additionally, we also make use of data on the percentage of land classified as tropical or a desert which is also included in this dataset.

Table 1: List of Variables Used

Variable name	Content
l_tradeflow_mean	Natural logarithm of tradeflows (mean of values reported by Comtrade and the IMF)
const	Constant
l_distw	Natural logarithm of population-weighted distance between most populated cities (km)
l_gdp_o	Natural logarithm of GDP (current thousands US$) of the origin country
l_gdp_d	Natural logarithm of GDP (current thousands US$) of the destination country
l_pop_o	Natural logarithm of the population (thousands) of the origin country
l_pop_d	Natural logarithm of the population (thousands) of the destination country
contig	Dummy equal to 1 if countries are contiguous
comlang_off	Dummy equal to 1 if countries share common official or primary language
comlang_ethno	Dummy equal to 1 if countries share a common language spoken by at least 9% of the population
comcol	Dummy equal to 1 if countries share a common colonizer post 1945
col45	Dummy equal to 1 if countries are or were in colonial relationship post 1945
comrelig	Religious proximity index [0 - 1]
gatt_joint	Dummy equal to 1 if both countries are GATT members during that year
wto_joint	Dummy equal to 1 if both countries are WTO members during that year
comreg	Dummy equal to 1 if both countries are in the same UNSD statistical region
island_o	Dummy equal to 1 if origin country is an island nation
island_d	Dummy equal to 1 if destination country is an island nation
landlocked_o	Dummy equal to 1 if origin country is a landlocked nation
landlocked_d	Dummy equal to 1 if destination country is a landlocked nation
rugged_popw_o	Population-weighted terrain ruggedness index for origin country
rugged_popw_d	Population-weighted terrain ruggedness index for destination country
desert_o	Percentage of origin country covered by sandy desert, dunes, rocky or lava flows
desert_d	Percentage of destination country covered by sandy desert, dunes, rocky or lava flows
tropical_o	Percentage of each origin country that has any Köppen-Geiger tropical climates.
tropical_d	Percentage of each destination country that has any Köppen-Geiger tropical climates.

After consolidating our dataset trough, we start by removing all observations which contain countries that did not exist at that specific year and the observations which do not have any trade flow data as reported by either importer or exporter from either source (Comtrade or IMF). As a final step, we split the dataset by year, creating a separate csv file for each year (this is necessary due to the vast number of rows, which well exceed the capacity for most software that we can work with.

After determining our variables, we create a log-log model, which is the standard model for the gravity model of trade, having each country's yearly bilateral exports and imports with each other as our dependent variable. This model reflects by which percentage bilateral trade will decrease if distance increases by 1% (elasticity). Due to an inconsistent availability on data over the years from our sources of import and export data (Comtrade and the IMF), we create an average of the bilateral trade flows as reported by both origin and destination countries by both Comtrade and the IMF. This method allows us to minimize the number of observations we inevitably must exclude due to lack of data on the dependent variable. and their GDP (constant prices) and distance as the main regressors and include all other covariates displayed above. We run this regression once for every year in our database (1949 – 2019).

Once we have created our regressions, we focus on the coefficient for the distance parameter and plot it against time in order to view its evolution over time. Additionally, we split up our global regressions into different geographical subregions (geoscheme) as defined by the United Nations Statistics Division (UNSD). Due to reduced data availability, for this paper, the subregions of Melanesia, Micronesia, and Polynesia have been consolidated into a single subregion: Pacific Islands.

Figure 4: Statistical Regions Used in Estimations.

Source: United Nations Statistics Division. Antarctica is not shown

After recreating our models for each specific subregion, we are able to identify how distance has affected different subregions over time. Optimistically, we will be able to recognize different stages and trending points which might be able to tell us if a certain subregion is or has been lagging in comparison with other subregions.

4. RESULTS

4.1 Analyzing covariates:

For the year 2019, we obtain a coefficient of -1.55 for *l_distw*. As this is a log-log model (both dependent and independent variables being in logarithms), its result indicates that an increase of the weighted distance parameter by 1% decrease the dependent variable, *tradeflow_mean* by 1.55%. In other words, the elasticity of trade with respect to distance for 2019 is 1.55.

Similarly, we observe the coefficients for *l_gdp_o*, *l_gdp_d*, *l_pop_o*, and *l_pop_d* of 1.52, 1.03, -0.26, and -0.03. As all of these results are highly significant (p-value practically equal to 0), we interpret that a country will increase their bilateral trade by 1.52% when their GDP grows by 1% and will increase their bilateral trade by 1.03% when the GDP of its trading partner increases by 1%.

In the case of population, the effect reduced, but it is also reversed. An increase of population of 1% will result in a decrease of trade flows by 0.26% and a 1% increase of the trading partner's population will decrease trade flows by 0.03%. However, as an increase of population will generally also increase a country's GDP, it's overall effect will still be positive as the negative coefficients are much lower than the positive coefficients for GDP. Therefore, if two countries have the same level of GDP, the country with a lower population will have higher trade flows. Thus, a high GDP per capita positively influences bilateral trade flows.

Figure 5: 2019 Regression Summary Results

	coef	std err	t	P>|t|
const	-24.4249	0.335	-72.919	0
l_distw	-1.4424	0.025	-57.021	0
l_gdp_o	1.5293	0.013	114.081	0
l_gdp_d	1.0529	0.013	78.966	0
l_pop_o	-0.2372	0.015	-15.641	0
l_pop_d	-0.0315	0.015	-2.097	0.036
contig	1.0712	0.136	7.878	0
comlang_off	0.4756	0.088	5.377	0
comlang_ethno	0.246	0.085	2.888	0.004
comcol	0.7074	0.068	10.413	0
col45	0.8118	0.187	4.335	0
comrelig	0.0497	0.079	0.632	0.528
wto_joint	0.8977	0.05	17.985	0
rugged_popw_o	-0.0552	0.022	-2.529	0.011
rugged_popw_d	-0.0987	0.022	-4.476	0
desert_o	0.0121	0.002	7.792	0
desert_d	0.0125	0.002	8.039	0
tropical_o	-0.001	0	-2.071	0.038
tropical_d	0.0002	0	0.322	0.748
island_o	-0.3593	0.048	-7.51	0
island_d	-0.1973	0.048	-4.119	0
landlocked_o	-0.4562	0.048	-9.452	0
landlocked_d	-0.3837	0.048	-8.051	0

For the rest of the covariates, as we do not use their natural log values, we interpret their coefficients as Log-linear. Meaning that if covariate *a* increases by 1, the bilateral trade flows will increase by $(e^a – 1) * 100\%$. Therefore, we find that contiguous countries, countries which share a land border, experience a 191.89% increase their trade flows.

We estimate that in 2019, the effect of sharing a common official or primary language results in a trade flow increase of 60.90%. The increase is of 27.89% in the case of sharing a language spoken by at least 9% of the population. Regarding colonial ties, countries which have shared a common colonizer (post 1945), have 102.87% increased trade flows and countries which were in a colonial relationship (post 1946), have their trade flows increased by 125.20%. These coefficients are shown to be highly statistically significant. On the contrary, the effect of *comrelig*, the religious proximity index, fails to produce statistically significant results.

The dummy variable for GATT, which is replaced by the dummy variable for the WTO in 1995 onwards, takes the value of 1 when both origin and destination countries are GATT/WTO members. For 2019, we observe that this results in an increase of bilateral trade flows of 145.40%.

The roughness of the terrain is measured by the population weighted mean of altitude changes between cells (each cell being approximately 0.8km2). We observe that the maximum roughness index of 1 for the origin country results in a decrease of trade of 5.37% and a decrease of 9.40% for the destination country.

While the indexed variables for the tropical land percentage of a country present negligible coefficients which are not statistically significant, we do find statistically significant effects for the desert land percentage of countries. The maximum index of 1 for the origin country desert land percentage results in a decrease of trade of 1.22% and a decrease of 1.26% for the destination country.

Finally, the dummy variables which classify island nations and landlocked countries also reproduce significant effects. Island nations see their trade flows reduced by 30.18% while countries generally trade 17.91% less with other island nations. Similarly, landlocked nations see their trade flows reduced by 36.63% while countries generally trade 31.87% less with landlocked nations.

4.2 Coefficients over time

While interpreting the values of our coefficients for 2019 is worthwhile, we should also consider the effects of our covariates over time. Analyzing the changes over time allows us to illustrate different trends on international trade over an extended time period (1949 – 2019). Below we summarize the results for our first year (1949) and the middle point between our first and last years (1984).

Figure 6: 1984 Regression Summary Results

	coef	std err	t	P>|t|
const	-13.7757	0.425	-32.436	0
l_distw	-1.1812	0.033	-35.843	0
l_gdp_o	1.1432	0.019	60.52	0
l_gdp_d	0.9131	0.019	49.209	0.00E+00
l_pop_o	-0.2193	0.022	-10.19	0
l_pop_d	-0.1019	0.021	-4.76	0
contig	0.5907	0.159	3.714	0
comlang_off	0.282	0.11	2.575	0.01
comlang_ethno	0.2293	0.102	2.237	0.025
comcol	0.3744	0.091	4.108	0
col45	2.1934	0.19	11.56	0
comrelig	0.0858	0.095	0.903	0.366
gatt_joint	0.3148	0.052	6.05	0
rugged_popw_o	-0.0621	0.03	-2.073	0.038
rugged_popw_d	-0.0789	0.03	-2.602	0.009
desert_o	0.0038	0.002	1.774	0.076
desert_d	0.0083	0.002	3.903	0
tropical_o	0.001	0.001	1.629	0.103
tropical_d	-0.0011	0.001	-1.726	0.084
island_o	-0.4822	0.064	-7.579	0
island_d	-0.0599	0.063	-0.946	0.344
landlocked_o	-0.0808	0.066	-1.231	0.218
landlocked_d	-0.137	0.066	-2.09	0.037

Figure 7: 1949 Regression Summary Results

	coef	std err	t	P>|t|
const	-11.1897	0.892	-12.543	0
l_distw	-0.4316	0.055	-7.8	0
l_gdp_o	0.9757	0.05	19.611	0
l_gdp_d	0.886	0.051	17.428	0
l_pop_o	-0.3263	0.058	-5.674	0
l_pop_d	-0.2534	0.061	-4.149	0
contig	0.6822	0.204	3.346	0.001
comlang_off	-0.4647	0.244	-1.907	0.057
comlang_ethno	0.7743	0.227	3.412	0.001
comcol	2.1866	0.627	3.485	0.001
col45	1.8344	0.481	3.815	0
comrelig	0.1645	0.164	1.005	0.315
gatt_joint	0.6388	0.161	3.974	0
rugged_popw_o	-0.1541	0.044	-3.529	0

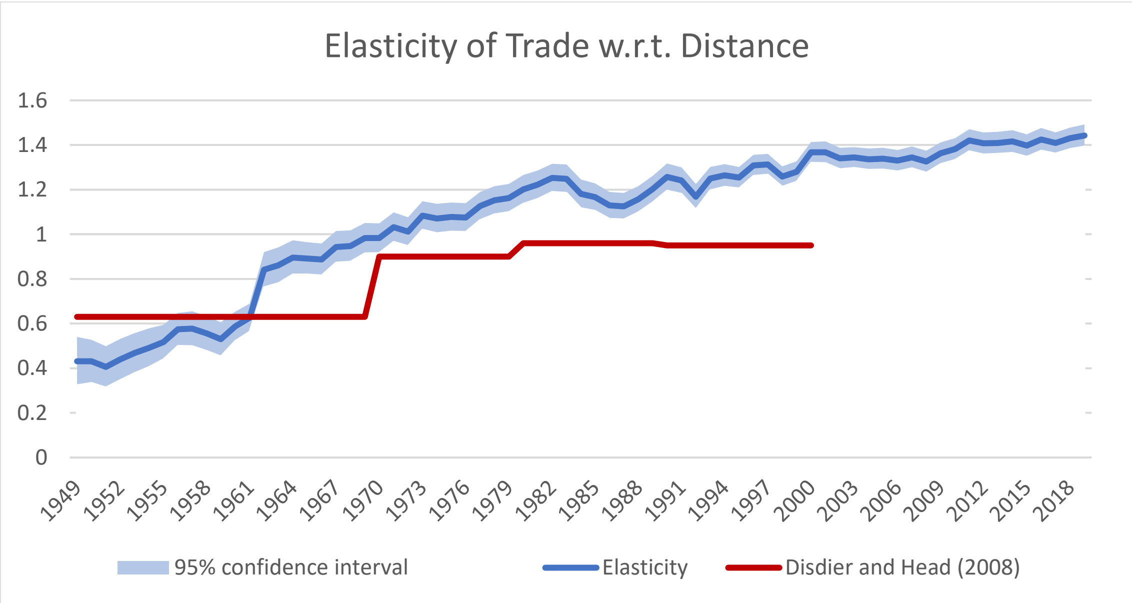
rugged_popw_d	-0.2099	0.049	-4.31	0
desert_o	-0.0135	0.005	-2.544	0.011
desert_d	0.0022	0.005	0.421	0.674
tropical_o	8.82E-05	0.001	0.068	0.946
tropical_d	0.0018	0.001	1.446	0.149
island_o	0.1612	0.136	1.185	0.236
island_d	-0.0265	0.131	-0.203	0.839
landlocked_o	-0.132	0.123	-1.07	0.285
landlocked_d	0.1096	0.121	0.903	0.367

Note: All models for all years are available in Appendix 2.

As expected, we observe a negative coefficient for *l_distw* (natural logarithm of the countries' distance between each other in km) for all time periods. However, the precise magnitude has increased considerably over time. As distance increases by 1%, trade will decrease by 0.50% in 1949, 1.25% in 1984, and 1.55% in 2019.

Following the literature from Disdier and Head (2008), we find that the negative effect of distance over bilateral trade increases over time. We find an elasticity of 0.43 in 1949 which grows to 1.44 in 2019.

Figure 8: Elasticity of trade with respect to distance.



Just as observed in Disdier and Head (2008), we observe a large effect increase in the 1960's and 1970's. This is then followed by a much more modest advancement which continues until 2019.

The largest spike in the data is found in 1962, resulting in an elasticity increase of 0.215 over the previous year, well over the 0.014 yearly average increase. A possible explanation for this phenomenon would be the Cold War. 1962 is the year when the Cuban Missile Crisis took place, therefore, an eventual decline of trade between the Capitalist Bloc and the Communist Bloc would artificially increase the elasticity of trade with respect to distance.

We also observe a turning point during the 80's as the elasticity drops for four consecutive years, and the value for 1982 is not reached again until 1993.

Finally, we observe short-lived shocks in 1992 and 1998, where the elasticity drops by 0.0724 and 0.055 respectively.

While having a relatively low impact on trade compared to other covariates, we find that the roughness of a country's terrain generally negatively impacts their bilateral trade. While this variable fails to be statistically different from zero in a few years, it generally ranges between -0.15 and -0.05. We can understand this negative relationship by thinking how mountain ranges can restrict bilateral trade by obstructing land transport and urban development.

With an average coefficient of -0.0995 (origin) and -0.0978 (destination), depending on their roughness index, a country's bilateral trade flows may decrease by up to 9.47%. Similarly, countries may trade up to 10.27% less with countries with a high terrain roughness index.

Figure 9: Effect of rugged terrain on origin countries (population weighted)

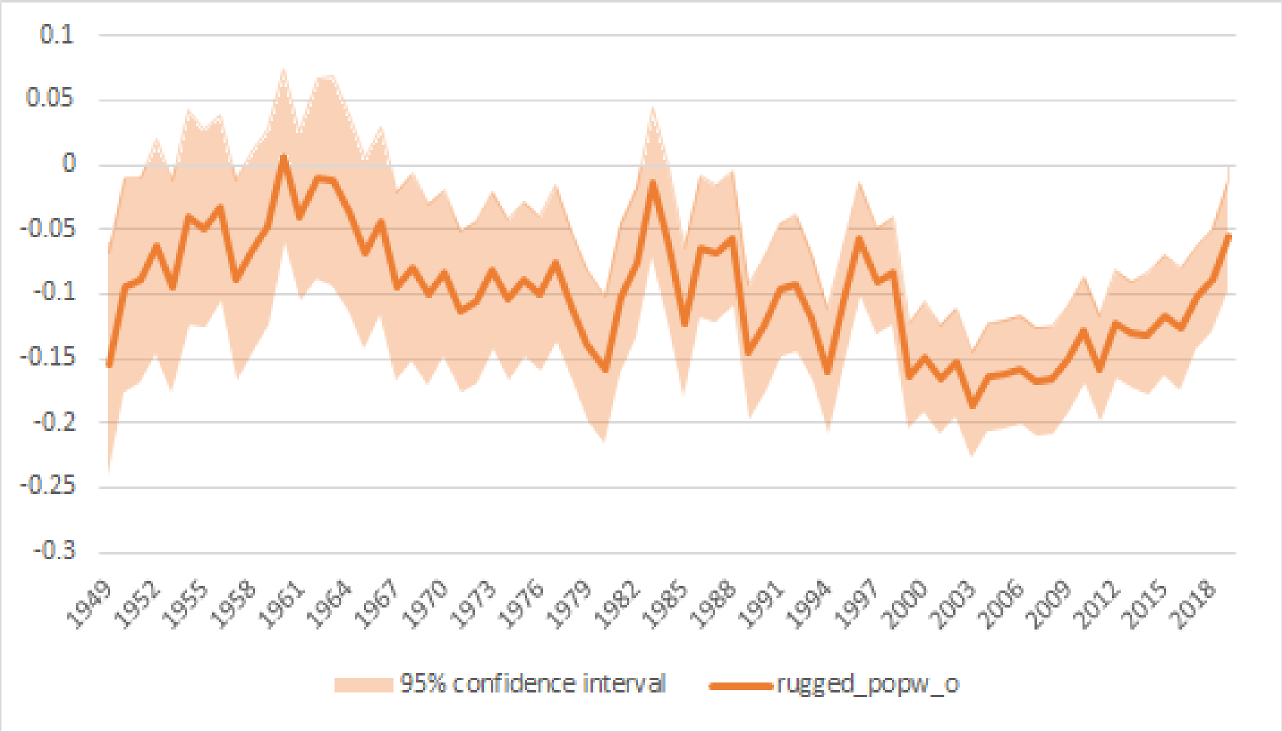
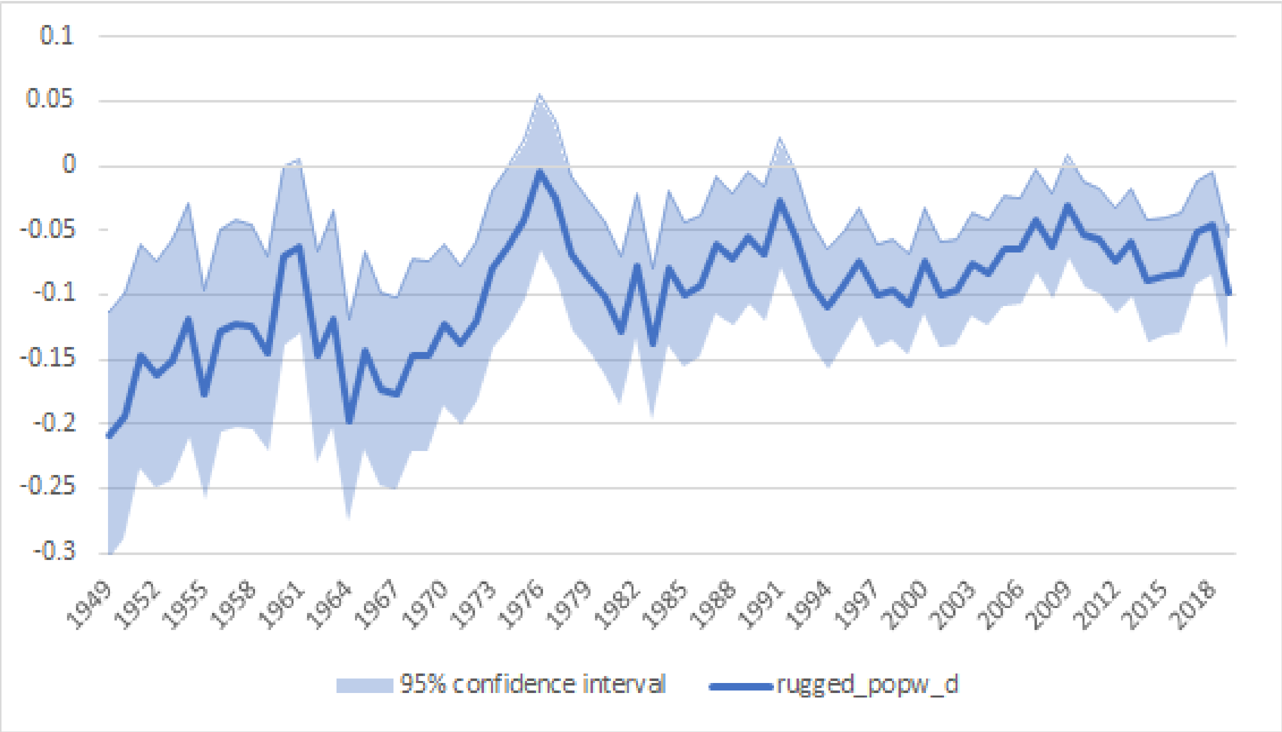


Figure 10: Effect of rugged terrain on destination countries (population weighted)



Despite this, most of the literature on gravity models do not take the roughness of the terrain into account. While it is not one of the most impactful coefficients, its effect remains considerable. In order to understand the effect of distance, it is important to quantify the roughness of the terrain. A shorter distance may prove to bear higher transport costs if its route is obstructed by mountain ranges and other obstacles. Therefore, we must consider the terrain in order to properly evaluate the effect of distance.

4.2 Analysis by Region

The following models have been divided by geographical categories as defined by the United Nations Statistics Division (UNSD).

Due to the unfortunate events of colonialism, data for African subregions will start in 1961. Similarly, the subregion of Central Asia will not have data until 1992, after the collapse of the Soviet Union. Prior to this period, the Soviet Union has been categorized under 'Eastern Europe'.

As a result, the number of observations used has been greatly reduced, causing highly statistically insignificant results during the first years, where the data availability is greatly reduced.

Therefore, in order to circumvent this, we will display data once a subregion has over 200 observations at its disposal, this will ensure highly statistically significant results for our coefficient of interest, *l_distw*. A number of subregions will not display data until the 1960's, and in the case of the Pacific Islands, until 1978.

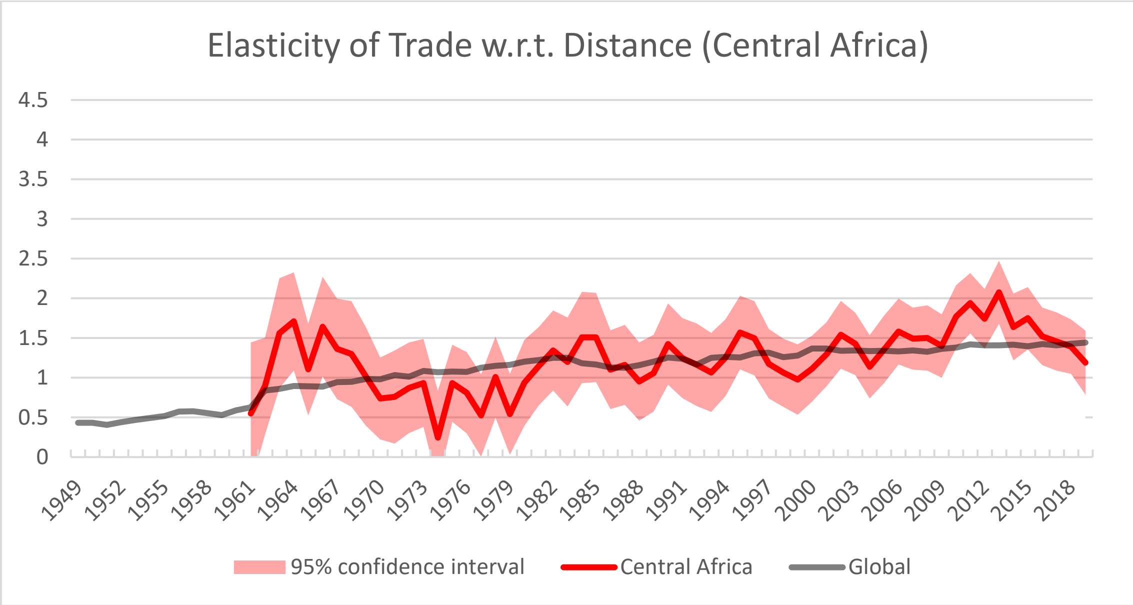
The data presented below is much noisier in comparison with the global coefficients. However, this is expected as the global trend utilizes a higher number of observations and opposite shocks from different regions can cancel out.

Note: Figures for all subregions are available in Appendix 1.

Africa:

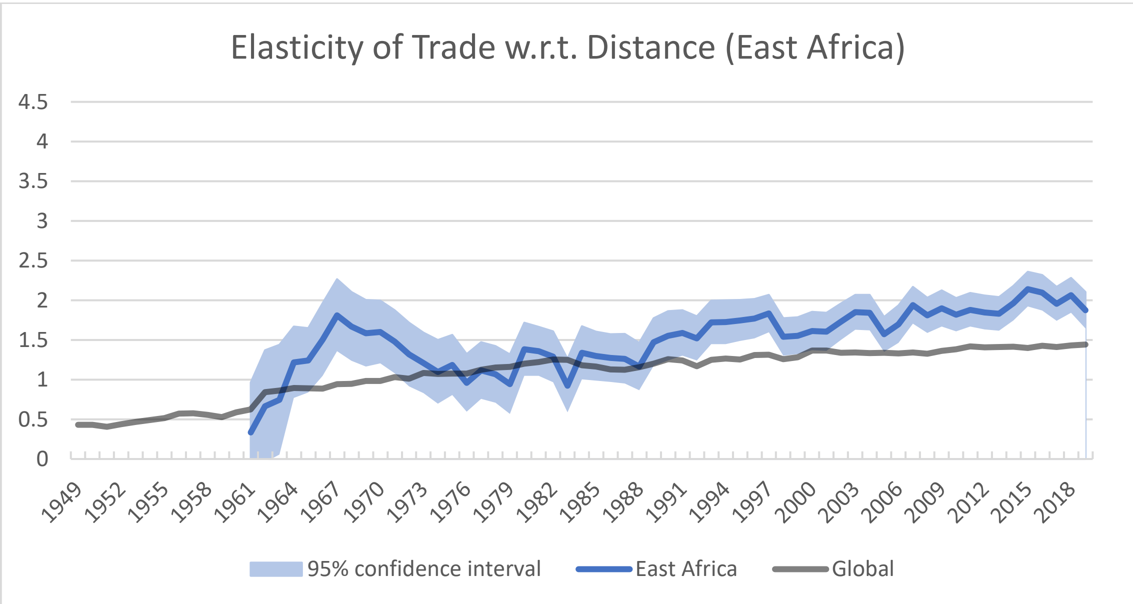
For West Africa, the elasticity of trade closely follows the Global trend, completely converging onto it since 1993. We do observe a small shock starting at 1966 and achieving its highest peak in 1971. This shock closely correlates with the Nigerian civil war (1967 – 1970).

Figure 11: Elasticity of Trade with respect to Distance (Central Africa)



In the case for Central Africa, the trend closely follows the global coefficients throughout the whole period. The major negative shock from 1966 to 1979 could correlate with the Chadian Civil War (1965 – 1979), and the negative shock from 1996 – 1999 might be related to the Republic of the Congo Civil War (1997 – 1999). However, these effects should be questioned due to the sheer volatility of the coefficients on a subregion which is sadly overcrowded with conflict. Therefore, it is relatively easy to find conflicts which could match the shocks. Moreover, we can also find conflicts such as the Second Congo War (1998 – 2003) which correlate with a positive, rather than negative, shock.

Figure 12: Elasticity of Trade with respect to Distance (East Africa)



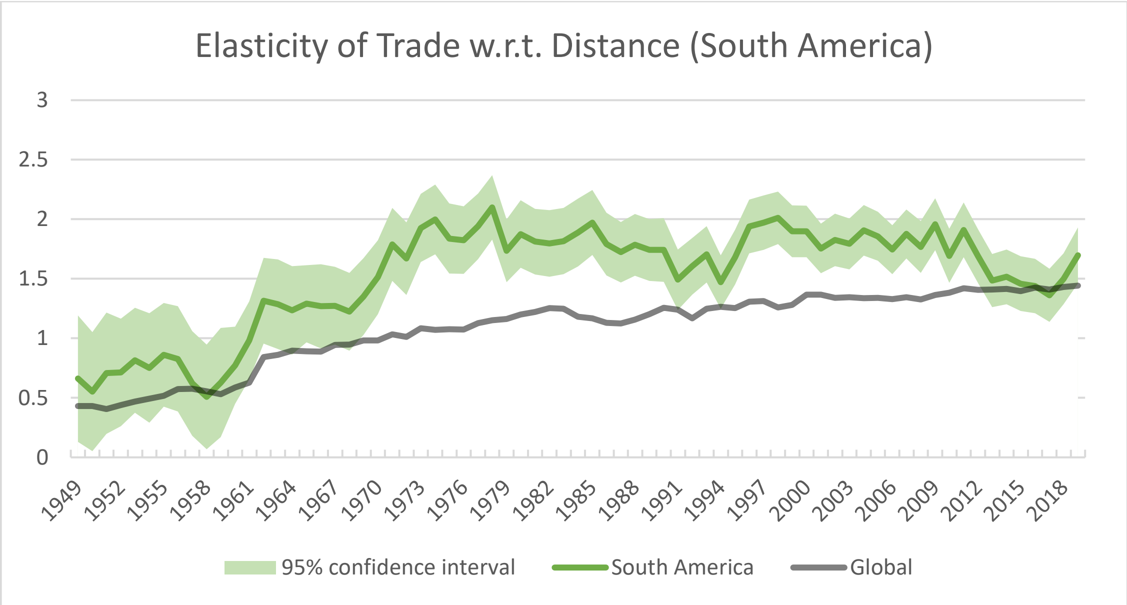
The elasticity in the case East Africa roughly follows the global trend at a steeper slope, which ultimately causes it to diverge from the rest of the world. A significant shock can be observed between 1964 – 1967, this period coincides with the Zanzibar revolution in Tanzania and the Shifta War in Kenya, however it is unlikely that these two events could create a shock of this dimension on their own.

Southern Africa presents the most volatile data from all the subregions. Unfortunately, due to the high variance and large confidence intervals, it is impractical to gather much insight from this figure. However, we would be able to reasonably tell that the coefficients for Southern Africa are much larger than the ones from the global model.

Americas:

Due to having Northern America only being composed of the United States and Canada (territories such as Greenland are excluded from our dataset), we observe a large variance in their elasticity. Nevertheless, the trend for North America is generally stays well below the global trend.

Figure 13: Elasticity of Trade with respect to Distance (South America)



The elasticity for South America starts converged with the global trend but quickly rises above it during the 1960's and 1970's. This correlates with the period when the governments of Argentina, Brazil, Chile, and Uruguay were overthrown by military dictatorships. During the 2010's, South America is again converging with the global trend.

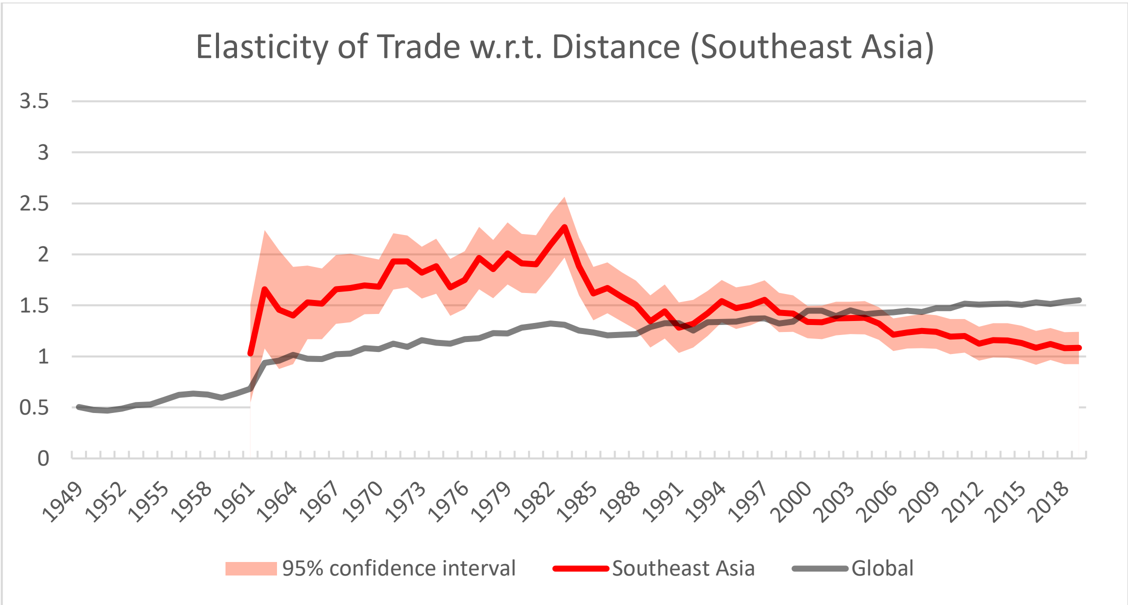
Asia:

The elasticity in Western Asia is surprisingly stable for such a conflictive area. Outside of the shock of 1961 – 1962, which occurs at a global level, the elasticity for Western Asia remains fairly stable at around the 1.5 value. After 1998, it converges with the global trend.

As the subregion of Central Asia is strictly composed of post-Soviet states, we are only able to start gathering data after the collapse of the Soviet Union. Despite being able to recollect data from 1993, these result in very noisy results with large confidence intervals. Similar to Southern Africa, it is impractical to gather much insight from this figure. However, we would be able to reasonably tell that the coefficients for Central Asia are much larger than the ones from the global model.

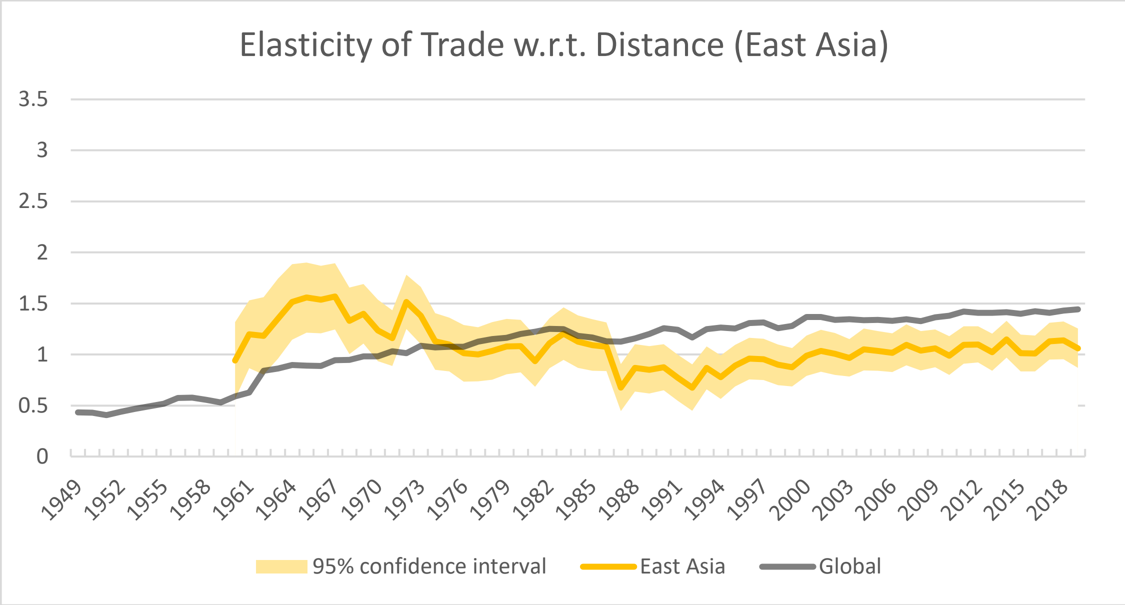
The elasticity trend for South Asia almost flawlessly follows the global trend, it only seems to diverge on the last decade, where the trend is slightly decreasing, in comparison with the global trend of slightly increasing. No major shocks seem to have disrupted this subregion.

Figure 14: Elasticity of Trade with respect to Distance (Southeast Asia)



In the case of Southeast Asia, their elasticity coefficients start well above the global trend. We observe a relatively mild positive shock after the end of the Vietnam War (1955 – 1975). The trend keeps increasing until the turning point of 1983, where it starts to decline. However, this does not seem to correlate with any major event from the subregion. The trend keeps declining and eventually ends up with values well below the global trend.

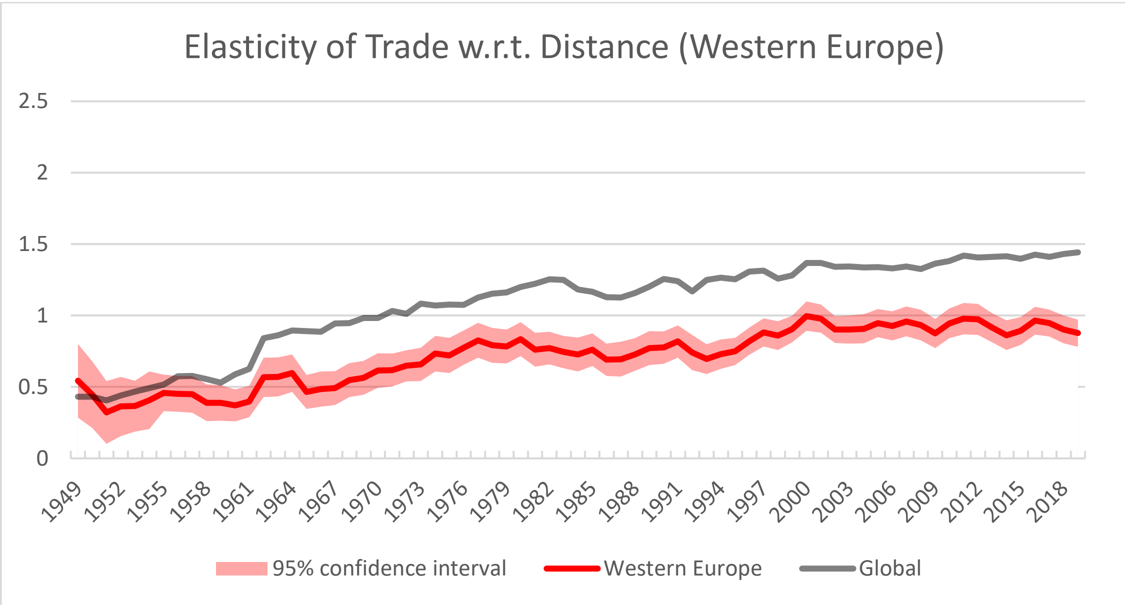
Figure 15: Elasticity of Trade with respect to Distance (East Asia)



In the case of East Asia, the elasticity starts off above the global trend. However, from 1967 to 1987 the East Asia trend declines as the global trend increases. After this period, their trends seem to grow at the same rate. Although this time, the East Asia coefficients are well below the global trend.

Figure 16: Elasticity of Trade with respect to Distance (Western Europe)

Europe:

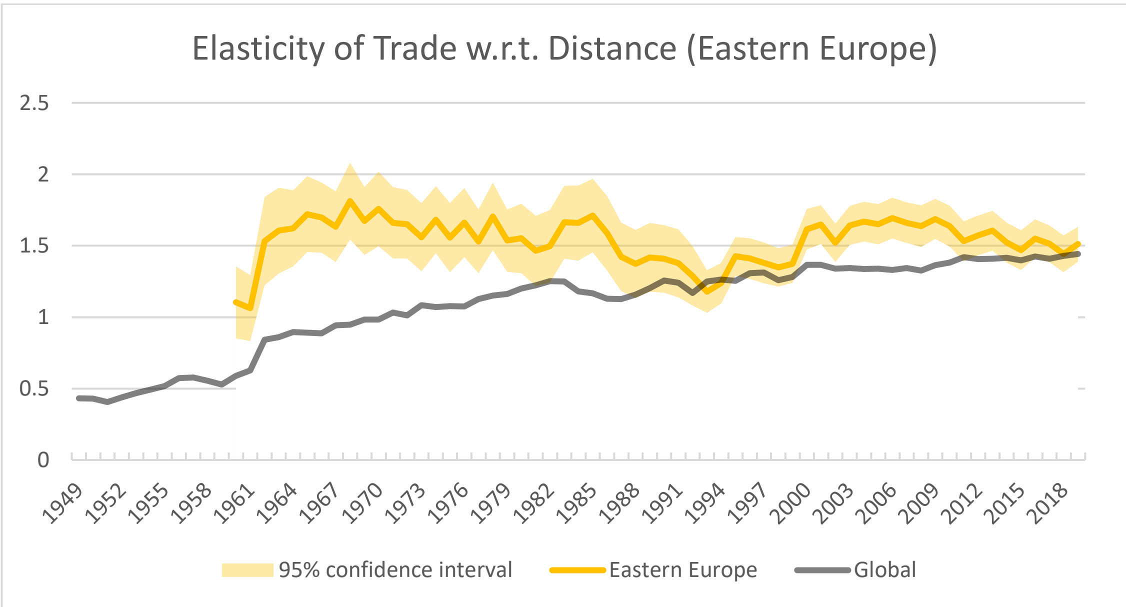


Western Europe retains the lowest level of elasticity. Until the start of the millennia, it has been following the same trend as the rest of the globe. However, after the year 2000, Western Europe seems to have stabilized its coefficients at around 0.9 while the rest of the world are still experiencing a slight upwards tendency.

Northern Europe seems to share the same trend as Western Europe, the only noticeable difference being the slightly noisier data and its overall structurally higher elasticity. Nevertheless, Northern Europe possesses the second lowest trade elasticity of the subregions.

Unlike Western and Northern Europe, Southern Europe starts off with a higher-than-average elasticity. Interestingly, it seems to start converging with the rest of the world starting in the mid 70's, which coincide with the end of the dictatorships in Greece, Portugal, and Spain. Therefore, it would make sense that the new democratic countries would then extend their international relations, causing the trade elasticity to comparatively decline.

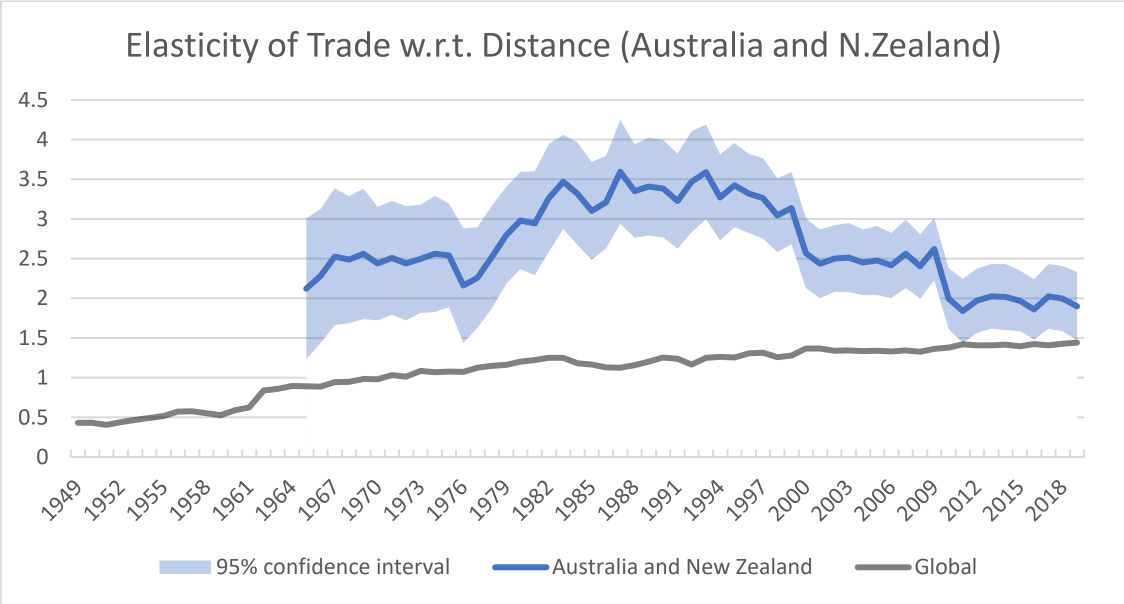
Figure 17: Elasticity of Trade with respect to Distance (Eastern Europe)



After the usual rise from 1961 to 1962, the elasticity of Eastern Europe doesn't seem to change all that much. We clearly see a negative shock during the times of the collapse of the Soviet Union (1988 – 1991), however by the year 2000, the coefficients return to the values previous to the collapse.

Oceania:

Figure 18: Elasticity of Trade with respect to Distance (Australia and New Zealand)



In the case of Australia and New Zealand, they seem to present a parabola-shaped trend. We observe a great elasticity increment starting at 1976 and ending in 1999.

Together with Central Asia, Southern Africa and the Pacific Islands, they present the highest coefficients. This is particularly interesting as it may seem that those which present the highest elasticities are the most isolated subregions.

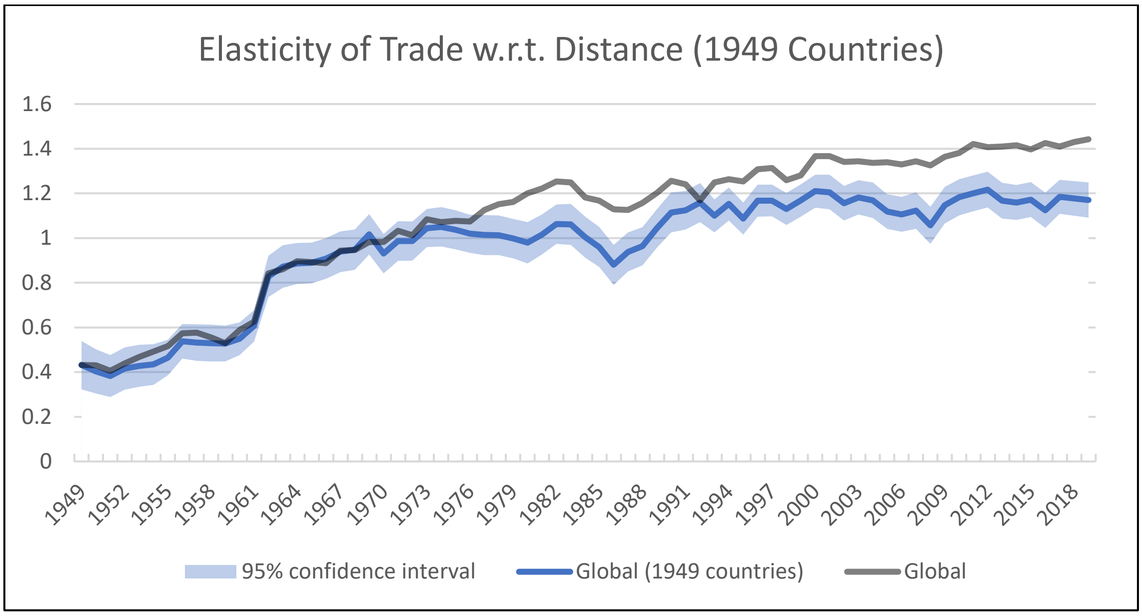
5. Data validation

One of the issues with working with country data over a considerable period of time is that our participants, countries, do not remain constant over time. The number of countries goes from 106 in 1949 to 195 in 2019. Therefore, the positive global trend might be simply explained by the entrance of data from new countries, which on average report higher coefficients.

Additionally, 25 countries gained their sovereignty from 1960 to 1962. This correlates with the sudden global increase of the elasticity of trade with respect to distance. Therefore, we should analyze if this shock is merely being caused by the introduction of these countries into our dataset.

In order to do this, we will create a secondary global model in which we will only consider countries which existed in 1949. We will also include countries which have merged back into one country (Germany) or split into two countries (Czechia and Slovakia).

Figure 19: Elasticity of Trade with respect to Distance (1949 Countries)



After plotting both global models we can clearly see that the decolonization in the early 1960's is not responsible for the major increase in the elasticity of trade. The new model, which doesn't include data from countries that didn't yet exist in 1949, only begins to diverge from our previous model after 1975. While the global trend continues to steadily increase, the new model seems to stagnate around 1.1 – 1.2. While the positive trend continues, in comparison, it does so at a very marginal rate.

During the 1975 – 2019 period, the 1949 model experiences a total increase of 12.84% while the original global model experiences a total increase of 33.91%. Therefore, it is safe to assume that the main cause of the increasing elasticity of trade with respect to distance is due to the introduction of newly formed countries into the dataset. Thus, these new countries are increasing the global average elasticity.

6. Discussion and Conclusion

As already uncovered by previous literature, the elasticity of bilateral trade with respect to distance has been increasing. Our research has produced higher coefficients than Disdier and Head (2008), but within a respectable margin of error. The positive trend that the authors had established until year 2000 has continued its course in our model. Therefore, the relative costs of trading with far-away countries in comparison with our neighbors has increased and, if the same trend continues, it will keep increasing.

However, the division of our model by subregions has proved quite intriguing. Western and Northern Europe currently enjoy the lowest trade elasticities. For Western Europe in 2019, a distance increase of 1% will result in a 0.8767% decrease in bilateral trade. This is a much more favorable result than from the global perspective, where a 1% increase of distance will result in a bilateral trade decline of 1.4424%. It is likely that the ports of Rotterdam, Antwerp, and Hamburg have significant responsibility for this.

However, the biggest ports in the world are mostly located in East and Southeast Asia. Coincidentally, these two subregions are not very far off from the coefficients of Western and Northern Europe, as in 2019, their trade elasticities are 1.0613 and 1.0825 respectively.

While most subregions generally follow the global trend, we can identify some exceptions. Southern Africa, Central Asia, Australia and New Zealand, and the Pacific Islands do not seem to follow the global trend. Coincidentally, all these subregions present the highest trade elasticities, having reached values twice as high as the global value for 2019. Interestingly, these are the most isolated subregions.

We are also able to spot specific shocks and, in some cases, reasonably guess the event which caused it. This is most obvious in the case of Eastern Europe, where the collapse of the Soviet Union has a paramount effect.

Disdier and Head (2008) mention in their paper "*Distance effects of this magnitude pose an important unsolved puzzle*". After limiting our model to only use countries which existed prior to 1950, we were able to see that while the trend continued to be increasing, it increased at a substantially lesser rate. Therefore, while we are not able to solve the puzzle of why the trend is increasing, even as transportation technology improves, we observed that the basis for the increasing global trend was due to the newer countries which were not included in the early years of our dataset.

6.1 Limitations

There are several limitations to our model based of our dataset. The most obvious limitation is the range of the period (1949 – 2019). While our main dataset, the CEPII database on gravity estimations, starts at 1948, there is no sufficient trade data for 1948 to be able to create a statistically significant model.

An additional issue arises with our model as our number of countries is not constant. This causes us to underrepresent specific regions during the earlier years of our models. This specially affects the continent of Africa, where no data is available until the 1960's. Data unavailability is also a persistent issue. As the smaller countries such as Andorra and the most underdeveloped countries tend to miss bilateral trade data, we encounter an issue of selection bias which might affect the distance effect. As we cannot use observations with missing trade data, we are indirectly weighting the model in favor of the larger and more developed economies.

Another issue arrives with the dataset of terrain ruggedness and other geographical characteristics from Nunn and Puga (2012). While it is reasonable to assume that the data on a country's terrain is not likely to change over a 70-year period, the dataset that we utilized did not have data on former sovereign states such as Czechoslovakia, Yugoslavia, and the Soviet Union. In order to circumvent this, we estimated their data based on the weighted average of the countries that used to form them.

Finally, the most significant limitation of the model is its lack of causal interpretation. While it is possible to identify several historical events, which may have caused a specific shock in a trend, we are unable to directly confirm the causal relationship. Moreover, the reason why the global trend is still increasing continues to remain a mystery. Therefore, we limit ourselves to identify this relationship and confidently recognize that the elasticity of bilateral trade with respect to distance is still increasing.

REFERENCES

Keith and Mayer, Thierry, 2014. “Gravity Equations: Workhorse,Toolkit, and Cookbook,” ch. Chapter 3, p. 131-195, Elsevier.

Keith & Mayer, Thierry & Ries, John, 2008. “The Erosion of Colonial Trade Linkages After Independence,” CEPR Discussion Papers 6951, C.E.P.R. Discussion Papers.

Anne-Celia Disdier & Keith Head, 2004. “The Puzzling Persistence of the Distance Effect on Bilateral Trade,” Development Working Papers 186, Centro Studi Luca d'Agliano, University of Milano.

Storper, Michael & Leamer, Edward, 2001. “The Economic Geography of the Internet Age,” Journal of International Business Studies.

Gilles Duranton & Michael Storper, 2005. “Rising Trade Costs? Agglomeration and Trade with Endogenous Transaction Costs,” CEP Discussion Papers dp0683, Centre for Economic Performance, LSE.

Thomas Chaney, 2018. “The Gravity Equation in International Trade: An Explanation,” Journal of Political Economy, vol 126(1), pages 150-177.

Michel Fouquin, Jules Hugot, 2016. “Two Centuries of Bilateral Trade and Gravity Data: 1827-2014,” CEPII Working Paper, N°2016-14

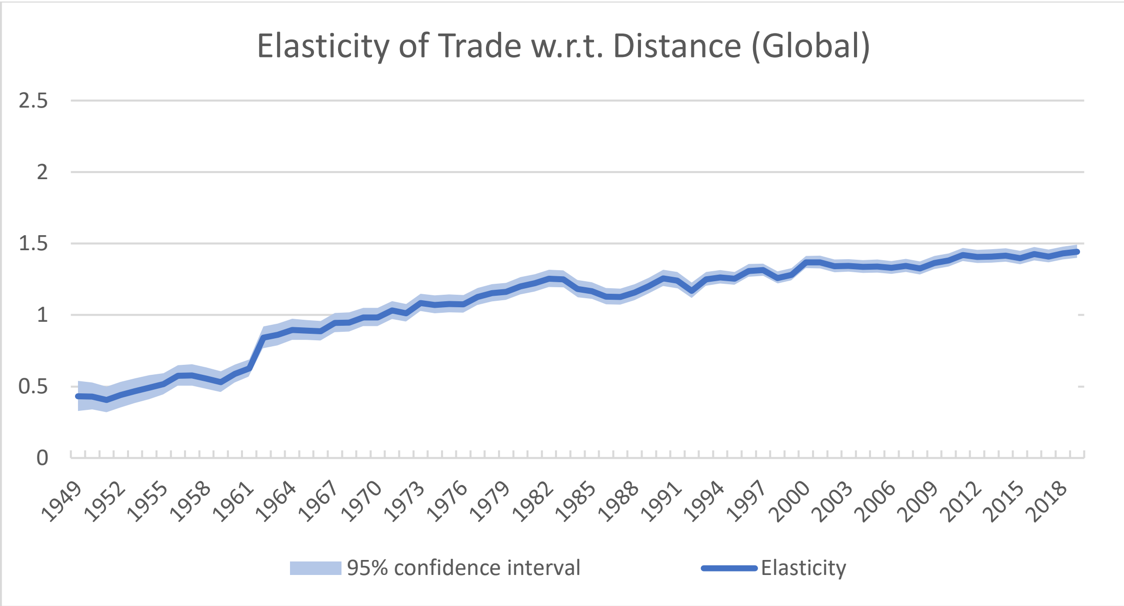
Maddalena Conte, Pierre Cotterlaz & Thierry Mayer, 2021. “The CEPII Gravity Database,” Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Version 202102, accessed 4 Feb 2021. http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8

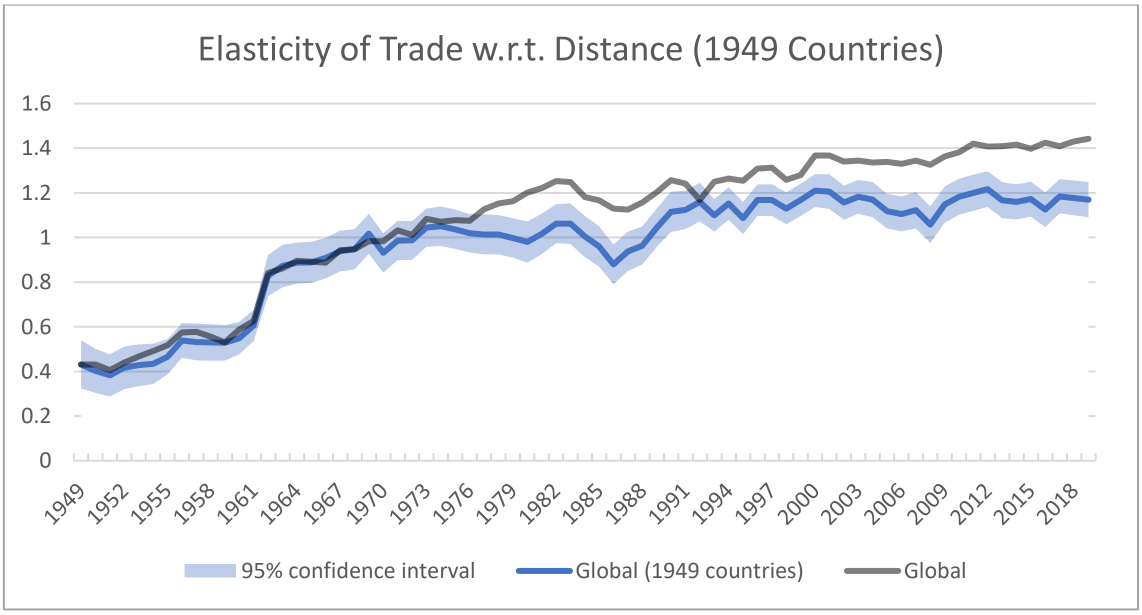
Nathan Nunn and Diego Puga, 2012. “Ruggedness: The Blessing of Bad Geography in Africa,” Review of Economics and Statistics. Accessed 17 April 2021. https://diegopuga.org/data/rugged/

APPENDIX 1

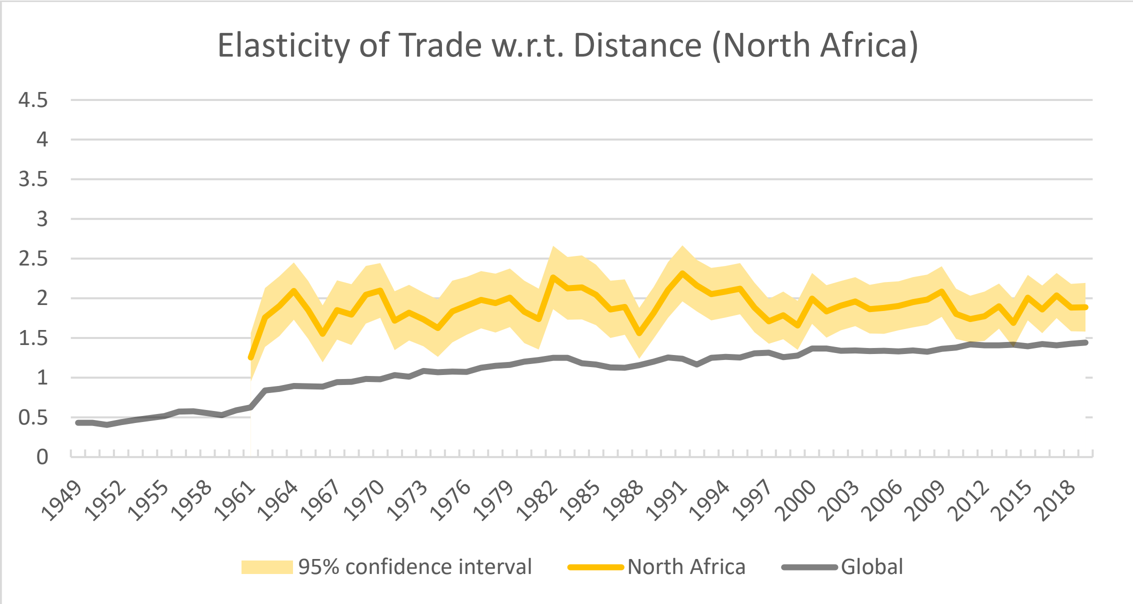
Elasticity figures

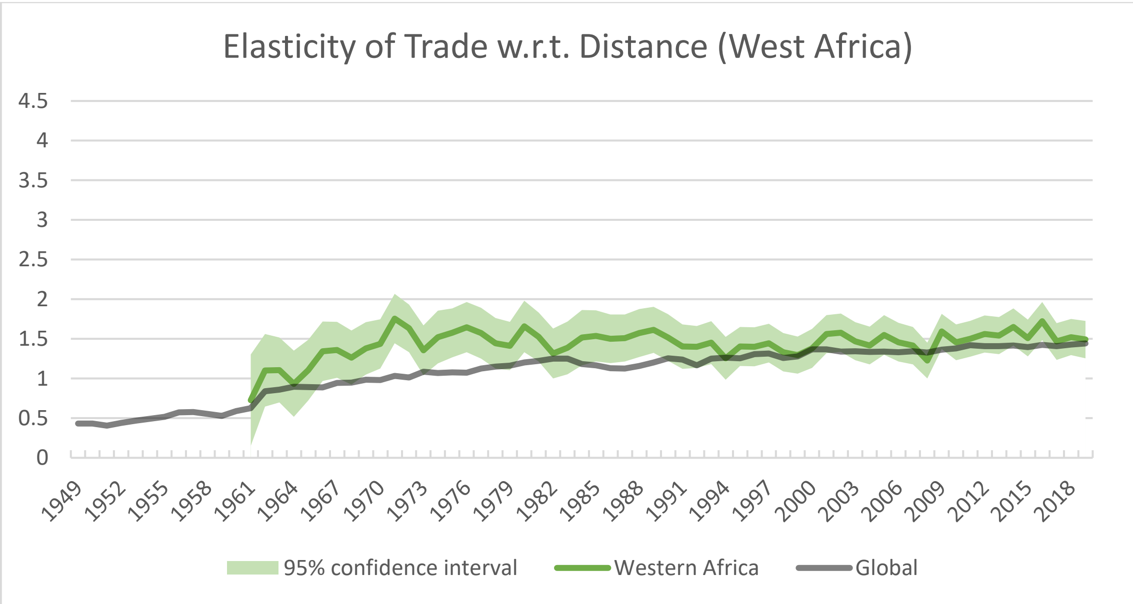
Global

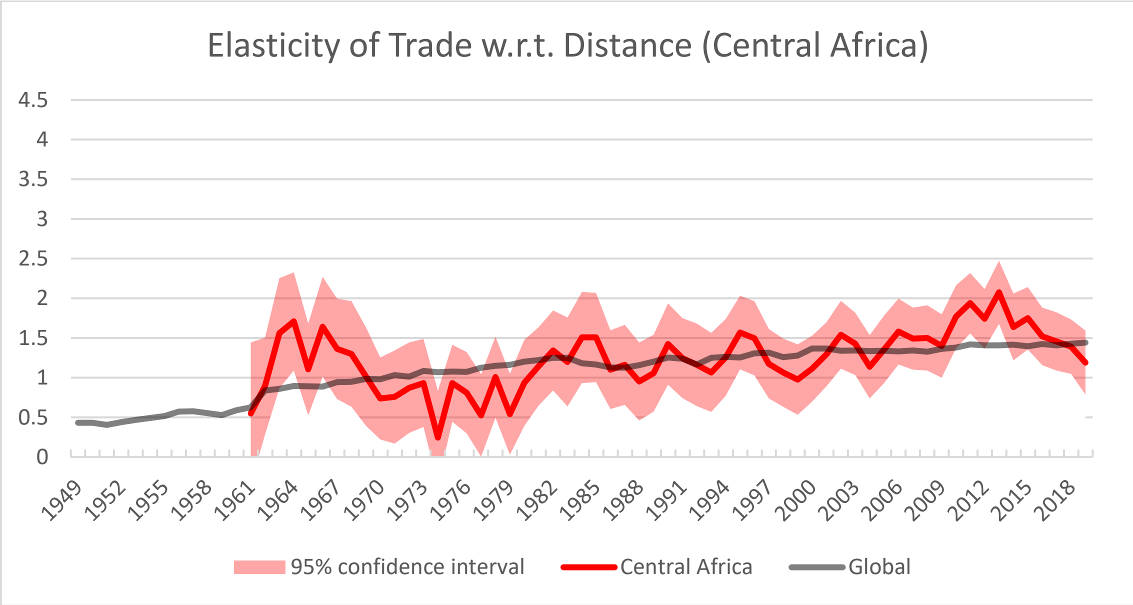


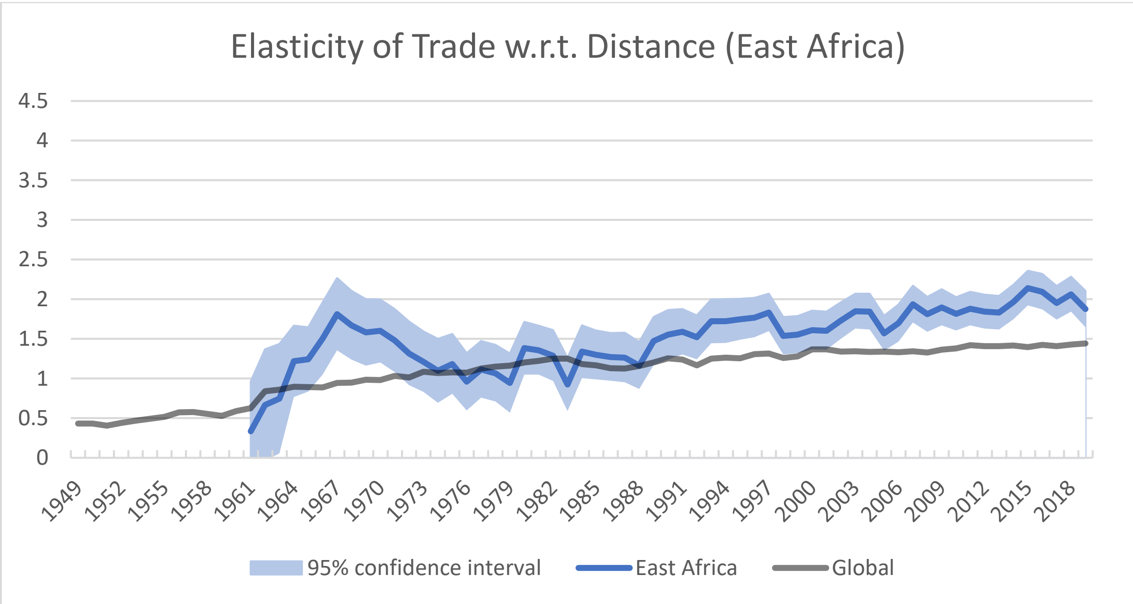


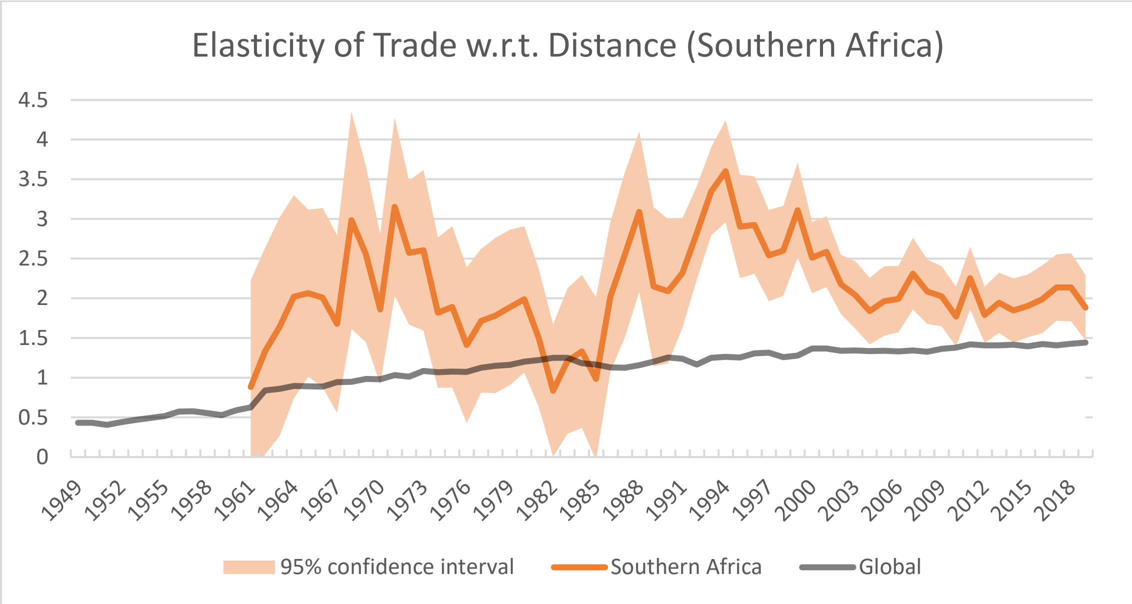
Africa


Elasticity of Trade w.r.t. Distance (North Africa)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
North Africa
Global

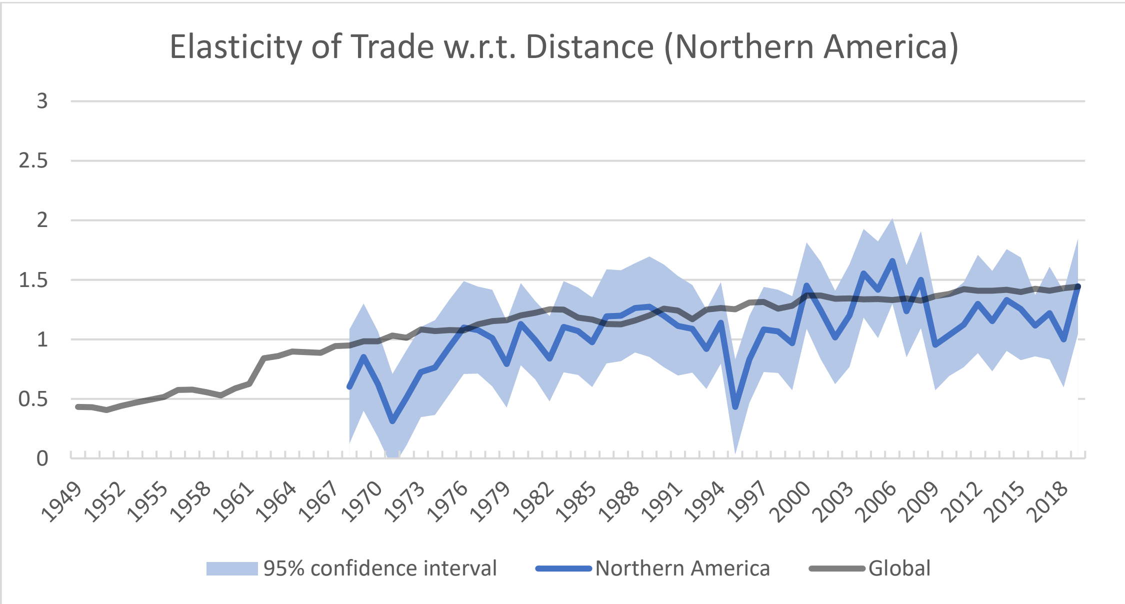

Elasticity of Trade w.r.t. Distance (West Africa)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Western Africa
Global

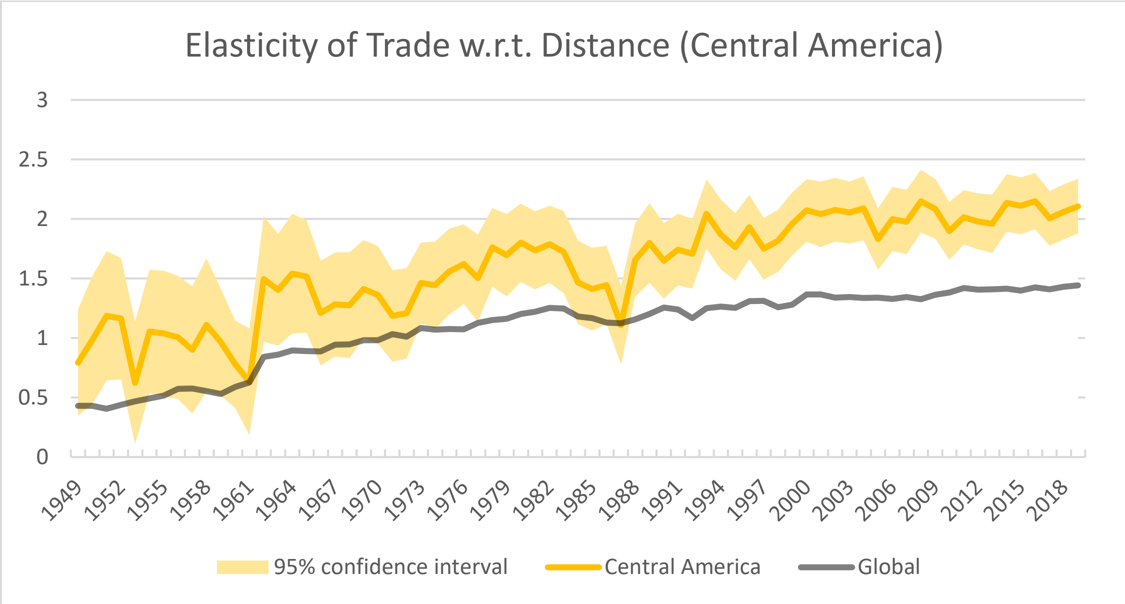

Elasticity of Trade w.r.t. Distance (Central Africa)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Central Africa
Global

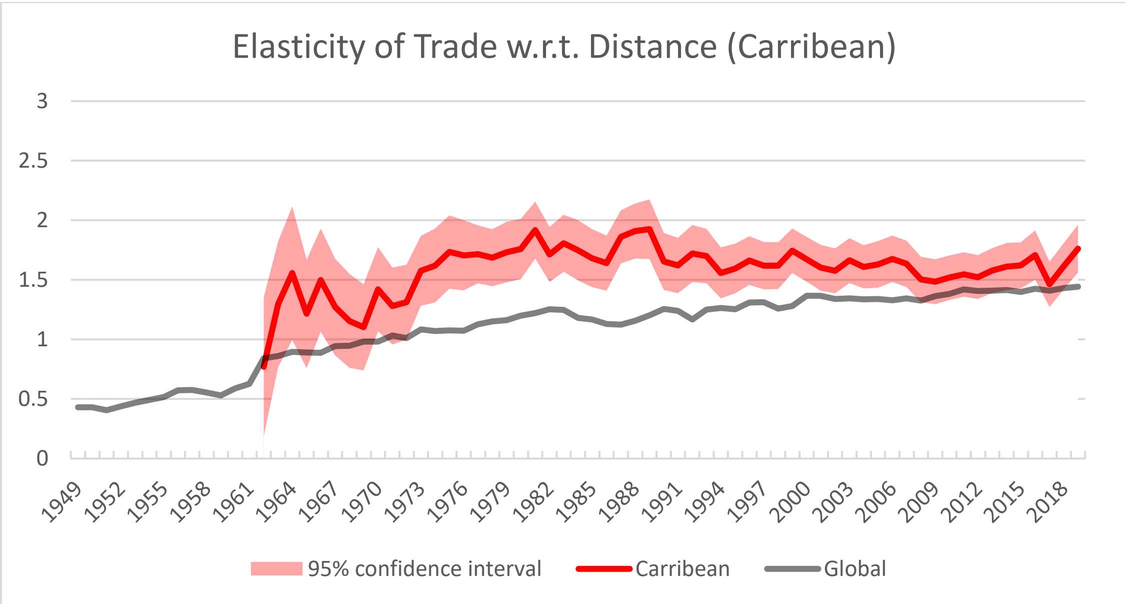

Elasticity of Trade w.r.t. Distance (East Africa)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
East Africa
Global

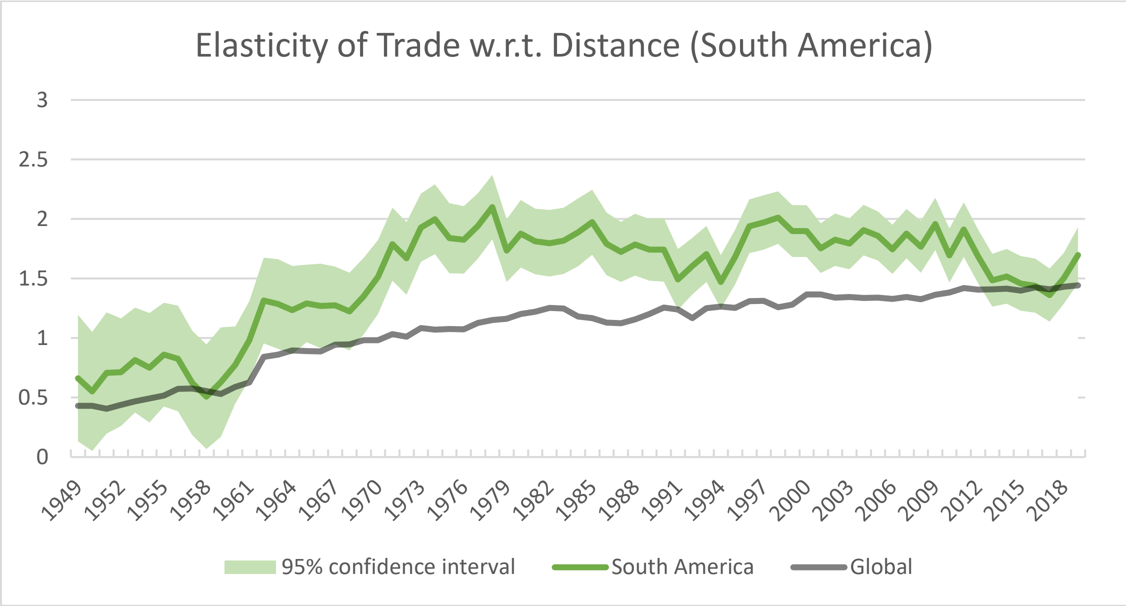

Elasticity of Trade w.r.t. Distance (Southern Africa)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949 1952 1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015 2018
95% confidence interval
Southern Africa
Global

Americas

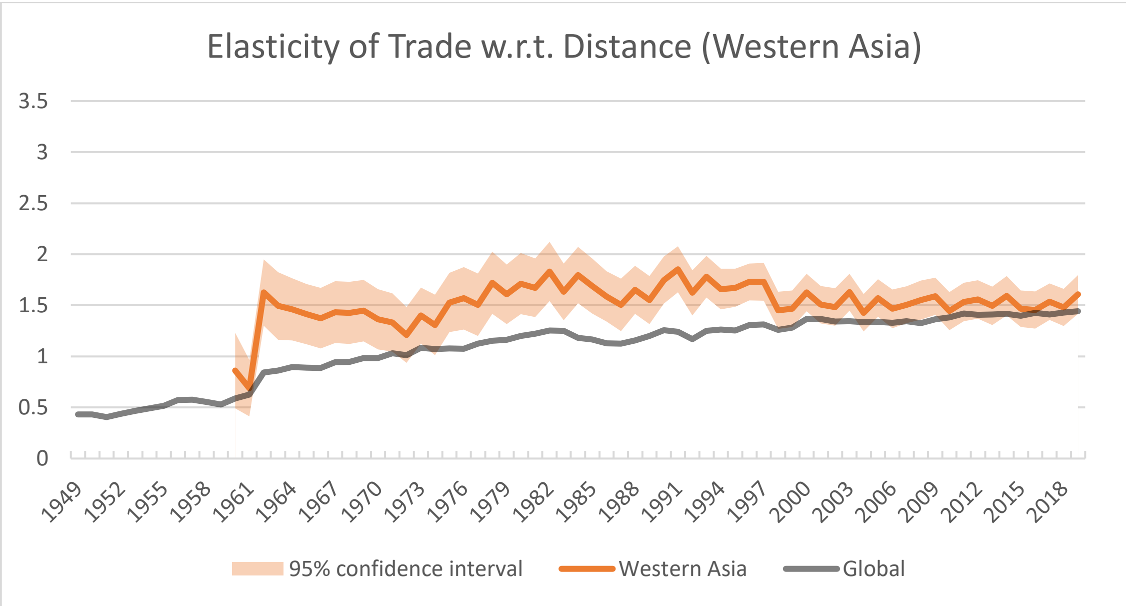

Elasticity of Trade w.r.t. Distance (Northern America)
3
2.5
2
1.5
1
0.5
0
1949 1952 1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015 2018
95% confidence interval
Northern America
Global

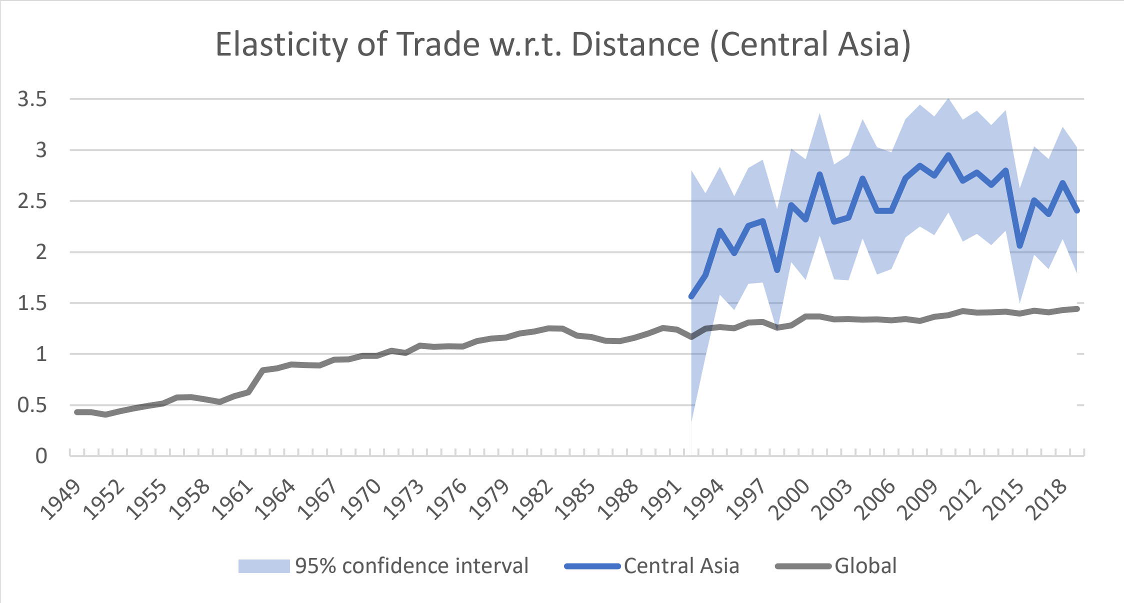

Elasticity of Trade w.r.t. Distance (Central America)
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Central America
Global


Elasticity of Trade w.r.t. Distance (Carribean)
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Carribean
Global

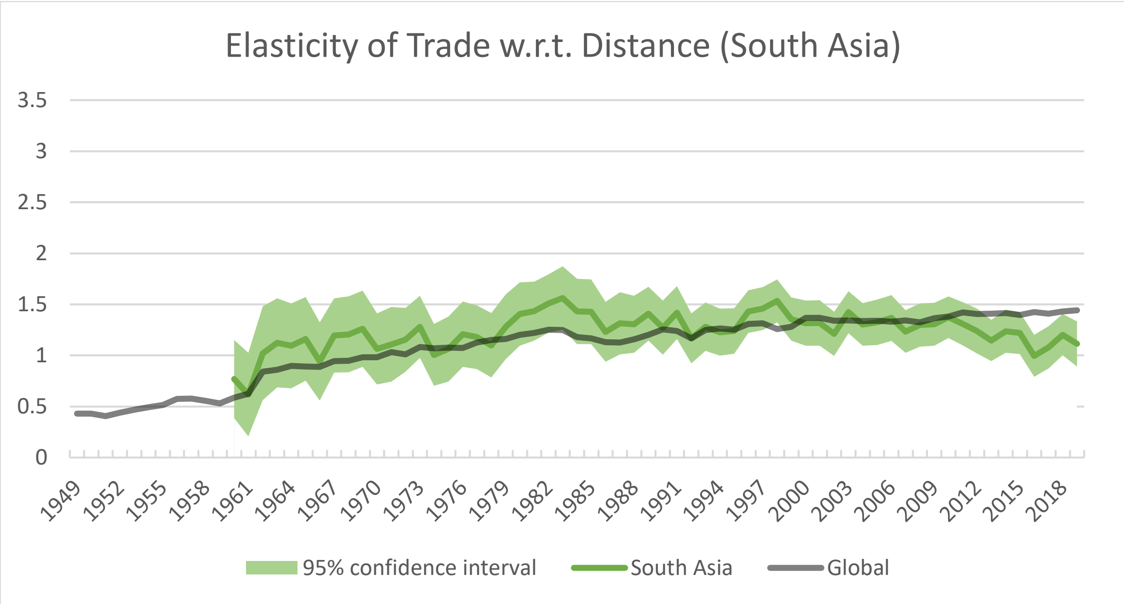

Elasticity of Trade w.r.t. Distance (South America)
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
South America
Global

Asia

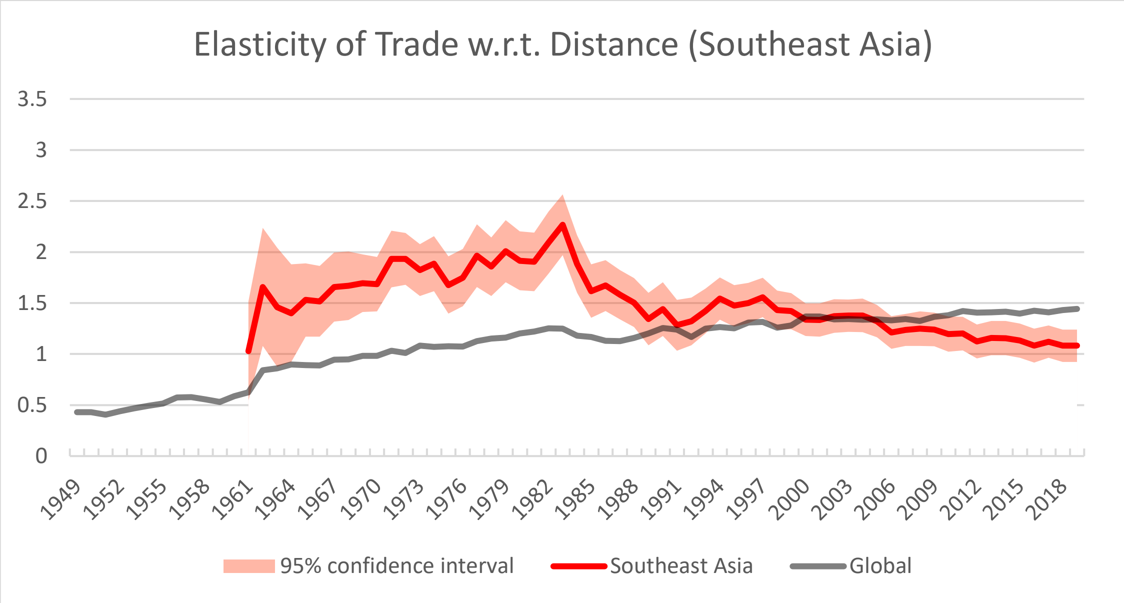

Elasticity of Trade w.r.t. Distance (Western Asia)
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Western Asia
Global

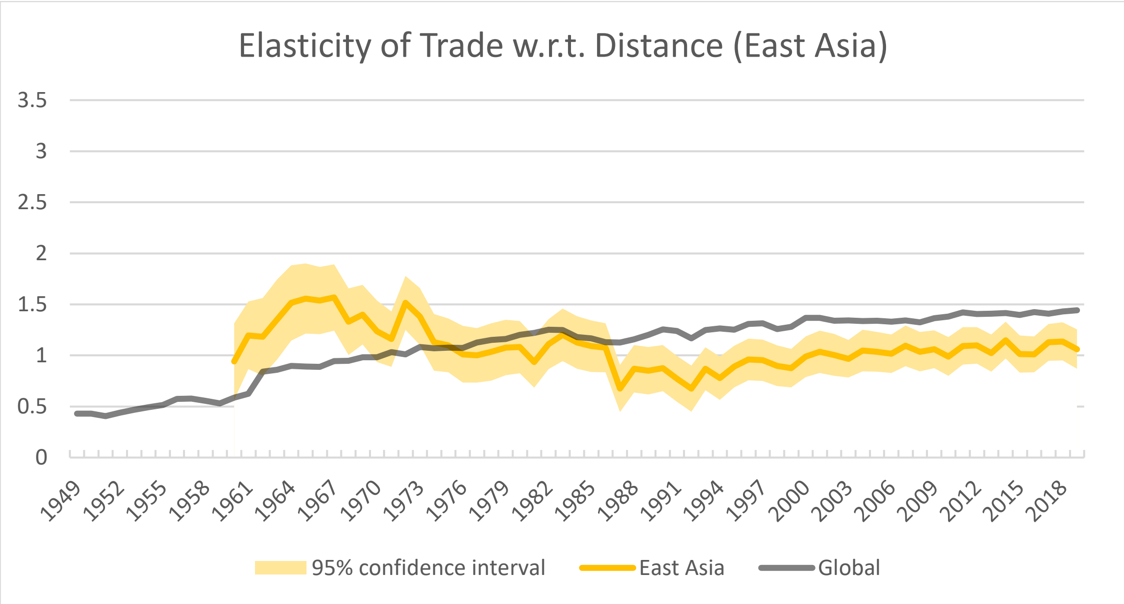


Elasticity of Trade w.r.t. Distance (Central Asia)
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Central Asia
Global

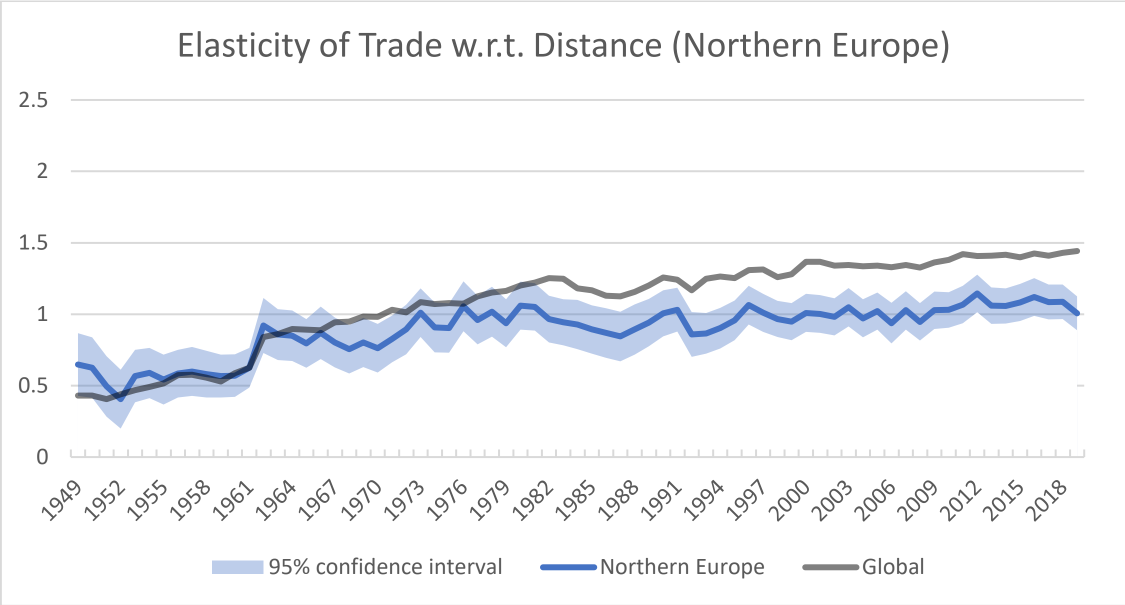


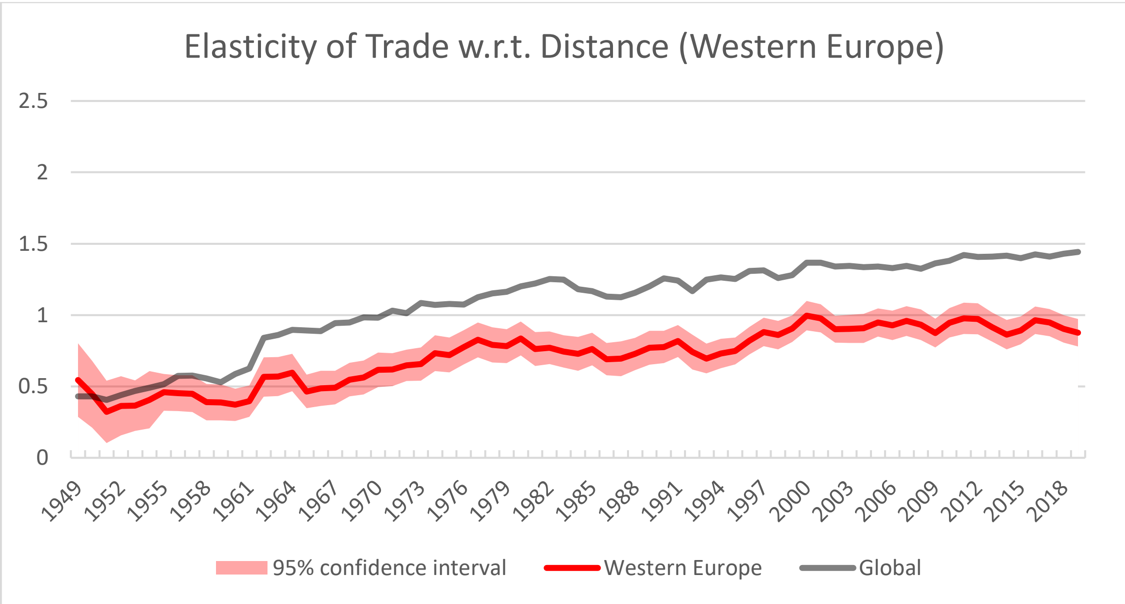
Elasticity of Trade w.r.t. Distance (South Asia)
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
South Asia
Global

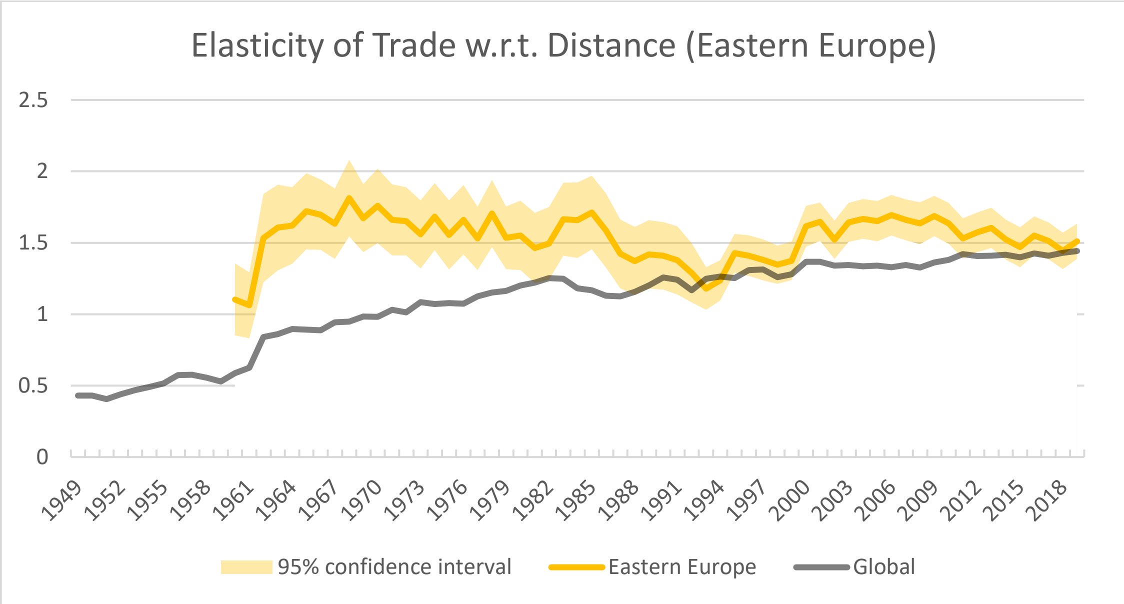

Elasticity of Trade w.r.t. Distance (Southeast Asia)
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Southeast Asia
Global

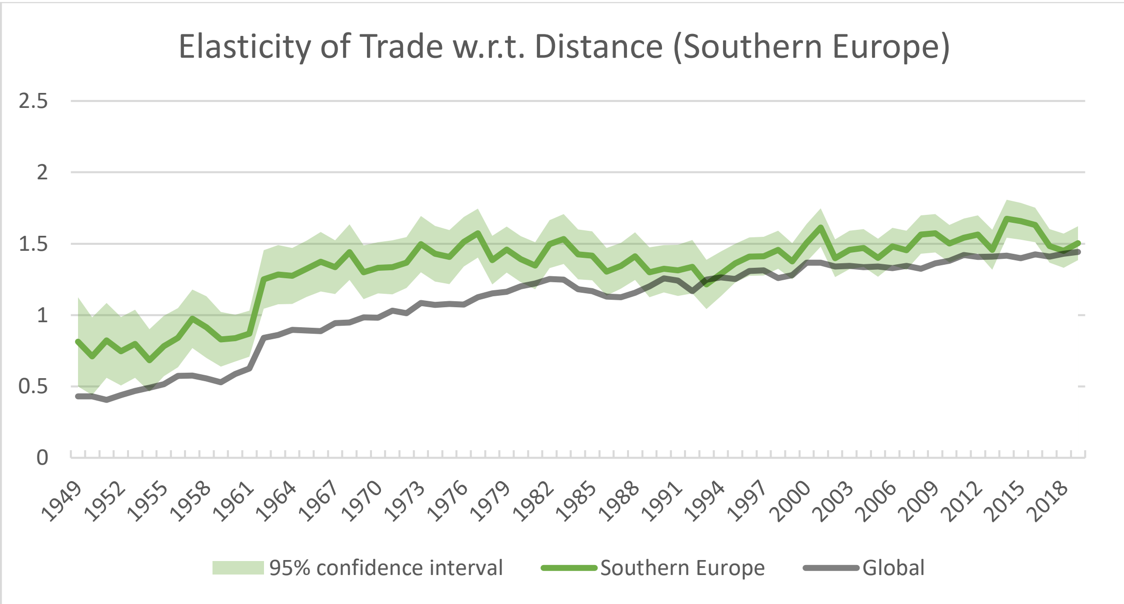

Elasticity of Trade w.r.t. Distance (East Asia)
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
East Asia
Global

Europe

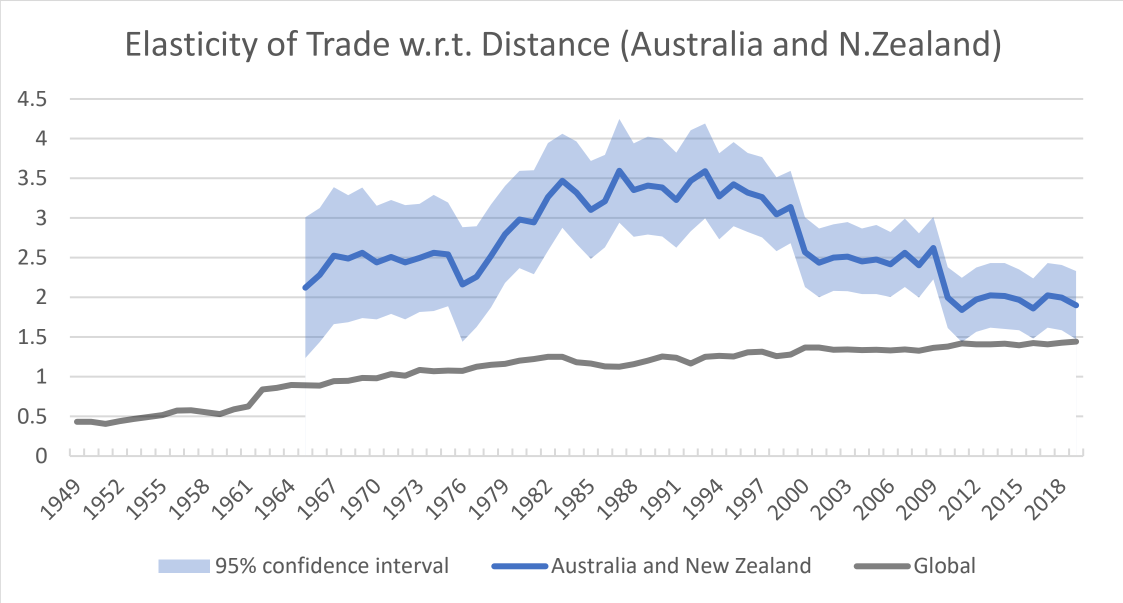

Elasticity of Trade w.r.t. Distance (Northern Europe)
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Northern Europe
Global

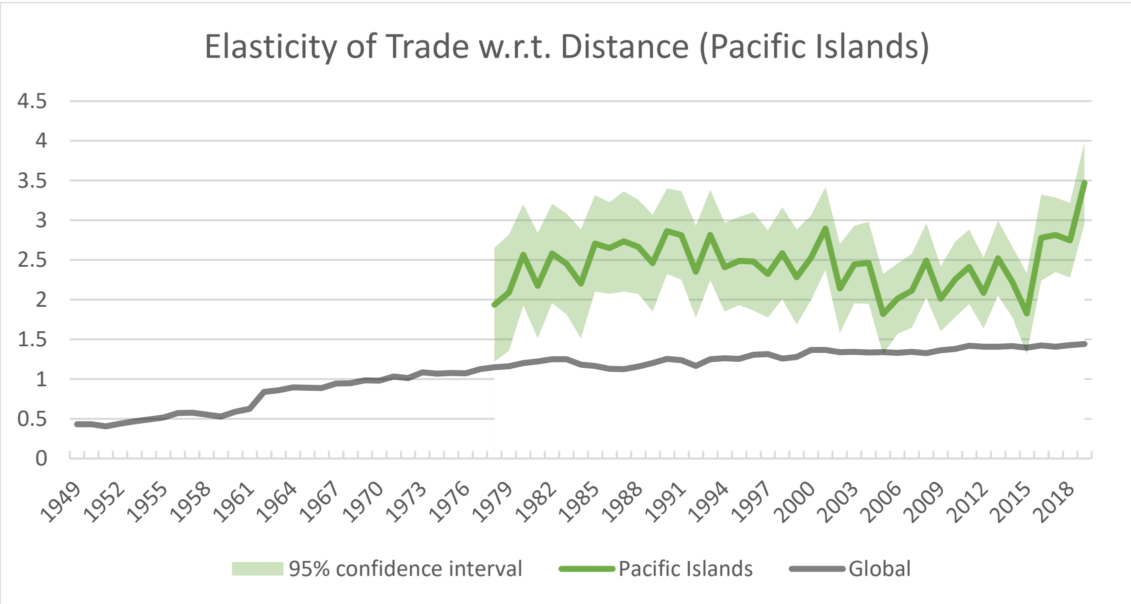

Elasticity of Trade w.r.t. Distance (Western Europe)
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Western Europe
Global


Elasticity of Trade w.r.t. Distance (Eastern Europe)
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Eastern Europe
Global


Elasticity of Trade w.r.t. Distance (Southern Europe)
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Southern Europe
Global

Oceania


Elasticity of Trade w.r.t. Distance (Australia and N.Zealand)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Australia and New Zealand
Global


Elasticity of Trade w.r.t. Distance (Pacific Islands)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
95% confidence interval
Pacific Islands
Global

APPENDIX 2

Dataframes

- Dataframe generator: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Dataframe/Data_Generation.ipynb

Regressions

- Global: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_Global.ipynb

- Global (1949 countries): https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_Global(1949).ipynb

- Australia and New Zealand: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_AustraliaNewZealand.ipynb

- Caribbean: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_Carribbean.ipynb

- Central Asia: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_Central%20Asia.ipynb

- Central Africa: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_CentralAfrica.ipynb

- Central America: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_CentralAmerica.ipynb

- East Africa: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_EastAfrica.ipynb

- East Asia: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_EasternEurope.ipynb

- Eastern Europe: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_EasternEurope.ipynb

- North Africa: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_NorthAfrica.ipynb

- Northern America: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_NorthernAmerica.ipynb

- Northern Europe: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_NorthernEurope.ipynb

- Pacific Islands: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_PacificIslands.ipynb

- South America: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_SouthAmerica.ipynb

- South Asia: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_SouthAsia.ipynb

- Southeast Asia: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_SoutheastAsia.ipynb

- Southern Africa: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_SouthernAfrica.ipynb

- Southern Europe: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_SouthernEurope.ipynb

- West Africa: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_WestAfrica.ipynb

- Western Asia: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_WesternAsia.ipynb

- Western Europe: https://github.com/M-Soler/MSc_Economics_Thesis/blob/main/Regressions_WesternEurope.ipynb