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Research Report

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Reevaluating the Gravity Model: The Role of Distance in Modern International Trade beyond Geography

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Reevaluating the Gravity Model: The Role of Distance in Modern International Trade beyond Geography

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Abstract

The classical Gravity Model of international trade posits that trade volume between countries is determined by the geographic distance between them. Despite globalization, such distance remains a persistent yet puzzling factor. This paper reevaluates the Gravity Model by incorporating cultural, political, and social distances into the analysis of international bilateral trade. Constructed various distance measures, including Hofstede's cultural dimensions theory, Facebook's social connectedness index, and the "Affinity of Nations" database, are integrate into a structural gravity model. Through Poisson Pseudo-Maximum Likelihood (PPML) estimation, I analyze the robustness and contributions of each variable. The findings suggest a complex interplay between physical and nonphysical distances, calling for a more nuanced understanding of trade barriers. This research offers valuable insights for policymakers and researchers, emphasizing the multifaceted nature of international trade in an increasingly interconnected world, and contributes to the development of more effective strategies for global economic growth.

Keywords: International Trade, Gravity Model, Distance Measures

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Commitments on Academic Honesty and Integrity

Research Report 2023 S.T. Yau High School Science Award (Asia)

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5. undertake to avoid getting in touch with assessment panel members in a way that may lead to direct or indirect conflict of interest.
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Name of team member: Zongda She

X

Name of supervising teacher:

Noted and endorsed by

SeemaDesai

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Name of school principal: SEEMA DESAI

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1. Introduction

Throughout history, humans have engaged in trade to obtain goods and services that are not readily available (Robertson 1938). Since the dawn of trade in human civilization, various factors have caused friction in trade, such as distance, language, culture, and more (Pomeranz and Topik 2017). Among these factors, distance has proven to be the most persistent cause of friction, shaping the dynamics of trade across different eras (Anderson and van Wincoop, 2003; Disdier and Head, 2008). In ancient times, the distance between traders in bilateral trade created significant barriers due to the high transportation time. The lack of advanced transportation methods meant that goods could take weeks or even months to reach their destination. Even today, the distance between countries determines the time it takes for goods to be transported from one country to another, affecting the overall efficiency and cost of trade. For example, Singapore has benefited significantly from international trade, occupying the strategic position as the shipment hub between Strait of Malacca and South China Sea (Huff 1997). According to World Trade Organization, Singapore has the highest trade to GDP ratio in the world (400%) on average, fueling its economic growth as one of the strongest forces (Liang 2005).

The Gravity Model was first introduced by (Tinbergen 1962) as a means of explaining trade patterns between countries. Drawing inspiration from the laws of physics, Tinbergen applied the concept of gravitational attraction to international trade. The model suggests that the trade volume between two countries is directly proportional to the product of their GDPs and inversely proportional to the distance between them. This model has been widely used by economists and policymakers to understand trade patterns and inform trade policies, reflecting its foundational importance in the field of international economics.

From a theoretical perspective, Krugman (1978) proposed a thought experiment on Interstellar trade between planets where traders are capable of traveling at speeds close to that of light. This imaginative scenario highlights the complexities of distance as a factor in trade, especially when considering the theory of relativity. In this case, distance does not represent transport time and thus transportation cost, so the use of the Gravity Model of trade may not apply. However, it would be counterintuitive if we were to say that trade volume would not vary given the insignificance of distance. This leads to the consideration that there may be other, less quantitative factors that influence trade, such as trust, cultural understanding, and political alignment.

The globalization leads the world to become flatter, and technology has advanced rapidly, significantly increasing the efficiency of international transportation, information exchange as well as migration, and marking the "death of distance" (Cairncross 1997). For example, Figure 1 shows the change in transportation and communication costs relative to those in 1930. The cost of sea freight decreased to almost 20% of what it was in 1930, and international calling costs have reduced to almost 0% (World Bank, 2021). These technological advancements have revolutionized trade, making it faster and more accessible.

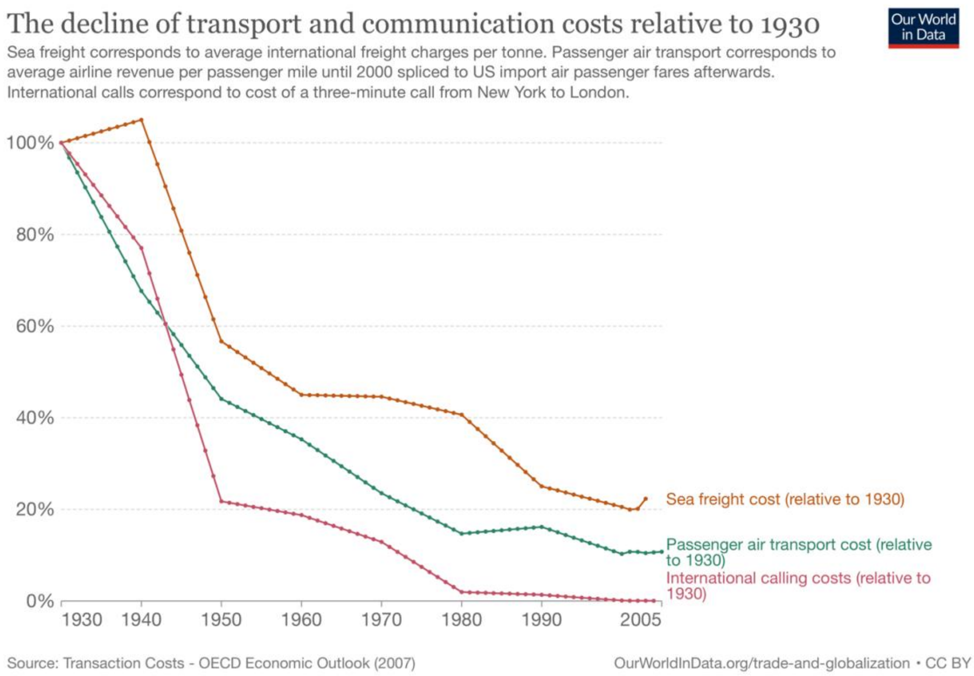

Figure 1. The decline of transport and communication costs relative to 1930 (source: OECD Economic Outlook (2007)

As distance in the Gravity Model of trade mainly represents transportation costs (Ramos, 2006), we might expect a similar decline in the role of distance in the Gravity Model today. However, studies analyzing trade data from the 1800s to the year 2000 have shown a surprising trend: the significance of distance decreased only between the years 1870 and 1950, after which it rose rather than declined (Disdier & Head, 2008). This counterintuitive finding, known as the "**puzzling persistence of distance effect**", lends us to a question why the significance of distance has not changed and even increased given the significant decrease in transportation costs (Berthelon and Freund 2008). As Coe et al. (2002) wittedly mentioned, "globalization is everywhere but in estimated gravity models".

It is important to note that distance is not the only factor influencing trade. Factors such as information (Anderson & van Wincoop, 2004) and trade agreements (Baldwin & Taglioni, 2006) also add or remove barriers in bilateral international trade. These factors may interact with distance in complex ways, potentially explaining the unchanging significance of distance. Moreover, the geographical distance that are used to proxy the trade friction in the gravity model may also need to be reevaluated in the globalization era. Beyond physical distance, other factors such as culture, social connectedness, and political relationships also influence trade patterns. Studies by Rauch and Trindade (2002), and Mayer and Zignago (2011) have shown that a common culture, stronger social ties, and closer political ties respectively, are positively correlated with trade volume. In Ghemawat, (2001)'s Harvard Business Review article "Distance still matters", he argued that distances between two countries should account for distance measures beyond geography, highlighting the importance of accoung for a a new measure of distance: the CAGE (Cultural, Administrative, Geographic and Economic) distance framework. This framework encompasses not only physical distance but also cultural, administrative, and economic distances, providing a more nuanced understanding of the barriers to trade.

Given the rapid advancements in technology and the evolving global landscape, it is essential to reevaluate the Gravity Model and its underlying assumptions. This essays aims to build on the existing body of research by examining the impact of various factors using *CAGE framework*, including, cultural, political, geographical and social distances, on international bilateral trade volumes. By incorporating these factors into a Gravity Model, we seek to analyze the robustness of each variable and their relative contributions. We have collected international trade data from CEPII database (Conte et al. 2022) and a variety of distance measures: i) cultural distance from Hofstede's cultural dimensions theory (Hofstede 1984); ii) social distance from Facebook's social connectedness index (Bailey et al. 2018); iii) political distance from "The Affinity of Nations" database constructed from country's voting records at United National General Assembly (Bailey et al. 2017). We then have integrate these distance measures into the dynamic gravity model and perform Poisson Pseudo-Maximum Likelihood (PPML) estimation to obtain coefficients. This approach will enable us to determine whether the traditional Gravity Model is in need of adjustment, or if these additional factors help to explain the puzzling persistence of distance in international trade patterns.

By expanding our understanding of the factors influencing trade patterns, policymakers and researchers can develop more effective strategies for promoting international trade and fostering global economic growth. This research will not only help to clarify the role of distance in the Gravity Model but also provide valuable insights into the broader dynamics of international trade in an increasingly interconnected world.

2. Literature review

The Gravity Model of international trade has long been a cornerstone for understanding trade patterns between countries. Its enduring relevance and the persistence of distance as a key factor in international trade, despite advancements in transportation and communication technologies, have puzzled researchers. This literature review seeks to provide a comprehensive overview of the existing research on the Gravity Model, the significance of distance in the model, and the potential factors that may influence the relationship between distance and trade volume.

2.1. Traditional Gravity Model

One of the early studies that examined the Gravity Model and its relationship to international trade was conducted by Linnemann (1966), who found a strong correlation between distance and trade volume. The findings of this research have been reinforced by subsequent studies, such as those conducted by Frankel and Romer (1999) and Rose and van Wincoop (2001), both of which reported a correlation of 0.9 between distance and trade volume. These studies suggest that distance continues to play a significant role in determining trade patterns between countries, reflecting the fundamental nature of geographical barriers in shaping economic interactions.

However, the seemingly persistent significance of distance has led some researchers to question whether there may be biases or omitted variables in the traditional Gravity Model. For example, Disdier and Head (2008) suggest that the puzzling persistence of distance in the Gravity Model may be due to the misspecification of variables in the model. The essay "Has Distance Died?" by Brun, Carrère, Guillaumont, and de Melo (2005) also postulates that omitted variable bias could be the reason behind the Gravity Model's continued emphasis on distance. These critiques highlight the need for a more nuanced understanding of the factors influencing trade patterns.

2.2. Culutral factors

In response to these concerns, several studies have sought to identify potential factors that might influence the connection between countries and their trade flows. One such factor is the culture of the countries involved in trade. Research on the role of culture in trade, such as the study by Rauch and Trindade (2002), suggests that a common culture simplifies transactions and can be expected to have a positive correlation with trade volume. This finding has been supported by other studies, including those by Guiso, Sapienza, and Zingales (2009) and Melitz (2008), which emphasize the importance of cultural similarities in facilitating trade.

Harms and Shuvalova's (2020) study on the role of culture in trade suggests that cultural differences may cause subtle inefficiencies in mutual understanding between producers and consumers, leading to lower trade volumes. Using cultural measures proposed by Hofstede, they show that trade volume is indeed negatively affected by cultural differences between two countries. More interestingly, investigations on the interactions between culture and Franco and Maggioni (2022) show that bilateral trade and cultural proximity influence each other. Especially, they suggest that increased trade volume increases interactions between two countries, leading to smaller distance between two cultures. These studies underscore the complex interplay between culture and trade, revealing that cultural factors can both facilitate and hinder international trade.

2.3. Social factors

Another factor that has been examined is the social connectedness between countries. Mayer and Zignago (2011) conducted research on the relationship between social connectedness and trade, finding that the two variables are positively correlated. This finding suggests that countries with stronger social ties are more likely to engage in trade with one another, potentially due to reduced transaction costs and increased trust between trading partners. Using the Facebook Social Connectedness Index, Bailey et al. (2021) discovered that social similarities between two regions can help mitigate information asymmetries, leading to more efficient trading with less cost. These findings highlight the importance of social networks and shared social norms in shaping international trade patterns.

2.4. Administrative factors

A third factor that has been explored is the political relationship between countries. Countries with close political ties have a higher likelihood of establishing trade agreements, which can, in turn, increase trade flows between them. Studies such as Fuchs and Klann (2013) and Song (2020) have shown that improving political relationships between countries is generally associated with higher trade flows. This is particularly evident in the case of China, where closer political ties with trading partners have led to increased trade volumes. Furthermore, Dajud (2013), using voting records in the General Assembly of the United Nations and the left-right political spectrum, found that political differences do have robust effects on determining trade volume between two countries. Studies on trade histories and political ties by Morrow et al. (2014) also show that political closeness can influence trade volumes through finding that democratic states tend to trade more with each other and countries with common interests have higher trade volumes than with other country pairs. These studies provide compelling evidence that political alignment and cooperation can significantly influence international trade patterns.

2.5. Further considerations

In addition to these factors, other variables have also been considered in the context of the Gravity Model, such as the impact of regional trade agreements (Baier & Bergstrand, 2007), the role of institutions in facilitating trade (Anderson & Marcouiller, 2002), and the influence of infrastructure on trade costs (Limão & Venables, 2001). These studies aim to provide a more nuanced understanding of the factors that influence international trade patterns and contribute to the ongoing discourse on the Gravity Model's validity in the modern world.

While the literature on the Gravity Model and the role of distance in international trade is extensive, there remain unanswered questions and areas for further investigation. This essay aims to build on the existing body of research by examining the impact of various factors, including physical, cultural, political, and social distances, on international bilateral trade volumes. By incorporating these factors into a structural gravity model, we seek to analyze the robustness of each variable and their relative contributions to the Gravity Model. This approach will enable us to determine whether the traditional Gravity Model is outdated and in need of adjustment, or if these additional factors help to explain the puzzling persistence of distance in international trade patterns.

Furthermore, we will examine the possibility of interactions between these factors, as they may not be independent of one another. For example, cultural and political factors may influence the strength of social connectedness between countries, which could, in turn, affect trade flows. Understanding these interrelationships is essential for developing a more comprehensive understanding of the factors driving international trade patterns.

3. Data

To investigate how cultural, social, and political factors influence bilateral international trade, we will need to use global trade data and find measures for all these qualitative factors. The complexity of international trade requires a multifaceted approach that considers not only economic but also cultural, social, and political dimensions. For this essay, I will use the trade flow data collected by Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) (Conte 2022). The database offers a range of variables that measure cultural, social, and political aspects of most countries in the world, providing a comprehensive framework for our analysis.

In particular, to account for bilateral trade flow, I will mainly use trade volume reported by the exporter and the importer in bilateral international trades to Comtrade database. In this essay, I will be considering the combined trade volume between two countries in their bilateral trade. This means that trade volume in this essay will be the sum of a country's imports from another country and the exports of the country i to the other country j:

$$trade\ volume = imports_{ij} + exports_{ij} \tag{1}$$

See Table 1 of the top 5 major parteners of Singapore, for example. Singapore is a country heavily dependent on trade, using the Comtrade data we can see the top five trade partners of Singapore since 1960. Other than the USA and the UK, most trade partners on the chart, such as Malaysia and Japan, have relatively small physical distances with Singapore. This corresponds with the inverse correlation between distance and trade volume of the Gravity model, reinforcing the traditional understanding of the role of distance in trade.

Table 1. The top 5 major trading partners of Singapore from 1960s-2020s

	Top 5 major trade partners of Singapore						
Ranks	1960	1970	1980	1990	2000	2010	2020
1	MYS	USA	USA	USA	MYS	HKG	HKG
2	VNM	MYS	MYS	MYS	USA	CHN	CHN
3	JPN	JPN	JPN	HKG	HKG	MYS	USA
4	GBR	HKG	HKG	JPN	CHN	IDN	MYS
5	USA	AUS	THA	THA	IDN	USA	IDN

3.1. Physical Distance and Control Variables

CEPII also provides the physical distance between countries, indicates whether two countries have a common language, and if they share borders. I will use the *physical distance* between countries' capitals as the measure of geographic distance in this essay. It is important to note that there are various ways to calculate the physical distance between two countries. This measure, while not perfect, provides a standardized and widely accepted proxy for the geographical barriers to trade.

Contiguity and *Common language* are represented as Boolean values, and they will act as control variables in the regression analysis later on. Contiguity indicates small physical distance between two countries, meaning that we should expect to see considerably large trade volumes between two countries sharing the same borders. Common language is known to have an effect on the efficiency of communication in international trade, thus we should expect to see a positive relation between common language and trade volume (Ferro and Ribeiro 2016). These control variables help to isolate the effects of other factors, ensuring a more robust analysis.

To quantify cultural differences of countries, I will utilize Hofstede's cultural dimensions theory, where Hofstede measures culture through six dimensions: individualism, power distance, masculinity, uncertainty avoidance, long-term orientation, and indulgence, where each dimension is measured on a scale of 0 to 100 (Hofstede and Hofstede 2011). This comprehensive framework captures the multifaceted nature of culture, providing a nuanced understanding of how cultural differences may influence trade. To find a measure of cultural distance, I will use the Euclidean distance calculation method to first find cultural similarity where a high value means greater similarity:

$$cultural\ similarity = \sqrt{\sum_{i=1}^{6} (\alpha_i - \beta_i)^2} \tag{2}$$

To turn cultural similarity into a measure of cultural distance, which in theory leads to lower trade volume if it is high, I will subtract it from 100:

$$cultural\ distance = 100 - cultural\ similarity \tag{3}$$

This transformation ensures that the measure aligns with our theoretical understanding of the relationship between cultural distance and trade.

For social distance, I will use the Social Connectedness Index created by Facebook (Bailey et al., 2018), which takes into account the number of friendship connections between two locations and the total Facebook users in these locations to measure the possibility of a Facebook friendship link between one user in one location and another user in the other location. This innovative measure captures the informal social ties that can facilitate trade by building trust and reducing information asymmetries.

The Social Connectedness Index is calculated as:

$$Social\ Connectedness\ Index_{i,j} = \frac{FB\_Connections_{i,j}}{FB\_Users_i \times FB\_Users_j} \quad (4)$$

As we found that social connectedness is positively correlated with trade volume in the previous section, we should expect to see a positive correlation between the Social Connectedness Index and trade volume. For the uniformity of distance measures, I will modify this index to make it account for social distance. As a smaller Social Connectedness Index means larger social distance, social distance will be calculated thus:

$$social\ distance = \log\left(\frac{1}{sci}\right) \quad (5)$$

The last distance measure would be political distance. To measure political distance, I will use the United Nations General Assembly voting data that includes voting recordings from 1946 to 2021. The amount of agreeing and disagreeing votes between two countries will represent the degree of political agreement between them. In this essay, I will use the ideal point distance model proposed by Bailey, et al., (2017) as political distance. This measure captures the formal political relationships between countries, reflecting the alignment or divergence of political interests that can facilitate or hinder trade.

One thing to note about different data sources may use different codes to label each country. All country codes from various sources will be universalize to ISO3 code when the data is processed, ensuring consistency with other data sources.

Table 2. The top 5 major trading partners of Singapore according to various distance measured in year 2020

	Top 5 closest major trade partners to Singapore			
Ranks	Physical distance	Cultural distance	Social distance	Political distance
1	MYS	ETH	MYS	DOM
2	IDN	ARM	BRN	ZWE
3	KHM	MKD	HKG	COM

4	BRN	AND	MAC	BLZ
5	THA	CYP	MMR	TLS

Again, take Singapore as the example, most similar countries under different distance measures would be different, and such distance measure may exhibit extra information that are commonly overlooked. Overall, by integrating these diverse measures of distance, this essay aims to provide a comprehensive analysis of the factors influencing bilateral international trade. The combination of traditional economic measures with innovative social, cultural, and political metrics offers a more nuanced understanding of the complex dynamics of international trade. This approach not only aligns with the theoretical foundations of the Gravity Model but also reflects the multifaceted nature of international trade in the modern world. By exploring these dimensions, I hope to shed new light on the role of distance in international trade and contribute to the ongoing discourse in this field.

4. Methodology

This essay adopts the structural gravity model which takes into account the presence of many countries in the world (Yotov et al. 2016). This complexity necessitates a more nuanced approach that can capture the multifaceted nature of international trade. This essay adopts a newer version called the structural gravity model, which takes into account the presence of many countries in the world and provides a more comprehensive framework for understanding international trade patterns.

More formally, the structural gravity model is expressed as:

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \quad (6)$$

Where X_{ij}, represents the trade volume between countries i and j, Y_i and E_j are the GDPs of the two countries, Y is the world GDP, t_{ij} is the trade cost, and Π_i and P_j are the price indices of the two countries. The parameter σ represents the elasticity of substitution between goods from different countries.

This model captures the fundamental economic forces that drive trade, including the size of the economies, the cost of trade, and the substitutability of goods. By considering the interactions between multiple countries, it provides a more realistic representation of the global trade network.

Empirically, We can add fixed effects to our regression analysis that uses the structural gravity model through using an empirical form of the gravity equation:

$$X_{ijt} = e^{\gamma_{it}+\eta_{jt}+\lambda_{it}+\beta Z_{ijt}} + \varepsilon_{\mathrm{ijt}} \tag{7}$$

where X_{ijt} is the trade volume between countries i and j at time t. γ_{it}, η_{jt} and λ_{it} are fixed effects for countries i and j, Z_{ijt} is a vector of other explanatory variables, and $\varepsilon_{\mathrm{ijt}}$ is the error term.

Many studies of the gravity model used the log-linear form of the expression above to conduct ordinary least square (OLS) estimations. However, that approach encounters many problems. There are many countries that do not engage in trade with one another. This leads to the presence of zero trade between two countries. As the log of zero does not exist, these values are ignored, leading to biases and inconsistency. Furthermore, there is also the problem of heteroscedasticity in trade data. The inconsistency of error means that a log-linear model may not achieve the best result. These challenges highlight the need for a more robust estimation technique that can handle the complexities of trade data.

In this essay, I will use the Poisson Pseudo Maximum Likelihood (PPML) estimator model instead of a standard linear regression model. In the study by Silva and Tenreyro (2006), it has been shown that PPML estimation is able to maintain its consistency regardless of the presence of zeros. Moreover, PPML is a non-linear estimation model, making it more suitable for heteroscedastic trade data. Thus, PPML is able to avoid common issues and biases met when using OLS estimations.

In particular, Silva and Tenreyro (2006) developed the PPML model through starting from the constant-elasticity model $y_i = e^{x_i\beta}$ and adding an error term to it to make:

$$y_i = e^{x_i\beta} + \varepsilon_i. \tag{8}$$

Acknowledging the problem of zero-trade and possible bias in log-linear analysis, Silva and Tenreyro (2006) estimates β through solving:

$$\sum_{i=1}^{n} \left[y_i - e^{x_i\beta}\right]x_i = 0 \tag{9}$$

instead of using OLS estimation.

The adoption of the PPML estimator in this essay represents a methodological innovation that addresses the unique challenges of trade data. By accommodating zero trade flows and handling heteroscedasticity, the PPML estimator provides a more robust and reliable analysis of the factors influencing international trade. This approach aligns with the theoretical foundations of the gravity model while also reflecting the empirical realities of international trade. By employing this advanced methodology, we hope to shed new light on the role of distance in international trade and contribute to the ongoing discourse in this field. The insights gained from this analysis will not only enhance our understanding of the dynamics of international trade but also provide valuable guidance for policymakers and researchers seeking to promote global economic growth.

5. Empirical results

The table 4 shows the results of the PPML estimation, reflecting the influence of various distance measures on bilateral international trade. A range of different combinations of variables are used to observe the changes in significance of each variable when placed together with other variables. This multifaceted approach allows us to see the possible presence of omitted variable bias and overlaps in the variables used in this essay, providing a more nuanced understanding of the underlying dynamics.

Table 3. Empirical result of structural gravity model using PPML estimation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
comlang_off	-0.0968*** (0.0129)	0.1277*** (0.0157)	-0.2143*** (0.0156)	-0.0948*** (0.0135)	-0.0531*** (0.0188)	0.1210*** (0.0156)	-0.2186*** (0.0156)	-0.0588*** (0.0186)
contig	1.0456*** (0.0196)	1.0583*** (0.0191)	0.9001*** (0.0197)	1.0431*** (0.0199)	0.9113*** (0.0200)	1.0828*** (0.0194)	0.9072*** (0.0205)	0.9380*** (0.0204)
physical_distance	-0.6510*** (0.0070)	-0.6997*** (0.0066)	-0.6700*** (0.0063)	-0.6527*** (0.0073)	-0.7048*** (0.0071)	-0.6859*** (0.0071)	-0.6659*** (0.0073)	-0.6917*** (0.0079)
cultural_distance		-0.0070*** (0.0003)			-0.0054*** (0.0004)	-0.0073*** (0.0003)		-0.0057*** (0.0004)
social_distance			-0.0098*** (0.0028)		-0.0053* (0.0028)		-0.0099*** (0.0028)	-0.0055** (0.0028)
political_distance				0.0034 (0.0062)		-0.0329*** (0.0059)	-0.0077 (0.0065)	-0.0280*** (0.0067)

Observations	56882	56882	36249	56882	36249	56882	36249	36249
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-Likelihood	-2.2040e+10	-2.0985e+10	-1.2248e+10	-2.2039e+10	-1.1961e+10	-2.0937e+10	-1.2246e+10	-1.1936e+10

Notes: *** p<0.001, ** p<0.01, * p<0.05. Standard errors are presented in parentheses.

Observations across the eight models range from 56,882 to 36,249 due to the lack of data for certain distance measures. Specifically, we can see that the decreases to 36,249 observations are always accompanied by the presence of social distance. This is due to many countries such as China banning and censoring Facebook, leading to limited social connectedness data in these regions. The absence of social connectedness data in some countries highlights the challenges of measuring social distance and underscores the importance of considering alternative data sources or methodologies to capture this complex dimension.

Throughout the eight different models generated, physical distance, cultural distance, and social distance remain significant. Physical distance's parameter fluctuates from -0.7048 to -0.6510, with the smallest effect on trade volume when it is modeled alone, and the largest effect on trade volume when it is modeled together with cultural and social distance.

Contrary to my hypotheses, the role of distance in the gravity model did not decrease as we added more distance measures to the model. This finding challenges the conventional wisdom that the significance of physical distance would diminish with the inclusion of other distance measures. Instead, it suggests that physical distance continues to play a vital role in shaping trade patterns, even in the presence of other factors.

Moreover, the consistent significance of cultural and social distance with negative parameters suggests that cultural and social differences between countries do, in fact, influence bilateral trade volume negatively. This supports the theoretical expectation that greater cultural and social distance would create barriers to trade, such as misunderstandings, mistrust, or lack of shared norms and values.

Political distance only seems to be significant when modeled together with cultural difference. When modeled alone without cultural distance, the p-value of political distance reaches 0.577 (with physical distance) and 0.235 (with physical and social distance). In contrast, when modeled with cultural distance, the p-value is reduced to 0.000.

This curious fluctuation in p-value suggests that political distance may be interacting with cultural distance in a way that affects their individual significance. It could be that political and cultural distances are correlated, with shared political ideologies often reflecting shared cultural values. Alternatively, political distance might only become a barrier to trade when it is accompanied by significant cultural differences. This finding points to the complexity of the relationship between political, cultural, and trade dynamics and underscores the importance of considering interactions between different factors.

The results of this analysis provide valuable insights into the role of various distance measures in shaping international trade patterns. The consistent significance of physical, cultural, and social distance underscores the multifaceted nature of trade barriers and highlights the importance of considering a broad range of factors in trade analysis.

The unexpected findings regarding political distance point to the need for further research to understand the complex interplay between political, cultural, and economic factors. By deepening our understanding of these dynamics, we can develop more effective trade policies that take into account the full range of barriers to trade.

Overall, this analysis contributes to the ongoing discourse on the gravity model's validity in the modern world, shedding new light on the role of distance in international trade and offering a more nuanced perspective on the factors that influence trade patterns.

Table 4. Fixed effect estimation for France as importer and exporter between years 2000-2019

Variable	Coefficient	Standard error	z	P>|z|	[0.025	0.975]
iso3_d_year_fe_FRA2000	23.9257	0.099	241.197	0.000	23.731	24.120
iso3_d_year_fe_FRA2001	23.8557	0.094	252.623	0.000	23.671	24.041
iso3_d_year_fe_FRA2002	23.7882	0.095	251.618	0.000	23.603	23.973
iso3_d_year_fe_FRA2003	23.8282	0.100	237.227	0.000	23.631	24.025
iso3_d_year_fe_FRA2004	23.9636	0.097	247.711	0.000	23.774	24.153
iso3_d_year_fe_FRA2005	24.0128	0.096	248.904	0.000	23.824	24.202
iso3_d_year_fe_FRA2006	24.1336	0.097	250.038	0.000	23.944	24.323
iso3_d_year_fe_FRA2007	24.2264	0.096	251.405	0.000	24.038	24.415
iso3_d_year_fe_FRA2008	24.3370	0.095	254.955	0.000	24.150	24.524
iso3_d_year_fe_FRA2009	24.1364	0.091	264.436	0.000	23.958	24.315
iso3_d_year_fe_FRA2010	24.1965	0.093	260.558	0.000	24.014	24.379
iso3_d_year_fe_FRA2011	24.3229	0.093	260.825	0.000	24.140	24.506
iso3_d_year_fe_FRA2012	24.2984	0.090	271.138	0.000	24.123	24.474
iso3_d_year_fe_FRA2013	24.3117	0.088	274.989	0.000	24.138	24.485
iso3_d_year_fe_FRA2014	24.3008	0.093	261.703	0.000	24.119	24.483
iso3_d_year_fe_FRA2015	24.2217	0.093	261.021	0.000	24.040	24.404
iso3_d_year_fe_FRA2016	24.2082	0.093	260.882	0.000	24.026	24.390
iso3_d_year_fe_FRA2017	24.2920	0.090	269.896	0.000	24.116	24.468
iso3_d_year_fe_FRA2018	24.3697	0.093	263.087	0.000	24.188	24.551
iso3_d_year_fe_FRA2019	24.4127	0.097	252.921	0.000	24.223	24.602
iso3_o_year_fe_FRA2000	-2.2710	0.108	-21.016	0.000	-2.483	-2.059

iso3_o_year_fe_FRA2001	-2.2055	0.109	-20.148	0.000	-2.420	-1.991
iso3_o_year_fe_FRA2002	-2.0955	0.097	-21.553	0.000	-2.286	-1.905
iso3_o_year_fe_FRA2003	-1.9983	0.096	-20.915	0.000	-2.186	-1.811
iso3_o_year_fe_FRA2004	-1.9573	0.097	-20.167	0.000	-2.148	-1.767
iso3_o_year_fe_FRA2005	-1.9690	0.095	-20.629	0.000	-2.156	-1.782
iso3_o_year_fe_FRA2006	-1.9868	0.104	-19.111	0.000	-2.191	-1.783
iso3_o_year_fe_FRA2007	-1.9838	0.101	-19.608	0.000	-2.182	-1.785
iso3_o_year_fe_FRA2008	-1.9702	0.098	-20.111	0.000	-2.162	-1.778
iso3_o_year_fe_FRA2009	-1.9811	0.099	-19.996	0.000	-2.175	-1.787
iso3_o_year_fe_FRA2010	-2.0327	0.099	-20.621	0.000	-2.226	-1.840
iso3_o_year_fe_FRA2011	-2.0587	0.098	-21.035	0.000	-2.251	-1.867
iso3_o_year_fe_FRA2012	-2.1266	0.099	-21.398	0.000	-2.321	-1.932
iso3_o_year_fe_FRA2013	-2.0929	0.085	-24.637	0.000	-2.259	-1.926
iso3_o_year_fe_FRA2014	-2.1348	0.095	-22.388	0.000	-2.322	-1.948
iso3_o_year_fe_FRA2015	-2.2739	0.109	-20.912	0.000	-2.487	-2.061
iso3_o_year_fe_FRA2016	-2.2654	0.109	-20.716	0.000	-2.480	-2.051
iso3_o_year_fe_FRA2017	-2.2092	0.104	-21.280	0.000	-2.413	-2.006
iso3_o_year_fe_FRA2018	-2.2465	0.096	-23.471	0.000	-2.434	-2.059
iso3_o_year_fe_FRA2019	-2.2671	0.100	-22.689	0.000	-2.463	-2.071

5.1. Case Study: France

The table 4 provides an illustrative example of country and year fixed effects for France in the 8th model, where iso3_d represents France as an importer (destination country) and iso3_o stands for France as an exporter (origin country). The p-values of all fixed effects are consistently 0 across all eight models, with no exceptions. Models 1 to 8 incorporate both country and year fixed effects to mitigate potential size bias. These fixed effects are designed to capture unobserved heterogeneity across countries and over time, allowing for a more nuanced understanding of each country's role in international trade from 2000 to 2019. This result strongly suggests that these fixed effects are significant indicators of every country's role in international trade during the study period. The significance of these fixed effects underscores the importance of considering both country-specific characteristics and temporal trends in analyzing international trade patterns.

In the example of France, we observe an increase in the coefficient of iso3_d_year_fe_FRA from 2000 to 2019. This positive trend in the coefficient reflects a growing presence of France in international trade as an importer during these years. The increase may be indicative of various underlying factors, such as changes in domestic consumption patterns, trade policies, or economic growth, that have contributed to France's enhanced role as a global importer.

Conversely, the absolute value of iso3_o_year_fe_FRA's coefficient exhibits a more complex pattern. It shows a decrease in the 2000s, followed by a gradual increase in the 2010s, returning to a value close to what it was in 2000. This pattern demonstrates a decrease in the significance of France as an exporter in the 2000s, followed by a resurgence in the 2010s. This fluctuation may reflect changes in France's export competitiveness, shifts in global demand for French products, or alterations in trade agreements and regulations. The decrease in the 2000s might be indicative of challenges faced by French exporters, while the subsequent increase in the 2010s could signal a recovery or strategic repositioning in global markets.

6. Discussion

The PPML models of trade volume, incorporating physical distance, cultural distance, social distance, and political distance, have revealed complex dynamics in bilateral international trade. While physical distance remains a significant factor, the emergence of nonphysical distances suggests a nuanced understanding of trade costs and frictions. This section delves into the theoretical and practical implications of these findings, as well as the limitations of the study.

6.1. The Continued Persistence of Physical Distance

Contrary to expectations, the importance of physical distance in bilateral international trade did not diminish. This finding underscores the persistent relevance of transportation costs in international trade. Despite advancements in technology and logistics, distance remains a useful indicator of cost, reflecting the tangible barriers that still exist in global commerce.

6.1.1. Theoretical Implications

From a theoretical standpoint, this result reaffirms the foundational principles of the Gravity Model, emphasizing the enduring role of geography in shaping trade patterns. It challenges the notion that globalization and technological advancements have rendered physical distance irrelevant, highlighting the need for continued attention to geographical factors in trade modeling and policy formulation.

6.1.2. Practical Implications

On a practical level, the significance of physical distance has implications for businesses and policymakers. It suggests that strategies to reduce transportation costs, enhance logistical efficiency, and foster regional trade partnerships remain vital for promoting international trade and economic growth.

6.2. The Emergence of Nonphysical Distances

The models also reveal the significance of cultural, social, and political distances as indicators of trade costs, leading to different levels of trade friction.

6.2.1. Theoretical Implications

The recognition of nonphysical distances represents a shift in the understanding of trade costs, moving beyond mere transportation expenses to more subtle factors caused by differences in culture, social interactions, and politics. This shift expands the theoretical framework of international trade, calling for a more comprehensive approach that integrates sociocultural and political considerations.

6.2.2. Practical Implications

For businesses, the significance of cultural and social distances implies the need for cultural competence and relationship-building in international markets. Understanding and navigating cultural nuances can enhance communication, trust, and collaboration, fostering successful trade relationships.

For policymakers, the role of political distance emphasizes the importance of diplomatic relations, trade agreements, and international cooperation in facilitating trade. Strategies to bridge political differences and foster collaboration can reduce trade frictions and enhance economic integration.

7. Conclusion

In this study, we explored the enduring role of physical distance in bilateral international trade, questioning whether its persistence might be attributed to omitted variable bias. With the rapid advancements in transportation and communication technologies, we hypothesized that the significance of physical distance should have diminished, reflecting a reduced proportion of trade friction. By incorporating cultural, social, and political distances—

nonphysical distance measures—into the trade volume model alongside physical distance, we sought to uncover a potential shift in weight from physical to nonphysical distance measures and to investigate if previous gravity analyses suffered from omitted variable bias.

The results of this paper reveal a nuanced picture. While there is evidence of a shift from physical distance to nonphysical distance measures, with cultural, social, and political distances found to be significant, the role of physical distance has not decreased as substantially as anticipated. Cultural, social, and political distances emerged as significant factors in the trade volume model, signaling a complex interplay between tangible and intangible barriers. However, physical distance still holds significant across the eight PPML models of trade volume, indicating that advancements in technology may not have sufficiently reduced transportation costs to diminish its importance.

These findings contribute to the understanding of international trade by highlighting the multifaceted nature of trade costs and frictions. While physical distance remains a crucial determinant, the emergence of nonphysical distances signals a complex and evolving landscape in international trade dynamics. The study underscores the need for a holistic approach to international trade that recognizes both tangible and intangible barriers. The insights offer valuable guidance for theorists, practitioners, and policymakers, emphasizing the importance of considering cultural, social, and political factors in trade modeling, strategy development, and policy formulation.

The study's limitations lie in the data constraints, particularly concerning nonphysical distances. Future research could explore alternative data sources or methodologies to provide a more robust analysis of nonphysical distances. Additionally, further investigation into the interplay between physical and nonphysical distances and their combined impact on trade could yield valuable insights, deepening our understanding of the complex dynamics at play.

In conclusion, this study challenges the conventional wisdom regarding the role of physical distance in international bilateral trade, revealing a more intricate picture. While we cannot attribute the persistence of physical distance solely to omitted variable bias, the study illuminates the significant influence of nonphysical distances. The findings enrich the discourse on international trade, calling for a more comprehensive and nuanced approach that embraces the multifaceted nature of trade barriers in an increasingly interconnected world.

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