Maritime Connectivity and International Trade: Distance in a Globalized World

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Abstract

This paper provides a novel theoretical and empirical discussion on observed spatial patterns in global trade relations. The argument of this paper is that a state's access to international sea routes is an important determinant of a state's ability to conduct global economic relations. Building off new ideas of transportation in the field of geography, this paper presents a discussion of how we should think about the distance between states in a globalized world. I Use new data from the United Nations Commission on Trade and Development to understand a state's connectivity in global maritime pathways. Using this data, I discuss how global trade relations suffer from structurally determined spatial biases. Past research has already discussed the presence of spatial patterns in trade data, but research has yet to theoretically examine why these patterns exist and look the way they do in modern relations. I show that trade through maritime activity create violations of IID assumptions in many models and can lead to spatial biases in understanding global economic activity. Following this, I use spatial modeling techniques to account for these biases and discuss how the maritime industry creates important geographic connections between states. These connections should be thought of in similar ways to how economic geography scholars view distance. Given the temporal variation in these connections and the possibility of them being influenced by domestic and international institutions, IPE scholars are well suited to study how the maritime industry connects states. By understanding the determinants of spatial patterns, scholars can theorize about how these patterns manifest in different circumstances and affect different state's abilities to trade and engage in other interstate activities.

How are state's connected to each other is a fundamental question of international relations. Liberal theories often argue that the connections between states are an important driver of state actions. It is the connections between states that scholars such as Robert Keohane (2005) point to as methods to drive cooperation in a world without major power structures. Thus, scholars of IPE have spent much effort discussing how states are increasingly connected in today's globalized world (Barbieri & Schneider, 1999). Work on international trade has especially focused on how increased economic connectivity between states might lead to important outcomes such as the reducing the probability of war (Hegre et al. 2010), the spread of democracy (Lopez-Cordova & Meissner, 2005; Ahlquist & Wibbels, 2012) and economic growth (Singh, 2010).

There is little debate that the world is far more interconnected today than it once was. However, understanding how states connect to each other remains a vital topic. This paper presents a novel theory focused on how global maritime routes act as the connections between states in the modern globalized world. Around ninety percent of all commodity trade occurs via the sea (OECD, 2022). Modern sea routes between countries act as the highways connecting once distant lands. As technological innovation has decreased the costs of transporting goods abroad, there has been a global transformation in the ability of states to trade with each other. The research question this paper asks is how do the spatial patterns of these maritime highways affect the ability of different states to connect to each other in international trade?

Geographic distance was once considered the main detractor to global economic relations. Isard and Peck (1954, 101) present the empirical regularity of commodity trade decreasing as distance increases.[1] Isard (1954, 308) references this analysis to formally introduce the gravity model of trade. The gravity model uses economic mass[2] and distance between two countries as a powerfully predictive model of international economic relations. Additional work on economic geography by Krugman (1991, 1994, 1997, 1999) introduced a wide range of spatial-empirical models to study economic flows between states. Krugman (1998) summarizes the literature on economic geography and attributes geography as a principal cause of trade flows.

This paper looks at how the maritime shipping industry creates spatial patterns of trade connections. In doing so, this paper builds a geographical theory of international trade. However, this paper views the concept of *distance between countries* as far different than geographic distance as the crow flies, which is the standard usage of this term in the IR literature. In a world where maritime pathways act as the geographical connections between states, distance between states should be thought of in terms of these routes. Unlike past economic geography theories, this paper demonstrates that these maritime connections between states are not static and have changed throughout the past half century [3]. The spatial clusters these connections create offer a novel lens through which to think about how geography shapes our world and allows states to connect with each other.

Recent work in international relations has begun analyzing spatial patterns that are common in much of our data (Beck et. al., 2006; Franzese & Hays, 2007; Hays et. al., 2010; Plümper & Neumayer, 2010; Ward and Gleditsch, 2018). This paper will argue that these spatial patterns

[1] The geographic term for this is "friction."

[2] Often measured as GDP, but conceptually something unique.

[3] Potentially due to major events of interest to IR scholars such as the rise of China, consolidation of the EU, and proliferation of liberal economic agreements.

are being driven in part by the use of maritime shipping as the method of trade. The more connected via sea any country is, the easier it will be to engage in trade with other countries. However, as one state becomes increasingly connected, it will reshape global sea routes by pulling more shipping activity towards it. This shift of sea routes will then give that state's neighbors increased access to global shipping creating a spatial cluster of highly connected states.

Isard (1954, 306) argues that a major drawback in traditional trade studies is their tendency to view relations as solely dyadic. Ward, Ahlquist, and Rozenas (2013) use spatial network techniques to show that geography continues to have an important effect by creating high-order spatial dependencies between countries. These dependencies exist between more than two countries, and as such, the dyadic gravity model struggles to capture them. The study by Ward et al. (2013) reflects a large range of empirical analysis in international relations seeking to move beyond dyadic analysis (Erikson et al. 2014, Poast 2016). Geospatial modeling techniques, which are highly related to network analysis, offer a way to fundamentally advance the understanding of complex international phenomena. This is especially relevant in international relations where we can use a deep theoretical understanding of the connections between states to create spatial models capturing a wide range of outcomes. Beck Gleditsch and Beardsley (2006) discuss how international relations scholars are well poised to use spatial models for analysis of theories based on more than distance alone. In a globalized world, the *distance* between states can be fluid and scholars should spend more time thinking about how to conceptually understand the idea of *distance*.

In this paper, I discuss how the location of maritime pathways affects distance between countries and thus trade. Importantly, I reject the assertion that a simple measure of *miles/kilometers between states* as the best measure of distance. Distance is a a misleadingly simple concept which needs more theoretical discussion. This study brings into IPE important ideas from the field of transportation geography which has argued for novel ways of viewing geographic effects on individual activities and business.

The field of transportation geography originated in the first half of the 20th century with the need to create roads connecting various points. The point to point model was introduced as potentially the best way to accomplish this. Scholars and engineers used consumer surveys to plot household locations of shoppers with the idea being to build roads directly connecting where consumers live with stores of a specific location (Kuwahara 1987, Hajek 1977). This is similar to how scholars of trade view connectivity between states, as having specific origin and destination points and moving directly between them.

However, more recent studies of consumer and transportation behavior in geography has rejected the idea that a simple point to point model is sufficient (Keeling, 2007; Shaw & Hesse, 2010; Shaw & Sidaway, 2011; Schwanen, 2016). These studies make two major points. First, it is common for consumers to visit multiple locations on a single trip, as such when understanding consumer travel patterns we must think about the trip as an aggregate as opposed to individual point-to-point movements. Second, shoppers will be rational in selecting the route that connects them to the most of their desired stops with as little distance as possible (Vidana-Bencomo et al. 2018). Importantly this can lead to very different outcomes from the gravity model which predicts a consumer to choose shops based on a direct analysis of geographic proximity between that shop and their home. These geographers use network techniques to understand travel patterns by creating networks of stops along travel paths throughout the city (De Beul et. al., 2014). Work in this field has focused on optimizing business activity and public transit networks based on individual travel patterns. A significant amount of the field has been dedicated to the idea of optimizing freight distribution (Hesse & Rodrigue, 2004; Bowen & John, 2008; Cidell, 2010). The idea is that everything from warehouses, to franchises, to bus stations should be located in a way that optimizes access to them from the whole network of travel as opposed to from a single location (Garcia, 2012; Tong and Murray, 2012).

These more complicated geographic models rely on network techniques to link all potential destinations and determine how movement between any two points is affected by their proximity to other points. This modeling technique highly resembles the work by Ward, Ahlquist, and Rozenas (2013) who create a spatial network model of international trade. In a world where countries trade with many partners and trade is facilitated by the movement of goods along maritime pathways via large cargo ships, a point to point gravity model is likely too simplistic to understand space and state connectivity. This paper takes as a starting point that international companies use the logic discussed in transport geography to rationally choose trade and supply chain locations. These choices then have important substantive effects on the distribution of global trade patterns. I build off the logic of transportation geographers to discuss how maritime pathways create spatial patterns in global trade data[4]. In this way, I provide a novel geographic theory of international trade built from the methods used to facilitate modern trade relations.

This paper directly builds off the growing IPE literature of geography by theoretically discussing the causes and consequences of observed geographic correlations. The core argument of this paper, is that the global maritime industry connects countries together and forms clusters of high and low trade, referred to as spatial correlation. A recent booklet by Ward and Gleditsch (2018) introduces the idea of spatial modeling to scholars of international relations and discusses the benefits of these tools. Failure to account for spatial patterns can lead to biases in studies of important IR outcomes including trade, war, and the spread of democracy. In their booklet, Ward and Gleditsch discuss models such as the spatial lag and spatial error model and encourage scholars to integrate these techniques into their own work.

Today, the vast majority of all commodity trade occurs via the sea. A country without access to the major global sea routes will find it difficult to attract trade and investment[5]. These sea routes represent the important webs of the modern global economy and the transmission of goods. However, rather than acting as simple connections between two states, the location of sea routes to and from one state directly affects other states in the region. When one state, for example China, has a strong maritime industry and acts as a major location along global shipping routes, it means that nearby states; such as Vietnam, South Korea, and Japan are also located along major sea routes. An entire field of transport economics has risen to discuss how essential maritime trade is to the modern world (Brooks et. al., 2002; Button, 2010; Cullinane, 2011). In this paper, I argue that this maritime trade, which structures global economic relations, is ripe with spatial correlations which grant some countries far more access to

[4]Just a roads and business locations create spatial patterns in consumer shopping behavior.

[5]A significant amount of work for example demonstrates that landlocked countries struggle in these aspects (Collier, 2008; Paudel, 2014 & Carmignani, 2015; Moore, 2018).

world markets than would otherwise be predicted while disadvantaging other countries located far from maritime routes. The maritime industry creates these spatial patterns which can lead to bias in studies that treat all states or dyads as independent. This paper studies the spatial dynamics as a theoretically interesting phenomena and seeks to provide a novel argument for why they form and how they influence the global economy. In this way, this paper contributes to other research in IPE which has focused more on the empirical problems of handling spatially correlated data.

In this paper I start by demonstrating the strong presence of spatial patterns in global trade data between the years of 2006 and 2020. I discuss how these spatial patterns create biases in standard modeling techniques and so must be accounted for using spatial lag models. Following this, I present a discussion of the structural determinants of the spatial correlation in this data. This discussion presents the fact that not every country is equally similar to its neighbors. In this section, I introduce the idea of "Maritime Connectivity" as an important factor creating links between neighbors. I argue that the spatial patterns observed in international relations data are often complex and dependent on state specific factors. I empirically demonstrate this by showing that the more connected via maritime activity a country is, the more it is correlated with its neighbors. Following this, I present an empirical model showing state-year trade activity and how it is shaped by global maritime connections. In this model I use spatial techniques to account for geographic patterns and present novel hypotheses to discuss how these patterns can be theoretically important parameters to the study of trade. This section concludes by showing that modern spatial patterns occurring in the global maritime industry are both statistically significant and substantively meaningful predictors of a state's trade flows. Following this I present the global network of maritime connectivity. I examine this network to discuss how connectivity can act as a better determinant of trade than distance as the crow flies. I also look at the most connected countries and show how these countries have shifted in maritime connectivity over the past twenty years. This section ends with a discussion of how scholars of IPE can utilize maritime connectivity to better understand important phenomena. I conclude the paper with a brief discussion of how these results can impact studies of global trade and other IR outcomes.

1 Spatial Patterns of Trade

Economic Geography is a methodological branch of economics using spatial analysis to understand the economic activity within and between states[6]. The foundation of economic geography goes back to the gravity model of trade which argues that trade between any two countries can be predicted by the size of their economies and the distance between them (Isard, 1954)[7]. In the 1990s, economic geography was revitalized by Dr. Paul Krugman and 'New Trade Theorists' which used economic models focused on returns to scale and network effects (Neary, 2009).

[6]A related but distinct area also referred to as "Economic Geography" is a branch of Human Geography focused on economic activity. For this paper, I focus on the literature of economic geography found in economics and political science.

[7]Some might even argue that spatial research goes back to the founding of social science with Jon Snow's work on the spread of cholera (Snow, 1855)

The New Trade Theorists used more complex spatial and network models to understand how distance creates friction for global trade (Chandra, 2022).

Despite the dominance of geographical explanations of trade in the 20th century, around the turn of the century new work sought to argue that institutions provided the best explanation for trade patterns. These economists, such as Acemoglu Johnson and Robinson (2002,2005,2006) argued that much of the observed prominence of geographic variables in reality came from the important role of geography in shaping institutions which then shaped economic patterns. These scholars helped pave a bridge between economists and political scientists to understand how political institutions, both domestic and international, influence economic outcomes. Most of the work in IPE has focused on the role of these institutions in shaping global economic relations. This work grew in importance as scholars found that gravity explanations seemed unable to explain modern trade (Brun et al. 2005).

Recently, IPE scholars have brought the discussion of geography back to the forefront. Ward, Ahlquist, and rozenas (2013) use spatial network models to discuss how geography continues to matter in global relations. Ward et al. (2013) show that instead of geography influencing trade through dyadic relations, it does so by creating multilateral dependencies. Trade relations between any two countries are highly related to spatial patterns between themselves and other nearby countries. Therefore, to understand the effects of geography on trade, it is important to go beyond dyadic analysis and look at the effects among groups of countries.

Geographers have developed a large group of models capable of handling these complex relations. Spatial models work by creating weighted matrices to account for the spatial spillover of nearby observations. The logic of these models stems from the idea that nearby units tend to be more similar than distant units. The term used for this is "Spatial correlation"(Getis, 2010).

In International relations, discussion of spatial correlation has increased in recent years. In 2006, Beck et al. discuss the use of spatial econometrics as a potential tool for scholars seeking to study international phenomena. A common use of these techniques is to model conflict, which has long been identified as having a heavy spatial component (Ward & Gleditsch, 2002; Gleditsch & Ward 2000; Weidmann & Ward 2010; Buhaug & Gleditsch 2008). However, the usage of spatial modeling techniques remains a niche method of which few scholars are proficient. One potential reason for this might be the preference among many scholars to have theoretically informed models. Adding spatial components to models without having a spatial theory to justify their inclusion might seem like over complicating models. However, failure to think about and control for the spatial relations of different units in international relations risks biasing any empirical model and leading to false conclusions.

The major problem is that spatial relations violate Independent and Individually Distributed (IID) assumptions that are common in most commonly used empirical models (Pesaran & Tosetti, 2011). For example, if conflict is spatially correlated as past research shows, failure to account for the spatial impacts of conflict in one country on its neighbors might lead to other regionally concentrated variables seeing more prominent effects than is true. One example of this is terrorism. Terrorism, and other types of non-state conflict, are shown to be spatially correlated (Harb 2019). This might be one explanation for the large number of terror groups in the Middle-East and North Africa. Failure to empirically account for the fact that terrorism in one country increases the likelihood of terrorism in other nearby countries might lead to other spatially correlated variables, such as religious identity, being shown as a more prominent predictor than would otherwise be true. Empirically, failure to account for spatial correlation creates an omitted variable which is correlated with the error term, in other words, endogeneity.

Thankfully there is an easy way to test for spatial correlation in any dateset. The Moran's I test conducts a simple test to show if spatial correlation is a worry or not. This test conducts a bivariate regression of a unit measure (for example country trade flows) on the average value of that same measure for all other units in the data identified as neighboring that unit[8]. The bivariate regression tests if a variable is geographically clustered. In a world where the IID assumptions hold across space, there will be no correlation in this regression. If a correlation does exist, it means that there is potentially spatial correlation occurring which must be accounted for [9].

Scholars of International Relations data would likely do well to become more familiar with this method as much of our data tends to suffer from spatial biases. *Figure 1* provides a Moran's I plot for four important variables to the Study of IPE. These variables are Trade flows[10], GDP[11], Democracy [12], and Maritime Connectivity [13]. As can be seen in this figure, all variables show significant positive spatial correlation. The data in figure 1 represents data from the year 2020[14]. For the adjacency matrix, I coded neighbors based on the State Continuity dataset published as part of the correlates of war project (Stinnett et. al., 2002)[15]. A neighbor is here defined as any country sharing a land or river border, or a country separated by a sea distance of no more than 40 miles. The unfilled circles represent normal observations, the diamonds represent influential observations, and the large filled circles represent observations with no neighbors in the data[16].

[8]This identification comes from the creation of an adjacency matrix which codes how different units are connected geographically with each other. Such a technique is also used in Network analysis which demonstrates how highly related these two empirical techniques are.

[9]It is important to note that a correlation does not necessarily mean that the variable is causing itself in nearby countries (i.e. terror causes terror) it is possible that there is an omitted variable which is driving this spatial correlation. Either way, it is essential to control for the causes of spatial correlation to eliminate the violation of IID.

[10]Measured as imports + exports obtained from the United Nations Commission on Trade and Development

[11]Measured in millions of USD also obtained from the United Nations Commission on Trade and Development

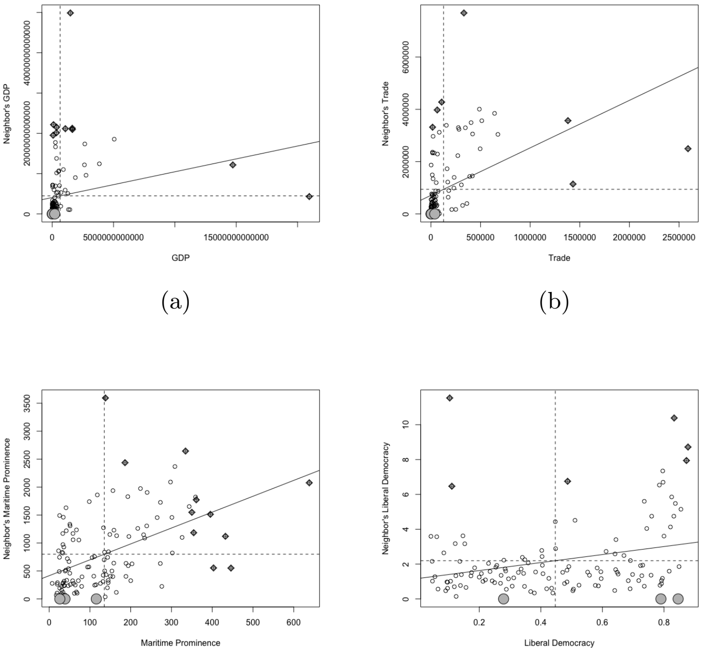
[12]Using the "liberal democracy" score obtained from the varieties of democracy dataset (Limberg et al. 2014)

[13]An important variable for this paper, obtained from the United Nations Commission on Trade and Development and discussed in detail further on.

[14]In the online appendix of this paper I conduct the test for all years in the data (2006-2020) and show that the same spatial patterns are present regardless of year.

[15]Correlates of War Project. Direct Contiguity Data, 1816-2016. Version 3.2.

[16]These are small island nations



(a) (b) (c) (d)

Figure 1: **Global Spatial Correlation for Important Variables**

In each of these variables, there is a statistically significant (at the 0.01 level) relationship between a country and its neighbors. This trend is most pronounced for the Maritime Connectivity variable, this fact will be discussed in the next section. This represents a potential problem when any of these variables are used in an econometric model because it will lead to endogneity from omitted variables. Spatial techniques were designed to solve these issues and the booklet by Ward and Gleditsch (2018) discusses what to do when data fails a Moran's test. While solving these empirical problems is an important goal, this paper argues that the spatial patterns present in *figure 1* are of themselves important theoretical constructs. The goal of this paper is therefore to provide a novel theoretical argument about how these spatial patterns form and the effect they have on global trade.

Before making the use of these spatial models, I want to spend the next section providing a novel theoretical argument for why spatial patterns form and look the way they do in international trade. As can be seen in *figure 1* there is large variance in the correlation between a given state and its neighbors. Very few observations fall directly on the best fit line and many observations appear as potential outliers. I argue in the next section that different countries are affected differently by neighbors. In the next section I present a theoretical argument based on the idea that international sea routes act as the geographic connections between modern states. In the following section I introduce new data on state level maritime connectivity, and conduct a linear mixed effect regression with local spatial correlation as the dependent variable to show that maritime connectivity and GDP structurally affect how related a state is with its neighbors.

2 A Spatial Theory of Maritime Connectivity and Trade

The vast majority, around 90%, of international commodity trade occurs via the sea (OECD, 2022). This fact is responsible for some of the complex trade relationships that exist in current data. When thinking about a sea route, the fundamental understanding is that rarely are these routes dyadic. On a single voyage, a ship can stop at many different countries. This cluster of countries represent a grouping that can trade with each other in a relatively straightforward process[17]. For example, a ship sailing from the United States to China also often stops at Canada, Japan, and South Korea[18]. This North Pacific Sea Route links these countries and creates international network dependencies. In this example, it would be impossible to understand trade connections between Canada and South Korea without viewing them simultaneously with trade connections between the U.S. and China. In other words, these two separate dyads are actually highly dependent on each other via the single sea route.

Ward et al. (2013) identified the strong presence of high-ordered spatial dependencies in international trade data. They discussed how trade between any dyad is highly affected by trade with other countries located proximal to these dyads. To ward et al (2013), a trade path looks more like a rainbow connecting multiple countries than a straight line between two partners. Sea Routes can account for the mechanism driving these effects and creating this rainbow. The North Pacific Sea Route discussed above clearly demonstrates how multiple countries connect along a single route to form complex dependencies.

In today's globalized trade, sea routes forming clusters of multiple countries as opposed to dyads has become the norm. These sea route clusters have become common in international trade for two reasons that have important impacts on how to understand distance. First, technological advancements in international shipping have led to massive container ships capable of handling a tremendous amount of cargo. This phenomenon is often referred to as the "container revolution." The container revolution is composed of two major trends in world shipping. The first consists of the increased use of container ships to transport goods internationally. This trend began in the 1960s and was associated with a drastic decrease in shipping costs (Rodrigue & Notteboom, 2009). The second trend is the creation of "super" cargo ships in the mid-2000s capable of carrying an incredibly large number of containers. Larger cargo ships are more capable of handling multi-country trade due to their ability to carry a huge amount of goods (Bernhofen et al. 2010). Transport economists such as Hummels (2007) have argued that this growth in technology has lowered the cost of engaging in long distance trade which has led to a reduction in the friction caused by distance.

The container revolution has had tremendous consequences to the global transportation markets and continues to have widespread economic ramifications. Since the mid-2000s, there has been a significant oversupply in cargo ship capacity meaning most ships travel at only 50-70% capacity (Kwon and Kim, 2019). As anyone familiar with basic economics understands,

[17] Previous work has identified that "trans-shipments" or moving cargo from one ship to another, is a major cause of transport costs increasing, if countries are connected via a single ship, they can avoid this cost (Hummels 2007; Fugazza, 2015).

[18] The spherical shape of the world means that a ship sailing from the U.S. to China typically goes north past Canada and Alaska, a faster and cheaper route than traveling straight across the Pacific Ocean. Air flights do a similar curved route.

an oversupply leads to a price decrease. This leads to shipping firms having to adopt strategies designed to guarantee a profit despite being unable to charge high prices. For example, ships often travel at only a quarter of their normal speed to save gas costs[19]. One other strategy to ensure a profit is for ships to increase the number of stops on their voyage and handle trade between more countries leading to larger clusters connected via a single vessel. Today rarely do ships handling containers only work for a single company. Shipping firms are instead independent operators contracted by global corporations to handle the transportation of goods. While the global firms might prefer a ship to only stop at that firms desired locations, often to make a profit a shipping company must make many stops and contract with as many global firms as possible.

Considerable work in transport geography discusses how to optimize the transportation patterns for deliveries. These studies analyze organizations tasked with delivering goods between consumers and companies ranging from the United States Postal Service to pizza delivery (Nirwan et al. 2021; Wang et al. 2020; Turska et al. 2019; Wikare & Sitek 2020; Rizwanullah & Nilofer 2018). These scholars seek to design optimal routes between all warehouse locations and consumers. This method requires a complex analysis using simulations of the costs and benefits of adding stops at any specific location and how it impacts the entirety of the delivery network. This method is used to understand where to stop and where is not worth stopping, for instance these studies can explain why the pizza shop might not deliver to your specific area or why public transportation stops are located where they are.

Global cargo transportation networks are subject the same analysis as those above. When choosing the routes to transport goods it is important to think in terms of the network of connections between countries as opposed to a simple point to point analysis. Global maritime transportation companies will desire to optimize their routes by choosing the paths that connect them to the most profitable stops possible with the minimal costs of transport. While the costs of transport have decreased, the incentive to optimize these networks have not. Just as domestic transport optimization networks lead to differences in spatial patterns of access to goods, so too will international cargo transport networks. In other words, these networks can explain why some countries might find it easier/harder than others to connect to other countries in international trade.

Due to the container revolution, international sea shipping is now both the dominant way to trade internationally and highly spatially correlated. When sea transportation companies choose to add a stop, they will be strategic in their choices of where to do so. A shipping company seeking to add a stop will maximize profit by identifying a port with the largest potential market for the lowest additional transport costs. If a country is too far away from a ship's planned path, that country is an undesirable stop due to the increased transportation costs of getting to that location and the increase in time that it will take to then complete its other routes. If a country lacks a large enough market, a ship might not want to stop because it can make more money by completing the routes it already has larger contracts on more often, or stopping at larger nearby states. Importantly, these represent the same parameters as in the

[19] This is why the clogging of the Suez Canal in 2020 did not have widespread consequences. Ships plan on spending almost four times the needed amount of time to get to their stops allowing them to overcome any delays such as a hurricane or jammed canal by speeding up when they are past the obstruction.

gravity model, economic mass (market size) and distance. The important note though is that here distance represents the distance from a planned sea route and network of connections as opposed to the distance from another country.

Quite a bit of literature looks at how changes in transport costs affect global economic relations. Limao and Venables (2001) argue that remote countries and countries with poor transportation infrastructure tend to be isolated from global trade flows (451). Bougheas, Demetriades, and Morgenroth (1999) present a discussion of transport costs based on infrastructure as opposed to distance and finds that when transportation costs increase due to poor infrastructure (holding distance even) trade flows decrease (173). More recent work by Clark, Kozlova, and Schaur (2014) discusses how uncertainty caused by the global transportation system can act as a significant barrier to international trade (20). Access to maritime routes is clearly a vital part of global trade. In this paper, I expand the literature on access to maritime routes by showing how global maritime activity is spatially correlated. Prominent maritime countries tend to be spatially clustered due to the presence of ships stopping at nearby countries having an incentive to stop at them as well. This spatial correlation is an important factor determining the ability of different states to engage in global trade.

Another reason for the increase in sea route clusters is the increased use of international supply chains. Trade scholars have identified that most trade today tends to occur within firms along global supply chains. Baldwin and Lopez-Gonzalez (2015) discuss how global trade patterns in the 20th century transitioned from trade in luxury and finished goods to trade in parts along global supply chains. Bernard, Jensen, and Redding (2010) investigate global trade patterns and find that over 90% of all global trade takes place within only 10% of corporations(105). These large multinational corporations are responsible for driving global economic flows by instituting international chains for their own production.

Behar and Venables (2011) contribute to the work on supply chains by discussing different methods of transporting goods internationally. They conclude that over any long distance or with large volume, sea transport is by far the most cost-effective method of establishing trade (15). Rail networks come in second, followed by road, and then air. This fact can explain the tendency for prices to be higher in landlocked countries who lack access to sea transport (Arvis et al. 2007). This result indicates that global sea activity is likely an important factor in determining state trade flows by significantly influencing the cost of trade.

When choosing where to establish an element of an international supply chain, companies need to consider the various costs and benefits of a given location. While examples of benefits might include reduced labor costs, lower taxation, and fewer regulations, the largest cost of an international supply chain is the transport costs of moving goods. Firms seeking to establish a global supply chain will focus on countries that have the most access to international sea shipping to lower these costs. This trend can account for some of the complicated aspects of global trade data. High trading countries should find it easier to expand trade while lower trading countries struggle to connect their markets globally. Many poor countries lack the infrastructure needed to attract global supply chains and without these supply chains lack the income to invest in needed infrastructure creating a causal loop.

The transportation geographers have spent considerable effort in optimization studies looking at how to optimize the location of warehouses and factories (Asgari et al, 2021). These are similar to the decisions to locate elements of supply chains internationally. The decision on where to establish a supply chain is based on access to needed supplies as well as how well that location can integrate with the network of global transportation. These decisions lead to spatial clustering of trade via supply chains.

I argue that the fact that most trade occurs via supply chains, leads to very different spatial patterns throughout the world. In their analysis of the decreased effect of the gravity model over time, Brun, Carrere, Guillaumont, and De Melo (2005) find that the change in effect differs strongly based on GDP. They find that for high GDP countries, the friction of distance on commodity trade has been almost completely eliminated while for poor countries, a significant amount of friction remains. One potential reason for this difference is the distinct role different sized economies play in global supply chains. For rich countries, the final goods are brought in for sale to the consumer or for final assembly. Rich countries tend to import more than they export (Matsuyama, 2015). Poor countries on the other hand are more likely to be a part of an earlier stage of a supply chain. This could involve the manufacturing of components or the provision of raw materials.

These different roles should be expected to affect spatial correlation in trade and sea activity as well as gravity models. Clusters of rich countries (like in Europe) are all able to benefit from each others sea trade by using their sizable markets to attract ships to stop at them as well. If a ship is already transporting goods to and from different parts of Europe, it is likely easy to justify the addition of new countries into the transportation network. Poorer countries on the other hand, are likely less able to be justified as an additional stop and might even be in competition with each other because when a certain country becomes a supply chain hub, it doesn't necessarily mean other countries nearby will see a similar effect. Work in the business supply chain literature discusses how global supply chains tend to become geographically concentrated. This literature empirically demonstrates the trend for not only specific countries, but specific cities or areas within countries to see widespread investment in global supply chains while other nearby areas do not (Patti, 2006; Boldyreva et al. 2020; Karlsson, 2010). The clustering of supply chain factories might occur for a variety of reasons but one main reason that concerns this paper is transportation related expenditures[20]. Assume a company requires three factories to assemble its goods. If all three factories are located proximal to each other, it can have a significant reduction in the costs of transporting goods to and from these factories (Tan 2002). Wildgoose (2012) argues that the over concentration of supply chain factories in single areas might make the global economy vulnerable to disruptions [21]. Regardless of the reasons or the potential worries of concentration, the fact that an empirical trend of locating factories in small geographic clusters exists, means there might be far less international spatial correlation in countries at this stage of the supply chain. If one specific country, or even city, in a region becomes a hub for supply chain investment it could lead other countries to be less attractive. As investment in the first country increases, the neighboring countries will

[20]"Cluster Theory" is the literature in business and development journals that discusses this phenomena (Patti, 2006; DeWitt et. al. 2006; Tolossa et. al., 2013)

[21]The COVID-19 Pandemic might be evidence of this as major supplier locations were closed down leading global companies with few options to get needed materials.

have less to offer companies seeking to locate factories in them. At an extreme, this can lead to competition between nearby countries for investment and negative spatial correlation[22].

Previous literature has argued that developing countries are often in competition with each other to attract supply chain investment. The race to the bottom literature for example argues that countries might restrict labor standards relative to their neighbors in a bid to attract more supply chain investment (Chan 2003). This competition is associated with negative spatial correlation and might exist in spatial maritime patterns. When a country acts as a shipping hub in a region, it might decrease the probability of nearby countries also acting as shipping hubs. This is especially true in the developing world where the funds to create the expensive but necessary shipping infrastructure are scarce.

The use of these supply chains coupled with technological improvements in transportation has drastically increased the trade connections between states along sea routes. While this paper aims to provide a state-level analysis of international trade, it is essential to understand that multinational firms drive these relations. Political Scientists increasingly have been looking at the roll of firms in shaping global economic patterns. Johns and Wellhausen (2016) for instance argue that the links between companies formed by global supply chains can explain why some autocracies seem unwilling to violate property rights for foreign investors (33). Jensen, Quinn, and Weymouth (2015) discuss how vertical integration of multiple companies internationally leads to a reduction in anti-dumping complaints (914). While leading international relations theorists have expanded the scope of IR to talk about the role of firms, these discussions have so far been limited to the firms engaging in the trade. This paper expands this discussion by showing how the shipping firms themselves can have a strong influence on global trade patterns. Literature from transport geography indicates that the incentives of these firms should have a large effect on global connectivity. This paper argues that it is these firm incentives which drive shipping prices which create large spatial effects in international relations.

While Ward et al. (2013) provide strong evidence that trade clusters exist, why do the groups look the way they do? I argue that the primary factor determining which states are in a cluster is the shipping industry and its ability and willingness to connect to that state. Some states, notably those proximal to major zones of international sea activity, will find it much easier to engage in international trade than other states. While past literature has identified that one way a state can increase its ability to attract trade is through infrastructural investment (Clark et a. 2004), this paper argues that a large element of determining trade patterns is outside the control of any one state. A state's location on the globe and who their neighbors are plays a major role in determining its ability to connect to major sea routes and thus to trade.

If distance is viewed as connectivity, in the manner transport geographers view it, it can lead to drastically different predictions of what world trade patterns look like. First, just because two countries are proximal to each other, doesn't mean they are well connected. The United States is far more connected to developing countries in South-East Asia than it is with developing countries in South America. Point to Point distance models cannot explain why this is the case. Network optimization and Route selection models on the other hand can explain this relative

[22]Negative spatial correlation exists when increasing the value of one unit decreases the value of neighboring units.

to important US trade partners in Asia.

Additionally, in international relations, point to point models treat distance as a fixed variable. Rarely do the geographic locations of states change sufficiently to affect distance between themselves and others. Viewing distance through a connectivity lens however allows for it to change overtime. A wide range of factors likely influence connectivity between states. One such factor might be international trade agreements or other international institutions. Analyzing connectivity offers a way to integrate the theories and methods focused on geography with the theories of institutions.

Maritime trade offers a novel way to look at the connections between states. In the next section I discuss the maritime connectivity data used in this paper and discuss how it relates to spatial trade patterns. This data and empirical analysis will build off the discussion presented here to show evidence that maritime connections have a strong influence on trade. The analysis will additionally show that these maritime connections directly lead to the spatial patterns previously discussed in the data.

3 Maritime Data and Local Spatial Relations

While identifying the location of cities, states, and other geographic constructs is relatively straightforward, identifying the location of major sea activity is not. Various organizations, including private consulting firms and the United Nations Conference on Trade and Development (UNCTAD), have begun using satellite data to track international ships moving throughout the world. While useful, this data needs heavy sorting and manipulation for more detailed state-level analysis. Thankfully, in 2020 UNCTAD used this technology to compile the first state-centric measure of global maritime connectivity refereed to as the Linear Shipping Connectivity Index (LSCI) [23]. In this section, I discuss how the LSCI identifies state connectivity in sea trade in the modern world. I then conduct some preliminary descriptive analysis of this data and discuss how it relates to global spatial patterns discussed above.

This paper uses the LSCI published by UNCTAD through their online stat database[24]. This statistic is prepared for the years 2006-2020 and is created from six individuals metrics. First, the number of scheduled ship calls per week in a country. Second, The annual capacity in Twenty-Foot-Equivalent Units (TEU) offered at that country. Third, The number of shipping services to and from that country. Fourth, The number of different companies providing service to and from that country. Fifth, the average size in TEU of the ships deployed by the service with the largest average vessel size Finally, the number of other countries connected to the country through direct shipping services. This scale is a relative scale with China in 2006 given a value of 100 and all other state-year data points relative to this value. More information on this measure can be obtained via the UNCTAD website[25].

This measure of maritime connectivity is in its own right a very interesting variable worthy

[23]The raw data of satellite tracking can be obtained from various companies such as www.fleeetmmon.com which acts as a repository for the United Nations. While potentially useful for future research, the sheer amount of data and fact that it's locked behind a sizable paywall, means scholars should think carefully about how to best apply this raw data

[24]https://unctadstat.unctad.org/EN/Index.html

[25]https://unctadstat.unctad.org/wds/TableViewer/summary.aspx?ReportId=92

of further analysis. When looking at maritime connectivity alone, it becomes clear that this is capturing something interesting but slightly different than simple trade flows or economic size. For example, the top ten list of countries based on most maritime connectivity in 2020 are the following; China, South Korea, Singapore, United States, Malaysia, Netherlands, Hong Kong, Spain, United Kingdom, and Belgium. Clearly economic size has something to do with how connected a state is but that is not enough to explain this alone. The fact that both South Korea and Singapore are ranked higher than the United States shows how this measure can potentially offer meaningful differences from prior concepts. Importantly, of these countries South Korea, Singapore, Malaysia, the Netherlands, Hong Kong, and Belgium are all states famous for having major shipping industries[26]. The correlation between GDP and sea connectivity is around 0.75.

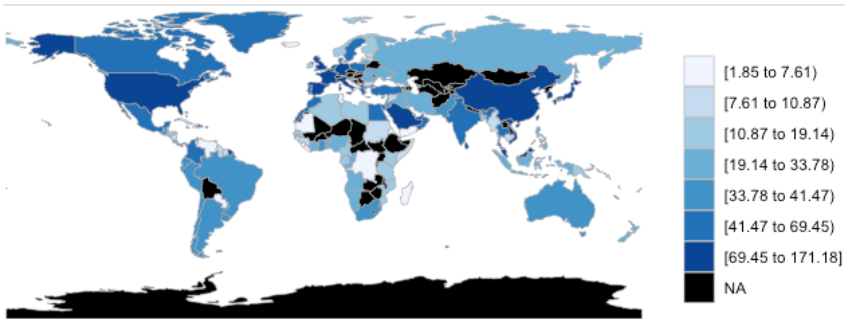


Figure 2: **Global Maritime connectivity in 2020**

Sea connectivity is a distinct concept and questions should be asked about what might cause it. For example, why are South Korea, Singapore, and Malaysia top five countries when no other economic indicators would put them at such a high level. The answer according to this paper is spatial patterns in the data. A ship traveling to China is almost certainly going to travel close to other states in East Asia such as South Korea if traveling from the US and Singapore or Malaysia if traveling from Europe. This represents spatial correlation. The values of nearby states directly affect a given state's own values. As seen in *figure 1* maritime connectivity is a highly spatially correlated variable. Due to the locations of some states, they are able to have increased access to maritime activity due to the fact that sea routes to major economies pass near their borders. On the other hand countries in less prominent areas, see lower rankings because they are far away from any major sea routes. Sea activity of any state cannot be understood without also looking at who that state borders and where on the globe it is located. This connectivity variable represents an understanding of the distance between states compatible with the transport network approach discussed in the previous section.

The connections between states occurring due to the sea provide a way to structurally understand the spatial patterns previously discussed. The more connected a country is via the sea, the more integrated it should be with its neighbors. This is due to the logic discussed in the previous section about why a ship is more likely to stop at its neighbors. How integrated a state is with its neighbors is referred to as local spatial correlation. The Moran's I test provides

[26]China also has a humongous shipping industry, but given its economic size, it isn't as surprising that it is in the top ten

evidence for global spatial correlation across the entire sample of countries while local spatial correlation looks at how linked a single unit is with its neighbors. Empirically, this involves creating a score for each unit based on how correlated a unit is with its neighbors. As can be seen in *figure 1* where each individual point counts as a unit, this value is very different for each country.

Using this value of Local Correlation for global trade as the dependent variable I conduct Linear Mixed Effect Regression with three main independent variables. These three independent variables represent the first three hypotheses of this paper and seek to understand how the spatial patterns in the data form. To repeat, the dependent variable represents the level of spatial correlation for a unit while the independent variables represent things that this paper, or past literature, would argue make a country more integrated with their neighbors.[27]

The first independent variable, and the main one for this section, is maritime connectivity. States that are highly connected via maritime trade to the rest of the world should also be highly related to their neighbors trade flows. This statement represents the first hypothesis of this paper.

Hypothesis 1 (H1): *State's with higher maritime connectivity will have a higher local spatial correlation.*

The second independent variable for this section is GDP. Wealthy countries are more likely to economically intertwined with their neighbors through trade and other economic activities. As such, it should be expected that countries with a high GDP see more local spatial correlation. This represents the second hypothesis for this paper.

Hypothesis 2 (H2): *State's with a higher GDP will have a higher local spatial correlation*

The final independent variable for this section is Liberal Democracy, obtained from the varieties in democracy dataset. While this paper seeks to contribute mostly to the work on economic geography, it should not be ignored how important the concept of liberal democratic institutions have become to the study of international trade. As such I include this hypothesis to test the extent to which this measure fits in with the spatial understanding of trade relations. The general idea on the literature is that liberal democratic institutions provide an increase in economic engagement with the world. As such, I would predict that the more liberal democratic a state is, the more local spatial correlation it will have. This represents the third hypothesis of this paper.[28]

Hypothesis 3 (H3): *State's with a higher liberal democratic score will see a higher local spatial correlation.*

[27] to create a more accurate measure of local correlation, I create the measure for each state based on its correlations with its neighbors in all years from 2006-2020. This allows for more information to be taken into account and a finer measure of local correlation.

[28] Please note that this hypothesis does not seek to act as a definitive answer to the question of how institutions influence spatial patterns. Such a question is likely worthy of its own research and would require different methodological techniques from those employed here. Instead, this hypothesis seeks to provide interesting information based on what is likely expected from a review of past literature.

To test these hypotheses I conduct a linear mixed effect model. The linear mixed effect model is conducted for all states included in the UNCTAD data[29] between the years 2006 and 2020. Local Spatial Correlation of Trade is the dependent variable with Maritime Connectivity, GDP, and Liberal Democracy acting as the main independent variables. In addition, state level fixed effects and year level random effects are included.[30]

	DV = Local Correlation of Trade	
	Scaled Variables	**Non Scaled Variables**
Intercept	-0.005	-1.704
	0.171	(0.203)
Maritime Connectivity	0.422***	0.025***
	(0.019)	(0.001)
GDP	0.386***	0.001***
	(0.019)	(0.0001)
Democracy	0.005	0.357
	(0.017)	(0.357)

N = 1904; Years 2006-2020; Significance Levels = 0.1*, 0.05**,0.01*** Country Fixed and Yearly Random Effects.

Table 1: **Linear ME regression on Local Correlation of Trade.**

The results presented in *Table 1* provide strong evidence for both hypothesis 1 and hypothesis 2. Both maritime connectivity and GDP are strong predictors of how related a state's trade flows are with its neighbors. This model fails to provide evidence for Democracy being a predictor of local correlation. The model results demonstrate an important finding for the spatial study of trade and economic geography. Spatial patterns in the international system are neither equal nor random. Some countries are far more related to their neighbors than other countries and this relation can be predicted by state specific factors. While past research has looked at spatial correlations as simply a problem to be empirically solved for, these results demonstrate how it can be used to create a better theoretical understanding of the connections of states through trade. These results also demonstrate the need for theoretically understanding the spatial patters that exist in a specific area being studied. Based on these results, a scholar studying trade integration within Europe would likely find very different spatial relations from a scholar studying the same topic within sub-Saharan Africa. This demonstrates the need to be theoretically informed about spatial patterns and use this knowledge to further our research.

[29]Due to it representing maritime connectivity, landlocked countries are not included in the data, neither are some very small countries

[30]The state fixed effects are used to account for state specific unobserved variables which could influence spatial correlation. The Year random effects allow for the coefficients of the independent variables to change overtime and are needed to account for the technological changes occurring in this time period which likely lead countries to becoming more integrated, although there was also a major economic recession during this sample which likely had the opposite effect.

4 Spatially Modeling Trade and Maritime Connectivity

Based on the above information, we know a few important things. First, we know that international trade is ripe with spatial correlation which can institute sever biases in empirical techniques. Second, we know that this spatial bias is neither random nor equal. States with a high GDP and states with higher maritime connectivity are more spatially correlated with their neighbors. Using this knowledge, it is possible to theorize about how the modern global maritime industry affects global trade flows.

To empirically model the impact of the maritime industry on global trade, it is important to use special empirical techniques to capture the spatial patterns. In this section I present three empirical models. The first is a standard linear mixed effect model with no spatial component. This model is included to show how failing to control for spatial relations can lead to incorrect results. To empirically model the spatial patterns, I use a spatial lagged model as the second technique. This model includes a spatial lag of the main explanatory variables of GDP and Maritime Connectivity to account for spatial relations. This model, which is suggested for use by Ward and Gleditsch (2018), adds an independent variable to represent the spatially lagged value of relevant independent variables. Finally, I conduct a spatial Durbin model which spatially lags all explanatory variables, the dependent variable, and the error term to act as a complete spatial model[31]. The Spatial Durbin model is the only one of these three that does not suffer from potential spatial biases, however, given how complicated it is and the lack of flexibility it affords I think it is important to also look at the other modeling options.

Before presenting the empirical model itself, I discuss the important hypothetical expectations based on the discussions above. For these hypotheses the dependent variable will be a state's Trade flows. The first hypothesis represents the effect of a state's maritime connectivity on its international trade flows. States with a higher maritime connectivity score are expected to trade more due to 1) it being easier for them to send/receive goods from abroad and 2) states that trade more will likely be become more connected.

Hypothesis 4 (H4): *State's with higher maritime connectivity will have higher trade flows.*

I also provide a spatially lagged value of maritime connectivity which represents the average value of a state's neighbor's connectivity. However, I provide no specific hypothesis for the valuation of this parameter. Based on the analysis in the last section, we know that the spatial effects for a state will highly depend on the GDP of that state and its neighbors. As such, I present two interaction effects which can be tested to show how spatial patterns are not constant throughout. I present these hypotheses based on the discussion of GDP as an important factor differing the ability of different states to connect locally and the discussion of the differing roles states play in global markets based on their wealth. The first interaction hypothesis discusses the effect of a state's neighbor's connectivity as the neighbor's GDP increases. As a state's neighbor's GDP goes up, this will on average decrease the effect of the neighbor's connectivity on the state being analyzed. This happens because the state is becoming a relatively less

[31] This technique requires the model to be numerically solved. One consequence of this is that all variable should be center-scaled in the analysis. As such, to allow for direct comparison I use center-scaled data for all models in this section.

attractive stop than its neighbors. Companies making rational route choice selections would likely prioritize the neighbors with higher GDPs for both trade and supply chain investment. While I still expect the effect of maritime connectivity to be positive for these states, holding all else equal it is better to be the richest state in the area as opposed to being a poorer state next to a rich state. Therefore the interaction coefficient is expected to be negative and significant.

Hypothesis 5 (H5): *The interaction between neighbor's GDP and neighbor's connectivity will be negative and significant.*

The final hypothesis for this paper represents the interaction between neighbor's connectivity and a state's personal GDP. This interaction is expected to be the opposite of that in hypothesis five. As a state's GDP rises, it is expected to increase the effect of a neighbor's connectivity on its own trade flows. As previously discussed, ships have a higher incentive to stop at nearby states with large markets. Therefore, as a given state's GDP goes up, its ability to attract ships and trade from well connected neighbors will also increase. As such, the interaction between GDP and lagged connectivity is expected to be positive and significant.

Hypothesis 6 (H6): *The interaction between a state's GDP and neighbor's connectivity will be positive and significant.*

The table below presents the three models to test these effects. The first model is a linear mixed effect model with state fixed and year random effects. The second model is the same as the first model but with lagged variables for connectivity and GDP added. The final model is a fully specified spatial durbin model which uses simulation techniques to solve for the parameters in a spatially endogenous setting.

	DV = State Trade Flows (Imports + Exports)		
	Linear Model	Linear Lag Model	Durbin Model
Intercept	-0.073***	-0.084***	-0.157***
	(0.023)	(0.022)	(0.02)
Maritime Connectivity	0.421***	0.375***	0.381***
	(0.012)	(0.013)	(0.012)
GDP	0.244***	0.186***	0.208***
	(0.024)	(0.023)	(0.022)
Democracy	0.034***	-0.001	-0.029
	(0.01)	(0.01)	(0.011)
Total Pop	0.093***	0.072***	0.104***
	(0.012)	(0.011)	(0.012)
Urban Pop	0.037***	0.034***	-0.007
	(0.01)	(0.01)	(0.011)
Neighbor's Connectivity	-	-0.013	-0.007
		(0019)	0.005
Neighbor's GDP	-	0.038***	0.115***
		(0.019)	(0.011)
Neighbor Connectivity*Neighbor GDP	-	-0.014***	-0.027***
		(0.007)	(0.003)
Neighbor Connectivity*GDP	-	0.137***	-
		(0.008)	
Neighbor's Population	-	-	-0.018***
			(0.004)
Neighbot's Urban Population	-	-	-0.001
			(0.004)
Neighbor's Trade	-	-	0.016
			(0.004)

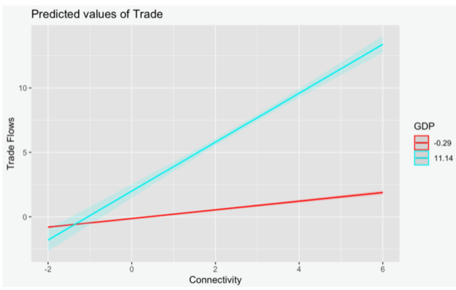
N = 1904; Years 2006-2020; Significance Levels = 0.1*, 0.05**,0.01*** Country Fixed and Yearly Random Effects. All variables are center scaled

Table 2: **Regression Tests Maritime connectivity and Trade.**

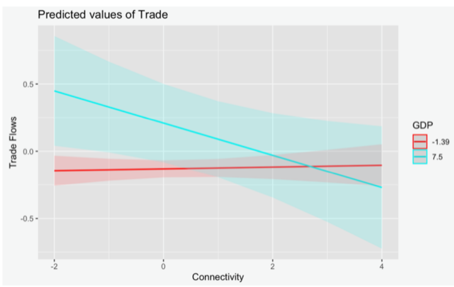
The coefficients in this table confirm the hypotheses of this section. To begin with, maritime connectivity is positive and significant. This leads to the conclusion that states who are better connected to maritime networks, are likely to engage in more trade. This result holds even when the spatial relations are controlled for. Notably, even when neighbor's trade flows are controlled for this variable is still significant meaning it is having an important independent effect on a states ability to connect and trade. The past work in transport economics indicates that maritime trade should be an important factor in modern trade. The results of this model demonstrate that this is likely the case.

This result demonstrates the importance of understanding the factors that connect states and facilitate trade. Given how important the maritime industry is, it is vital to think about how this industry affects global trade. This measure of maritime connectivity is thus an important component of modern trade. This measure represents important geographic connections between states created by the transport industry and the high-order relations identified by scholars of IR. In order to understand the connections between states, maritime routes act as one potentially important factor.

The lagged value of connectivity is on its own not significant but this isn't unexpected and we must look at the interactive hypotheses to understand this relationship. Both interactive hypotheses are confirmed. Sates located next to rich neighbors are likely to see less of a benefit from the maritime connectivity of their neighbors. All else equal, as a state's neighbors become more wealthy compared to it, it will see less of a benefit from that neighbor's connections. However, states with a high GDP are able to benefit more from highly connected neighbors than states with low GDP. When a state has a high GDP it benefits more from a state that is closely located and highly connected. This confirms the hypothesis that rich states react differently to the spacial dynamics of trade. A rich state is an attractive stop to ships looking to add to their routes. Thus, when a state has a higher GDP, nearby states which are highly connected will see a sizable effect on the states trade. The coefficient substantive size for the second interaction is much larger than for the first interaction. This indicates that when a high GDP country is located next to a high GDP country, for example in much of Europe, the effect of lagged maritime connectivity will be larger than when GDP is held at its mean. *Figure 3* below provides interaction plots for these variables.



(a) Interaction Between GDP & Neighbor's Connectivity



(b) Interaction Between Neighbor's GDP and Neighbor's Connectivity

Figure 3: **Interaction Plots for Lagged Connectivity Analysis**

The plots above show the changing relationship between Connectivity and trade for different

GDP. In Each plot I show the minimum GDP (in red) and the maximum GDP (in blue) with all other GDP between these not shown[32]. As can be seen there is clear fluctuation in the relationship between Connectivity and Trade based on the GDP of different states. These plots therefore confirm the final two hypotheses.

In this section, I have confirmed three separate hypotheses related to how maritime connectivity affects global trade. The connections that the global maritime industry forms between states are complicated and yet important to understand when predicting a state's ability to trade. I have shown that the relations between maritime connectivity and trade include theoretically interesting spatial relations. While previous studies in IPE have identified the empirical presence of these spatial patterns, the patterns have been largely ignored from a theoretical perspective. This study shows that it is possible to think theoretically about how different components of the world economy are spatially located.

Maritime connections are an important aspect of the global economy. These connections can explain various states ability to trade and due to their spatial component can have widespread regional consequences. In the next section, I introduce the Bilateral Shipping Connectivity Index and use it to create a network of global sea connectivity. Using this network I conduct some general descriptive and preliminary analysis to understand state's prominence in the network. Understanding how prominent a state is in the network of sea connections is vital to understand how both itself, and surrounding states should be expected to engage in global trade. This approach also fits with work in transport geography that uses distance and connectivity as the bases of transport networks.

5 Dyadic Connectivity and the Global Maritime Network

The global maritime industry is responsible for creating a web of sea routes moving throughout the world. The analysis in the previous section demonstrates that connection to this web is likely an important part of a states ability to trade. However, the analysis above has looked at a monadic value of sea connectivity. Scholars of IPE are increasingly looking at network data to try to understand how states are connected. Based on the discussion of transport geography, using connectivity data to create a network of connectivity might lead to valuable insights on global transportation. Maritime routes form a natural network connecting states around the world. In this section I will introduce the Bilateral Shipping Connectivity Index, use it to create a network of global maritime routes, and provide some brief descriptive about this network and the prominence of states within it.

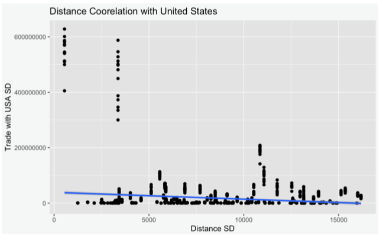
The Bilateral Shipping Connectivity Index (BSCI) was created by UNCTAD in 2021 as an update to their linear shipping connectivity index. The BSCI has data for the years 2006-2021 and represents how connected via sea any two countries are. This measure is created from the following five components. First, the number of transshipments (number of ship changes) which are needed to get between countries. Second, The number of direct sea connections between these countries. Three, The number of shared direct connections in other countries. Four, the competition on shipping services between the two countries. Five, the size of ships traveling

[32]However, since these are linear hypotheses the change from the red line to the blue line will occur at an even pace as GDP increases.

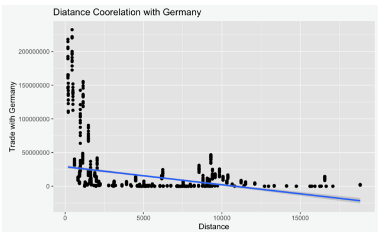
between the two countries. These five components create a dyadic value which can be used to represent how connected these two countries are.

Based on the discussion above, I argue that this measure represents a potentially better measure of *distance* between these two countries than miles between them. If we treat *distance* the way geographers do, as a somewhat fluid concept, then defining distance as how connected two countries are might be the better option. In a globalized world, our understanding of distance should take into account the transportation infrastructure in place to facilitate connections between countries. A state unconnected to this infrastructure should be viewed as distant no matter how close it is to other countries.

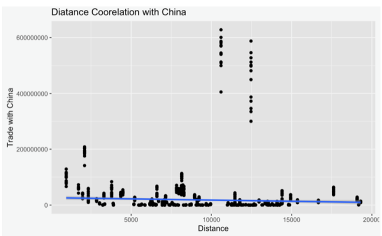
To demonstrate this, I present correlations below of Germany, the United States, and China trade values with the two ideas of distance. For each plot I present a correlation of trade and the measure of distance or maritime connectivity. As can be seen in these plots, in each case maritime connectivity far surpasses distance alone in predictive power. Distance, alone has very little direct correlation with trade while maritime connectivity alone has a clear positive correlation. I believe this is because the idea of connectivity better represents the distance between any two states in a modern globalized world than a simple miles between measure does.



(a) USA



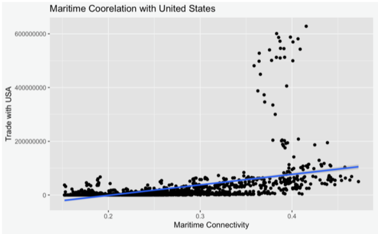
(b) Germany



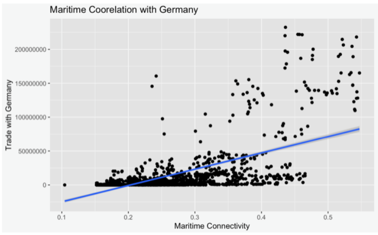
(c) China

Figure 4: **Correlation Between Distance and Trade**

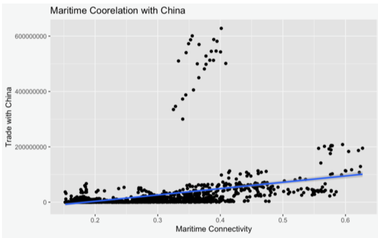
The plots in *Figure 4* show what literature on gravity would predict. There is a negative relationship between the distance between a partner and trade with that partner. However, this correlation appears to be very weak and barely noticeable. While there is a statistical correlation between these terms, the actual impact of distance on trade seems to be minimal. The next plots present the bivariate correlation between Connectivity of two countries and their trade.



(a) USA



(b) Germany



(c) China

Figure 5: **Correlation Between Connectivity and Trade**

Figure 5 shows a much stronger correlation. Here there is a clear positive correlation between trade and how connected two countries are. In a modern globalized world with maritime trade as the dominate method of moving goods, it is the connectivity between two countries via sea that influences trade in the same way that distance once did. This new measure takes into account important things pointed to by geographers such as infrastructure and accessibility which directly affect the ability of two states to trade. Just as the meaning of distance has evolved in Geography to discuss how far countries are on a more theoretical level, so too should the concept evolve in the study of economic geography.

Expanding the idea of distance to account for this newer understanding can have tremendous impacts on the understanding of international trade. The most notable benefit of this conceptualization is that connectivity of two countries changes overtime while distance alone remains constant. This can allow for an understanding of why different countries might see differing trade flows overtime. This measure actually sees remarkable variation overtime as can be seen in *figure 6* which provides a bump plot of how the top ten countries have changed between 2006 and 2021.

Using the transport geographers idea of distance, I utilize the network approaches common in that field by creating a network of connectivity. In such a network the edges between two countries are represented by the connectivity between them. Transport geographers use such a network to understand how connections between two states might effect connections throughout the rest of the network. While I refrain from doing empirical analysis on this network in this paper, future studies can look at these networks in more detail to understand how changes between any two countries lead to changes in the rest of the sample. Modern geographers resemble modern IR scholars who use these networks to understand the connections between states and understanding the connectivity caused by maritime connectivity can expand our knowledge in this area. The plot in *figure 6* uses this network and conducts a closeness analysis to rank each country in terms of closeness centrality[33]. As can be seen, the geographic center of maritime world has shifted considerably in the past fifteen years.

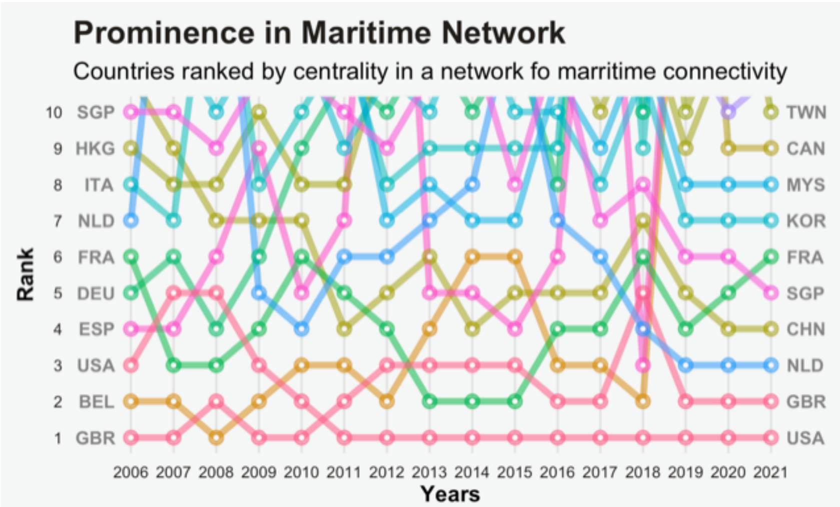


Figure 6: **Top Ten Most Central Countries Overtime**

In *figure 6* interesting patterns can be observed. Notably the rise of East Asia between 2006 and 2020 can be directly observed as China, Singapore, Korea, Malaysia, and Taiwan all gain rankings. North American countries of the United States and Canada also gained in ranks during these time periods. These two regions came at the expensive of some European countries; notably Belgium, Spain, Germany, and Italy who all lost significant spots. Looking at how connected different countries are in the global network of sea routes is an important factor for modern scholars of IR.

The ability of this connectivity to change overtime is an interesting part of treating this as a geographic explanation. This variance overtime opens the door for institutional scholars, who make up the bulk of IPE research, to have a profound impact on geographic work. An important question after viewing this plot is why is there so much change in connectivity overtime? I would hypothesize, and future work can verify, that both domestic and international institutions play a major role in how connected and central a given state is. This can explain

[33]A network measure used in Transport geography to understand concepts such as Urban Geographic centers. This measure looks at how easy it is to get from one country to another along all possible paths and the easiest country is considered to be most central. I convert the measure into rankings but the raw score can also be used in analysis.

why the United States is clearly the most central state in the maritime network despite not having the highest individual connectivity score and being geographically distant from most of its trade partners. Acemoglu et al. (2002) famously said that institutions are caused by geography as setters from certain, notably liberal, regions choose locations and climates to settle in. However, what if institutions also influence geography? Does joining a PTA move countries closer together in terms of connectivity? What about joining a larger international agreement? How has the rise of china, especially with the Belt and Road initiative, affected how far countries are from each other? Rephrasing geography to understand connectivity along pathways as opposed to simple measures of distance can dramatically increase our understanding of interstate connectivity, how geography affects this connectivity, and the relationship between institutions and geography. Scholars of IPE are well placed to make such advancements which can lead to important understandings about modern trade.

However, there is one major drawback in this type of analysis which should be discussed before concluding. It is probably clear that there is a reverse causality component occurring in this relationship. How connected two countries are likely increases a state's trade flows while trade flows between two states likely also increase how connected they are. This reverse causality, while not a problem for showing a correlation, is undesirable when making a causal argument. For this paper I have sought to avoid using strong causal language yet my wording has clearly indicated my belief in a causal pathway being present. The transport geographers who discuss a connectivity assessment of distance tend to more empirical studies with less influence on theoretically identifying causal processes. As such, it is not surprising that this worry isn't considered a major problem in that field.

While future research might seek ways to break the reverse causality, for the purpose of this study I argue that keeping it in demonstrates how important spatial relations are. If, for example, the United States and China increase trade this will likely increase how connected these two countries are. This can lead to a spiral between these two countries as increased connectivity causes increased trade which causes increased connectivity. While this might make it hard to determine which factor is primal in the dyadic relations, the spatial components demonstrated in this paper show how important connectivity really is. Even if it is an exclusive trade causes connectivity relationship, the fact that connectivity is spatially correlated matters. If increased trade between china and the USA causes increased connectivity between the pair, this increased connectivity will also increase USA connectivity with other nearby countries such as Vietnam, Japan and the Philippines. The complex connections that make the study of empirical trade difficult also can be used to help explain how related different countries are. Future research should think about these connections while recognizing that despite potential empirical challenges in establishing well defined causal effects, the underlying processes of what is occurring are essential to our understanding of the modern world.

6 Results and Conclusions

The claim that maritime connectivity affects a state's trade, likely does not come as a surprise. The entire field of transport economics, which stems from the entire field of economic geography, would predict this to be the case. Nonetheless this paper provides strong evidence for this to be the case. What this paper contributes the most to however is a deepening understanding of how the maritime industry connects different countries and how this relates to notions of distance, which are common in economic studies.

This paper reviewed transport geography as a field and argued that the novel methods being developed in that field to expand on the idea of distance, should be used in international political economy as well. In a globalized world distance as the crow flies is rarely an accurate, or even useful, metric for what is occurring. The global maritime infrastructure and transport industry creates the pathways that connect states and any understanding of distance must account for this. Just as businesses choose warehouse locations and delivery paths based on the location of major roads, international businesses will make these decisions based on global transportation and sea routes.

Transport geographers increasingly use network methods to understand connectivity between different areas. Scholars of international political economy have also recently shown an interest in understanding how networks can be used to understand how connected different states are. Creating a global connectivity network based on sea transport can lead to new understandings of how connected states are in the modern world. This is especially true given the complicated spatial dynamics present in the relations. This paper demonstrated that maritime connectivity is composed of strong spatial biases and that these spatial biases violate important IID assumptions. Spatial modeling techniques which are based off a network adjacency approach are needed to account for these biases. A deeper theoretical understanding of distance and the geographical connections between states is thus an important part of the growth of IPE knowledge.

Future research should look at what aspects of a country determine its maritime connectivity. It is possible that this connectivity is determined solely by market factors such as GDP and Trade flows. It is also possible that quite a bit of other factors help determine how connected a state is. These factors could include institutional factors that guarantee the protection of property for shipping companies. Other factors might be various laws put in place to increase a state's connectivity. These could include treaties signed between countries or domestic laws aimed at protecting the shipping industry. The Jones act in America for instance likely has had important implications on the US shipping industry. Future research can look into how various items independent of market forces affect maritime connectivity. A good place to start would be to build off the recent research in international relations looking at the belt and road initiative. This initiative specifically seeks to increase China's maritime connectivity to countries throughout the world, notably in Europe and the Global South. Maritime connectivity offers an interesting framework for understanding these relations.

In a globalized world the connections between states matter more than ever before and yet how states are connected has become harder to identify. In this paper I have put forward a novel argument about how the maritime industry binds states together in an economic web. I put forth an argument that connectivity is a better representation than miles between when looking at how distance affects state relations. I argue this by demonstrating the geographic patterns in trade between states are driven in part by spatial correlations in maritime connectivity. I presented a novel theory for how maritime connections create spatial patterns in global trade data. I end the paper by showing how a global web of maritime connections looks and how it can be used to understand distance.

Distance is a term which likely has a fixed definition in many people's minds. However, as the world becomes more globalized, the meaning of distance has changed. What once would be an insurmountable distance is now a short trip away. It is important to understand how these changes affect global connectivity between states. This paper concludes with the understanding that maritime connectivity between states offer an important avenue of exploring distance in a globalized world.

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