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THE IMPACT OF THE COVID-19 PANDEMIC ON INTER-EUROPEAN MARITIME AND AVIATION TRADE FLOWS

A GRAVITY MODEL AND NETWORK ANALYSIS

Student number: 6511791
Words: 32.819 (25.242)

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Abstract

This study examined the impact of the Covid-19 pandemic on inter-European maritime and aviation trade flows. It focused on changes in bilateral trade flows between pre-Covid-19 and post-Covid-19 periods, as well as testing the significance of the effects between Covid-19 and these trade flows divided by transport mode. This research used a combination of network analysis and a gravity model of trade to uncover and visualize changes in the trade networks and determine the extent to which Covid-19 influenced bilateral trade flows. The results showed changes in both maritime and aviation trade. Maritime trade experienced a decrease in connectivity and trading volumes, while aviation trade saw a decrease in connectivity but increased trading volumes. The gravity model analysis confirmed that gross domestic product (GDP) and distance were key factors influencing maritime and aviation trade flows, with higher GDP associated with increased trade and greater distances leading to decreased trade. The study also explored the influence of Covid-19 proxied by the number of Covid-19 deaths, the stringency of Covid-19 restrictions, and the pre-Covid-19 China dependency ratio on maritime and aviation trade. The findings revealed a significant negative relationship between the number of Covid-19 deaths in the destination country and maritime trade and a negative relationship between the number of Covid-19 deaths in the origin country and aviation trade. Stringency in Covid-19 restrictions did not significantly influence trade flows, and a higher pre-Covid-19 China dependency ratio negatively affected maritime trade in the destination country and aviation trade in both the origin and destination countries. This research contributes to understanding the impact of the Covid-19 pandemic on inter-European trade, the varying trade effects of different transport modes, and confirms the importance of economic factors and geographic proximity in shaping trade patterns.

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1. Introduction

1.1 Background

The Covid-19 pandemic was a worldwide outbreak of a highly contagious respiratory illness discovered in Wuhan, China, in December 2019. In 2020, the pandemic caused reduced global trade by 9% (IMF, 2021). According to the World Trade Organization (2021), supply chain disruptions caused by Covid-19 were the primary cause of the decrease in global trade. In advance of the Covid 19 pandemic, a global shift occurred in which China and Korea became market leaders and export hubs (Baldwin & Tomiura, 2020). China became an important player in the pre-Covid-19 global trade network. According to Fernandes and Tang (2020), the increased interconnectedness between China and other countries worldwide was risky because over-reliance on Chinese supply may cause significant disruptions in supply chains. According to Hayakawa and Mukunoki (2020), China's export value decreased by 64 billion USD in the first quarter of Covid-19. There can be concluded that in the period of the Covid-19 pandemic, the global trade landscape had been reshaped.

Most studies that examined the impact of Covid-19 focused on the global or country-specific impact (Hayakawa & Mukunoki, 2021; Zainuddin et al., 2021). This study aims to determine the extent to which decreasing trade is visible in trade networks between European countries. Even though the number of Covid-19-related studies has increased over time, Europe appears to be a less researched research area. The study of Kejžar et al. (2022) was one of the few studies that examined the impact of Covid-19 on European trade. The European single market is interesting to research because it adheres to the same policies, has no trade restrictions, and is practically a monetary union (Aims and Values | European Union, n.d.). Because different countries' policies, trade restrictions, and exchange rates are usually determinants of international trade (Mahdavi & Sohrabian, 1993; Lee & Swagel, 1997; French, 2016; Grechyna, 2017). The European Union as a research area also ensures reliable data, mainly from Eurostat.

Besides studying the bilateral trade flows between European countries, this study tries to distinguish itself by studying two different modes of transport. The trade flows of maritime trade and aviation trade will be studied separately.

“My interest in studying A maritime trade-related topic started due to personal interests. I was born and raised along the Westerschelde in Zeeland, the most Southwestern of the Netherlands. The Westerschelde is a busy waterway with Antwerp's port as its destination. Besides that, my father worked for the Belgian pilotage service in Vlissingen. In high school, I researched the economic importance of the Westerschelde and always had in mind to do this again, but then with scientific research.”

Apart from the personal interest in a maritime trade related topic, the choice of studying maritime and aviation trade separately from each other was based on the study of Hummels (2007). According to Hummels (2007), maritime and aviation trade differ significantly. Maritime transport mainly supplies bulk and intermediate commodities, while aviation transport primarily supplies non-bulk, luxury and other goods (Hummels, 2007). Differences in shipping costs mainly drive the mutual differences between those two transport modes. The transportation costs of maritime transport are significantly lower than the costs of air transport. An incidental of low transport costs is a relatively slower delivery speed. The transportation costs of air transport are higher than maritime trade costs, and the incidental is a higher speed of delivery. According to E-Commerce Europe (2021), consumers favoured online shopping during Covid-19. A required service of online shopping is the service of fast delivery. The shift to digital trade could probably open new markets for aviation trade.
The objective of studying maritime trade and aviation trade flows is to gain insights into the effect of Covid-19 on these two modes of transport separately. Furthermore, see whether there are mutual differences between those “obvious” different modes of transport, according to Hummels (2007).

As the world navigates through the ongoing pandemic, it is crucial to examine the impact of the pandemic on international trade. International trade plays a vital role in boosting domestic economies, enabling consumers to benefit from a greater variety of goods, creating jobs and playing a vital role in raising living standards (Zainuddin et al., 2021). This study could be essential to manage the effects of the Covid-19 pandemic effectively. On top of that, exploring the trends and challenges that have emerged during this time of uncertainty will complement existing literature regarding the impact of Covid-19 on trade. Within the study of international trade are the determinants of trade, an important area of research. The general impact on trade between European countries during the Covid-19 pandemic and divided by transport mode will be analysed by network analysis. This network analysis aims to see whether the trade networks of pre- and post-Covid-19 differ. Because the network analysis will not imply the significance of the effect of Covid-19 on the expected changing trade volumes, another model will be executed to test this significance. The model that will be used is one of the most widely used models for this purpose and is named the gravity model of trade, it was developed by Tinbergen (1962). This study uses the gravity model of trade to assess the influence of Covid-19 on European bilateral trade by transport mode. The gravity model can help determine the extent to which Covid-19, proxied by the number of Covid-19 deaths, the stringency of Covid-19 restrictions, and the China dependency ratio, influence trade between European countries by transport mode.

1.2 Societal and Academic Relevancies

When discussing the challenges of the twentieth and twenty-first century of the European Union, it is sufficient to say that the Covid-19 pandemic is one of the most devastating events in its history. This study will serve as an indicator of the inter-European maritime and aviation trade network's resilience. Since these two modes of transport are shipping the vast majority of the total international trade (Hummels, 2007), it is a good indicator of the overall resilience of the inter-European trade network. The network analysis and gravity model analysis results will determine how vulnerable the inter-European maritime and aviation trade network are and to what extent Covid-19 impacted these trade networks. This study has the potential to help policymakers and economists understand the factors that potentially influence trade flows between European countries. Although the European Union is a single market, this research could be helpful for global policymakers and economists (Aims and Values | European Union, n.d.).

The Covid-19 pandemic is relevant to study thoroughly because worldwide pandemic are rare. Several times an economic crisis disrupted global trade flows, but these disruptions are caused by reducing demands due to the crises. Covid-19 caused disruptions in global production networks, which caused a reduction in the supply of mainly intermediate products (Vidya & Prabheesh, 2020). For this reason, the impact of Covid-19 on trade flows is a unique and relevant topic to research. In this way, this master's thesis will be complementary literature for future crises and pandemics that cause supply disruptions in trade networks. The Covid-19 pandemic has disrupted global trade and had severe economic and social ramifications. Analysing these consequences can provide helpful information. In conjunction with follow-up studies, this study can be used to reduce the impact of supply-disrupting disasters on trade. This thesis emphasises researching the indirect consequence of Covid-19, which are the trade disruptions on the supply side. This study will research the impact of these supply chain disruptions by adding a variable related to this. The variable pre-Covid-19 dependency on China highlights the degree of dependence on Chinese supply before the pandemic. This variable has been combined with the study of Kejžar et al. (2022). Kejžar et al. (2022) already found evidence for the so-called 'China effect', and Yu Zhao et al. (2020) that state that covid-19 had a significantly negative effect on Chinese export volumes, which implies that countries with high China dependency prior to Covid-19 will be hit harder by the supply chain disruptions. In this way, this master's thesis investigates the direct impact of Covid-19 (Covid-19 deaths and restriction stringency) and the indirect impact of Covid-19 due to supply chain disruptions on inter-European maritime and aviation trade flows. The aim is to find out whether there are differences between covid-19 relations and maritime trade compared to covid-19 relations and aviation trade.

Aside from testing the resilience of the inter-European maritime and aviation trade network, the relevance of Covid-19 to be researched due to the rare occurrence of a globally scaled pandemic, the unique circumstances due to disrupting global production networks caused by the supply side instead of the demand side, this study makes another essential contribution to Covid-19 related trade literature. This master's thesis investigates the effects of Covid-19 on two modes of transportation: maritime and aviation. These modes of transport have already been researched, in relation to Covid-19, on a country scale and a global scale. However, there is no existing literature that combine the effect of Covid-19 on maritime and aviation transport, and certainly not in Europe.

This study fills a significant gap in Covid-19-related literature by investigating a previously unexplored topic. This study provides complementary literature into the existing body of Covid-19-related research. This study provides a comprehensive understanding of inter-European trade's overall dynamics and patterns by examining both modes of transportation. Because both modes of transportation differ significantly (Hummels, 2007), maritime and aviation trade may react differently. Combes & Lafourcade (2005), Hummels (2007) and Wessel (2019) all state the varying trade effects of different transport modes and the essence of analysing these effects more often. This master's thesis adds to the existing literature on varying trade effects of different transport modes regarding the differences in trade effects of Covid-19 on maritime and aviation trade.

The way of research by combining a network analysis and a gravity model with the same export data is another crucial aspect of this research. Both methods have been widely used to examine trade flows. However, the combination of the two is scarce. By combining both approaches, this study hopes to uncover and visualise as many changes in the maritime and aviation networks as possible and determine whether the independent Covid-19 variables could influence these trade flows. This research can provide a thorough understanding of the pandemic's impact on trade flows in the European Union divided by maritime and aviation trade. This analysis complements the literature that helps policymakers develop effective strategies to mitigate the risks and challenges associated with future pandemics and other supply-disrupting crises.

2. Theoretical framework

International trade

The leading concept regarding international trade studies is the international trade theory. Once created by the founders' Smith (1776) and Ricardo (1817). Their classic theories, such as the absolute and comparative advantage theories, emphasise that countries engage in trade based on their unique production advantages. Another essential expansion of the international trade theory was the Hecksher-Ohlin model. Ohlin (1933) published a work combined with the work of Hecksher (1919). This model suggests that countries tend to export goods that utilise their abundant factors of production. Another essential addition to international economic studies was the new trade theory, primarily developed by Krugman (1979; 1980). The new trade theory focuses on economies of scale, product differentiation and imperfection as drivers of international trade.

The most recent studies regarding international trade are about the increasing importance of trade in intermediate goods and global value chain (GVC) related studies. The occurrence of global value chains are linked with the international fragmentation of production processes. First, according to Hummels (2007), transportation costs is one of the main determinants of international trade. Decreasing transportation costs are caused by better transportation infrastructures (Zheng & Kuroda., 2013). According to Taylor (2021), transportation infrastructures provide mobility and accessibility to services and the movement of goods and facilitate economic activity. The transportation infrastructure includes harbours, airports, rail, roads and pipe networks. Hummels (2007) emphasises that international trade increases due to decreasing transportation costs of ocean and air transport. Asturias (2020) suggests that trade costs decline when total bilateral trade increases. Lai et al. (2019) state that a country's transport logistics development will bolster its global trade development. So, the development of information, communication and technology that, among others, have been described by Levy (2007) contributed to a better transportation infrastructure. Also, Shepard et al. (2008) emphasise the vital role of transport infrastructure in enhancing international trade. Due to the decreasing transport and communication costs (Doz, 1987), international fragmentation of production processes has developed. According to Vidya & Prabheesh (2020), production processes have fragmented goods across different countries. The international fragmentation of production processes created a new concept, global value chains (GVC).

Global value chain-related studies use the comparative advantages theories from Smith (1776) and Ricardo (1817) because countries with an absolute advantage will be used in the production processes. This ongoing process of international exchange of people, goods, money and information is known as Globalization (Robertson & White, 2007). A well-known synonym of the economic focus of Globalization is global economic integration (Greenspan, 2001). According to Baldwin et al. (2004), global economic integration is a phenomenon of lowering the costs of trade in goods and making capital more mobility. Globalisation transformed human life and changed economies, politics, technology, culture and the environment (Held et al., 2019). On top of that is Globalization brought the world together to consume services, goods and knowledge (Zhang, 2008). According to (Faini, 2005), the world has become more interconnected. This increasing interconnectedness ensures that the global economy has experienced an enormous increase in international trade movements of goods (Faini, 2005). The nature of the world economy changed at the global level, and globalisation processes accelerated. The world has become a global marketplace, ensuring that the global trade network continues to expand and that international trade increases even more (Levy, 2007).

Case study: Economic integration of Europe (Crouzet, 2001; Lee, 2004; Laursen, 2016).

Not only the world became a global marketplace with global economic integration. Also in Europe was the development of European economic integration visible in daily life. The inter-European trade expanded significantly in the 19th century due to advanced technology, good transportation, and increased specialization, which eventually resulted in the industrial revolution. The first collaboration between, nowadays, European countries was the European Coal and Steel Community (ECSC). The community was founded in 1951 and was a decisive development for the economic integration of nowadays European Union. The ESCC was established after World War II to advance economic cooperation and prevent new wars. The ECSC was the foundation for the European Economic Community (EEC) in 1957. The EEC aimed to create a single market with the free movement of goods, services, capital and people and a unified economic space that eliminates trade barriers, fosters economic growth and tries to promote closer ties with European nations. These objectives were an ambitious goal and required cooperation and harmonization of regulations. The EEC became very beneficial, and the economic integration was materially visible compared to before the EEC. The industries flourished, markets became more prominent, and trade within the EEC grew exponentially. The next step in the success of the EEC was the signing of the Single European Act in 1986. This act aimed to deepen economic cooperation and strengthen the institutional framework. Eventually, these developments served as the foundation for the creation of the European Union in 1993, a milestone in the history of European economic integration.

Transport and transaction costs

As mentioned before, the development of transport technologies and transport infrastructure made it possible that international trade has increased so dramatically in recent decades (Levy, 2007; Hummels, 2007). Several studies researched the critical role of the transport sector in the world economy. Bottasso et al. (2018) also emphasised this critical role of transportation infrastructure in increasing export volumes; the study focuses on the maritime trade sector by emphasising port infrastructure. Complementary to Bottasso et al. (2018) the studies of Blonigen & Wilson (2008) and Marquez-Ramos et al. (2011) estimate that better port infrastructure ensures higher bilateral trade volumes between ports and decreasing transportation costs. The development of the transportation sector ensured increasing financial outcomes. Because transportation is linking different production zones and consumption zones, ensuring cultural exchanges, creating new job opportunities, and assuring people and goods movement (Scala & Delahaye, 2021). According to Gudmundsson and Merkert (2021), transport could be categorised by pathway and by service type. Pathway consists of water, road or air transport, and service consists of goods, passengers, or both. This thesis focuses on maritime and aviation transport.

The article "Transportation Costs and international trade in the second area of Globalization by Hummels (2007) states the relationship between globalisation, international trade, transportation costs and transport modes. According to Hummels (2007), 23% per cent of world trade by value occurs between countries that share a border; this means that 67% of world trade by value occurs between nonadjacent trading partners. On top of that, Hummels (2007) states that surface transport modes dominate the shared border trade, and all nonadjacent trade moves via maritime and aviation trade.

Yildiz (2015) and Ducruet (2020) confirmed the importance of maritime trade. These studies state that international trade and global economic activity rely heavily on maritime trade. They emphasize that maritime transport makes it easier to exchange a variety of goods, move goods across long distances efficiently, support global supply chains, and foster economic integration, maritime trade connects nations and regions. Martini (2015) emphasised the importance of aviation trade by stating that aviation is a crucial component of expanding national economies. Furthermore, Njoya et al. (2018) emphasised the value of aviation trade as a significant mode of transportation and defines maritime or shipping trade as the transporting goods, commodities, and resources through maritime routes like oceans, seas, and waterways.

According to Hummels (2007), most international trade in terms of weight exists out of bulk cargoes. Maritime trade has the most significant trade volumes measured in weights (tonnes, for example) because bulk commodities are shipped almost exclusively with maritime trade. When measuring trade volumes in terms of value, the share of maritime trade is much smaller and still decreasing. This is partly explained because the most valuable goods are transported by air transport, and the transported weight in air tonnages is growing significantly. An important determinant in this process is the rapid technological change in the commercial aviation sector, which caused an overtime decline in air shipping prices (Hummels, 2007).
Combes and Lafourcade (2005) emphasised that expanding the literature regarding transport-mode-specific trade effects of different infrastructure types is essential. Their study states that transport costs differ because of differences in transportation infrastructure types and transport modes. According to Combes and Lafourcade (2005), this could be caused by different energy consumption levels, taxation, operation costs or the general market structure of the different transport modes. Hummels (2007) adds that trade determinants such as distance between two trading partners can affect different transport modes differently (Hummels, 2007; Wessel, 2019). Wessel (2019) states that because trade effects could vary over different transport modes, it is essential to analyse further the exact infrastructure and transport mode-specific effects.

For analysing international trade flows, most research uses bilateral trade data. Data about exchanging goods and services between two countries or trading partners are referred to as bilateral trade flows. It represents these two countries' import and export activities, capturing the movement of services, commodities, and capital across their borders (Eaton & Kortum, 1997). Bilateral trade flows shape economic relationships and significantly impact economies, international competitiveness, and trade balance (Eaton & Kortum, 2002; Helpman et al., 2008; Anderson & van Wincoop, 2003). When analysing bilateral trade, multiple methods could be used.

Methods for analysing international trade

According to Zainuddin et al. (2021), there are two methods for analysing trade implications, ex-ante and ex-post analysis. Ex-ante analyses such as computable general equilibrium, network analysis and system dynamics are examples of simulation-based studies. Network analysis is the most common ex-ante analysis regarding international trade; it has been used for analysing the structure of trade flows, for example, by (Aller et al., 2015; Sun et al. 2021 and Ducruet et al. 2018). Ex-post methods are dissimilar to ex-ante analysis. An important ex-post method is the Gravity model. Greene & Zhang (2019) emphasised that a gravity model is a standard approach for analysing trade flows between countries. Moreover, according to Grumiller (2014), the Gravity model uses real-time trade data, to ensure that a variable's actual impact on trade flow could be investigated.

Network Analysis

The idea of network analysis, also known as social network theory, was introduced by Moreno (1934). The social network theory was extended by Erdös and Rényi in 1959 because they made the mathematical foundations of the network analysis (Erdös, 1959; Rényi, 1959). Since 1960 the social network theory has developed significant growth because of the development of computer technology. Eventually, Milgram (1967), Granovetter (1973), Burt (1995) and Freeman (1979) laid the foundation for the use of network analysis as we know it nowadays. Modern scholars with new applications and insights are still improving network analysis. Network analysis includes modelling, simulation, and descriptive analysis (Pastor-Satorras et al., 2015; Barbási, 2013). Network analysis is an analytical technique for studying the relationships and interactions among entities in a network. It provides a framework for understanding complex systems' structure, behaviour, and dynamics by examining their components' connections and dependencies (Wasserman & Faust, 1994). Social, transportation, biological, and communication networks are examples of networks (Newman, 2010).

A network is a fundamental concept in network analysis, and it is made up of nodes (also known as vertices) and edges (also known as links or connections). Edges represent the relationships, interactions, or dependencies between nodes, while nodes represent individual entities or units within the system (Barbási, 2013). These connections can be binary (present or absent) or weighted (indicating the strength or intensity of the connection) (Barbási, 2013; Wasserman & Faust, 1994). Network analysis employs various techniques and measures to understand their structure and properties. Sahoo et al. (2016) described three network structure measurement dimensions dominating the literature. These are, respectively, network density, network centrality and network clustering. Network centrality is one of the three main measurement dimensions for analysing a network. Vidya & Prabheesh (2020) used these centrality measures to gain insights into the degree of interconnectedness. Freeman (1978/1979) network centrality includes node degree centrality, betweenness centrality and closeness centrality. The centrality measures are widely used, quantifying a node's importance or prominence in the network based on its connectivity. For analysing the overall structure of a network, metrics could be obtained such as clustering coefficient, average path length and degree of distribution (Kaiser, 2008; Albert & Barbási, 2002). High-centrality nodes may play critical roles in information dissemination, resource flow, or influence propagation (Borgatti et al., 2009). Network analysis is a widely used tool for analysing international trade networks (e.g., Nemeth & Smith, 1985; Smith & White, 1992; Gong et al., 2018). Regarding Covid-19, Vidya & Prabheesh (2020) used network analysis to analyse the interconnectedness between countries before and after Covid-19.

Gravity Model

The Gravity model was introduced by Tinbergen (1962). Tinbergen refers to the gravity of the law of Netwon. Newton assumed that the value of trade between two countries was proportional to the result of the multiplication of the income, and their masses, in combination with the proportion to the distance that divides them. The gravity model uses distances as a proxy for transport costs because it is reducing the attractiveness of trade (Martínez-Zarzoso, 2003). The Gravity model concept was also proposed by Poyhonen (1963) independently from Tinbergen (1962). Theoretical support of the model started slowly; in the second half of the 1970s, theoretical developments appeared supporting the Gravity model (Martínez-Zarzoso, 2003). Starting with Anderson (1979), he tried to derive the gravity equation from a model that assumed product differentiation. Followed by Bergstrand (1985; 1989), who also explored bilateral trade by looking into monopolistic competition models. After that, Helpman & Krugman (1985), Deardorff (1995), and finally, Anderson and Wincoop (2001) contributed to the primary literature on the Gravity model.

Meanwhile, the model has been applied to several flows, specifically international trade flows. According to the Gravity model, exports from country X to country Y could be explained by economic size, population, and direct geographical distances (Martínez-Zarzoso, 2003). Eventually, the model became the prime model for trade modelling, primarily because of the ability to develop equations with new variables for testing the effects on trade flows. Most studies use the gravity model to add a vector of explanatory variables in combination with the core gravity model. The Gravity model can be adjusted by other quantitative variables, such as Covid-19, in this master's thesis. (Maciejewski & Wach, 2019). According to Sá (2013), Gravity models have long been used to explain bilateral trade in goods. They explain trade flows between countries i and j by various variables. For this reason, Gravity models of trade consist of a pervasive theoretical framework of determinants of international trade. The next part discusses the empirical evidence and theoretical underpinnings behind these determinants, offering a comprehensive overview of their significance in shaping international trade.

General overview of factors impacting bilateral trade flows.

Economic factors

This section delves into various economic factors extensively discussed in the literature. According to the study of Guang-hu (2008), the main determinants of bilateral trade are GDP, population size and (regional) trade agreements. Tinbergen (1962) and other Gravity models researchers such as Anderson (1979), Bergstrand (1985; 1989), Krugman (1985) and Anderson and Wincoop (2001; 2003) all agree with the importance of national income (proxied by GDP). Among other studies, also the study of Genç et al. (2011), found evidence that a country's GDP and population size affects trade flows positively. Martinez-Zarzoso et al. (2003) confirm that income-related rates are important determinants of bilateral trade flows. Changes in GDP have a stronger effect on trade flows than changes in relative trade prices (Bussière et al., 2009). Nuroglu (2010) researched the impact of population on bilateral trade flows by executing a Gravity model analysis. The study resulted in a positive significance for the exporting country, implying that with a higher population number, bilateral trade flows will increase. Paas et al. (2002) also concluded that the size of an economy, most often expressed by population size, has a positive and statistically significant impact on bilateral trade. Also Musila (2005) states that 'size factors', GDP and population size, are essential in determining international trade flows. Mhaka & Jeke (2018) join the previous statements by concluding that a country's economic size and market size have a strong positive impact on trade.

The study of Bussière et al. (2020) describes the importance of changes in exchange rates in addressing global trade imbalances. Also, the study of Appuhailage & Alhayhky (2010) emphasised that changing exchange rates between two countries significantly affects total trade. On top of that, the study of Mahdavi & Sohrabian (1993) stated that movements in exchange rates between countries ensure decreasing trade volumes on the export side.

Lastly, high inflation can have several effects on trade flows. Firstly, it can reduce the competitiveness of a country's exports as the prices of goods and services increase. This may lead to a decline in export volumes. Secondly, high inflation can erode the purchasing power of consumers, leading to a decrease in domestic demand for imported goods. This could result in a reduction in import volumes. Lastly, inflation can introduce uncertainty into the market, making it difficult for businesses to plan and make informed decisions, negatively impacting trade (Stockman, 1981; Angeloni & Ehrmann, 2007; Abdih et al., 2018).

Geographical and infrastructural factors

Tinbergen (1962) and other Gravity models researchers such as Anderson (1979), Bergstrand (1985; 1989), Krugman (1985) and Anderson and Wincoop (2001; 2003) all agree with the importance of geographical distances by determining trade flows between two countries. According to Martínez-Zarzoso (2003), distance is used as a proxy for transport costs in the Gravity Model approach, reducing trade attractiveness (Martínez-Zarzoso, 2003).
The effect of transportation costs on trade flows is studied by Martinez-Zarzoso and Nowak-Lehmann (2003) and Baier and Bergstrand (2009). To understand how trade costs affect trade volumes, these studies look at explicit measures of transportation costs, such as freight rates or the calibre of transportation infrastructure. The study of Daniels & Ruhr (2014) suggests that transportation costs have a positive and statically significant relationship with trade flows. Lastly, another study by Martinez-Zarzoso et al. (2008) shows that higher transportation costs significantly deter trade, especially in high-value-added sectors.

According to Wang et al. (2010), geographical distance between trade partner countries has a negative impact on trade. Jansen et al. (2019) also concluded that the geographical distance between two countries is a significant determinant of trade. Besides geographical distance also, landlock status is a considerable determinant of trade. The studies of Faye et al. (2004) and Kawai et al. (2011) research the impact of being 'landlocked', having no access to the sea, on trade. The main conclusion is that, for the most part, these 'landlocked' countries have lower levels of human development and external trade than their maritime neighbours. So, these studies highlight how essential waterways and ports are as nodes in the global trade networks.

Another important determinant of trade is connectivity and infrastructure. Trade flow patterns are significantly influenced by transportation infrastructure. Donaldson et al. (2010) suggest that transportation infrastructure can improve welfare significantly because they allow regions to exploit gains from trade. Nordås and Piermartini (2004) conclude that the quality of infrastructure is an important determinant of trade performance. Regarding transportation infrastructure, port efficiency significantly impacts trade among all infrastructure indicators. The study of Rehman et al. (2020) suggested that infrastructure promotes exports positively. On top of that, the study of Martincus et al. (2013) states that diminished transportation infrastructure significantly negatively impacted firm export.

Infrastructure for communication also plays a critical role in trade flows. Multiple studies emphasise how effective communication networks, like internet connectivity, telecommunications systems, and ICT infrastructure, enable quicker and more efficient information exchange, business activity coordination, and trade facilitation. Bankole et al. (2015) suggest that telecommunication infrastructure enhances efficiencies in African trade flows. The authors state that their empirical analysis shows that telecommunication infrastructure significantly impacts African trade (Bankole et al., 2015). Another study suggests that investment in ICT infrastructure that decreases international communication costs will positively affect trade in the long run (Mupela & Szirmai, 2013). Another study found a positive and significant effect of ICT infrastructure and the availability of the Internet on the volume of international trade (Vermuri et al., 2009). Rehman et al. (2020) demonstrate that transport, electricity, communication, and finance infrastructure positively and significantly impact trade flows.

Trade networks, information flows, and social ties between nations can all impact trade flows. These specifications are covered by multiple studies, among others Combes et al. (2003). The study states that business and social networks help reduce informational trade barriers, which appear to be a strong determinant of trade patterns. Huot & Kakinaka (2007) found evidence that a higher degree of trade complementarity is associated with higher levels of trade flows. Helliwell et al. (1997) state something similar; the study suggests that shared networks positively affect trade flows. Another study demonstrates that countries whose networks are not connected to the interconnected networks do not have success in trade compared to connected countries (Kikuchi, 2003). So, countries with established trade networks, information-sharing mechanisms, and social ties may experience higher levels of trade because business relationships are facilitated, and access to market knowledge and trust-building processes are more readily available in these countries.

Trade facilitation measures like border controls, documentation requirements, and customs procedures also impact trade flows. Multiple studies emphasise that reducing administrative burdens, streamlining trade processes, and improving the effectiveness of customs and border controls can lower trade costs and encourage greater trade integration. Zaki et al. (2013) show that trade facilitation boosts trade and welfare in a significant way. Another study suggests that trade facilitation measures will help countries improve their trade performance (Porto et al., 2015). Calì et al. (2011) found evidence that aids for trade facilitation reduce the costs of trading and thus positively influence trade in the long run. Zhang et al. (2018) show that trade facilitation has the most significant positive relationship with bilateral trade.

Policy and institutional factors

Besides economic and geographical considerations, policy and institutional considerations are crucial determinants of how trade flows are shaped. Lee and Swagel (1997) and French (2016) conclude that trade flows are directly impacted by trade barriers such as quotas, non-tariffs, and tariffs. These studies emphasise that lower trade barriers ensure greater trade integration between nations, and higher trade barriers limit trade volumes.

Another crucial element of policy and institutional considerations are trade agreements. Multiple studies examine the impact on trade volumes and patterns of regional trade agreements, multilateral agreements, and preferential trade arrangements (Egger et al. 2020; Helpman et al., 2008; Anderson & van Wincoop, 2003; Kepaptsoglou et al., 2010; Carrere, 2006; Kohl, 2014; Urata & Okabe, 2010).

According to Guang-hu (2008), economic integration, such as (regional) trade agreements, is another factor to consider. Complementary literature has been found by the study of Laget et al. (2018), which also found evidence that trade agreements increase bilateral trade. On top of that, the study of Ngepah & Udeagha (2018) confirmed that regional trade agreements enhance trade. Also, the study by Yeo & Dang (2019) states that free trade agreements positively impact international trade. Mattoo et al. (2017) and Urata & Okabe (2007) agree with this statement, and their studies state that trade agreements lead to more trade creation and less trade diversion.

Political stability has a significant impact on trade flows. Martínez-Zarzoso and Nowak-Lehmann (2003) and Silva & Tenreyro (2006) examine the impact of political stability on trade. These studies show that countries with higher political stability often have higher levels of trade because they have lower investment risk, a more favourable business climate, and higher investor confidence. Grechyna (2017) state that political instability reduces trade openness, negatively affecting the trade margin. Also, another study emphasises that political instability increases fiscal volatility, negatively affecting trade (Dutt & Mitra, 2007). Decker et al. (2009) state that political stability is strongly connected with democracy, and that democracy is positively related to trade flows.

According to multiple studies, a country's legal system impacts trade flows. According to Shin et al. (2018), a country's legal system contributes to trade liberalisation, and by rectifying trade problems, better market access will be provided for all WTO members. Turrini et al. (2006) state in their study that international trade between OECD countries will be supported when there are no legal asymmetries which would ensure obstacles to trade. Linders et al. (2005) also found evidence for the negative effect of a country's legal system on bilateral trade, presumably due to the higher trade transaction costs between the countries.

History, Cultural and social factors

The gravity model recognizes how crucial historical, cultural, and social factors determine trade flows. The literature's discussion of significant historical, cultural, and social influences is examined in this section. Language can significantly impact trade flow dynamics, multiple studies study language and trade. Oh et al. (2011) confirmed in their study that speaking a common language increases trade and FDI flows between countries. Egger & Lassman (2015) confirmed this statement, stating that the effect of a common native language ensures intensive margins of trade. Isphording & Otten (2012) found evidence during a data study on 178 countries and 52 years that linguistic distance has a strong negative influence on bilateral trade volumes. Another study by Ismail (2010) suggests that a country with a common language will trade more with each other because it reduces the information costs in trade. Lastly, a common language increases trade flows directly by 44%, according to Egger & Lassman (2011).

The cultural similarities between nations influence trade flows. Martínez-Zarzoso et al. (2005; 2006) trade is significantly deterred by higher transport costs and fostered by cultural similarities. Kokko & Tingvall (2014) concluded that cultural distance influence trade negatively. The higher the cultural distance, the less trade is due to higher transaction costs. Felbermayr et al. (2006) found evidence for a sizable preferences effect; the impact of cultural proximity on trade runs mainly through its cost effects. Disdier et al. (2007) showed a positive and significant influence of cultural flows on overall trade, suggesting that fostering domestic cultural creation might have impacts beyond what is generally expected.

Another factor that affects trade flows is migration. Multiple studies suggest that immigrant communities can serve as a trade conduit by strengthening connections, transferring knowledge, and fostering cross-cultural understanding. Hatzigeorgiou et al. (2010) stated that the results of their research concluded that there is a statistically strong, positive link between migration and increased trade flows. In later research, Hatzigeorgiou et al. (2015) concluded that migration reduces fixed trade costs resulting from information and trust friction across migrant hosts and source countries. Sgrignoli et al. (2013) stated that migration significantly boosts trade across countries, and they can identify product categories for which this effect is powerful. According to the empirical analysis based on a gravity model by Jansen (2009), temporary migration positively and significantly affects trade.

Lastly, trade history can also influence current trade flows, which refer to previous trade relationships between nations. Multiple studies have studied this specification. Among others, Pollins et al. (1989), the findings of the study support that trade flows are significantly influenced by historical political relations and enmity between nations. Another study by Campbell et al. (2010) shows that historical shocks and trade patterns persist for centuries. Head et al. (2010) focus on how historical colonial trade connections affect present-day trade flows.

The Covid-19 pandemic

This master's thesis tends to research to what extent Covid-19 impacted inter-European trade flows. Because the Covid-19 pandemic has been a very recent event, the literature regarding the impact of Covid-19 on trade is sparse. However, last two years, Covid-19 was a very often researched topic. This section describes all the Covid-19 literature related to (international) trade. Singh et al. (2021) state that large-scale pandemics have led to international demographic and economic revolutions. The Covid-19 pandemic was terrifying because of the mysterious, deadly, and quickly spreading effects on people globally. The Covid-19 pandemic is a global outbreak of a highly contagious respiratory illness caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The human-to-human transmission of the virus characterized this public health crisis. It was first identified in December 2019 in Wuhan, China. The virus spread itself rapidly through other parts of China. Eventually, the World Health Organization (WHO) declared it a global pandemic on March 11, 2020, due to the rapid spread of the virus across multiple countries and continents (Coronavirus Disease (COVID-19) Pandemic, 2023).

According to Vidya & Prabheesh (2020) pre, Covid-19 Global Production Networks (GPNs) ensured that many developing economies benefited from the GPNs. The GPNs promoted industrialization and increased productivity in the world trade scenario. Lastly, the relative distances between the centre and periphery regions decreased (Vidya & Prabheesh, 2020). In recent years there has been talking about a global shift, where China and Korea became market leaders and export hubs because of trade diversification and production fragmentation (Vidya & Prabheesh, 2020). This development is called the global shift, wherein also India, Japan, and Korea became information hubs, and China emerged as the supplier of industrial parts and components (Baldwin & Tomiura, 2020). According to Baldwin & Tomiura (2020), India, Japan, and Korea became "factory Asia" and China became the "workshop of the world". Covid-19 had a significant impact on the Chinese economy and its export volumes, which was noticeable in disruptions in supply chains, production interruptions (as "workshop of the world") and a decrease in both domestic and international trade (Vidya & Prabheesh, 2020; Baldwin & Tomiura, 2020).

Studying the effect of a pandemic like Covid-19 has never been done because, in the past, there were no similar scaled global pandemics. For this reason, pre-Covid-19 studies that could be useful for analyzing the Covid-19 pandemic are only available in the paper of Fernandes & Tang (2020), which examines the impact of the SARS epidemic on Chinese trade in 2003-2005. The study concluded that products upstream in the supply chain, more capital and skill intensive, experienced a smaller decline in exports. The paper also stated, in October 2021, that because of its global position of China on the global value chain, the outcome of Covid-19 could be very different as China is during Covid-19 specialized in capital and skill-intensive products, compared to processing exports in 2003. According to Fernandes & Tang (2020), this could imply that China may experience a smaller decline in exports due to the pandemic because, nowadays, foreign buyers will not find substitute products from other countries easily compared to 2003. Because of the increased interconnections between China and other countries globally and the dependency on Chinese supply, it could likely ensure significant disruptions in supply chains. These supply shocks could have more significant effects on the connected countries and economies than in 2003.

Besides the analysis of the SARS epidemic by Fernandes & Tang (2020), there could be expected that other studies that have a significant impact on trade flows, such as financial crisis-related studies, are also usable for this study. Unfortunately, a financial crisis distorts the production network by reducing demand from the crisis that originated in developed countries. This is the opposite of the Covid-19 situation. Covid-19 disrupted GPNs because of a reduction in the supply of intermediate products (Vidya & Prabheesh, 2020).

Studies highlighting the impact of Covid-19 on trade

Because of the fragmentation of production, intermediate products cross the border several times before the final product is shipped to the last customer. A negative supply shock could disrupt the trade networks because of disrupted production processes and hindered transportation and logistics (Korniyenko et al., 2017; Lafrogne-Joussier et al., 2023). Trade and supply chain disruptions in the global supply chains due to Covid-19 may lead to a high demand contraction (Baldwin & Freeman, 2020). And as Krugman (1997) told us that production networks and locations could be distorted due to random shocks, which may lead to shifts in economic fundamentals (Vidya & Prabheesh, 2020). Evidence for this has been found by Yu Zhao et al. (2021). This article states several interesting quotes. At first, Covid-19 has a significant negative effect on the export trade of China. Secondly, the Covid-19 pandemic situations in trading partner countries significantly positively affect China's total exports. This means that when a country's Covid-19 situation is relatively good, the export rate of China to this specific country increases.

Büchel et al. (2020) examined the impact of Covid-19 on Swiss international trade flows. Büchel et al. (2020) were investigating the impact of Covid-19 cases and stringency measures on Swiss trade flows. The study concluded that the pandemic affected both foreign trade's demand and supply. The study also examined the effect of trade restrictions and exchange rate fluctuations; both variables did not play a significant role in the decline of Swiss trade in that period. Khorana et al. (2021) employed the gravity model of international trade to examine the effect of the Covid-19 pandemic on global trade flows. The study uses bilateral monthly exports data as the dependent variable and Covid-19 cases, deaths, and stringency measures as independent variables to estimate the effect of the pandemic on countries' trade. Khorana et al. (2021) concluded that high Covid-19 deaths in specifically low-income importing countries reduced exports. In contrast, high numbers of Covid-19 deaths in high-income importing countries led to an increase in export. Also, the incidence of Covid-19 cases and deaths in exporting countries impacted trade between countries. Lastly, restrictions aiming to contain Covid-19 in high-income countries were associated with increased trading volumes.

Barbero et al. (2021) also examined the impact of Covid-19 on bilateral trade flows using a gravity model. This study concluded that the study found a significant negative impact of Covid-19 on trade flows, especially for high-income countries with identical economic conditions. Also, the study by Hayakawa & Mukunoki (2021) estimated a gravity equation to examine Covid-19 damage on international trade by analyzing the impact of Covid-19 cases, deaths, immobility, and lockdown. The conclusion also found evidence of a significant negative impact of Covid-19 on international trade of both exporting and importing countries. ElFayoumi et al. (2020) concluded that Covid-19 policy responses affected countries' exposure to the global shock, and the study also mentioned that pre-Covid-19 macro-economic conditions such as higher trade openness contributed to more significant trade flows during the Covid pandemic.

Kejžar et al. (2022) found an overall decline of more than 20% in trade between European countries during the Covid-19 outbreak. Both supply and demand shocks are contributing to this decline. The impact of Covid-19 has been proxied by both infection rate and policy stringency index. The study concluded that an increase in Covid-19 cases in the destination country leads to a more significant decrease in exports and policy stringency did not have a significant relationship. On top of that, Kejžar et al. (2022) found evidence for the China effect. The bigger the Chinese supply chain trade share, the bigger the Covid-19 shock.

Baldwin and Tomiura (2020) discuss the potential impacts of the pandemic, and they argue that the pandemic represents a unique shock to global supply chains and trade patterns due to its simultaneous global nature and the disruption of both the demand and supply sides of economies. The key aspects discussed in the article are trade interdependence, supply chain disruptions, shifts in trade patterns, trade policy responses and digital trade and services (Baldwin & Tomiura, 2020). According to the article of Liu et al. (2022), a country's own Covid-19 deaths and lockdowns significantly reduced its import from China, suggesting that the negative demand effects prevailed over the negative supply effects of the pandemic. Another study found that negative trade effects induced by Covid-19 shocks varied widely across sectors. Sectors that were more amenable to remote work contracted less throughout the pandemic.

Furthermore, participation in global value chains increased traders' vulnerability to shocks suffered by trading partners, reducing their vulnerability to domestic shocks (Espitia et al., 2022). Bassett et al. (2021) state that the Covid-19 pandemic highlighted the realization that over-reliance on global trade networks is very risky. The last article measured the trade interconnectedness among countries before and after the Covid-19 outbreak and forecasted the future direction of trade. They used a network analysis, and the authors concluded that: there is a drastic reduction in trade interconnectedness, there is a visible change in the trade network, and there will be a drastic decline in trade after December 2020 (Vidya & Prabheesh, 2020).

Studies highlighting the impact of Covid-19 on maritime trade

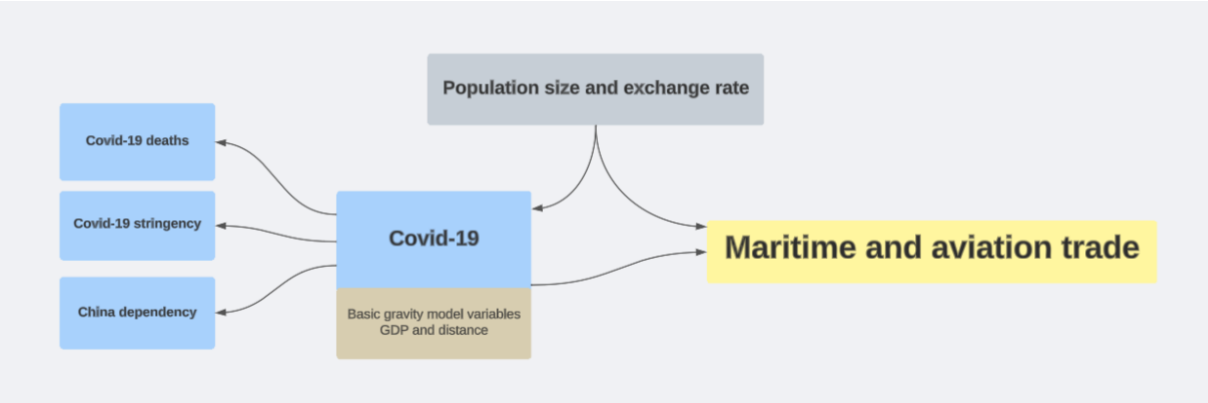
Only a few studies say something noteworthy about maritime trade concerning Covid-19. First, Doumbia-Henry (2020) provides an overview of the impact of and the response to the Covid-19 pandemic on the maritime industry. According to Doumbia-Henry (2020), shipping is responsible for 80% of global trade, and Covid-19 will continue to significantly impact the maritime industry and world trade for the foreseeable future. According to Oyenuga (2021), the maritime transport sector has been impacted by Covid-19 due to significant disruptions to maritime activity along established transport routes. According to Ralby (2020), the volume of maritime trade will decrease due to a global economic recession, the number of maritime bankruptcies will increase, and crew problems on vessels will increase. Also, Ralby argues that route interruptions will occur due to the rescheduling of cargo that generally would be transported by aviation cargo.

Studies highlighting the impact of Covid-19 on aviation trade

Similar to the number of noteworthy studies about maritime trade, studies about aviation trade related to Covid-19 are scarce. Most of the studies regarding aviation are about the impacts on passengers; only a few help analyse the impact on the aviation trade. One of the most important studies is the research of Dadak & Oudeh (2021). This study states that air transport is the primary driver of international trade and is probably among the most damaged by the Covid-19 pandemic. Although it is a victim of Covid-19, aviation has been recognised as contributing to extending diseases, transforming a national epidemic into an international pandemic. This caused many companies to stop all their flights and trade activities. The study concluded that Covid-19 negatively affected aviation trade in the EU, both in numbers of passengers and in transported goods. Each new infected case caused a decrease of 99 passengers and 0.075 transported tons (Dadak & Oudeh, 2021). Nižetić (2020) state that cargo traffic was not significantly affected by Covid-19, and the study mentioned that the trading volumes were higher due to the medical equipment supply. Sun et al. (2021a) conducted a cross-comparison study between China, the United States, and the European Union.
Li (2020) did a SWOT analysis of the air cargo sector of China in the context of Covid-19; the conclusion was that the pandemic had highlighted the significance of the Chinese air cargo sector.

This theoretical framework could be summarised in the following conceptual model (figure 1). Existing literature state that Covid-19 has a significant impact on trade. This master's thesis separates both maritime and aviation trade. With the objective to investigate whether Covid-19 impacts both maritime and aviation trade. This will be investigated by executing a gravity model with added Covid-19, basic gravity model, and control variables.

Figure 1: Conceptual model with dependent, independent and control variables



Source: own creation

The theoretical framework and conceptual model lead to the following central question and sub-questions:

To what extent has Covid-19 affected inter-European maritime and aviation trade flows?

- To what extent did the inter-European maritime and aviation network change during the Covid-19 pandemic?
- To what extent did the number of Covid-19 deaths in a country affect maritime/aviation trade flows between European countries?
- To what extent did the stringency of Covid-19 restrictions in a country affect maritime/aviation trade flows between European countries?
- To what extent did the pre-Covid-19 China dependency of a country affect the maritime/aviation trade flows between European countries?

Hypothesis 1: The inter-European maritime and aviation trade network of 2021 changed compared to 2018.

Hypothesis 2: Covid-19 deaths significantly negatively impact maritime and aviation trade between European Countries.

Hypothesis 3: Covid-19 restriction stringency significantly negatively impacts maritime and aviation trade between European countries.

Hypothesis 4: Pre Covid-19 China dependency significantly negatively impacts maritime trade and aviation between European countries.

3. Methodological Framework

This research uses basic descriptive statistics and two quantitative analyses to analyse the objectives of this research. The first step aims to provide a main descriptive analysis of inter-European maritime and aviation trade flows, primarily of the independent variables.
Zainuddin et al. (2021) described two models for analysing trade implications. Ex-ante and ex-post models. Ex-ante are simulation-based studies models, and ex-post are models that investigate the actual impact of a variable on trade. According to the existing literature about Covid-19, two models were used structurally. First, a Network Analysis, among others Vidya & Prabheesh (2020) executed a Network Analysis (ex-ante) to analyse the changes of the overall trade networks before and after Covid-19. Network Analysis is a widely used tool for analysing international trade networks (e.g., Nemeth & Smith, 1985; Smith & White, 1992; Gong et al., 2018). This master's thesis uses network analysis to compare inter-European maritime and aviation trade flows of 2018 and 2021. Four different network analyses will be executed; in this way, is it possible to compare the inter-European maritime and aviation trade networks of 2018 with the network of 2021. Along with the visual aspect of the network analysis, with the display of all four inter-European trade networks, the Network analysis also employs a variety of techniques and measures to gain insight into the changing structure and properties of the network (Barbási, 2002; Kaiser, 2008 & Borgatti et al. 2009). These network metrics ensure that all four networks can be compared. For example, Vidya & Prabheesh (2020) analysed the interconnectedness between countries before and after Covid-19. To investigate whether the trade network between countries changed during the Covid-19 pandemic. This master's thesis will calculate multiple quantitative measurements to analyse the network structure of the inter-European maritime and aviation trade networks.

The Network analysis of the maritime trade network of 2018 and 2021 are both directed weighted network analyses. In this way, the network of trade flows between European countries represents direct connections with weights. The weight of this thesis is in tonnes. According to Sahoo et al. (2016), three network structure measurement dimensions dominate the literature. Respectively, network density, network centrality and network clustering. Because this thesis is not interested in clusters in the inter-European trade network, the dimension of network clustering will not be included. Yang et al. (2015) calculate network density and diameter to determine the overall network connectivity of the network. Because this thesis is interested in the overall network structure of the network and the interconnectedness of the network (Vidya & Prabheesh, 2020), this thesis will use network density and network diameter as indicators for the general level of connectedness of the network (Yu & Ma, 2020). As Sahoo et al. (2016) described, network centrality is one of the three main measurement dimensions for analysing a network. According to Freeman (1978/1979), network centrality includes three aspects: node degree centrality, betweenness centrality and closeness centrality; these measurements determine the importance of a node (Freeman, 1978/1979; Abbasi & Hossain, 2013). This thesis only examines the closeness centrality and node degree of centrality metrics. Betweenness centrality may be less pronounced because this thesis involves direct bilateral relationships and fewer intermediaries than more complex international trade networks. A complimentary centrality metric has been added to the model to find the most influential countries. According to Lee et al. (2016), eigenvector centrality is an important metric to include for analysing the effect of nodes on the entire network.

Within this network analysis are the nodes referring to the countries and the network to the inter-European trade networks of maritime and aviation trade.

Network metrics

Network density
Network diameter

Firstly, network density and network diameter will be analysed to examine the overall network connectivity. According to Otte and Rousseau (2002) is the **network density** the number of links divided by the number of vertices in a complete network with the same number of nodes. It is an indicator of the overall network structure as the network density is calculated as the number of relationships in the network divided by the most significant number of relationships that could exist. The value of this ratio is between zero and one (network density); the closer to one, the stronger and more interconnected the network is (Yu & Ma, 2020). Yang et al. (2015) described the importance of the **network diameter**. The network diameter (D) is the maximum Dij. It means that the diameter is the shortest topological distance between the two most distant nodes in the network.

Node metrics

Degree of centrality
Closeness centrality
Eigenvector centrality

Secondly, network centrality will be analysed for the importance of the nodes in the network, measured by the degree of centrality and closeness centrality. **The degree of centrality** represents the number of other nodes connected directly to a node, which shows the node's popularity (Yu & Ma, 2020). Because the inter-European maritime trade network is directed, this thesis calculated both in-degree, out-degree and total degree (sum of in and out). These three elements are, according to Sajedianfard et al. (2021), representing the situation of importing (in-degree) and exporting countries (out-degree). The higher the in-degree of centrality for a node indicates that the country receives a larger volume of imports in tonnes from multiple countries within the inter-European trade network. It suggests the market share of the node, making it an attractive destination for trade partners within the network (Yu & Ma, 2020; Sajedianfard et al., 2021). The higher the out-degree of centrality for a node indicates that the country has a larger volume of exports in tonnes to multiple countries within the inter-European trade network. It suggests that the node has a significant supply function (Sajedianfard et al., 2021). **Closeness centrality** is equal to the distance of this node from all other nodes (Otte & Rousseau, 2002; Goldbeck, 2013; Perez & Germon, 2016). The larger the value of closeness centrality represents, the less central a node is, and the smaller the value is, the more central the node is (Yu & Ma, 2020). **Eigenvector centrality** is used to examine the importance and influence of a single node on the whole network. It represents the relative centrality of all nodes (Lee et al., 2016). A node with high eigenvector centrality can impact trade due to its strong connections to other central nodes. Thus, high-level centrality nodes can contribute more to connected nodes than low-level ones (Ruhnau, 2000).

The analysis and network metrics will be executed and obtained in R. The network analysis will mainly have a descriptive function in this thesis because the research's primary focus is determining to what extent Covid-19 may have impacted inter-European maritime and aviation trade flows. For this reason: network analysis will only answer the first sub-question: To what extent did the inter-European maritime and aviation network change during the Covid-19 pandemic?

Besides the network analysis, the principal referencing methodology for analysing the significance of the effects of independent variables on trade is the Gravity Model (ex-post). Prior to the Gravity model analysis, a correlation test will be executed. The correlation coefficient shows the strength and direction of a relationship between two variables (De Vocht, 2017).

Research regarding the impact of Covid-19 on trade mostly used bilateral trade Gravity models for analysing their specific variables of interest. Among others are the studies of Khorana et al. (2021), Barbero et al. (2021), and Hayakawa & Mukunoki (2021). According to Martínez-Zarzoso (2003), the model is the prime model for trade modelling because it can develop equations with new variables. Maciejewski & Wach (2019) confirm that the model can be adjusted with other quantitative variables, such as Covid-19, in this master's thesis.
Combining both quantitative analyses ensures a visual display of the inter-European maritime and aviation trade network. To investigate whether the inter-European maritime and aviation trade network changed during the Covid-19 pandemic. The Network analysis will not imply the significance of the effects between Covid-19 and the expected changing trade volumes. At this point, the Gravity model of trade will be executed. The main objective of this empirical model is to investigate the extent to which Covid-19 may have influenced maritime and aviation bilateral trade flows between European countries. The Gravity model is a broadly used framework to analyse patterns of international trade (Tinbergen, 1962; Anderson & van Wincoop, 2003; Bergstrand & Egger, 2007). Tinbergen (1962) states that bilateral trade flows between two countries seem to increase with per capita income and decrease due to transportation costs. Transportation costs have been proxied by the physical distance between the countries. The basic simple Gravity model is based on the economic sizes of the countries and the geographical distance between the countries (Martínez-Zarzoso, 2003; Anderson & Wincoop, 2001).

Equation 1: Basic Gravity equation

$$Xij = \frac{GDPi * GDPj}{DISTij}$$

Source: Anderson & Wincoop, 2003 and Zainuddin et al. (2021)

Where Xij denotes the export from country i (origin) to country j (destination), GDPi and GDPj denote the income for country i (origin) and country j (destination), respectively. Distij denotes the geographical distance (initially trade costs, but proxied by geographical distance) between country i (origin) and country j (destination). This model implies that bilateral export from country I to country j is proportional to their income and inverse to geographical distance (Zainuddin et al., 2021).
According to Maciejewski & Wach (2019), other quantitative variables can adjust the gravity model. The process of augmenting the Gravity model has been shown by Zainuddin et al. (2021). They augmented the gravity model with variables related to Covid-19, such as Covid-19 cases and deaths, but separately to avoid multicollinearity. This master’s thesis has augmented the basic gravity model with Covid-19. Population size and exchange rates are added as extra control variables. According to Vargas (2023), A logarithmic operator can be applied to form a log-linear model. This ensures that a standard estimation method such as OLS could be performed.

Equation 2: Augmented Gravity equation

$$\boldsymbol{Ln(Xij) = \beta 0 + \beta 1Ln(Ai) + \beta 2Ln(Aj) + \beta 3Ln(Bij) + \beta 4Ln(Ci) + \beta 5Ln(Cj) + \beta 6Ln(Di) + \beta 7Ln(Dj) + \beta 8Ln(Ei) + \beta 9Ln(Ej) + \beta 10Ln(Fi) + \beta 11Ln(Fj) + \beta 12Ln(Gi) + \beta 13Ln(Gj) + \varepsilon ij}$$

Source: Martínez-Zarzoso & Nowak-Lehmann (2003), Zainuddin et al. (2021) and Vargas (2023)

- Ln(Xij): denotes the natural logarithm of the dependent variable, representing the maritime or aviation export value between the origin country (i) and the destination country (j).
- Ln(Ai): denotes the natural logarithm of the GDP (Gross Domestic Product) of the origin country (i), capturing its economic size and potential influence on maritime/aviation exports.
- Ln(Aj): denotes the natural logarithm of the GDP of the destination country (j), capturing its economic size and potential impact on maritime/aviation exports.
- Ln(Bij): denotes the natural logarithm of the distance between the origin country (i) and the destination country (j), reflecting the geographical distance as a factor that may affect maritime/aviation trade volumes.
- Ln(Ci): denotes the natural logarithm of the number of COVID-19 deaths in the origin country (i), indicating the impact of the pandemic on maritime/aviation exports.
- Ln(Cj): denotes the natural logarithm of COVID-19 deaths in the destination country (j), capturing the pandemic's influence on maritime/aviation exports.
- Ln(Di): denotes the natural logarithm of the COVID-19 stringency index in the origin country (i), representing the level of government restrictions and measures related to the pandemic that may affect maritime/aviation trade.
- Ln(Dj): denotes the natural logarithm of the COVID-19 stringency index in the destination country (j), reflecting the level of government restrictions and measures in the destination country that may impact maritime/aviation trade.
- Ln(Ei): denotes the natural logarithm of the level of pre Covid-19 dependency of the origin country (i) on Chinese supply, indicating the influence of pre-Covid-19 dependency on China and maritime/aviation exports.
- Ln(Ej): denotes the natural logarithm of the level of pre-Covid-19 dependency of the destination country (i) on Chinese supply, indicating the influence of pre-Covid-19 dependency on China and maritime/aviation exports.
- Ln(Fi): denotes the natural logarithm of the population size of the origin country (i), representing the size of the consumer market and potential demand for maritime/aviation exports. This variable has been added as a control variable to the model.
- Ln(Fj): denotes the natural logarithm of the population size of the destination country (j), reflecting the size of the consumer market and potential demand for maritime/aviation exports. This variable has been added as a control variable to the model.
- Ln(Gi): denotes the natural logarithm of the presence of exchange rates in the origin country (i). This variable has been added as a control variable for accounting for the potential impact of exchange rate variations on trade flows.
- Ln(Gj): denotes the natural logarithm of the presence of exchange rates in the destination country (j). This variable has been added as a control variable for accounting for the potential impact of exchange rate variations on trade flows.

The coefficients β0,..., β13 represent the estimated effects of each independent variable on maritime or aviation exports. The error term εij captures the unobserved factors that influence maritime or aviation exports but are not included in the model.

4. Data Framework

4.1 Research area and panel data sample

The research area of this thesis is the European Union. The European Union exists out of 27 member states (CBS, n.d.). Aviation export data was available for all 27 member states. Unfortunately, maritime export data was not available for all 27 member states. Maritime export data was absent for Austria, Czechia, Hungary, Luxembourg, Malta and Slovakia. These countries have been excluded from the research on maritime trade.

According to Crouzet (2001), Lee (2004) and Laursen (2016), the European Union's foundation was made in 1957 by creating the European Economic Community (EEC). This community aimed to create a single market and eliminate trade restrictions. These standards from the EEC have been transformed into European Union standards. The European Union seeks to establish an internal market, economic growth and price stability, and a highly competitive market economy, enhance economic cohesion and establish an economic and monetary union whose currency is the Euro (Aims and Values | European Union, n.d.). This thesis researches trade between countries in a single market, without trade restrictions and the same currency. According to Goods (n.d.), the European single market has dramatically improved inter-European trade while facilitating the free movement of goods, services, capital, and people.

The European Union has been chosen as the research area because they form the European single market and thus are prevalent to the same policies, without trade restrictions. The European Union also strives for a monetary union with one currency, the Euro. However, eight countries do not use the Euro as their currency: Bulgaria, Denmark, Hungary, Croatia, Poland, Romania, Czechia and Sweden (Countries Using the Euro | European Union, n.d.). Besides that, the European Union provides reliable data sources on Eurostat, and there have not been earlier studies that researched the impact of Covid-19 on maritime and aviation trade within the European Union.

For the network analysis, panel data have been collected. Panel data have been used often for analysing international trade flows, among others: Feenstra et al. (2005) used panel data to analyse world trade flows from 1962 to 2000. This thesis distinguishes between pre-Covid-19 and post-Covid-19, derived from the research of Vidya & Prabheesh (2020). The pre-Covid-19 year was easy to choose, namely, the year before the pandemic started, 2018. Using data from a year before the global outbreak would be a reference point representing the 'normal economic' and trade conditions before the pandemic's effects. The data was composed of Eurostat.
On the other hand, the post Covid-19 year was harder to choose. Unfortunately, data from 2022 was not available for all variables. To ensure a legitimate comparison, there was decided to choose the year with the most recent data available, which was 2021.

4.2 Data and operationalization

The main objective of this research is to determine to what extent Covid-19 affected inter-European maritime and aviation trade flows. This section will outline the operationalization of the variables used in this research. Operationalization means defining and measuring the concepts of interest into concrete and measurable variables.

Table 1: Variables descriptions and sources

Variable	Descriptions	Sources
Maritime trade	Maritime bilateral export values in tonnes	Eurostat
Aviation trade	Aviation bilateral export values in tonnes	Eurostat
GDP origin country	Log of GDP for origin country X at time Z (proxied by Gross Domestic Product, base year 2021)	Eurostat
GDP destination country	Log of GDP for destination country Y at time Z (proxied by Gross Domestic Product, base year 2021)	Eurostat
Distance	Log of bilateral distance between capital in country X and Y (kilometers)	Simplemaps
Covid-19 deaths origin	Log of the total number of Covid-19 deaths until 31 December 2021 in country X	Our World in Data
Covid-19 deaths destination	Log of the total number of Covid-19 deaths until 31 December 2021 in country Y	Our World in Data
Covid-19 stringency index origin	Log of the stringency index until 31 December 2021 in country X	Our World in Data
Covid-19 stringency index origin	Log of the stringency index until 31 December 2021 in country Y	Our World in Data
Pre-Covid-19 China dependency ratio origin	Log of the pre Covid-19 China dependency ratio in country X	WITS Worldbank
Pre-Covid-19 China dependency ratio destination	Log of the pre Covid-19 China dependency ratio in country Y	WITS Worldbank
Population size origin	Log of Population size for destination country Y at time Z (proxied by Population of 1 January 2022)	Eurostat
Population size destination	Log of Population size for origin country Y at time Z (proxied by Population of 1 January 2022)	Eurostat
Exchange rate NO	Log of the presence the Euro as main currency for the origin country Y at time Z (proxied by the country's main currency in 2021, binary variable)	European Union
Exchange rate YES	Log of the presence the Euro as main currency for the destination country Y at time Z (proxied by the country's main currency in 2021, binary variable)	European Union

Source: own creation

4.2.1 Dependent variables

The objective of this master's thesis is to investigate whether Covid-19 impacted maritime and aviation trade flows between European countries (inter-European). Maritime and aviation trade are two completely different transportation modes. Hummels (2007) states that bulk commodities are shipped almost exclusively with maritime trade, and the most valuable goods are transported with aviation trade. The main reason for these mutual differences is the cost of shipping, which is considerably lower for maritime trade and higher for aviation trade. Multiple studies emphasise the relevance of researching the mutual differences between maritime and aviation trade. Combes and Lafourcade (2005) emphasised that expanding the literature regarding transport-mode-specific trade effects or different infrastructure types is essential.

On top of that, Wessel (2019) states that because of the varying trade effects of different transport modes, it is essential to analyse further the exact infrastructure and transport mode-specific effects. Lastly, Hummels (2007) states that trade determinants such as distance between two trading partners can affect transport modes differently. Distance is a well-studied determinant of trade, among others, by studies regarding the Gravity model. On the contrary, regarding Covid-19, there are no studies that compared the impact of Covid-19 on both aviation and maritime trade flows and compared the results afterwards. For this reason, this study tends to investigate whether Covid-19 impacted differently between maritime and aviation trade. Because both maritime and aviation trade have mutual differences, this master's thesis tends to investigate whether their reactions to Covid-19 also could differ. For analysing the explained variance due to Covid-19, there will be investigated whether Covid-19 has impacted export rates in the year 2021. Export rates have been chosen because the export from country X to country Y is the same as the import of country Y from country X. This thesis proxies trade flows with bilateral export data from 2021. Maritime trade flows have been operationalised using the gross weight of goods transported by maritime transport; this data was directly available from Eurostat in thousand tonnes. Aviation trade flows have been operationalised using the total freight and mail by air transport per year. This data was also directly available from Eurostat in tonnes. Eventually, both export maritime and aviation export data for 2021 have been transformed into tonnes.

4.2.2 Basic gravity model variables and control variables

4.2.2a Distance

Distance denotes the geographical distance between the trading partners. According to the gravity model literature, the leading reason distance is an important determinant of trade is transportation costs (Tinbergen, 1962; Martínez-Zarzoso, 2003). According to Smarzynska (2001), countries close to each other's are most likely to have bilateral trade.
Distance is a complex concept because a country is an area, not a point, and measuring the distance between a country and another country is impossible. There are multiple options to measure the distance between a country and another country. According to Montobbio & Sterzi (2013), there are three different options: Option 1) distance uses the latitude and longitude of the most populated cities, option 2) distance uses the latitude and longitude of the capital cities and option 3) weighted distance by the share of the country population.

This research will use 'distance uses the latitude and longitude of the capital cities to measure the distances between the European Union member states. The main reason for this choice is that most gravity model studies use latitude and longitude data based on the capital cities, among others Zainuddin et al. (2021). Besides that, population size is a control variable of this gravity model. When using weighted distance or distance based on most populated cities, the distance would depend on population size also, and then there would be controlled twice for the population size of a country. On top of that, capital cities are usually located in a geographically central position in a country (Demonceau, 2016). This thesis operationalises distance using the latitude and longitude of capital cities to calculate mutual distance. The latitude and longitude data were gathered from all selected European countries from Simplemaps. The Haversine formula (Equation 3) made it possible to calculate the mutual distances on the surface of a sphere between the latitude and longitude data of all country pairs. Besides latitude and longitude data of all country pairs, the sphere's radius was necessary, which is 6371 for the Earth.

Equation 3: Haversine Formula

$$= 2R\, asin(\sqrt{sin^2\left(\frac{lat_2 - lat_1}{2}\right) + cos(lat_1)\, cos(lat_2)\, sin^2\left(\frac{long_2 - long_1}{2}\right)}$$

4.2.2b Gross Domestic Product

According to Gravity model researchers such as Tinbergen (1962), Anderson (1979), Bergstrand (1985; 1989), Krugman (1985) and Wincoop (2001; 2003), exports from country X to country Y could be explained by the economic sizes, their populations and direct geographical distances. Also, other researchers, for example, Martinez-Zarzoso et al. (2003), Guang-hu (2008), and Genç et al. (2011) found evidence that GDP is one of the most important determinants of trade. General Domestic Product is a measure of the total value of all goods and services produced within a country's borders during a year, and it is a widely used economic indicator (Eurostat. Nd.). The General Domestic Product of both countries can explain import, export, and total trade flows (Maryam & Mittal, 2019). According to Smarzynska (2001), larger and more prosperous countries (high GDP) have more varieties of goods to offer and automatically are more likely to trade. In addition, larger and more prosperous countries can afford to import more goods and have better infrastructure, transportation routes and equipment.

Gross domestic product (GDP) was operationalised with GDP data from Eurostat. Eurostat follows international standards and guidelines in measuring GDP to ensure comparability. Only the GDP 0f 2021 has been used since the trade data from 2021 will be analysed. This thesis operationalises GDP by using Eurostat data on GDP at market price for 2021. Since bilateral trade flows are involved, this research operationalises the independent variables in country pairs. For example: for analysing inter-European trade between Belgium and Bulgaria. The GDP of both Belgium and Bulgaria will be analysed in two separate columns (GDPi and GDPj, i = origin country and j = destination country). This will indicate the specific impact of GDP in each country pair on the trade flow between the two countries of interest. With an approach like this, is it possible to investigate interesting relationships between the GDP of the country of origin compared to the GDP of the country of destination and its effect on trade flows between the origin and destination country.

4.2.2c Population size

Population size will be included for potential confounding factors or alternative explanations. Confounding factors are related to the research's dependent and independent variables. In this way, the relationship between the independent and dependent variables is not biased by the influence of other factors. By including the control variables, it is possible to isolate the effect of the independent variables on the dependent variable. Control variables are always variables that affect the dependent variables for sure. According to multiple studies regarding international trade flows, population size is one of the main determinants of trade. Guang-hu (2008) states that population size is one of the main determinants of trade. Also, Genç et al. (2011), Nuroglu (2010), Paas et al. (2002) and Musila (2005) found evidence for a positive statistically significant relationship between population size and trade flow. Population size refers to the number of individuals residing in a specific geographic area, such as a country, region, or city, at a given time.

Population size has been operationalised by using population data from Eurostat. The Eurostat dataset consists of the number of persons having their usual residence in a country on the first of January of the respective year. It is a demographic indicator that quantifies the size of a population (UN, n.d.). This research uses the Population size of 2022 since the population size of each country was displayed on the first of January. When using population size data from Eurostat of 2021, this data will be composed from the first of January 2021. Using the population size of 2021 will not be legitimate because all country data have been collected for the 31st of December 2021. Since bilateral trade flows are involved, this thesis operationalises the independent variables, thus also control variables, in country pairs. For example: for analysing inter-European trade between Belgium and Bulgaria. The population size of both Belgium and Bulgaria will be analysed in two separate columns (population size i and population size j, i = origin country and j = destination country). This will indicate the specific impact of the population size in each country pairs on the trade flow between the two countries of interest. With an approach like this, is it possible to investigate interesting relationships between population size in the country of origin compared to the population size of the country of destination and its effect on trade flows between the origin and destination country.

4.2.2d Exchange Rates

In the Eurozone, exchange rates are replaced by the Euro. Nevertheless, in the European Union, eight countries still have their own currencies (*Countries Using the Euro | European Union*, n.d.). As the exchange rate is an important determinant of trade, it is necessary to include an exchange rate-related control variable in the gravity model for potential confounding factors or alternative explanations. According to multiple studies regarding international trade flows, exchange rates are one of the main determinants of trade. For example, Cobham (2007) suggested that exchange rate regimes and transaction costs are important determinants of trade. Naseer (2013) suggested that GDP and real effective exchange rate (operationalisation of exchange rates) significantly affect trade. The study of Mahdavi & Sohrabian (1993) stated that movements in exchange rates between countries ensure decreasing trade volumes on the export side. Appuhailage & Alkayhky (2010) emphasised that changing exchange rates between countries significantly affect total trade. The study of Bussière et al. (2020) describes the importance of changes in exchange rates in addressing global trade imbalances. The most used exchange rate variable is the real effective exchange rate (REER); for example, the study of Zainuddin (2021) used this operationalisation of exchange rates. However, only eight of the 27 countries have currencies other than the Euro. It was decided to make a binary exchange rate variable. The “zero” value has been given to countries in the Eurozone, with the Euro as its main currency. Furthermore, “one” has been given to countries not in the Eurozone, with another currency as the primary currency.

Since bilateral trade flows are involved, this thesis operationalises the independent variables, thus also control variables, in country pairs. For example: for analysing inter-European trade between Belgium and Bulgaria. The exchange rate variable of both Belgium and Bulgaria will be analysed in two separate columns (binary variable exchange rate i and binary variable exchange rate j, i = origin country and j = destination country). This will indicate the specific impact of having the Euro as the main currency in country i and having the Bulgarian lev as the main currency impact the trade flow between Belgium and Bulgaria. With an approach like this, is it possible to investigate interesting relationships between the binary exchange rate variable in the country of origin compared to the binary exchange rate variable of the country of destination and its effect on trade flows between the origin and destination country.

4.2.3 Independent variables

The independent variable of this master's thesis is Covid-19. Covid-19 is not a measurable variable, but multiple Covid-19-related variables that are measurable can be found in recent literature. Covid-19 variables derived from the theoretical framework could be divided into two forms of variables. First, incidence variables display the number of persons in a population group with the disease during a given period. Second, response variables indicate the reaction of the Governments in response to the pandemic. Most of the time, a combination of both types of variables has been used. Büchel et al. (2020) used Covid-19 cases and Covid-19 stringency measures to operationalise Covid-19. Also, Khorana et al. (2021) employed a gravity model with Covid-19 cases, Covid-19 stringency measures and Covid-19 deaths as operationalisations of Covid-19. Next, Hayakawa & Mukunoki (2021) also examined Covid-19 proxied by Covid-19 cases, deaths, immobility and lockdowns. Elfayoumi et al. (2020) only focused on the impact of Covid-19 stringency on trade.

Moreover, Liu et al. (2022) only examined Covid-19 proxied by Covid-19 deaths. Kejžar et al. (2022) also used the Covid-19 stringency index and the infection rate as a proxy for Covid-19. Another interesting finding of Kejžar et al. (2022) was the discovery of 'the China effect'. The bigger the share of a country's Chinese supply chain trade, the bigger the Covid-19 shock. Other studies confirm the risk and vulnerability for countries where over-reliance on global trade networks is risky (Espitia et al., 2022; Bassett et al., 2021). This master's thesis selected three variables for the empirical analysis. In the first place, four were selected, but due to the high linearity between Covid-19 cases and deaths, only deaths will be used. Covid-19 deaths are more precisely tracked as the cause of death of an individual has been determined in hospitals mainly.

This thesis operationalizes the Covid-19 deaths, strigency and China dependency in country pairs. For example: for analyzing the impact of Covid-19 deaths between Belgium and Bulgaria. The Covid-19 deaths of both Belgium and Bulgaria will be analyzed in two separate columns (Covid-19 deaths i and Covid-19 deaths j, i = origin country and j = destination country). This will indicate the specific impact of the number of Covid-19 deaths in each country pairs on the trade flow between the two countries of interest. With an approach like this, is it possible to investigate interesting relationships between Covid-19 deaths, stringency and China dependency in the country of origin compared to the Covid-19 deaths, stringency and China dependency in the country of destination and its effect on trade flows between the origin and destination country.

4.2.3a Covid-19 deaths

The number of registered Covid-19 deaths directly measures the Covid-19 pandemic. This operationalization will directly reflect the disease's incidence, severity and impact. The number of Covid-19 deaths is a standardized metric consistently measured across different countries. This standardized metric allows comparisons and analysis of the impact of the pandemic worldwide. The data is widely available, specifically standardized data from World Health Organization (WHO). Covid-19 deaths are also a regularly used operationalization of the Covid-19 pandemic (Flaxman et al., 2020; Chinazzi et al., 2020; Haug et al., 2020; Khorana et al., 2021; Hayakawa & Mukunoki, 2021; Liu et al. (2022). Lastly, the study by Yu Zhao et al. (2021) concludes that the fewer Covid-19 deaths in the partner country, the higher the export rate to that country.

This thesis uses data that displays the cumulative confirmed Covid-19 deaths per million people from 1 January 2021 till 31 December 2021. This data was obtained from Our World in Data. The population size has been used to calculate the total deaths in 2021. The population size of 2022 has been divided by 1.000.000, and this population size in millions has been multiplied by the Covid-19 deaths per million people. The outcome of the calculation is the total number of people that died of Covid-19 in the year 2021 till 31 December 2021.

4.2.3b Covid-19 stringency

Covid-19 restrictions are a more complex and more difficult concept to operationalise compared to Covid-19 deaths. This variable tries to clarify the impact of Covid-19 restrictions on Inter-European maritime and aviation trade flows. This Covid-19 restriction stringency is a response variable that indicates the reaction of the Governments in response to the pandemic. Multiple studies used restriction and response-related data to operationalise the Covid-19 pandemic. For example, The study of Büchel et al. (2020) quotes the effect of the stringency of Covid-19 measures on trade flows.

Furthermore, ElFayoumi et al. (2020) stated that Covid-19 policy responses affected countries' exposure to global shock. Khorane et al. (2021) examine the effect of Covid-19 stringency measures on global bilateral trade flows. Liu et al. (2022) also found evidence for the impact of Covid-19 restrictions, such as lockdowns, on bilateral trade.

This thesis operationalises this Covid-19 restriction variable by the Covid-19 stringency index. This composite index is based on nine response indicators, including workplace and school closures and travel bans, rescaled from 0 to 100 (100 = strictest). This stringency index was created by the study of Hale et al. (2021). This index created in the paper named 'A global pandel database of pandemic policies' had been transferred to data by Our World in Data (OWID). This scientific organisation investigates global issues. The data have been composed from Our World in Data (OWID) for each country in country pairs until 31 December 2021.

4.2.3c China dependency

Covid-19 arose in China, and in a short time, it spread globally (Coronavirus Disease (COVID-19) Pandemic, 2023). At the time of the outbreak, China was an essential character in the global trade network; according to Vidya & Prabheesh (2020), and Baldwin & Tomiura (2020), a global shift has occurred. Due to trade diversification and production fragmentation, China and Korea became market leaders and export hubs. According to Yu Zhao et al. (2021), Covid-19 significantly affects Chinese export volumes negatively. Baldwin and Freeman (2020) complemented how trade and supply chain disruptions in the global supply chains may lead to a high contraction in Demand. Fernandes & Tang (2020) suggest that because of the increased interconnections between China and other countries globally and the dependency on Chinese supply, Covid-19 may ensure significant disruptions in supply chains. Kejžar et al. (2022) already found evidence for this so-called ‘China effect’. The previous study found that the bigger the share of a country’s Chinese supply chain trade, the bigger the Covid-19 shock. This suggests that the impact of Covid-19 on maritime and aviation trade flows could be explained by changing export volumes from China.

There was decided to add the ‘China dependency’ variable as an extra Covid-19-related variable. This China dependency variable has been proxied by the share of imports originating from China compared to the total imports of the country in question before the Covid-19 pandemic, called the ‘China dependency ratio’.

The data have been composed of WITS World Bank. First, import data between the country i and China were collected for the pre Covid-19 year, 2018. Afterwards, import data between country i and World was also collected for the pre-Covid-19 year, 2018. Afterwards, 2018 import data from country i and China was divided by import data from country i and World.

This calculation resulted in the ‘China dependency ratio, which is the share of imports originating from China compared to the total imports of the country in question. This ratio shows how dependent a country was on Chinese supply prior to the Covid-19 pandemic. Since bilateral trade flows are involved, this research operationalises the independent variables in country pairs.

4.3 Data gathering process.

The data of the previously mentioned variables was gathered after the literature review. First, the data for maritime and aviation inter-European trade flows was compiled with data from Eurostat. The Eurostat datasets that were used consist of data about the gross weight of goods transported to/from the main ports of that specific country. Unfortunately, data was not present for all countries of interest. The dataset lacked export data from Austria, Czechia, Hungary, Luxembourg, Malta, and Slovakia; 21 countries remained. Aviation trade data was also gathered from Eurostat; the dataset used is freight and mail air transport by reporting country. The data was present for all 27 countries of interest. Both maritime and aviation export of 2018 and 2021 are the dependent variables of this research. After gathering the maritime and aviation export trade data for 2018 and 2021, the data for the network analysis was present. All data was joined in four different datasets with the countries in the rows and maritime export 2018/2021 and aviation export 2018/2021 in the columns. Afterwards, all data had been transformed to tonnes, all zero export values (e.g., Belgium to Belgium) were removed from the dataset, and the datasets were ready for running the network analysis in R.

The Gravity model analysis used the same bilateral export data as the data that was used for the network analysis. The Gravity model only used 2021 data to test the independent variables' relationship with maritime/aviation export rates in 2021. The independent variables, including control variables, were gathered based on the literature research that had been done before. Gross domestic product (GDP) was composed of Eurostat, proxied by the gross domestic product at market prices per year per country. The distance was proxied by the geographical distances between the capitals of the country pair. The distance was calculated by adding latitude and longitude data (composed from Simplemaps) to the Haversine Formula. Covid-19 deaths and the stringency index were composed of Our World in Data. The Covid-19 stringency index was directly available from Our World in Data. Covid-19 deaths had to be composed using the 'confirmed Covid-19 deaths per million people' from 2021. The total of deaths in 2021 were calculated by multiplying the 'confirmed Covid-19 deaths per million people on 31 December 2021 with the population size of 2021 (proxied by the countries' population size on 1 January 2022). The China dependency variable was composed of the WITS World Bank. The data used for compiling this variable was the Import data in 2018 from China to Country X and the total Import data of Country X. After obtaining import data from all selected European Countries, this calculation resulted in the China dependency ratio. The control variable population size per European country was composed of the Eurostat dataset: population on 1 January of each European country. The last control variable was obtained from the official site of the European Union and is a proxy of exchange rates. It is a binary variable that describes whether a country uses the euro as its main currency. After gathering the maritime and aviation export data of 2021, standard gravity model variables (distance and GDP), the control variables (population size and exchange rates), and the added Covid-19 variables (Covid-19 deaths, stringency, and China dependency), the data for the gravity model was present. All data was joined in a dataset with the countries in the rows and all variables in the columns. Afterwards, all data had been transformed to tonnes, all zero export and distance values were removed from the dataset, and the dataset was ready for running the Gravity model analysis in R.

5. Results

5.1 Descriptive statistics

Table 2: Descriptive statistics maritime trade

Variable	Minimum	Maximum	Mean	Std. deviation
Maritime trade	1000	13477000	1279951,66	2141076,45
GDP exporting country	24018.90	3601750	739956.73	954840.18
GDP importing country	24018.90	3601750	748496.92	949225.46
Distance	82.15	4634.75	1678.85	935.05
Covid-19 deaths exporting country	646	137708.79	42441.77	46777.49
Covid-19 deaths importing country	646	137708.79	42819.68	46927.62
Covid-19 stringency exporting country	30.58	72.28	45.28	10.53
Covid-19 stringency importing country	30.58	72.28	45.32	10.47
China dependency exporting country	2.43	11.57	6.35	2.54
China dependency importing country	2.43	11.57	6.32	2.49
N = 331				
Source: see table 1, composed in SPSS				

Table 3: Descriptive statistics aviation trade

Variable	Minimum	Maximum	Mean	Std. deviation
Aviation trade	0.1	127709.7	3502.06	12356.90
GDP exporting country	15011.50	3601750	670055	913809.56
GDP importing country	15011.50	3601750	674759	917706.23
Distance	82.15	4634.75	1525.63	852.00
Covid-19 deaths exporting country	461.62	137708.79	40029.67	44169.55
Covid-19 deaths importing country	461.62	137708.79	40572.49	44253.41
Covid-19 stringency exporting country	27.96	72.28	44.60	9.91
Covid-19 stringency importing country	27.96	72.28	44.60	9.96
China dependency exporting country	2.43	14.09	6.50	2.93
China dependency importing country	2.43	14.09	6.55	2.94
N = 510				
Source: see table 1, composed in SPSS				

Correlation

The correlation coefficient is a descriptive statistic that shows the strength and direction of a relationship between two variables. A positive correlation indicates a positive linear relationship; higher values of the independent variable are associated with higher values of the dependent variables. A negative correlation indicates a negative linear relationship; higher independent variable values are associated with lower dependent variable values. The strength of the correlation is based on the value of the correlation coefficient. The closer to zero, the less strong the relationship is. The closer to one, the stronger the relationship is (De Vocht, 2017).

A classification has been made to interpret the coefficient, and the correlation coefficient is denoted as R (De Vocht, 2017).

R	0	No correlation
R	0 < 0.2	Very weak correlation
R	0.2 < 0.4	Weak correlation
R	0.4 < 0.6	Moderately strong correlation
R	0.6 < 0.8	Strong correlation
R	0.8 < 1.0	Very strong correlation
R	1	Perfect correlation

Table 4: Correlation of maritime export (2021) and all independent variables

Covid-19 deaths origin country	0.121
Covid-19 deaths destination country	0.154
Covid-19 Stringency origin country	-0.059
Covid-19 Stringency destination country	-0.015
China dependency origin country	0.136
China dependency destination country	0.194
GDP origin country	0.181
GDP destination country	0.254
Population size origin country	0.162
Population size destination country	0.217
Distance	-0.093
Source: own creation, composed from SPSS	

Table 4 presents the results of the correlation test of the dependent variable maritime export in 2021 and all independent variables. The Covid-19 Stringency index of origin and destination country has a negative but very weak correlation with maritime export in 2021. Also, distance negatively but very weakly correlated with maritime export in 2021. All other variables: Covid-19 deaths of both origin and destination country, China dependency of both origin and destination country, Gross domestic product of both origin and destination country and population size of both origin and destination country seems to correlate positively with maritime export in 2021. Except for the population size of the country of destination and the GDP of the country of destination, which have a weak positive correlation, the countries all have very weak positive correlations. The stronger correlation of the variables in the destination countries is remarkable.

Table 5: Correlation of aviation export (2021) and all independent variables

Covid-19 deaths origin country	0.283
Covid-19 deaths destination country	0.288
Covid-19 Stringency origin country	-0.031
Covid-19 Stringency destination country	-0.016
China dependency origin country	0.118
China dependency destination country	0.111
GDP origin country	0.399
GDP destination country	0.368
Population size origin country	0.353
Population size destination country	0.341
Distance	-0.048
Source: own creation, composed from SPSS	

Table 5 presents the correlation test results of the other dependent variable, aviation export in 2021, and all independent variables. The Covid-19 Stringency index of both origin and destination country has a negative but very weak correlation with aviation export in 2021. Also, distance has a negative but very weak correlation with aviation export in 2021. All other variables: Covid-19 deaths of both origin and destination country, China dependency of both origin and destination country, Gross domestic product of both origin and destination country and population size of both origin and destination country seems to positively correlate with maritime export in 2021, besides China's dependency on both origin and destination country, which have a very weak positive correlation. All other variables have a weak positive correlation. Remarkable results for maritime export in 2021 is the stronger correlation of the variables in the destination countries. This observation is not the same with aviation trade flows; the differences in strength are minor and mostly slightly more substantial for the variables in the origin countries.

5.2 Network Analyses

Four network analyses have been executed to examine whether the network of maritime and aviation trade changed when comparing the network of 2021 with the network of 2018. The hypothesis that will be tested is: The inter-European maritime and aviation trade network of 2021 changed compared to 2018.

5.2.1 Network analysis: Maritime trade

At first sight, the inter-European maritime trade network 2021 seems differently shaped than the inter-European maritime trade network 2018 (Appendix F). Although the differences seem minimal, various network metrics have been calculated.

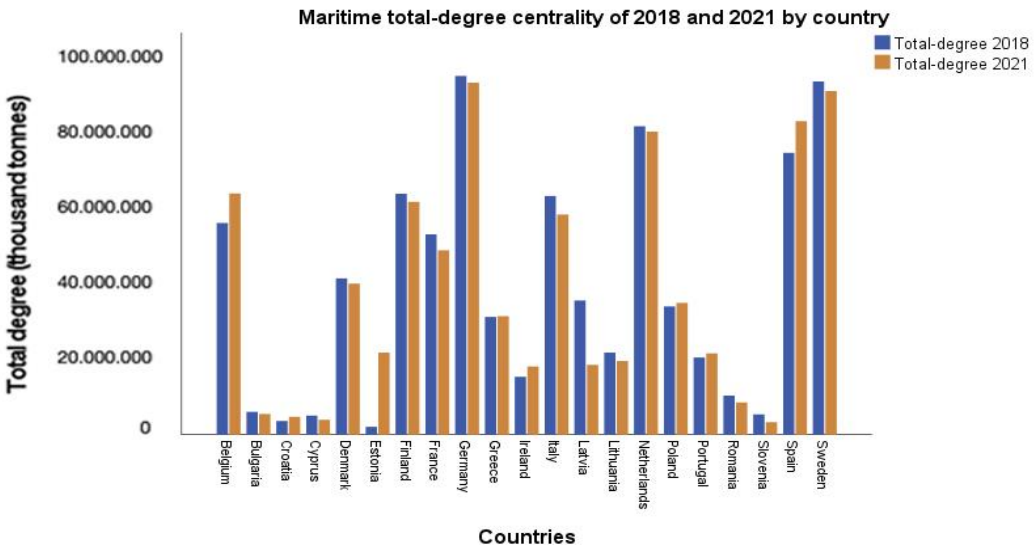
Table 6: Network metrics inter-European maritime trade 2018 and 2021

	Maritime 2018	Maritime 2021
Network Density	0.802381	0.788095
Network Diameter (tonnes)	61000	93000

Source: own creation, composed from network output R

The network density, an indicator of the overall network structure, was 0.802381 in 2018, and in 2021 the network density slightly decreased to 0.788095 (see table 6). According to Yu & Ma (2020), the closer to 1, the stronger and more interconnected the network is. The decrease in network density implies that the network is slightly less interconnected but still is quite interconnected (close to 1). Furthermore, the network diameter indicates the maximum distance between the two most distant points in the network. The network diameter was 61000 in 2018, and in 2021 the network diameter had increased by 52.5% to 93000 (see table 6). According to Yang et al. (2020), a change in network diameter means that the maximum distance or maximum path length between the two most distant points has changed. The increase in network diameter implies that the distance between the most distant points in the weighted network has been increased; this signifies a more separated inter-European maritime trade network.

Figure 2: Maritime total-degree of centrality of 2018 and 2021 by country



Source: own creation, composed from Network analysis metrics R in SPSS.

Three node metrics have been executed to analyse further the decrease in the network density and network diameter. At first, regarding the degree of centrality of the network, this thesis calculated both in-degree, out-degree and total degree metrics. In-degree and out-degree centrality, which represents the situation of importing and exporting countries, have both decreased (Sajedianfard et al., 2021). Both in-degree and out-degree centrality decreased by -10.320.000 tonnes, which resulted in a total inter-European maritime trade network decrease of -20.640.000 tonnes (see Appendix J). Comparing both 2018 and 2021 most influential nodes in the inter-European maritime trade network shows that 4 of the 21 countries remained there ranking and 17 of the countries changed (see table 7). This suggests that the relative importance of nodes within the inter-European maritime trade network has changed when comparing the period prior to Covid-19 with the period during Covid-19 (see Figure 2).

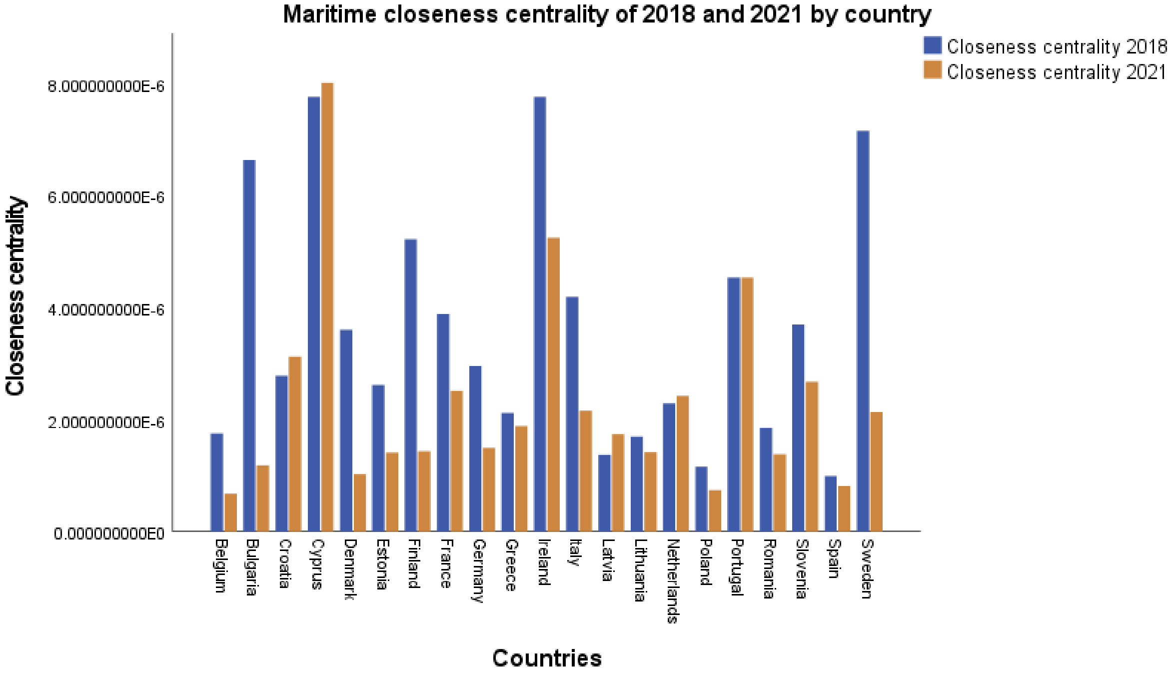
Table 7: Maritime total-degree of centrality 2018 and 2021 compared (high-low, in tonnes).

Ranking	Countries	Total-degree 2018	Ranking	Countries	Total-degree 2021
1	Germany	99160000	1	Germany	97301000
2	Sweden	97642000	2	Sweden	94979000
3	Netherlands	85233000	3	Spain	86660000
4	Spain	77889000	4	Netherlands	83781000
5	Finland	66584000	5	Belgium	66700000
6	Italy	65991000	6	Finland	64365000
7	Belgium	58490000	7	Italy	60868000
8	France	55371000	8	France	50964000
9	Denmark	43196000	9	Denmark	41752000
10	Latvia	37108000	10	Poland	36409000
11	Poland	35455000	11	Greece	32757000
12	Greece	32559000	12	Estonia	22702000
13	Lithuania	22680000	13	Portugal	22475000
14	Portugal	21318000	14	Lithuania	20381000
15	Ireland	15990000	15	Latvia	19302000
16	Romania	10789000	16	Ireland	18827000
17	Bulgaria	6288000	17	Romania	8907000
18	Slovenia	5576000	18	Bulgaria	5708000
19	Cyprus	5255000	19	Croatia	4937000
20	Croatia	3765000	20	Cyprus	4096000
21	Estonia	2162900	21	Slovenia	3457000

Source: own creation, composed from Network analysis metrics R.

Secondly, the closeness centrality is equal to the distance of a node from all other nodes (Otte & Rousseau, 2002). The larger the closeness centrality value, the less central a node is. The smaller the closeness centrality value, the more central a node is Yu & Ma (2020). When comparing the maritime closeness centrality metrics of 2018 and 2021, there could be concluded that, except for Croatia, Cyprus, Latvia, Netherlands and Portugal, the closeness centrality measures decreased (see Figure 3). So, 17 nodes became relatively more central in the network, and only five nodes became less central in the network (Appendix N). Comparing both 2018 and 2021, closeness centrality nodes in the inter-European trade network show that 2 of the 21 countries remained their ranking and 19 countries changed (see table 8).
These results suggest that the nodes of the maritime network made a positive shift in closeness centrality, which means that the mutual distances from a node with all other nodes decreased (see Figure 3).

Figure 3: Maritime closeness centrality of 2018 and 2021 by country



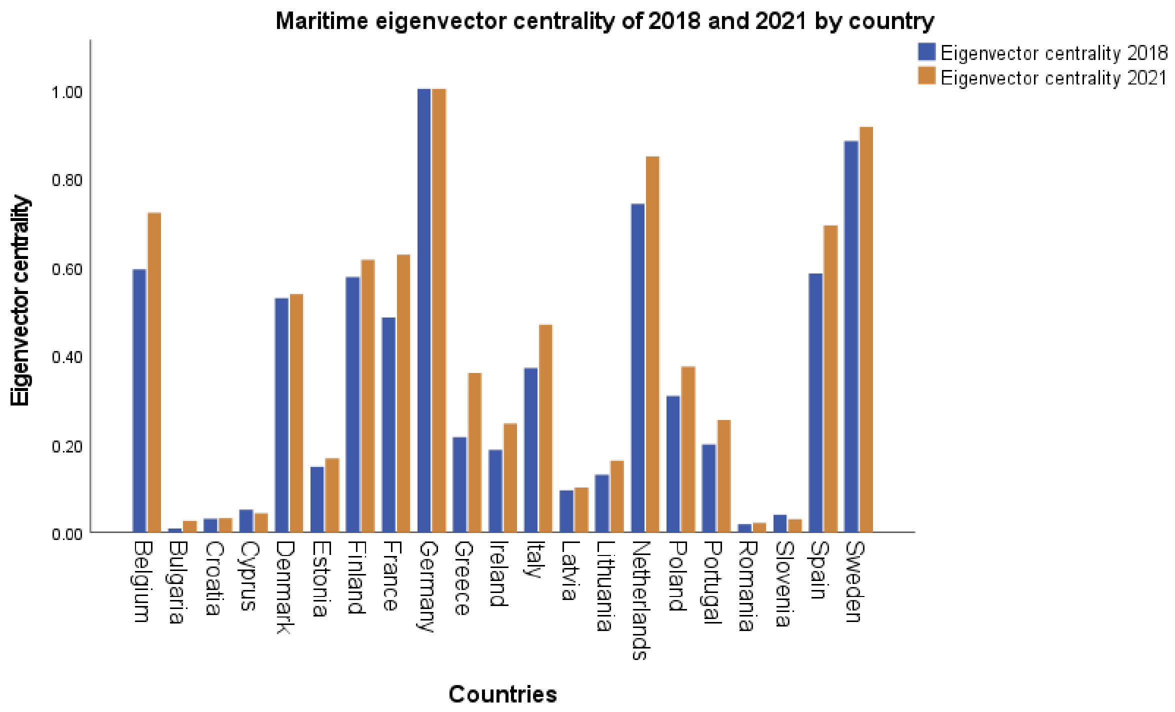
Source: own creation, composed from Network analysis metrics R in SPSS.

Table 8: Inter-European maritime closeness centrality metrics of 2018 and 2021 compared (ranked from low to high)

Rank	Countries	Closeness centrality 2018	Rank	Countries	Closeness centrality 2021
1	Poland	0.000001150748	1	Denmark	0.000001017294
2	Latvia	0.000001369863	2	Bulgaria	0.000001183432
3	Lithuania	0.000001689189	3	Romania	0.000001379310
4	Belgium	0.000001745201	4	Estonia	0.000001408451
5	Romania	0.000001845018	5	Lithuania	0.000001414427
6	Greece	0.000002114165	6	Finland	0.000001430615
7	Netherlands	0.000002283105	7	Germany	0.000001492537
8	Estonia	0.000002617801	8	Latvia	0.000001733102
9	Croatia	0.000002777778	9	Greece	0.000001883239
10	Germany	0.000002949853	10	Sweden	0.000002132196
11	Denmark	0.000003597122	11	Italy	0.000002155172
12	Slovenia	0.000003690037	12	Netherlands	0.000002415459
13	France	0.000003875969	13	France	0.000002506266
14	Italy	0.000004184100	14	Slovenia	0.000002673797
15	Portugal	0.000004524887	15	Croatia	0.000003115265
16	Finland	0.000005208333	16	Portugal	0.000004524887
17	Bulgaria	0.000006622517	17	Ireland	0.000005235602
18	Sweden	0.000007142857	18	Belgium	0.0000006765900
19	Ireland	0.000007751938	19	Poland	0.0000007374631
20	Cyprus	0.000007751938	20	Cyprus	0.000008000000
21	Spain	0.0000009852217	21	Spain	0.0000008116883

Source: own creation, composed from Network Analysis metrics R.

Figure 4: Maritime eigenvector centrality of 2018 and 2021 by country



Source: own creation, composed from Network analysis metrics R in SPSS.

Lastly, the eigenvector centrality is a more sophisticated view of centrality that assigns a centrality score to each node based on the concept that a node is important if it is connected to other important nodes (Hansen et al., 2020). High-level eigenvector centrality nodes can contribute more to connected nodes than low-level ones (Ruhnau, 2000). Looking at the increasing trend of the eigenvector centrality metric when comparing the eigenvector centrality outcomes of 2018 and 2021 (see Figure 4). Influential nodes got increased importance, and these nodes are likely well-connected to other influential nodes. Comparing 2018 and 2021, eigenvector centrality nodes (countries) in the inter-European trade network show that 14 21 countries remained in their ranking, and only seven countries changed. The top 5 countries on the ranking (from high to low) remained the same and increased their eigenvector centrality value (see table 9). This suggests that a decrease in closeness centrality goes hand in hand with an increase in eigenvector centrality. In that case, the network is relatively more connected because of the decreasing closeness centrality. The lower the closeness centrality, the better connected. Furthermore, the increasing eigenvector centrality means that the connected nodes got increased importance. So, these nodes are likely well-connected to other influential nodes (Hansen et al., 2020).

Table 9: Inter-European maritime eigenvector centrality metrics of exporting countries 2018 and 2021 compared (ranked from high to low)

Ranking	Countries	Eigenvector centrality 2018	Ranking	Countries	Eigenvector centrality 2021
1	Germany	1	1	Germany	1
2	Sweden	0.88250	2	Sweden	0.91399
3	Netherlands	0.74094	3	Netherlands	0.84798
4	Belgium	0.59269	4	Belgium	0.72035
5	Spain	0.58327	5	Spain	0.69297
6	Finland	0.57568	6	France	0.62607
7	Denmark	0.52803	7	Finland	0.61496
8	France	0.48439	8	Denmark	0.53697
9	Italy	0.37107	9	Italy	0.46878
10	Poland	0.30730	10	Poland	0.37397
11	Greece	0.21442	11	Greece	0.35899
12	Portugal	0.19829	12	Portugal	0.25307
13	Ireland	0.18625	13	Ireland	0.24522
14	Estonia	0.14800	14	Estonia	0.16644
15	Lithuania	0.12956	15	Lithuania	0.16177
16	Latvia	0.09536	16	Latvia	0.10140
17	Cyprus	0.05122	17	Cyprus	0.04368
18	Slovenia	0.03933	18	Croatia	0.03165
19	Croatia	0.03027	19	Slovenia	0.02972
20	Romania	0.01853	20	Bulgaria	0.02600
21	Bulgaria	0.00897	21	Romania	0.02112

Source: own creation, composed from Network Analysis metrics R

5.2.2 Network analysis: Aviation trade

At first sight, the inter-European aviation trade network 2021 also seems differently shaped than the inter-European aviation trade network 2018 (Appendix P). Although the differences seem minimal, various network metrics have been calculated.

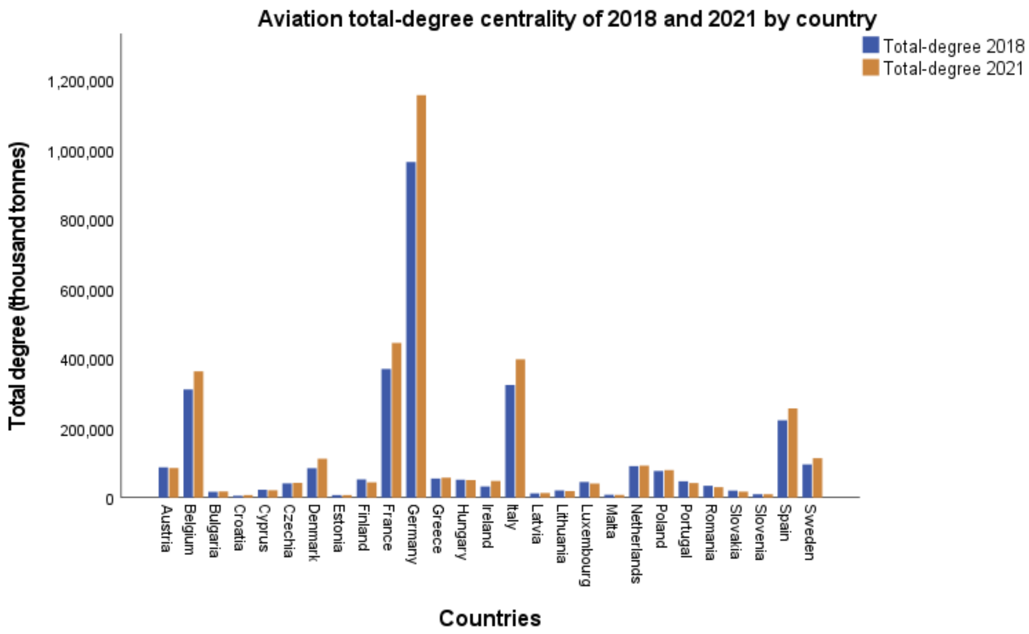
Table 10: Network metrics inter-European aviation trade 2018 and 2021

	Aviation 2018	Aviation 2021
Network Density	0.7792023	0.7264957
Network Diameter (tonnes)	270.7	438.5

Source: own creation, composed from network output R

The network density, an indicator of the overall network structure, was 0.7792023 in 2018, and in 2021 the network density slightly decreased to 0.7264957 (see table 10). According to Yu & Ma (2020), the closer to 1, the stronger and more interconnected the network is. The decrease in network density implies that the network is slightly less interconnected but still is quite interconnected (close to 1). Furthermore, the network diameter indicates the maximum distance between the two most distant points in the network. The network diameter was 270.7 in 2018, and in 2021 the network diameter had increased by 62% to 438.5 (see table 10). According to Yang et al. (2020), a change in network diameter means that the maximum distance or maximum path length between the two most distant points has changed. The increase in network diameter implies that the distance between the most distant points in the weighted network has been increased; this signifies a more separated inter-European aviation trade network.

Figure 5: Aviation total-degree of centrality of 2018 and 2021 by country



Source: own creation, composed from Network analysis metrics R in SPSS.

Three node metrics have been executed to analyse further the decrease in the network density and network diameter. At first, regarding the degree of centrality of the network, this thesis calculated both in-degree, out-degree and total degree metrics. Both in-degree and out-degree centrality increased with +234745 tonnes, which resulted in a total inter-European maritime trade network increase of +469490 tonnes (see Appendix Q) Comparing both 2018 and 2021 most influential nodes in the inter-European aviation trade network shows that 13 of the 27 countries remained there ranking and 14 of the countries changed. The visible changes in these 14 countries are primarily minor (see table 11). This suggests that the relative importance of nodes within the inter-European maritime trade network has not changed when comparing the period prior to Covid-19 with the period during Covid-19. On the other hand, the absolute changes in total degree values have changed properly positive (see Figure 5).

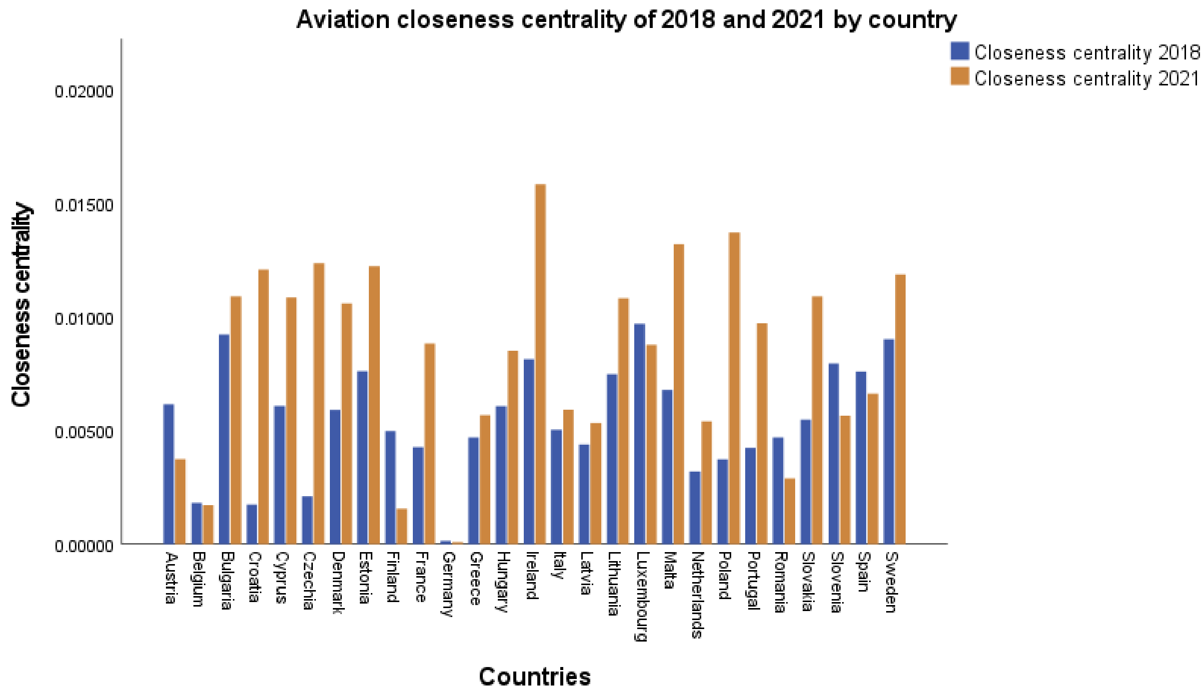
Table 11: Aviation total degree of centrality 2018 and 2021 compared (ranked from high to low, in tonnes)

Rank	Countries	Total degree 2018	Rank	Countries	Total degree 2021
1	Germany	964134,30	1	Germany	1156384,30
2	France	369672,20	2	France	444496,40
3	Italy	323763,10	3	Italy	397375,80
4	Belgium	310633,60	4	Belgium	362773,30
5	Spain	222258,40	5	Spain	256359,70
6	Sweden	95573,00	6	Sweden	113026,60
7	Netherlands	90283,90	7	Denmark	111838,10
8	Austria	87141,50	8	Netherlands	91833,50
9	Denmark	84538,60	9	Austria	85069,60
10	Poland	76361,90	10	Poland	79060,40
11	Greece	54888,80	11	Greece	57193,50
12	Finland	52082,80	12	Hungary	50507,40
13	Hungary	51271,30	13	Ireland	47729,20
14	Portugal	46616,80	14	Finland	44041,40
15	Luxembourg	44621,50	15	Czechia	42451,60
16	Czechia	41035,60	16	Portugal	41925,10
17	Romania	33800,80	17	Luxembourg	40433,50
18	Ireland	31918,90	18	Romania	29765,70
19	Cyprus	22461,00	19	Cyprus	21269,10
20	Lithuania	20494,60	20	Lithuania	18711,20
21	Slovakia	19990,70	21	Bulgaria	17508,50
22	Bulgaria	16457,40	22	Slovakia	17141,30
23	Latvia	12149,70	23	Latvia	13335,00
24	Slovenia	9585,60	24	Slovenia	9639,80
25	Malta	8113,70	25	Malta	7671,80
26	Estonia	7413,90	26	Croatia	7354,10
27	Croatia	5347,00	27	Estonia	7204,80

Source: own creation, composed from network output R

Secondly, regarding the closeness centrality, the larger the value of closeness centrality, the less central a node is. The smaller the closeness centrality value, the more central a node is Yu & Ma (2020). When comparing the aviation closeness centrality metrics of 2018 and 2021, there could be concluded that 19 of the 27 closeness centrality measures increased (see Figure 6). So, 19 nodes became relatively less central in the network, and only eight nodes became more central in the network (Appendix U). Comparing both 2018 and 2021, closeness centrality measures in the inter-European aviation trade network show that only 2 of the 27 countries remained their ranking and 25 countries changed (see table 12). These results suggest that the nodes of the aviation network made a negative shift in closeness centrality, which means that the mutual distance from node's to all other nodes increased (see Figure 6).

Figure 6: Aviation closeness centrality of 2018 and 2021 by country



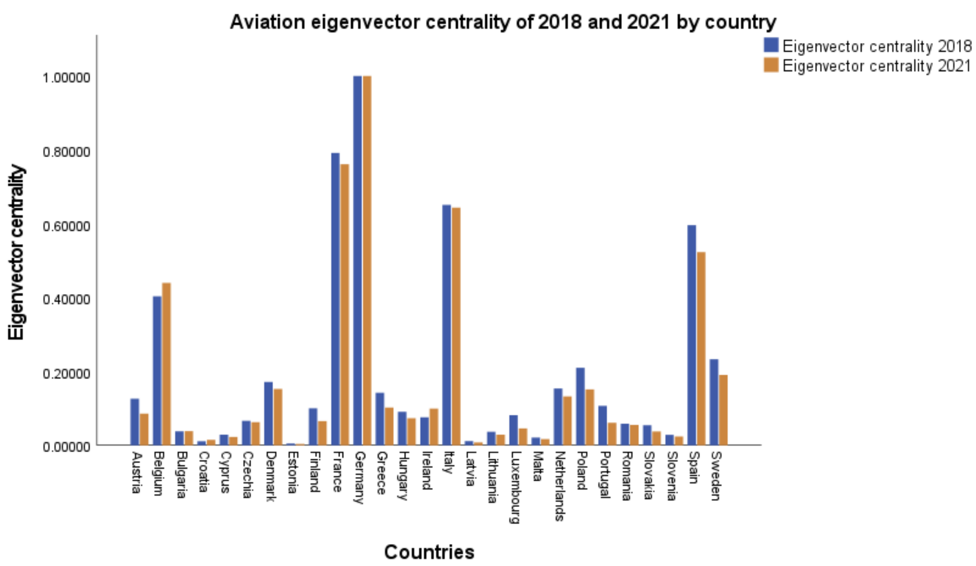
Source: own creation, composed from Network analysis metrics R in SPSS.

Table 12: Inter-European aviation closeness centrality metrics of 2018 and 2021 compared (ranked from low to high)

Rank	Countries	Closeness centrality 2018	Rank	Countries	Closeness centrality 2021
1	Germany	0.00015	1	Germany	0.00009
2	Croatia	0.00174	2	Finland	0.00155
3	Belgium	0.00181	3	Belgium	0.00171
4	Czechia	0.00210	4	Romania	0.00288
5	Netherlands	0.00319	5	Austria	0.00374
6	Poland	0.00373	6	Latvia	0.00532
7	Portugal	0.00424	7	Netherlands	0.00539
8	France	0.00427	8	Slovenia	0.00564
9	Latvia	0.00439	9	Greece	0.00567
10	Greece	0.00468	10	Italy	0.00591
11	Romania	0.00468	11	Spain	0.00660
12	Finland	0.00496	12	Hungary	0.00851
13	Italy	0.00502	13	Luxembourg	0.00875
14	Slovakia	0.00547	14	France	0.00881
15	Denmark	0.00590	15	Portugal	0.00971
16	Hungary	0.00607	16	Denmark	0.01059
17	Cyprus	0.00608	17	Lithuania	0.01080
18	Austria	0.00615	18	Cyprus	0.01083
19	Malta	0.00677	19	Bulgaria	0.01088
20	Lithuania	0.00747	20	Slovakia	0.01088
21	Spain	0.00758	21	Sweden	0.01186
22	Estonia	0.00760	22	Croatia	0.01207
23	Slovenia	0.00794	23	Estonia	0.01222
24	Ireland	0.00813	24	Czechia	0.01236
25	Sweden	0.00900	25	Malta	0.01318
26	Bulgaria	0.00921	26	Poland	0.01370
27	Luxembourg	0.00968	27	Ireland	0.01582

Source: own creation, composed from Network analysis metrics R in SPSS.

Figure 7: Aviation eigenvector centrality of 2018 and 2021 by country



Source: own creation, composed from Network analysis metrics R in SPSS.

Lastly, the eigenvector centrality is a more sophisticated view of centrality that assigns a centrality score to each node based on the concept that a node is important if it is connected to other important nodes (Hansen et al., 2020). High-level eigenvector centrality nodes can contribute more to connected nodes than low-level ones (Ruhnau, 2000). Looking at Figure 7, the eigenvector centrality metrics of 2021 compared to 2018 show a decreasing trend. Comparing 2018 and 2021, eigenvector centrality nodes (countries) in the inter-European aviation trade network show that 11 out of 27 countries maintained their ranking, and 16 countries changed. The top 6 countries on the ranking (from high to low) remained the same, and these top 6 countries slightly decreased their eigenvector centrality values (see table 13). This suggests a mainly decreasing eigenvector centrality, which implies reduced node importance in the network.

Table 13: Inter-European eigenvector centrality of 2018 and 2021 compared (from high to low)

Rank	Countries	Eigenvector centrality 2018	Rank	Countries	Eigenvector centrality 2021
1	Germany	1.0	1	Germany	1.0
2	France	0.79169	2	France	0.76090
3	Italy	0.65077	3	Italy	0.64360
4	Spain	0.59616	4	Spain	0.52304
5	Belgium	0.40317	5	Belgium	0.43961
6	Sweden	0.23283	6	Sweden	0.19060
7	Poland	0.20967	7	Denmark	0.15250
8	Denmark	0.17130	8	Poland	0.15128
9	Netherlands	0.15367	9	Netherlands	0.13228
10	Greece	0.14201	10	Greece	0.10208
11	Austria	0.12600	11	Ireland	0.09935
12	Portugal	0.10673	12	Austria	0.08578
13	Finland	0.10003	13	Hungary	0.07332
14	Hungary	0.09049	14	Finland	0.06538
15	Luxembourg	0.08168	15	Czechia	0.06269
16	Ireland	0.07556	16	Portugal	0.06104
17	Czechia	0.06633	17	Romania	0.05520
18	Romania	0.05839	18	Luxembourg	0.04580
19	Slovakia	0.05426	19	Bulgaria	0.03808
20	Bulgaria	0.03787	20	Slovakia	0.03737
21	Lithuania	0.03666	21	Lithuania	0.02879
22	Cyprus	0.02868	22	Slovenia	0.02387
23	Slovenia	0.02836	23	Cyprus	0.02255
24	Malta	0.02085	24	Malta	0.01690
25	Latvia	0.01137	25	Croatia	0.01476
26	Croatia	0.01113	26	Latvia	0.00787
27	Estonia	0.00489	27	Estonia	0.00366

Source: own creation, composed from Network analysis metrics R in SPSS.

5.2.3 Findings network analysis

Based on the results, we can conclude that the inter-European maritime trade network of 2021 has undergone multiple negative changes compared to 2018. The decrease in the total degree of centrality, network density and the increase in network diameter indicate a potential decline in overall connectivity and efficiency. However, the eigenvector centrality increases the growing concentration of power and may have negative implications for the overall resilience and stability of the network. Lastly, the closeness centrality could partially offset some of the negative changes. When looking at the inter-European aviation trade network, there can be concluded that the inter-European aviation trade network 2021 has undergone multiple negative changes compared to 2018. While the increase in both in-degree and out-degree centrality is positive, the negative changes outweigh these positive changes. An increasing trend of the closeness centrality metric means that the distance of a node from all other nodes increased (Otte & Rousseau, 2002), and thus, the less central a node is (Yu & Ma, 2020). In addition, the eigenvector centrality decreased, which implies that the importance of crucial nodes in the network got less important.

On top of that, the network density decreased. This indicates fewer connections relative to the total possible connections in the network. Moreover, the network diameter increased. This suggests that the distance between the two most distant nodes increased, negatively impacting the network's connectivity. The network condition (proxied by all network and node metrics) has gone backwards while the trading volume increased significantly. The inter-European aviation trade network's interconnectedness decreased despite the increasing trade volumes. Overall, the network of the inter-European maritime and aviation trade networks of 2021 changed significantly compared to 2018, which is precisely hypothesis 1, and this could be verified.

5.3 Gravity models

This chapter will be divided into the gravity model for maritime trade without control variables and the maritime trade with control variables (model 1 and model 2). The second part includes the gravity model for aviation trade without control variables and the aviation trade with control variables (model 3 and model 4). These four models will answer the sub-questions and test the remaining hypotheses.

The Gravity model has been executed by using ordinary least squares (OLS) for estimating the parameters of a linear regression model. The OLS is based on a log-linear model, which is one of the key characteristics of the gravity model. This means that both the independent variables as the dependent variable are scaled by the natural logarithm. This option has been discussed by Vargas (2019). Vargas argues that a log-linear model could be applied by adding a logarithmic operator. According to (R Core Team, 2018; Fox & Weisberg, 2019), interpreting both dependent and independent variables that are log-transformed ensures an interpretation of the coefficient as the per cent increase in the dependent variable for every 1% increase in the independent variable. For example, the coefficient is 0.4. For every 1% increase in the independent variable, the dependent variable increases by about 0.4%.

The standard errors of all four models are relatively small; this indicates that the parameters are relatively precise (close to their actual values). High precision in the estimates means little variability, and this can suggest a well-fitting model that explains the observed data well (Smith, 2015). Besides the standard error, the R-squared of models 2 and 4 (final models) are 0.3062 for maritime and aviation trade 0.4412. The R-squared indicates the percentage of the dependent variable's variance explained by the independent variables (Barret, 2000). Model 2 explained 30.6% of the variance of maritime trade by the independent variables. Model 4 explained 44.1% of the variance of maritime trade by the independent variables. So, model 5 provides a better fit to the aviation trade data, capturing more of the variation in the outcome variable. Model 4 also contains 510 observations, while Model 2 only contains 330 observations.

Finally, the defiance residual from all gravity models is displayed below (see Table 14). They indicate that the residues are normally distributed, a requirement for using this model, with similar absolute values of Min/Max and 1Q/3Q, a median close to zero and no residues greater than 3 (Agresti, 2002).

Table 14: Defiance residuals from all executed models

-	Min	1q	Median	3q	Max
Model 1	-5.6946	-1.2337	0.3526	1.3892	3.2565
Model 2	-5.4214	-1.2663	0.2718	1.4395	4.1989
Model 3	-7.767	-1.370	0.238	1.581	7.500
Model 4	-7.6750	-1.3228	0.2178	1.4110	7.0790

Source: own creation, composed from Gravity model output in R

5.3.1 Maritime trade

5.3.1a Maritime: basic Gravity model variables

Table 15: Maritime Gravity model output of basic gravity model variables: GDP and distance

Trade mode (maritime) / variables	Model 1		Model 2	
Coefficients	Estimate	P-value	Estimate	P-value
GDP origin country	0.609	2.01e-05 ***	0.5304	0.0591
GDP destination country	1.192	2.00e-05 ***	0.9620	0.0004 ***
Distance	-1.038	7.88e-10 ***	-1.0827	2.84e-10 ***

Source: own creation, composed from Gravity model output in R

The data presented in Table 15, model 1, shows that the origin and destination countries' GDP have a statistically significant positive relationship with maritime trade. The coefficient estimates (0.609 and 1.192, respectively) are positive, and the p-values (2.01e-05 and 2.00e-05, respectively) are significant (<0.05). They indicate that a 1% higher GDP of the origin and destination countries are associated with a 0.609% and 1.1926% increase in maritime trade between European countries. Besides the GDP variables, the distance variable also demonstrates a statistically significant relationship with maritime trade; this relationship is negative (see Table 15, model 1). The coefficient estimate (-1.038) is negative, and the p-value is extremely small (7.88e-10), indicating a significant negative relationship. It implies that when the distance between the origin and destination country increases by 1%, the volume of maritime trade decreases with respectively -1.038%.

As shown in Table 15 Model 2, after adding the control variables (population size and exchange rate), the estimates and p-values of the variables have changed. First, the GDP estimates from the origin and destination country decreased (0.530 and 0.962, respectively). Besides that, the influence of the GDP of the origin country appears to have diminished and is no longer statistically significant (>0.05). Only the GDP of the destination country maintained a statistically significant positive relationship with maritime trade. This implies that with a 1% higher GDP of the destination country, the maritime trade between European countries increases by 0.530%.
On the other hand, distance changed positively after adding the control variables (see Table 15, model 2). The distance estimate increases (-1.083), indicating a stronger negative relationship with maritime trade. Additionally, the p-value has become more significant, suggesting a more reliable association. This implies that when the distance between the origin and destination country increases by 1%, maritime trade decreases by -1.083%.

5.3.1b Maritime: Gravity model with Covid-19 variables

Table 16: Maritime Gravity model output of added Gravity model variables: Covid-19 deaths, restriction stringency and China dependency

Trade mode (maritime) / variables	Model 1		Model 2	
Covid-19 deaths origin country	0.0353	0.7756	-0.0334	0.9050
Covid-19 deaths destination country	-0.5674	5.16e-06 ***	-0.7023	0.0128 *
Covid-19 stringency index origin country	-0.3993	0.4750	-0.3802	0.5051
Covid-19 stringency index destination country	1.2805	0.0253 *	1.1010	0.0607
China Dependency ratio origin country	-0.4999	0.0912	-0.5250	0.1159
China Dependency ratio destination country	-0.7819	0.0106 *	-0.7703	0.0268 *

Source: own creation, composed from Gravity model output in R

Maritime: Covid-19 deaths

The data presented in Table 16, Model 1, shows that Covid-19 deaths in the origin county do not demonstrate a statistically significant relationship with maritime trade. The coefficient estimate (0.0353) is positive, suggesting a potential positive impact. However, the p-value (0.7756) is non-significant (>0.05). Therefore, the number of Covid-19 deaths from the origin country does not significantly impact maritime trade between European countries.
In contrast, the number of Covid-19 deaths from the destination country does demonstrate a statistically significant relationship with maritime trade. The coefficient estimate (-0.5674) is negative, and the p-value is extremely small (5.16e-06), indicating a significant negative relationship (<0.001). Therefore, the number of Covid-19 deaths from the destination country significantly impacts maritime trade between European countries. This indicates that with an increase of Covid-19 deaths in the destination country by 1%, the maritime trade between European countries will decrease by -0.5674%.

As shown in Table 16, model 2, after adding the control variables (population size and exchange rate), the number of Covid-19 deaths from the destination country remained the only significant influencer of maritime trade between European countries. The estimate of the number of Covid-19 deaths in the destination country shows an increase (-0.5674, is -0.7023), indicating a stronger negative relationship with maritime trade. However, the p-value decreased and remained statistically significant (0.0128<0.05). This implies that when the number of Covid-19 deaths in the destination country increases by 1%, the maritime trade decreases by -0.7023%.

Maritime: Covid-19 restriction stringency

Table 16 Model 1 shows that the Covid-19 restriction stringency index of the origin country does not demonstrate a statistically significant relationship with maritime trade. The coefficient estimate (-0.3993) is negative, suggesting a potential negative impact of higher stringency measures. However, the p-value (0.4750) is non-significant (>0.05). Therefore, the Covid-19 restriction stringency index of the origin country does not significantly impact maritime trade between European countries. On the other hand, the Covid-19 restriction stringency index of the importing country does demonstrate a statistically significant relationship with maritime trade. The coefficient estimate (1.2805) is positive, and the p-value (0.0253) is significant (<0.05). Therefore, the Covid-19 restriction stringency index of the destination country does have a significant impact on maritime trade between European countries. This indicates that with an increase of the Covid-19 restriction stringency index in the destination country by 1%, the maritime trade between European countries will increase by 1.2805%.

Table 16 Model 2 shows that after adding the control variables (population size and exchange rate), the estimates and p-values of both Covid-19 stringency in origin and destination countries decreased. In model 1, only the Covid-19 stringency in the destination country had a statistically significant positive relationship with maritime trade. After adding the control variables, the influence of Covid-19 stringency of the destination country appears to have diminished and is no longer statistically significant (0.0607>0.05). Eventually, none of the Covid-16 stringency variables maintained a significant relationship with maritime trade.

Maritime: pre Covid-19 China dependency ratio

Lastly, Model 1 (table 16) shows that the pre-Covid-19 China dependency ratio of the exporting country does not demonstrate a statistically significant relationship with maritime trade either. The coefficient estimate (-0.4999) is negative, suggesting a potential negative impact of higher China dependency. However, the p-value (0.0912) is non-significant (>0.05). Therefore, the pre-Covid-19 China dependency ratio of the origin country does not significantly impact maritime trade between European countries.

On the other hand, the pre-Covid-19 China dependency ratio of the destination country does demonstrate a statistically significant relationship with maritime trade. The coefficient estimate (-0.7819) is negative, and the p-value (0.0106) is significant (<0.05). Therefore, the pre-Covid-19 China dependency ratio of the destination country significantly impacts maritime trade between European countries. With an increase of the China dependency ratio in the destination country by 1%, the maritime trade between European countries will decrease by -0.7819%.

Model 2 (table 16) shows that after adding the control variables (population size and exchange rate), the estimates and p-values of the variables have changed minorly. The pre-Covid-19 China dependency ratio of the destination country remained the only significant influencer of maritime trade between European countries. The estimate of the pre Covid-19 China dependency ratio of the destination country shows a minimal decrease (was -0.7819, is -0.7703), indicating a minimal weaker negative relationship with maritime trade. The p-value also decreased but remained statistically significant (0.0268>0.05). This implies that when the pre-Covid-19 China dependency ratio of the destination country increases by 1%, maritime trade decreases by -0.7703%.

5.3.2 Aviation trade

5.3.2a Aviation: basic Gravity model variables

Table 17: Aviation Gravity model output of basic gravity model variables: GDP and distance

Trade mode (aviation) / variables	Model 3		Model 4	
Coefficients	Estimate	P-value	Estimate	P-value
GDP origin country	1.2830	<2e-16 ***	0.6851	0.0002 ***
GDP destination country	1.4241	<2e-16 ***	1.1885	2.04e-10 ***
Distance	-1.1779	2.43e-11 ***	-1.2119	3.00e-12 **

Source: own creation, composed from Gravity model output in R

The data presented in Table 17 Model 3 shows that the GDP from the origin and destination countries have a statistically significant positive relationship with aviation trade. The coefficient estimates (1.2830 and 1.4241, respectively) are positive, and the p-values are extremely small (0.0002 and 2.04e-10, respectively), indicating a significant positive relationship (<0.001). There could be concluded that a 1% higher GDP of the origin and destination countries are associated with a 1.2830% and 1.4241% increase in aviation trade between European countries. Besides the GDP variables, the distance variable also demonstrates a statistically significant relationship with aviation trade; this relationship is negative (see Table 17, model 3). The coefficient estimate (-1.1779) is negative, and the p-value is extremely small (3.00e-12), indicating a significant negative relationship (<0.001). There could be concluded that when the distance between the origin and destination country increases by 1%, the volume of maritime trade decreases with respectively -1.7779%.

As shown in Table 17, model 4, after adding the control variables (population size and exchange rate), the estimates and p-values of the variables have changed. The estimates of both GDP variables show a decrease (0.6851 and 1.1885, respectively), indicating a weaker relationship with aviation trade. However, the p-values decreased they remained statistically significant (0.0002 and 2.04e-10, respectively). This indicates that both a 1% higher GDP of the origin country and the destination country are associated with a 0.6851% and 1.1885% increase in aviation trade between European countries. Also, distance changed positively after adding the control variables (see Table 17, model 4). The distance estimate increases (was -1.1779, is -1.2119), indicating a stronger negative relationship with aviation trade. Additionally, the p-value became more significant. This means that when the distance between the origin and destination country increases by 1%, aviation trade decreases by -1.1779% and -1.2119.

5.3.1b Aviation: Gravity model with Covid-19 variables

Table 18: Maritime Gravity model output of added Gravity model variables: Covid-19 deaths, restriction stringency and China dependency

Trade mode (aviation) / variables	Model 3		Model 4	
Coefficients	Estimate	P-value	Estimate	P-value
Covid-19 deaths origin country	0.0041	0.9692	-0.3914	0.0423 *
Covid-19 deaths destination country	-0.2162	0.0426 *	-0.1442	0.4337
Covid-19 stringency index origin country	-0.6359	0.2106	-0.8943	0.1044
Covid-19 stringency index destination country	0.6244	0.2211	0.1499	0.7865
China Dependency ratio origin country	-1.2159	16.86e-06 ***	-1.3215	2.59e-05 ***
China Dependency ratio destination country	-1.3315	1.19e-06 ***	-1.0553	0.0009 ***

Source: own creation, composed from Gravity model output in R

Aviation: Covid-19 deaths

Model 3 (table 18) shows that the number of Covid-19 deaths in the origin county does not demonstrate a statistically significant relationship with aviation trade. The coefficient estimate (0.0041) is positive, suggesting a weak potential positive impact. However, the p-value (0.9692) is non-significant (>0.05). Therefore, the number of Covid-19 deaths from the origin country does not significantly impact maritime trade between European countries.

In contrast, the number of Covid-19 deaths from the destination country does demonstrate a statistically significant relationship with aviation trade. The coefficient estimate (-0.2162) is negative, and the p-value (0.0426) is significant (<0.05). Therefore, the number of Covid-19 deaths from the destination country significantly impacts aviation trade between European countries. There could be concluded that with an increase of Covid-19 deaths in the destination country by 1%, the aviation trade between European countries will decrease by -0.2162%.

As shown in Table 18 Model 4, after adding the control variables (population size and exchange rate), the estimates and p-values of both Covid-19 stringency in origin and destination countries have changed. The estimate of the number of Covid-19 deaths in the origin country shows both an increase and a change of direction. The estimate was +0.0041 and changed to -0.3914. Remarkable is also the switch from the number of Covid-19 deaths in the origin country from a non-significant variable to a significant variable (0.9692 > 0.0423). On top of that, the influence of Covid-19 deaths on aviation trade in the destination country has diminished and is no longer statistically significant (0.0426 > 0.4337). This indicates that after adding control variables (population size and exchange rate), the significance of the variables completely reversed. Eventually, the number of Covid-19 deaths from the destination country no longer significantly impacts aviation trade between European countries. On the contrary, the number of Covid-19 deaths from the origin country now significantly impacts aviation trade between European countries. This implies that when Covid-19 deaths in the origin country increase by 1%, the aviation trade decreases by -0.3914%.

Aviation: Covid-19 restriction stringency

Model 3 (table 18) also shows that the Covid-19 restriction stringency index of the origin and destination country does not demonstrate a statistically significant relationship with aviation trade. The estimate of the Covid-19 restriction stringency index of the origin country (-0.6359) is negative, indicating a potential negative impact of higher stringency measures. Furthermore, the estimate of the Covid-19 restriction stringency index of the destination country (0.6244) is positive, indicating a potential positive impact of higher stringency measures. However, for both origin and destination stringency indexes, the p-values (0.2106 and 0.2211, respectively) are non-significant (>0.05). Therefore, there can be concluded that the Covid-19 restriction stringency index of both origin and destination countries does not significantly impact aviation trade between European countries.

As shown in Table 18 Model 4, after adding the control variables (population size and exchange rate), the estimates and p-values of Covid-19 stringency in origin and destination countries changed. However, both p-values remained non-significant (>0.05). Therefore, after adding the control variables, there can be concluded that the Covid-19 restriction stringency index of both origin and destination countries does not significantly impact aviation trade between European countries.

Aviation: pre-Covid-19 China dependency ratio

Lastly, model 3 (table 18) shows that the pre-Covid-19 China dependency ratio of the origin and destination countries demonstrates a statistically significant association with aviation trade. The estimates of the pre-Covid-19 China dependency ratio (-1.2159 and -1.3315, respectively) are negative, and the p-values are extremely small (6.86e-06 and 1.19e-06, respectively), indicating a significant negative relationship (<0.001). Therefore, the pre-Covid-19 China dependency ratio of both the origin and destination country significantly impacts aviation trade between European countries. With an increase of the China dependency ratio in the origin country by 1%, the aviation trade between European countries will decrease by -1.2159%. Moreover, indicating that with an increase of the China dependency ratio in the destination countries with 1%, the aviation trade between European countries will decrease by -1.3315%.

Table 18 Model 4 shows that after adding the control variables (population size and exchange rate), the estimates and p-values of the variables have changed. The estimate of the China dependency ratio of the origin country increased (was -1.2159, is -1.3215), indicating a stronger relationship with aviation trade. The estimate of the China dependency ratio of the destination country decreased (was -1.3315, is -1.0553), indicating a weaker relationship with aviation trade. Because both p-values remained extremely small, there could be concluded that the China dependency ratio of both the origin and destination country significantly impacted aviation trade between European countries, even after being controlled by population size and exchange rate. This implies that with an increase of the China dependency ratio in the origin and destination countries with 1%, the aviation trade between European countries will decrease respectively -1.3215% and -1.0553%.

5.3.3 Control variables

The control variables, the population size of the origin and destination country, have no significant effect on maritime trade. The control variable of exchange rate significantly negatively affects maritime trade when the destination country has another currency compared to the origin country. The presence of an exchange rate in the destination country has an estimate of -0.5305, and the p-value (0.0399) is significant (<0.05). Therefore, the exchange rate in the destination country significantly impacts maritime trade between European countries. With an increase of the binary variable exchange rate in the destination country by 1%, the maritime trade between European countries will decrease by -0.5305%.

Regarding aviation trade, the control variable population size in the origin country has a positive and significant relationship with maritime trade. The estimate is 1.1262, and the p-value (0.0009) is significant (<0.05). With an increase in the population size by 1%, maritime trade between European countries will increase by 1.1262%. The control variable of exchange rate also significantly negatively affects aviation trade when the destination country has another currency compared to the origin country. The presence of an exchange rate in the destination country has an estimate of -0.7825, and the p-value (0.0054) is significant (<0.05). Therefore, the exchange rate in the destination country significantly impacts aviation trade between European countries. Indicating that, with an increase of the binary variable exchange rate in the destination country by 1%, the maritime trade between European countries will decrease by -0.7825%.

5.3.4 Findings Gravity model

The gravity model of trade was executed to provide an answer to the subquestions and test the hypotheses that were composed. Three hypotheses remain. Hypothesis 2 states that Covid-19 deaths significantly negatively impact maritime and aviation trade between European Countries. To test hypothesis 2, the relationship between Covid-19 deaths and maritime and aviation trade must be examined. When investigating the relationship between Covid-19 deaths and maritime trade, both Covid-19 deaths of the origin and destination country have negative estimates. Negative estimates indicate a potential negative impact of Covid-19 deaths on maritime trade for both origin and destination countries. However, only the Covid-19 deaths in the destination country are statistically significant. Regarding the relationship between Covid-19 deaths and aviation trade, both Covid-19 deaths of the origin and destination country have negative estimates, indicating a potential negative impact of Covid-19 deaths on maritime trade. Nevertheless, only Covid-19 deaths in the origin country are statistically significant.

To test hypothesis 3, the relationship between Covid-19 restriction stringency and maritime and aviation trade must be examined. Hypothesis 3 states that Covid-19 restriction stringency significantly negatively impacts maritime and aviation trade between European countries. When investigating the relationship between Covid-19 restriction stringency and maritime trade, the estimate of the origin country has a potentially negative impact on maritime trade. Also, the estimate of the destination country has a potentially positive impact on maritime trade, which is the same for aviation trade. However, the p-values are non-significant for both origin and destination countries of maritime and aviation trade.

The relationship between the China dependency ratio with maritime and aviation trade needs to be examined to test the last hypothesis. Hypothesis 4 states that Pre Covid-19 dependency on China significantly negatively impacts maritime trade and aviation between European countries. When investigating the relationship between pre-Covid-19 dependency on China and maritime trade, the estimates of origin and destination countries have a potentially negative impact on maritime trade. However, only the p-value of pre-Covid-19 dependency on China in the destination country is statistically significant. The origin and destination country estimates negatively affect the relationship between pre-Covid-19 dependency on China and aviation trade. This indicates a potentially negative impact on aviation trade. The p-values of the China dependency variables of the origin and destination country are extremely small. This indicates a statistically negative relationship between both pre Covid-19 dependency on China in the origin and destination country with aviation trade.

- Covid-19 deaths in the destination country significantly negatively impact maritime trade, and Covid-19 deaths in the origin country significantly impact aviation trade.
- ➔ Hypothesis 2 can be partly verified because there is a significant negative relationship, but it depends on the origin or destination country.
- Covid-19 restrictions in origin and destination countries do not significantly impact maritime and aviation trade.
- ➔ Hypothesis 3 could be rejected with high certainty since four out of four relationships are not statistically significant.
- Pre-Covid-19 dependency on China in the destination country has a statistically negative relationship with maritime trade, and pre-Covid-19 dependency on China in the origin and destination country has a statistically negative relationship with aviation trade.
- ➔ Hypothesis 4 could be verified with great certainty since three out of four relationships are statistically significant.

6 Conclusion & Discussion

This study examined inter-European maritime and aviation trade network changes when comparing pre-Covid-19 and post-Covid-19 bilateral export data. Besides the change during the Covid-19 pandemic, the significance of the effect of Covid-19 and these bilateral trade flows divided by transport mode has also been examined. This comprehensive research is related to the impact of Covid-19 on international trade. The study fills a gap by providing a comparative analysis of the impact of Covid-19 on maritime and aviation trade volumes. Where prior research on the impact of Covid-19 on trade distinguishes itself by analysing the impact of Covid-19 on sectors by type of goods, the impact of single transport modes, the impact of Covid-19 on a single country or the impact of Covid-19 on global trade.
On top of that, this research used a combination of two research methods, a network analysis and a gravity model of trade. By combining both methods, this study uncovered and visualised as many changes in the inter-European maritime and aviation trade networks as possible. Moreover, combining both made it possible to determine whether the independent Covid-19 variables could theoretically explain these network changes. Because a network analysis will not imply the of the effect of Covid-19 and changing trade volumes, the Gravity model had an important role. Because the main objective of this study was to investigate the extent to which Covid-19 influenced maritime and aviation bilateral trade flows between European countries.

The network analysis has been executed by comparing bilateral trade data from 2018 with bilateral trade data from 2021. Eventually, the weighted and directed network analysis results answered the following sub-question: "To what extent did the inter-European maritime and aviation network change in the period of the Covid-19 pandemic? Comparing the visualisation of the weighted and directed networks of maritime trade 2018 with 2021 and aviation trade 2018 with 2021 showed nothing worth mentioning. Further research was conducted through network metrics and node metrics. This research used network density, network diameter, in and out-degree of centrality, closeness centrality and eigenvector centrality to examine the structure of the networks (Sahoo et al., 2016; Freeman, 1978/79; Yu & Ma, 2020; Lee et al., 2016). The executed network analysis was directed and weighted; the in-degree is equal to the import volumes, and the out-degree is equal to the export volumes (Sajedianfard et al., 2021). The executed metrics provided valuable insights.

There can be concluded that both the inter-European maritime and aviation trade changed significantly. The node and network metrics of the maritime trade network all changed negatively, comparing the network of 2021 with the network of 2018. The in and out-degree of centrality measure indicates the ingoing and outgoing trade volumes (in terms of weight) decreased significantly. The decreasing connectivity and trading volumes aligned with the expectations that the total trade became less interconnected, and the trade volume (in terms of weight) decreased significantly. According to Hummels (2007), most of the international trade in weight exists out of bulk cargoes. For this reason, maritime trade has the most significant trade volumes. Because bulk commodities are shipped almost exclusively by maritime transport because of the cheaper transportation costs (Hummels, 2007). According to Vidya & Prabheesh (2020), Covid-19 caused disruptions in global production networks, which caused a reduction in the supply of intermediate products. Because intermediate products are almost exclusively shipped by maritime transport, the decline of maritime trade volumes in weight aligns with expectations.

The node and network metrics of the aviation trade network were more complex, comparing the network of 2021 with the network of 2018. The node and network metrics of the aviation trade network were more complex, comparing the network of 2021 with the network of 2018. The node and network metrics of the aviation trade network all changed negatively. Remarkably, only the in and out-degree of centrality indicates the increasing ingoing and outgoing trade volumes (in terms of weight). There can be concluded that both the inter-European maritime and aviation trade changed. Maritime trade network connectivity and trading volumes declined. Regarding aviation trade, the network connectivity had decreased, but trade volumes had increased. The increase in the total degree of centrality was very surprising. Hummels (2007) indicated that aviation transport mainly supplies non-bulk, luxury and other goods that can be delivered quickly. He also stated that the aviation trade was rapidly growing compared to other transport methods. However, existing literature regarding air transport AND Covid-19 stated a negative impact of Covid-19 on trade.

There could be several potential explanations for the increasing trade volume of aviation trade (in terms of weight). First, Nižetić (2020) was the only study that stated that aviation trade was not significantly affected by Covid-19. The study by Nižetić (2020) even says that in some cases, the trade volume of air transport has increased during the period of Covid-19. This increase in air trading volumes was because of the medical equipment supply used in the fight against Covid-19. This could be the reason for the increasing trade volume of aviation trade.

According to Korniyanko et al. (2017) and Lafrogne-Joussier et al. (2023), disrupted production processes and hindered transportation logistics were the causes of the negative supply shocks that disrupted international trade. It could be the case that these trade disruptions resulted in the forced search for alternative transport methods, for example, aviation transport, instead of hard-hit maritime transport. Where aviation trade usually transports non-bulk, luxury and other goods that weigh less. It could be that bulk commodities and intermediate goods were now transported by air transport. According to Vidya & Prabheesh (2020), intermediate goods were the most disrupted in the global trade network. These goods are usually transported by maritime transport, which weighs much more than non-bulk and luxury goods. This could explain the increase in trade volumes (in terms of tonnes). Another possibility is that bulk commodities and intermediate goods need to be purchased from other areas due to global supply chain disruptions. When these areas do not have suitable maritime trade routes, they could be forced to transport goods via aviation trade. This could explain the increase in trading volume (in terms of weight).

Lastly, due to the changing consumer demand, favouring online shopping during lockdowns created a new market in digital trade (E-Commerce Europe, 2021). Purchasing goods online causes people to buy their products online and want them to arrive as soon as possible. Hummels (2007) stated that aviation trade had been used for moving goods in a shorter period. The disruptions in the process that mainly affected maritime trade could be the reason for the decreasing trend of maritime trade volumes and the increasing trend of aviation trade volumes. Unfortunately, these are speculations and could be a captivating subject for subsequent research.

Regardless of whether the observed changes in the network analyses are caused by Covid-19 or not, a gravity model was performed. This analysis was performed by analysing bilateral export trade flows from 2021 using basic gravity model variables, added Covid-19 variables and control variables. The gravity model tends to research the potential explained variance of changing export volumes that Covid-19 could explain. The results of the gravity model analysis for maritime and aviation trade flows highlight the importance of GDP and distance as key factors influencing trade flows. Higher GDP in origin and destination countries is associated with increased maritime and aviation trade flows.

In contrast, greater distances between countries lead to decreased aviation and maritime trade flows. These findings emphasise the role of economic factors and geographic proximity in shaping maritime and aviation trade patterns between European countries. This is entirely in line with the expectations because the Gravity model predicts the volume of trade flows between two locations, considering the geographical distance between them, the economic size of the countries, and other trade-related variables (Tinbergen, 1962; Anderson & Wincoop, 2003; Head & Mayer, 2014; Helpman et al., 2006; Helpman et al., 2008). These other trade-related variables are meant to test variables that possibly affect trade. This study investigates the significance of Covid-19 related variables, as "other trade-related variables", by analysing the impact of Covid-19 deaths, the Stringency of Covid-19 restrictions and the pre-Covid-19 dependency ratio. This study suspected that these three independent variables would give an overall picture of the impact of Covid-19 because it discusses: the incidence of Covid-19, an indication of the response to Covid-19 and the potential impact of supply chain disruptions.

Eventually, the results of the augmented gravity model analysis answered the following sub-question(s): To what extent did the number of Covid-19 deaths, the stringency of Covid-19 restrictions, and the pre-Covid-19 dependency on China affect maritime/aviation trade flows between European countries? At first, the augmented gravity model analysis results for bilateral maritime and aviation trade flows between European countries concluded that the influence of Covid-19 and differences between countries of origin and destination.
Regarding the influence of the number of Covid-19 deaths, there is a significant negative relationship between the number of Covid-19 deaths in the destination country and maritime bilateral trade flows. Furthermore, a significant negative relationship exists between the number of Covid-19 deaths in the origin country and aviation bilateral trade flows.
There could be concluded that there is a statistically significant negative relationship, the relationship differs by transport mode, and it depends on the origin or destination country. There could be confirmed that the significant negative effect of Covid-19 deaths on maritime and aviation trade corresponds to the outcomes of the effect of Covid-19 deaths on international trade—for example, the study of Khorana et al. (2021).

Regarding the influence of the stringency of Covid-19 restrictions, there could be concluded that both for origin and destination country, stringency in Covid-19 restrictions did not significantly influence bilateral maritime and aviation trade flows between European countries. The literature about the effect of Covid-19 restrictions on trade is variably distributed, Khorana et al. (2021) found a significant positive impact of restrictions on trade, and both Kejžar (2022) and Büchel et al. (2020) found evidence that Covid-19 restrictions did not have a significant relationship with trade. This master's thesis confirmed Kejžar's (2022) and Büchel et al. (2020) studies. Lastly, regarding the influence of pre-Covid-19 dependency on China. There could be concluded that the pre-Covid-19 dependency on China was a statistically significant negative influencer of maritime trade in the destination country and for aviation trade in both the origin and destination country. This outcome is entirely in line with the expectations, Kejžar et al. (2022) found evidence for the China effect. The bigger the Chinese supply chain trade share, the bigger the Covid-19 shock. Besides that, emphasise the studies of Espitia et al. (2022) and Bassett et al. (2022) that by stating that over-reliance on global trade networks is very risky because it increases a country's vulnerability to domestic shocks. When comparing the strength of the relationship between maritime and aviation dependency in the destination country, the strength of the relationship for aviation trade was stronger.

The control variables, population size and exchange rate, made the final model more reliable. After adding the control variables to the model, multiple coefficients and p-values of the independent variables shifted. Especially the Covid-19 death variables were very sensitive after adding the control variables. This can probably be explained due to the population size control variable because the number of Covid-19 deaths is very likely to be influenced by population size. This significant relationship has been verified by Hamidi et al. (2020).

Final words. The sub-questions contributed to answering the central question of this research: To what extent has Covid-19 affected inter-European maritime and aviation trade flows? Eventually, Covid-19 has had a statistically significant negative influence on maritime and aviation trade flows. Despite this, the trade volumes of aviation trade had increased when comparing the 2018 and 2021 aviation trade networks. There were mutual differences between maritime trade and aviation trade.
Moreover, there were differences in the impact of Covid-19 on origin and destination countries. The differences that are mentioned above are interesting topics to investigate in follow-up studies. The most exciting topic to investigate in a follow-up study is how the increase in aviation trade volumes could have occurred during the Covid-19 pandemic that caused significant supply chain disruptions.

7. Limitations

Despite the satisfaction of continuing this research, the data and methods that have been used, and the results that were obtained. This research also has some limitations.
First, this research examines inter-European maritime and aviation network changes when comparing pre-Covid-19 and post-Covid-19 bilateral export data. The idea was to compare the periods in advance of covid-19 and after covid-19. However, because dependent and independent data was lacking, there was chosen to use 2021 data. Despite that, in 2021, Covid-19 was still a worldwide pandemic; this has been proxied as post-Covid-19 in the network analysis. For the gravity model analysis, the same bilateral trade data could be used, and on top of that, Covid-19 was still a worldwide pandemic. In this way also, the influence of Covid-19 restrictions could be investigated. For example: looking at the Covid-19 restrictions of the Netherlands, the last restrictions diminished in March 2022. When this study had taken 2022 as its base year, the Covid-19 restriction variable would be less valid because, in that case, there would be no restriction data from March to December.

Secondly, this research aims to study the inter-European maritime and aviation trade flows. Unfortunately, the 2022 export data was unavailable, and the 2021 export data on maritime trade was incomplete. Data for Czechia, Hungary, Luxembourg, Malta and Slovakia were absent, and these countries have been excluded from the research on maritime trade. The differences in the number of countries of maritime and aviation export data ensure that no legitimate comparative statements can be made.

Thirdly, as often indicated in trade flow-related studies, many zero values are present in trade data. This study had 219 missing values for aviation trade and 111 for maritime trade (including data from country x to country x). Because a long-linear regression model is only valid if export values are positive, these zero values are excluded from the research. These zero values cause omitted bias, confirmed by Burger et al. (2009).

Next is a limitation to the distance variable used in the gravity model. Based on Jacks & Pendakur (2010), transport costs are traditionally proxied as distance mapping into bilateral trade flows. This is almost all log-linear used and seems to be a suitable procedure.

Nevertheless, Jacks & Pendakur (2010) state that this approach suffers because the distance between countries is a time-invariant variable. For this reason, gauging the contribution of changes in transport costs to changes in trade flows is not a good proxy.
Another limitation is choosing the European Union as the research area, and an incidental is the relatively small number of countries, especially with the missing country data. This ensures that this research will be challenging to generalize globally. Although, it will be an accurate estimate of the impact of Covid-19 on maritime and aviation trade between European countries.

Lastly, a limitation of using Covid-19 incidence data is the inherent incompleteness of the data due to not testing or not going to a hospital. Both Covid-19 cases and deaths are incomplete. Especially the number of Covid-19 cases is incomplete. Covid-19 could have infected many people, but these numbers will be lower than the actual numbers due to not testing or not registering it. Since Covid-19 deaths are less sensitive to this bias because it is often diagnosed in hospitals, there was decided to use this incidence variable instead of Covid-19 cases.

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Appendix

Appendix A: Descriptive Statistics output maritime trade 2021

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Export2021	331	1000.000000	13477000.000	1279951.6616	2141076.4464
Coviddeaths1	331	646.00312686	137708.79381	42441.773484	46777.485061
Coviddeaths2	331	646.00312686	137708.79381	42819.675639	46927.616514
Covidstringency1	331	30.58	72.28	45.2812	10.53385
Covidstrigency2	331	30.58	72.28	45.3241	10.47185
Chinadep1	331	2.4327034911	11.569838138	6.3529917334	2.5420732599
Chinadep2	331	2.4327034911	11.569838138	6.3221379261	2.4927720060
gdp1	331	24018.900000	3601750.0000	739956.73112	954840.17821
gdp2	331	24018.900000	3601750.0000	748496.91873	949225.45985
distance	331	82.147441938	4634.7476381	1678.8541271	935.05199674
Pop_size1	331	904705.00000	83237124.000	22144391.347	25020878.522
Pop_size2	331	904705.00000	83237124.000	22272869.979	24974407.375
ExchangeR1	331	0	1	.22	.413
ExchangeR2	331	0	1	.23	.419
Valid N (listwise)	331				

Source: own creation, composed in spss

Appendix B: Descriptive statistics output aviation trade 2021

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Export2021	510	.1	127709.7	3502.060	12356.9020
Coviddeaths1	510	461.62048400	137708.79381	40029.673595	44169.549500
Coviddeaths2	510	461.62048400	137708.79381	40572.493772	44253.414906
Covidstringency1	510	27.96	72.28	44.6046	9.90618
Covidstrigency2	510	27.96	72.28	44.5979	9.95611
Chinadep1	510	2.4327034911	14.087980921	6.4969415602	2.9256897812
Chinadep2	510	2.4327034911	14.087980921	6.5458898713	2.9370978403
gdp1	510	15011.500000	3601750.0000	670055.29392	913809.55925
gdp2	510	15011.500000	3601750.0000	674758.88569	917706.22755
distance	510	82.147441938	4634.7476381	1525.6330179	852.00422714
Pop_size1	510	520971.00000	83237124.000	20052951.310	23891497.476
Pop_size2	510	520971.00000	83237124.000	20306420.792	23944305.638
ExchangeR1	510	0	1	.27	.447
ExchangeR2	510	0	1	.28	.451
Valid N (listwise)	510				

Source: own creation, composed in spss

Appendix C: Desriptive statistics Covid-19 variable, sorted high-low

Rank	Countries	Covid-19 deaths	Rank	Countries	Covid-19 stringency	Rank	Countries	China dependency
1	Italy	137708,79	1	Greece	72,28	1	Czechia	14,09
2	France	126633,01	2	Netherlands	63,89	2	Poland	11,57
3	Germany	118174,11	3	Romania	56,48	3	Germany	9,80
4	Poland	92146,08	4	Slovakia	56,34	4	France	8,95
5	Spain	91379,47	5	Slovenia	54,02	5	Netherlands	8,88
6	Romania	57347,30	6	Italy	53,5	6	Estonia	8,42
7	Hungary	38256,04	7	Portugal	48,15	7	Spain	8,13
8	Czechia	36334,91	8	Bulgaria	45,82	8	Italy	7,18
9	Bulgaria	31503,01	9	Luxembourg	45,81	9	Denmark	7,08
10	Belgium	28109,97	10	Poland	44,44	10	Finland	6,95
11	Greece	21293,62	11	Austria	44,16	11	Greece	6,51
12	Netherlands	20779,67	12	Latvia	44,14	12	Slovenia	6,23
13	Portugal	18987,51	13	Cyprus	43,95	13	Slovakia	5,97
14	Austria	16683,98	14	France	43,75	14	Austria	5,84
15	Slovakia	16093,58	15	Malta	43,52	15	Ireland	5,81
16	Sweden	15097,62	16	Spain	43,44	16	Hungary	5,43
17	Croatia	12511,57	17	Ireland	42,84	17	Romania	5,32
18	Lithuania	7520,74	18	Germany	42,69	18	Sweden	5,32
19	Slovenia	6088,64	19	Sweden	41,43	19	Cyprus	4,25
20	Ireland	6071,67	20	Czechia	39,59	20	Bulgaria	4,10
21	Latvia	4675,12	21	Croatia	38,05	21	Malta	3,62
22	Denmark	3232,64	22	Estonia	37,29	22	Croatia	3,39
23	Estonia	1937,83	23	Lithuania	34,58	23	Portugal	3,14
24	Finland	1702,86	24	Belgium	33,89	24	Latvia	3,10
25	Luxembourg	896,82	25	Denmark	31,52	25	Lithuania	2,84
26	Cyprus	646,00	26	Finland	30,58	26	Luxembourg	2,70
27	Malta	461,62	27	Hungary	27,96	27	Belgium	2,43
Source: see table 3								

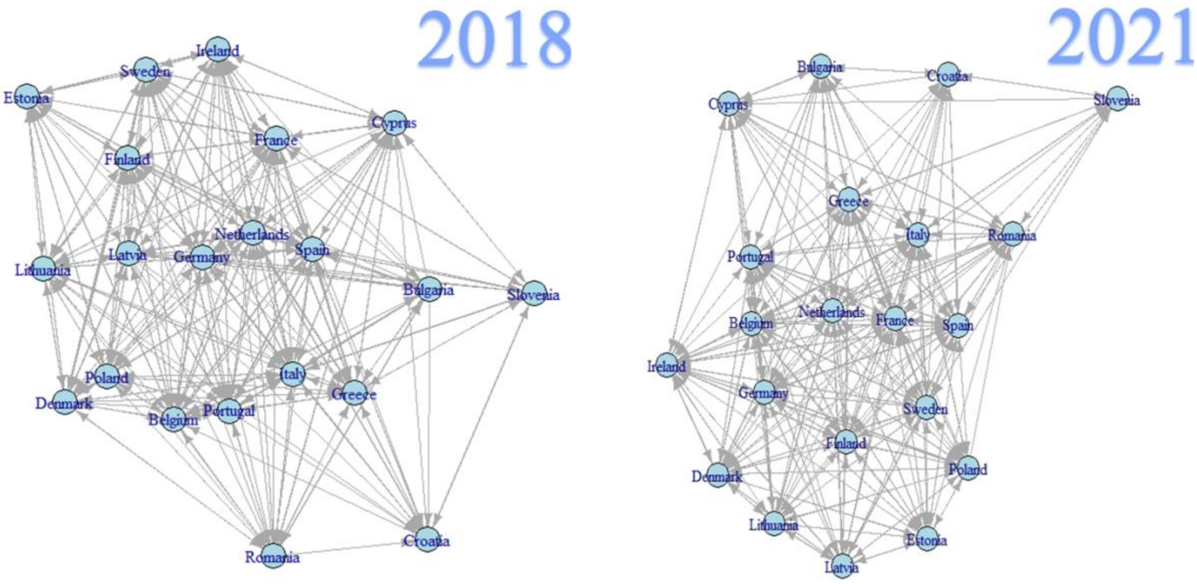
Appendix D: Descriptive statistics GDP & Population size, sorted high-low

Ranking	Countries	GDP2021	Ranking	Countries	Population size 2021
1	Germany	€ 3.601.750,00	1	Germany	83155031
2	France	€ 2.500.870,00	2	France	67656682
3	Italy	€ 1.787.675,40	3	Italy	59236213
4	Spain	€ 1.206.842,00	4	Spain	47398695
5	Netherlands	€ 855.470,00	5	Poland	37840001
6	Poland	€ 574.771,80	6	Romania	19201662
7	Sweden	€ 538.317,60	7	Netherlands	17475415
8	Belgium	€ 502.311,60	8	Belgium	11554767
9	Ireland	€ 426.283,40	9	Greece	10678632
10	Austria	€ 406.148,70	10	Czechia	10494836
11	Denmark	€ 336.718,80	11	Sweden	10379295
12	Finland	€ 250.594,00	12	Portugal	10298252
13	Romania	€ 241.268,40	13	Hungary	9730772
14	Czechia	€ 238.249,50	14	Austria	8932664
15	Portugal	€ 214.741,00	15	Bulgaria	6916548
16	Greece	€ 181.674,60	16	Denmark	5840045
17	Hungary	€ 154.120,10	17	Finland	5533793
18	Slovakia	€ 100.323,50	18	Slovakia	5459781
19	Luxembourg	€ 72.295,00	19	Ireland	5006324
20	Bulgaria	€ 71.077,00	20	Croatia	4036355
21	Croatia	€ 58.254,10	21	Lithuania	2795680
22	Lithuania	€ 56.153,50	22	Slovenia	2108977
23	Slovenia	€ 52.208,10	23	Latvia	1893223
24	Latvia	€ 33.587,60	24	Estonia	1330068
25	Estonia	€ 31.444,90	25	Cyprus	896007
26	Cyprus	€ 24.018,90	26	Luxembourg	634730
27	Malta	€ 15.011,50	27	Malta	516100
Source: see table 4					

Appendix E: Gravity model independent Covid-19 variables

Countries	Covid-19 deaths	Covid-19 stringency	China dependency
Belgium	28109,97	33,89	2,43
Bulgaria	31503,01	45,82	4,10
Czechia	36334,91	39,59	14,09
Denmark	3232,64	31,52	7,08
Germany	118174,11	42,69	9,80
Estonia	1937,83	37,29	8,42
Ireland	6071,67	42,84	5,81
Greece	21293,62	72,28	6,51
Spain	91379,47	43,44	8,13
France	126633,01	43,75	8,95
Croatia	12511,57	38,05	3,39
Italy	137708,79	53,5	7,18
Cyprus	646,00	43,95	4,25
Latvia	4675,12	44,14	3,10
Lithuania	7520,74	34,58	2,84
Luxembourg	896,82	45,81	2,70
Hungary	38256,04	27,96	5,43
Malta	461,62	43,52	3,62
Netherlands	20779,67	63,89	8,88
Austria	16683,98	44,16	5,84
Poland	92146,08	44,44	11,57
Portugal	18987,51	48,15	3,14
Romania	57347,30	56,48	5,32
Slovenia	6088,64	54,02	6,23
Slovakia	16093,58	56,34	5,97
Finland	1702,86	30,58	6,95
Sweden	15097,62	41,43	5,32

Appendix F: Maritime network visualisation output 2018/2021



Source: own creation, composed in R

(Yu & Ma, 2020)

Appendix G: Equations of in and out-degree centrality

$$k_h^{\text{in}}(t) = \sum_{j=1}^{N(t)} c_{jh}(t)$$

$$k_h^{\text{out}}(t) = \sum_{j=1}^{N(t)} c_{hj}(t)$$

K(h)in(t) represent in-degree and K(h)out(t) represent out-degree, (t) in year t
N(t) indicates the total number of countries in the inter-European trade network
Chj(t) indicates the exporting data of country h to country j in year t
Cjh(t) indicates the exporting country of country j to country h in year t

(Yu & Ma, 2020)

Appendix H: Equation of closeness centrality

Closeness centrality, c(i), of node I can be written as followed:
Dij is the number of links in a shortest path from node I to node j

$$c(i) = \sum_i d_{ij}$$

(Bonacich, 1972)

Appendix I: Equation of eigenvector centrality

$$\lambda \boldsymbol{c}(\upsilon_i) = \sum_{j=1}^{n} \alpha_{ij} \boldsymbol{c}(\upsilon_j) \quad \forall i.$$

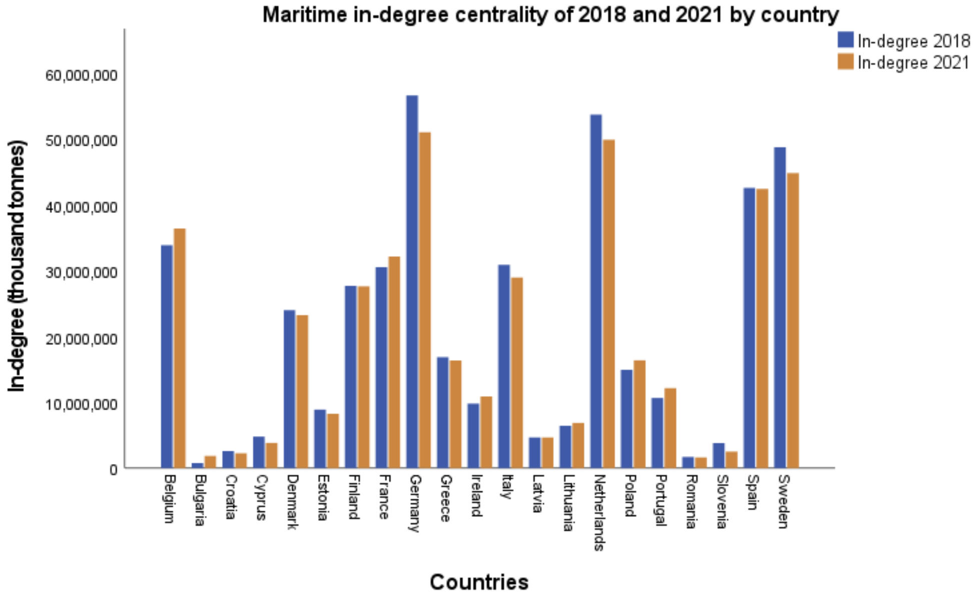
Eigenvector centrality C(Vi) of a node Vi as the multiple sum of adjacent centralities

Appendix J: Inter-European maritime in andout-degree centrality of 2018 and 2021 compared

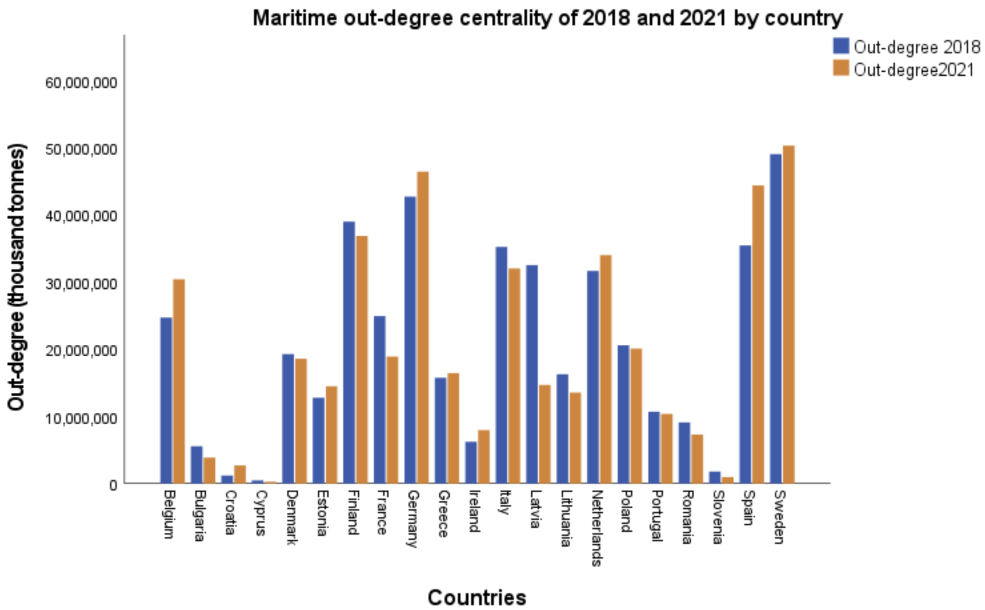
Countries	In-degree 2018	In-degree 2021	Difference	Countries	Out-degree 2018	Out-degree2021	Difference
Belgium	33833000	36358000	2525000	Belgium	24657000	30342000	5685000
Bulgaria	759000	1848000	1089000	Bulgaria	5529000	3860000	-1669000
Denmark	23961000	23221000	-740000	Denmark	19235000	18531000	-704000
Germany	56538000	50957000	-5581000	Germany	42622000	46344000	3722000
Estonia	8885000	8260000	-625000	Estonia	12744000	14442000	1698000
Ireland	9790000	10889000	1099000	Ireland	6200000	7938000	1738000
Greece	16844000	16344000	-500000	Greece	15715000	16413000	698000
Spain	42517000	42373000	-144000	Spain	35372000	44287000	8915000
France	30496000	32094000	1598000	France	24875000	18870000	-6005000
Croatia	2595000	2251000	-344000	Croatia	1170000	2686000	1516000
Italy	30838000	28910000	-1928000	Italy	35153000	31958000	-3195000
Cyprus	4784000	3836000	-948000	Cyprus	471000	260000	-211000
Latvia	4655000	4649000	-6000	Latvia	32453000	14653000	-17800000
Lithuania	6438000	6871000	433000	Lithuania	16242000	13510000	-2732000
Netherlands	53634000	49833000	-3801000	Netherlands	31599000	33948000	2349000
Poland	14911000	16362000	1451000	Poland	20544000	20047000	-497000
Portugal	10645000	12133000	1488000	Portugal	10673000	10342000	-331000
Romania	1708000	1638000	-70000	Romania	9081000	7269000	-1812000
Slovenia	3808000	2501000	-1307000	Slovenia	1768000	956000	-812000
Finland	27657000	27570000	-87000	Finland	38927000	36795000	-2132000
Sweden	48688000	44766000	-3922000	Sweden	48954000	50213000	1259000
Tonnes			-10.320.000				- 10.320.000

Source: own creation, composed from Network Analysis metrics R

Appendix K: clustered bar chart maritime in-degree centrality 2018/2021



Appendix L: Appendix K: clustered bar chart maritme out-degree centrality 2018/2021



Appendix M: Inter-European maritime total degree centrality of 2018/2021 compared

Countries	Total degree 2018	Total degree 2021	Difference
Belgium	58490000	66700000	8210000
Bulgaria	6288000	5708000	-580000
Denmark	43196000	41752000	-1444000
Germany	99160000	97301000	-1859000
Estonia	2162900	22702000	20539100
Ireland	15990000	18827000	2837000
Greece	32559000	32757000	198000
Spain	77889000	86660000	8771000
France	55371000	50964000	-4407000
Croatia	3765000	4937000	1172000
Italy	65991000	60868000	-5123000
Cyprus	5255000	4096000	-1159000
Latvia	37108000	19302000	-17806000
Lithuania	22680000	20381000	-2299000
Netherlands	85233000	83781000	-1452000
Poland	35455000	36409000	954000
Portugal	21318000	22475000	1157000
Romania	10789000	8907000	-1882000
Slovenia	5576000	3457000	-2119000
Finland	66584000	64365000	-2219000
Sweden	97642000	94979000	-2663000
Tonnes			-20.640.000

Source: own creation, composed from Network Analysis metrics R

Appendix N: Inter-European maritime closeness centrality metrics of 2018/2021 compared

Countries	Closeness centrality 2018	Closeness centrality 2021	Difference
Belgium	0.000001745201	0.00000067659	
Bulgaria	0.000006622517	0.000001183432	
Denmark	0.000003597122	0.000001017294	
Germany	0.000002949853	0.000001492537	
Estonia	0.000002617801	0.000001408451	
Ireland	0.000007751938	0.000005235602	
Greece	0.000002114165	0.000001883239	
Spain	0.0000009852217	0.0000008116883	
France	0.000003875969	0.000002506266	
Croatia	0.000002777778	0.000003115265	
Italy	0.000004184100	0.000002155172	
Cyprus	0.000007751938	0.000008	
Latvia	0.000001369863	0.000001733102	
Lithuania	0.000001689189	0.000001414427	
Netherlands	0.000002283105	0.000002415459	
Poland	0.000001150748	0.0000007374631	
Portugal	0.000004524887	0.000004524887	
Romania	0.000001845018	0.00000137931	
Slovenia	0.000003690037	0.000002673797	
Finland	0.000005208333	0.000001430615	
Sweden	0.000007142857	0.000002132196	

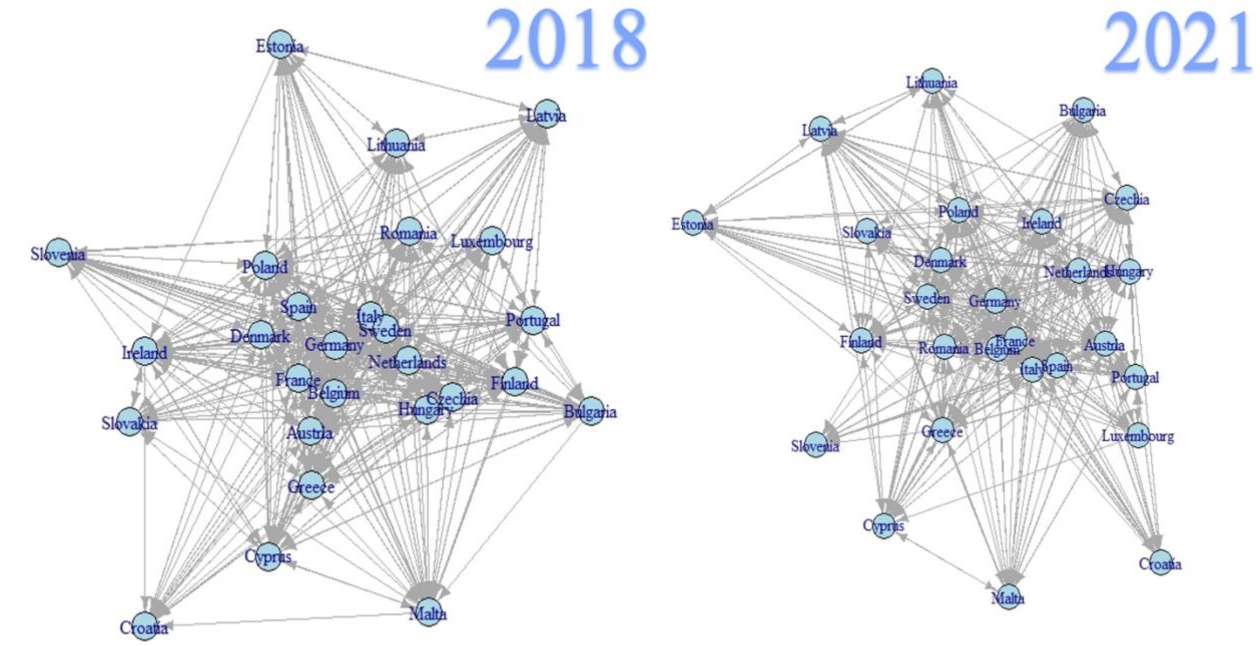
Source: own creation, composed from Network Analysis metrics R

Appendix O: Inter-European maritime eigenvector centrality of 2018/2021 compared.

Countries	Eigenvector centrality 2018	Eigenvector centrality 2021	Difference
Belgium	0.59269	0.72035	
Bulgaria	0.00897	0.02600	
Denmark	0.52803	0.53697	
Germany	1	1	
Estonia	0.14800	0.16644	
Ireland	0.18625	0.24522	
Greece	0.21442	0.35899	
Spain	0.58327	0.69297	
France	0.48439	0.62607	
Croatia	0.03027	0.03165	
Italy	0.37107	0.46878	
Cyprus	0.05122	0.04368	
Latvia	0.09536	0.10140	
Lithuania	0.12956	0.16177	
Netherlands	0.74094	0.84798	
Poland	0.30730	0.37397	
Portugal	0.19829	0.25307	
Romania	0.01853	0.02112	
Slovenia	0.03933	0.02972	
Finland	0.57568	0.61496	
Sweden	0.88250	0.91399	

Source: own creation, composed from Network Analysis metrics R

Appendix P: Aviation network visualisation output 2018/2021



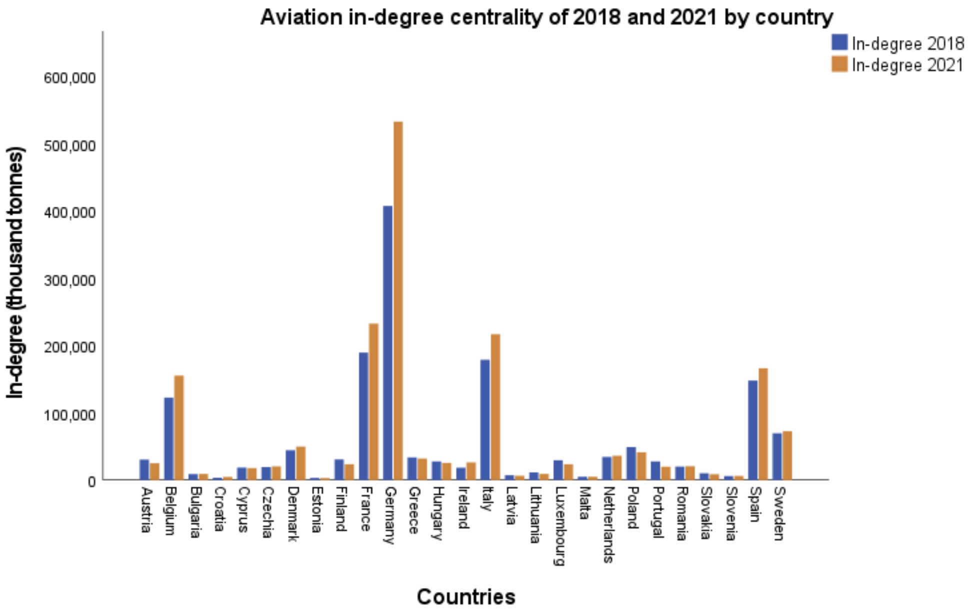
Source: own creation, composed in R

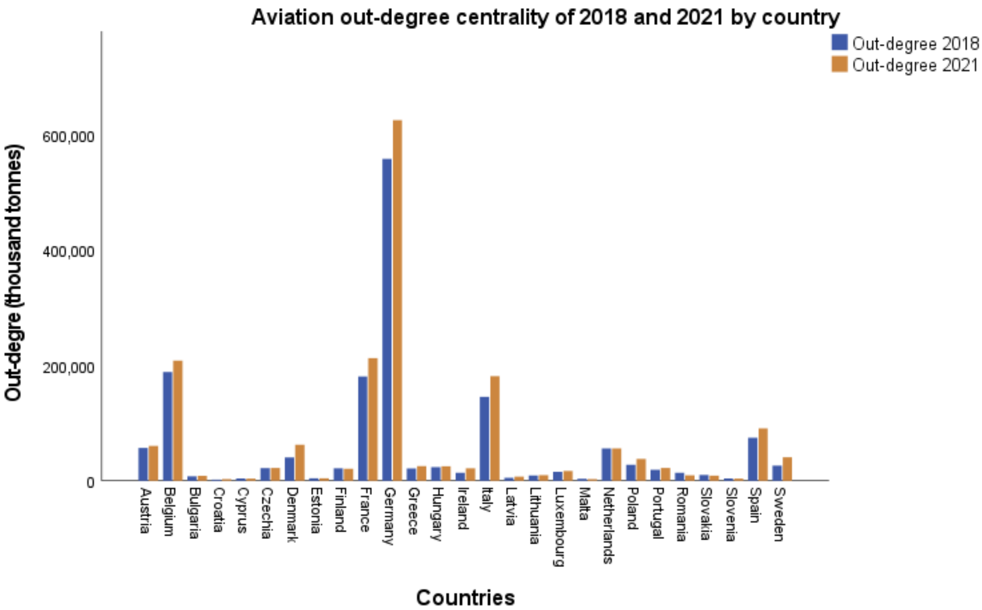
Appendix Q: Inter-European aviation in and out-degree centrality of 2018/2021 compared

Countries	In-degree 2018	In-degree 2021	Difference	Countries	Out-degree 2018	Out-degree 2021	Difference
Belgium	122400.6	155007.3		Belgium	188233.0	207766.0	
Bulgaria	8759.7	9083.4		Bulgaria	7697.7	8425.1	
Czechia	19312.7	20298.2		Czechia	21722.9	22153.4	
Denmark	44094.6	49649.1		Denmark	40444.0	62189.0	
Germany	407197.3	532261.2		Germany	556937.0	624123.1	
Estonia	3080.7	2924.6		Estonia	4333.2	4280.2	
Ireland	18145.7	26163.9		Ireland	13773.2	21565.3	
Greece	33679.3	31843.0		Greece	21209.5	25350.5	
Spain	147794.0	165928.0		Spain	74464.4	90431.7	
France	189338.1	232388.1		France	180334.1	212108.3	
Croatia	3406.0	4515.1		Croatia	1941.0	2839.0	
Italy	178561.1	216392.8		Italy	145202.0	180983.0	
Cyprus	18519.5	17677.0		Cyprus	3941.5	3592.1	
Latvia	7022.4	6244.8		Latvia	5127.3	7090.2	
Lithuania	11253.0	9126.2		Lithuania	9241.6	9585.0	
Luxembourg	29250.5	23530.5		Luxembourg	15371.0	16903.0	
Hungary	27624.3	25458.3		Hungary	23647.0	25049.1	
Malta	4794.5	4784.2		Malta	3319.2	2887.6	
Netherlands	34284.5	36049.1		Netherlands	55999.4	55784.4	
Austria	30436.6	24857.4		Austria	56704.9	60212.2	
Poland	48807.2	41254.0		Poland	27554.7	37806.4	
Portugal	27539.8	19819.5		Portugal	19077.0	22105.6	
Romania	20070.8	20466.7		Romania	13730.0	9299.0	
Slovenia	5792.3	5992.4		Slovenia	3793.3	3647.4	
Slovakia	10108.5	8437.9		Slovakia	9882.2	8703.4	
Finland	30550.0	23435.7		Finland	21532.8	20605.7	
Sweden	69481.6	72461.5		Sweden	26091.4	40565.1	
Tonnes			+234745,50				+234744,60

Source: own creation, composed from Network Analysis metrics R

Appendix R: clustered bar chart maritime in and out-degree centrality 2018/2021





Appendix S: Inter-European aviation total degree centrality 2018/2021 compared

Countries	Total degree 2018	Total degree 2021	Difference
Belgium	310633,60	362773,30	
Bulgaria	16457,40	17508,50	
Czechia	41035,60	42451,60	
Denmark	84538,60	111838,10	
Germany	964134,30	1156384,30	
Estonia	7413,90	7204,80	
Ireland	31918,90	47729,20	
Greece	54888,80	57193,50	
Spain	222258,40	256359,70	
France	369672,20	444496,40	
Croatia	5347,00	7354,10	
Italy	323763,10	397375,80	
Cyprus	22461,00	21269,10	
Latvia	12149,70	13335,00	
Lithuania	20494,60	18711,20	
Luxembourg	44621,50	40433,50	
Hungary	51271,30	50507,40	
Malta	8113,70	7671,80	
Netherlands	90283,90	91833,50	
Austria	87141,50	85069,60	
Poland	76361,90	79060,40	
Portugal	46616,80	41925,10	
Romania	33800,80	29765,70	
Slovenia	9585,60	9639,80	
Slovakia	19990,70	17141,30	
Finland	52082,80	44041,40	
Sweden	95573,00	113026,60	
Tonnes			+469490,10

Appendix T: Inter-European aviation out-degree of 2018/2021 compared

Countries	Out-degree 2018	Out-degree 2021	Difference
Belgium	188233.0	207766.0	
Bulgaria	7697.7	8425.1	
Czechia	21722.9	22153.4	
Denmark	40444.0	62189.0	
Germany	556937.0	624123.1	
Estonia	4333.2	4280.2	
Ireland	13773.2	21565.3	
Greece	21209.5	25350.5	
Spain	74464.4	90431.7	
France	180334.1	212108.3	
Croatia	1941.0	2839.0	
Italy	145202.0	180983.0	
Cyprus	3941.5	3592.1	
Latvia	5127.3	7090.2	
Lithuania	9241.6	9585.0	
Luxembourg	15371.0	16903.0	
Hungary	23647.0	25049.1	
Malta	3319.2	2887.6	
Netherlands	55999.4	55784.4	
Austria	56704.9	60212.2	
Poland	27554.7	37806.4	
Portugal	19077.0	22105.6	
Romania	13730.0	9299.0	
Slovenia	3793.3	3647.4	
Slovakia	9882.2	8703.4	
Finland	21532.8	20605.7	
Sweden	26091.4	40565.1	

Source: own creation, composed from Network Analysis metrics R

Appendix U: Inter-European aviation closeness centrality metrics of 2018/ 2021 compared

Countries	**Closeness centrality 2018**	**Closeness centrality 2021**	**Difference**
Belgium	0.00181	0.00171	
Bulgaria	0.00921	0.01088	
Czechia	0.00210	0.01236	
Denmark	0.00590	0.01059	
Germany	0.00015	0.00009	
Estonia	0.00760	0.01222	
Ireland	0.00813	0.01582	
Greece	0.00468	0.00567	
Spain	0.00758	0.00660	
France	0.00427	0.00881	
Croatia	0.00174	0.01207	
Italy	0.00502	0.00591	
Cyprus	0.00608	0.01083	
Latvia	0.00439	0.00532	
Lithuania	0.00747	0.01080	
Luxembourg	0.00968	0.00875	
Hungary	0.00607	0.00851	
Malta	0.00677	0.01318	
Netherlands	0.00319	0.00539	
Austria	0.00615	0.00374	
Poland	0.00373	0.01370	
Portugal	0.00424	0.00971	
Romania	0.00468	0.00288	
Slovenia	0.00794	0.00564	
Slovakia	0.00547	0.01088	
Finland	0.00496	0.00155	
Sweden	0.00900	0.01186	

Source: own creation, composed from Network Analysis metrics R

Appendix V: Inter-European aviation eigenvector centrality metrics of 2018/2021 compared

Countries	Eigenvector centrality 2018	**Eigen vector centrality 2021**	**Difference**
Belgium	0.40317	0.43961	
Bulgaria	0.03787	0.03808	
Czechia	0.06633	0.06269	
Denmark	0.17130	0.15250	
Germany	1.00000	1.00000	
Estonia	0.00489	0.00366	
Ireland	0.07556	0.09935	
Greece	0.14201	0.10208	
Spain	0.59616	0.52304	
France	0.79169	0.76090	
Croatia	0.01113	0.01476	
Italy	0.65077	0.64360	
Cyprus	0.02868	0.02255	
Latvia	0.01137	0.00787	
Lithuania	0.03666	0.02879	
Luxembourg	0.08168	0.04580	
Hungary	0.09049	0.07332	
Malta	0.02085	0.01690	
Netherlands	0.15367	0.13228	
Austria	0.12600	0.08578	
Poland	0.20967	0.15128	
Portugal	0.10673	0.06104	
Romania	0.05839	0.05520	
Slovenia	0.02836	0.02387	
Slovakia	0.05426	0.03737	
Finland	0.10003	0.06538	
Sweden	0.23283	0.19060	

Source: own creation, composed from Network Analysis metrics R

Appendix W: Correlation output maritime trade 2021

Correlations

Variable	Variable2	Statistic Correlation	Count	Lower C.I.	Upper C.I.	Notes
Export2021	Coviddeaths1	.121	331	.013	.226	
	Coviddeaths2	.154	331	.047	.257	
	Covidstringency1	-.059	331	-.166	.049	
	Covidstrigency2	-.015	331	-.123	.093	
	Chinadep1	.136	331	.029	.240	
	Chinadep2	.194	331	.088	.296	
	gdp1	.181	331	.075	.283	
	gdp2	.254	331	.151	.352	
	distance	-.093	331	-.199	.015	
	Pop_size1	.162	331	.055	.265	
	Pop_size2	.217	331	.112	.317	

Missing value handling: PAIRWISE, EXCLUDE. C.I. Level: 95.0

Source: own creation, composed in spss

Appendix X: Correlation output aviation trade 2021

Correlations

Variable	Variable2	Statistic Correlation	Count	Lower C.I.	Upper C.I.	Notes
Export2021	Coviddeaths1	.283	510	.201	.361	
	Coviddeaths2	.288	510	.206	.366	
	Covidstringency1	-.031	510	-.118	.056	
	Covidstrigency2	-.016	510	-.103	.071	
	Chinadep1	.118	510	.031	.203	
	Chinadep2	.111	510	.024	.196	
	gdp1	.399	510	.324	.470	
	gdp2	.368	510	.290	.441	
	Pop_size2	.341	510	.262	.415	

Missing value handling: PAIRWISE, EXCLUDE. C.I. Level: 95.0

Source: own creation, composed in spss

Appendix Y: R output maritime trade excl. control variables

```
Call:
lm(formula = Maritime_trade ~ gdp1 + gdp2 + distance + Deaths_export +
    Deaths_import + Covidstringency1 + Covidstrigency2 + Chinadep1 +
    Chinadep2, data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-5.6946 -1.2337  0.3526  1.3892  3.2565

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)       1.35735    3.18593   0.426   0.6704
gdp1              0.60926    0.14075   4.329 2.01e-05 ***
gdp2              1.19164    0.14263   8.355 2.00e-15 ***
distance         -1.03846    0.16385  -6.338 7.88e-10 ***
Deaths_export     0.03527    0.12361   0.285   0.7756
Deaths_import    -0.56744    0.12238  -4.637 5.16e-06 ***
Covidstringency1 -0.39930    0.55833  -0.715   0.4750
Covidstrigency2   1.28047    0.56973   2.247   0.0253 *
Chinadep1        -0.49990    0.29504  -1.694   0.0912 .
Chinadep2        -0.78194    0.30419  -2.571   0.0106 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.832 on 321 degrees of freedom
Multiple R-squared:  0.3236,    Adjusted R-squared:  0.3046
F-statistic: 17.06 on 9 and 321 DF,  p-value: < 2.2e-16
```

Source: composed from R

Appendix Z: R output Maritime trade incl. control variables

```
Call:
lm(formula = Maritime_trade ~ gdp1 + gdp2 + distance + Deaths_export +
    Deaths_import + Covidstringency1 + Covidstrigency2 + Chinadep1 +
    Chinadep2 + Pop_size1 + Pop_size2 + ExchangeR1 + ExchangeR2,
    data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-5.4214 -1.2663  0.2718  1.4395  3.1989

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      -1.09645    5.97625  -0.183 0.854549
gdp1              0.53042    0.28002   1.894 0.059108 .
gdp2              0.96207    0.26878   3.579 0.000398 ***
distance         -1.08270    0.16617  -6.516 2.84e-10 ***
Deaths_export    -0.03342    0.27974  -0.119 0.904982
Deaths_import    -0.70232    0.28064  -2.503 0.012833 *
Covidstringency1 -0.38021    0.56976  -0.667 0.505061
Covidstrigency2   1.10092    0.58478   1.883 0.060667 .
Chinadep1        -0.52496    0.33295  -1.577 0.115862
Chinadep2        -0.77033    0.34621  -2.225 0.026782 *
Pop_size1         0.17039    0.55865   0.305 0.760558
Pop_size2         0.41311    0.54653   0.756 0.450282
ExchangeR1yes    -0.13026    0.26139  -0.498 0.618597
ExchangeR2yes    -0.52845    0.25609  -2.064 0.039877 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.83 on 317 degrees of freedom
Multiple R-squared:  0.3336,    Adjusted R-squared:  0.3062
F-statistic: 12.21 on 13 and 317 DF,  p-value: < 2.2e-16
```

Source: composed from R

Appendix AA: Gravity model of maritime trade (model 1 and model 2)

Trade mode (maritime) / variables	Model 1		Model 2	
Coefficients	Estimate	P-value	Estimate	P-value
GDP origin country	0.609	2.01e-05 ***	0.5304	0.0591
GDP destination country	1.192	2.00e-05 ***	0.9620	0.0004 ***
Distance	-1.038	7.88e-10 ***	-1.0827	2.84e-10 ***
Covid-19 deaths origin country	0.0353	0.7756	-0.0334	0.9050
Covid-19 deaths destination country	-0.5674	5.16e-06 ***	-0.7023	0.0128 *
Covid-19 stringency index origin country	-0.3993	0.4750	-0.3802	0.5051
Covid-19 stringency index destination country	1.2805	0.0253 *	1.1010	0.0607
China Dependency ratio origin country	-0.4999	0.0912	-0.5250	0.1159
China Dependency ratio destination country	-0.7819	0.0106 *	-0.7703	0.0268 *
Population size origin country | control			0.1704	0.7610
Population size destination country | control			0.4131	0.4503
Exchange rate origin country (Y/N) | control			-0.1302	0.6186
Exchange rate origin country (Y/N) | control			-0.5285	0.0399 *

*Significancy codes: '***' 0.001, '**' 0.01, '*' 0.05*

Appendix BB: R output Aviation trade incl. control variables

```
Call:
lm(formula = Aviation_trade ~ gdp1 + gdp2 + distance + Deaths_export +
    Deaths_import + Covidstringency1 + Covidstrigency2 + Chinadep1 +
    Chinadep2, data = df)

Residuals:
   Min     1Q Median     3Q    Max
-7.767 -1.370  0.238  1.581  7.500

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)     -14.150245   2.968234  -4.767 2.45e-06 ***
gdp1              1.282978   0.125905  10.190  < 2e-16 ***
gdp2              1.424085   0.125331  11.363  < 2e-16 ***
distance         -1.177912   0.172398  -6.833 2.43e-11 ***
Deaths_export     0.004127   0.106923   0.039   0.9692
Deaths_import    -0.216157   0.106310  -2.033   0.0426 *
Covidstringency1 -0.635903   0.507277  -1.254   0.2106
Covidstrigency2   0.624423   0.509726   1.225   0.2211
Chinadep1        -1.215867   0.267456  -4.546 6.86e-06 ***
Chinadep2        -1.331467   0.270782  -4.917 1.19e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.306 on 500 degrees of freedom
Multiple R-squared:  0.451,     Adjusted R-squared:  0.4412
F-statistic: 45.64 on 9 and 500 DF,  p-value: < 2.2e-16
```

Appendix CC: R output Aviation trade incl. control variables

```
Call:
lm(formula = Aviation_trade ~ gdp1 + gdp2 + distance + Deaths_export +
    Deaths_import + Covidstringency1 + Covidstrigency2 + Chinadep1 +
    Chinadep2 + Pop_size1 + Pop_size2 + ExchangeR1 + ExchangeR2,
    data = df)

Residuals:
    Min      1Q  Median      3Q     Max
-7.6750 -1.3228  0.2178  1.4110  7.0790

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      -17.9265     4.6635  -3.844 0.000137 ***
gdp1               0.6851     0.1822   3.760 0.000190 ***
gdp2               1.1885     0.1830   6.494 2.04e-10 ***
distance          -1.2119     0.1693  -7.156 3.00e-12 ***
Deaths_export     -0.3914     0.1922  -2.036 0.042270 *
Deaths_import     -0.1442     0.1841  -0.784 0.433675
Covidstringency1  -0.8943     0.5496  -1.627 0.104355
Covidstrigency2    0.1499     0.5532   0.271 0.786542
Chinadep1         -1.3215     0.3112  -4.247 2.59e-05 ***
Chinadep2         -1.0553     0.3148  -3.352 0.000863 ***
Pop_size1          1.1262     0.3254   3.461 0.000584 ***
Pop_size2          0.1471     0.3161   0.465 0.641824
ExchangeR1yes     -0.5449     0.2838  -1.920 0.055454 .
ExchangeR2yes     -0.7825     0.2800  -2.795 0.005393 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.25 on 496 degrees of freedom
Multiple R-squared:  0.4815,	Adjusted R-squared:  0.4679
F-statistic: 35.43 on 13 and 496 DF,  p-value: < 2.2e-16
```

Appendix DD: Gravity model of Aviation trade (model 1 and model 2)

Trade mode (aviation) / variables	Model 3		Model 4	
Coefficients	Estimate	P-value	Estimate	P-value
GDP origin country	1.2830	<2e-16 ***	0.6851	0.0002 ***
GDP destination country	1.4241	<2e-16 ***	1.1885	2.04e-10 ***
Distance	-1.1779	2.43e-11	-1.2119	3.00e-12 ***
Covid-19 deaths origin country	0.004	0.9692	-0.3914	0.0423 *
Covid-19 deaths destination country	-0.2162	0.0426 *	-0.1442	0.4337
Covid-19 stringency index origin country	-0.6359	0.2106	-0.8943	0.1044
Covid-19 stringency index destination country	0.624423	0.2211	0.1499	0.7865
China Dependency ratio origin country	-1.2159	6.86e-06 ***	-1.3215	2.59e-05 ***
China Dependency ratio destination country	-1.3315	1.19e-06 ***	-1.0553	0.0009 ***
Population size origin country | control			1.1262	0.0006 ***
Population size destination country | control			0.1471	0.6418
Exchange rate origin country (Y/N) | control			-0.5449	0.0555
Exchange rate origin country (Y/N) | control			-0.7825	0.0005 *

*Significancy codes: '***' 0.001, '**' 0.01, '*' 0.05*