

Erasmus University Rotterdam

Erasmus School of Economics

Master Thesis Economics and Business

Examining the Effects of Rail, Road, and Inland Waterway
Infrastructure Investments on Port Container Throughput:
Evidence from Sea Bordering EU Countries

Name: Rianto Speelpenning
Student number: 563496
Master Specialization: Strategy Economics
Supervisor: prof. dr. F.G. Van Oort
Second assessor: M.A. Streng MSc
Date: 26-07-2024

The views stated in this thesis are those of the author and not necessarily those of the supervisor, second assessor, Erasmus School of Economics or Erasmus University Rotterdam.

Abstract

In this paper, the effects of rail, road, and inland waterway infrastructure investments on port container throughput are investigated in sea bordering European Union (EU) countries.

By estimating Fixed Effects and Random Effects models for different lags, it is concluded that rail infrastructure investments have a negative and significant effect on port container throughput after one year (Hypothesis 1). On the other hand, the effect of road infrastructure investments on port container throughput is positive and insignificant after two years (Hypothesis 2). The effect of inland waterway infrastructure investments on port container throughput is positive and significant after two years (Hypothesis 3). Additionally, it is concluded that inland waterway container transport does not have a statistically significant influence on the effects of rail and road infrastructure investments on port container throughput (Hypothesis 4).

The three conducted robustness checks indicate that the findings corresponding to the first, second and fourth hypothesis are not robust. Consequently, the obtained results of these hypotheses are not generalizable.

Therefore, we conclude that only inland waterway infrastructure investments have a positive and significant effect on port container throughput. However, the estimated effects are not causal because the estimated models suffer from omitted variable bias. Therefore, policy makers should be cautious with interpreting the estimated effects.

Despite the fact that the estimated effects are not causal, this research enriches our understanding of the effects of different types of inland infrastructure investments on port container throughput.

Keywords: rail infrastructure investments, road infrastructure investments, inland waterway infrastructure investments, connectivity, accessibility, port competitiveness, port container throughput.

Table of Contents

1. Introduction	5
1.1 Problem Definition	6
1.2 Main Research Question	6
1.3 Previous Research	7
1.4 Contributions to Previous Research	7
1.5 Relevance	8
1.6 Research approach	8
2. Literature Review	9
2.1 Infrastructure Investments	9
2.2 Direct Effect	10
2.2.1 Methodology Fachouridis	10
2.2.2 Results Fachouridis	11
2.3 Indirect Effect	12
2.4 Determinants Port Container Throughput	12
2.4.1 Macroeconomic Variables	13
2.4.2 Port Characteristics.....	14
2.5 Hypotheses	16
2.5.1 Hypothesis 1	16
2.5.2 Hypothesis 2	17
2.5.3 Hypothesis 3	17
2.5.4 Hypothesis 4	18
3. Methodology	19
3.1 Model Choice	20
3.1.1 Pooled OLS, Fixed Effects and Random Effects.....	20
3.1.2 Hausman Test	21
3.2 Lags	21
3.3 Main Analysis	22
3.3.1 Hypothesis 1	22
3.3.2 Hypothesis 2	22
3.3.3 Hypothesis 3	22
3.3.4 Hypothesis 4	23
3.4 Robustness Checks	23
3.5 Remarks Methodology	24
3.6 Comparison Methodology Fachouridis	24
4. Data	25
4.1 Data Background	25

4.2 Variables.....	26
4.3 Measurement Variables.....	29
4.4 Im-Pesaran-Shin Test.....	30
4.5 Correlation Tables	30
4.6 Variance Inflation Factor Scores.....	32
4.7 Robustness Checks	32
5. Results	33
5.1 Hypothesis 1 – Rail Infrastructure Investments.....	33
5.2 Hypothesis 2 – Road Infrastructure Investments.....	34
5.3 Hypothesis 3 – Inland Waterway Infrastructure Investments	35
5.4 Hypothesis 4 – Influence of Inland Waterway Container Transport.....	37
5.4.1 Rail Infrastructure Investments	37
5.4.2 Road Infrastructure Investments.....	37
5.5 Discussion Results.....	38
6. Robustness Checks	41
6.1 Robustness Check 1.....	41
6.2 Robustness Check 2.....	41
6.3 Robustness Check 3.....	42
6.4 Discussion Robustness Checks	43
7. Discussion.....	44
8. Conclusion.....	45
References	46
Appendices	53
Appendix A: Modal Split TEU European ports	53
Appendix B: Figures Port Container Throughput	54
Appendix C: Figures Rail Infrastructure Investments	57
Appendix D: Figures Road Infrastructure Investments	60
Appendix E: Figures Inland Waterway Infrastructure Investments.....	63
Appendix F: Variance Inflation Factor Scores	64
Appendix G: Models Rail Infrastructure Investments	66
Appendix H: Models Road Infrastructure Investments	72
Appendix I: Models IWW Infrastructure Investments	78
Appendix J: Hausman Tests	84
Appendix K: Robustness Checks	86

1. Introduction

Ports are vital nodes in the global transport network (Notteboom et al, 2020). In 2021, ninety percent of the world's goods were transported by sea, of which sixty percent was transported in standardized containers (Nagurney, 2021). Ports are required to transfer the standardized containers from the vessels to the mainland, and vice versa. Therefore, standardized containers and seaports play a crucial role in facilitating the trade of goods between countries and regions.

A diverse set of activities takes place in ports, from cargo handling and transshipment to storage and warehousing. For example, container terminals are specialized in loading and unloading container vessels. This indicates the crucial role (container) ports play in the global supply chain (Song & Panayides, 2008). The performance of ports is currently most often measured in terms of throughput volumes (Langen et al, 2006). Consequently, ports are ranked based on throughput volumes (Du, 2015). Throughput volumes are measured in tonnages, or in the quantity of handled containers (Talley, 2006).

Standardized containers were introduced in 1956 by Malcolm McLean, to make transportation and storage of goods more efficient (Nagurney, 2021). Therefore, standardized containers make the process of changing mode of transport less time consuming. Additionally, containers prevent damage to the products inside these large metal boxes. A diverse set of products is transported in containers, from fruit to televisions. Nowadays, the standardized container is twenty feet long, which is known as a Twenty feet Equivalent Unit (TEU).

Infrastructure is necessary to transport cargo from the port to the destination. For example, a container full of televisions is transported by truck from the port of Rotterdam to a distribution center in Noord-Brabant. Therefore, infrastructure links connect the port to the hinterland areas (Grossman et al, 2006).

The infrastructure networks in Europe have developed over time. Road infrastructure developed significantly since the mid-1990s, and railway infrastructure has grown (European Commission, 2014). For example, the road transport network in the Netherlands increased by 646 kilometers between 2000 and 2021, which reflects a thirteen percent increase (CLO, 2022). Moreover, the length of railways in the Netherlands increased by 8.2 percent from 2810 kilometer in 2005 to 3041 kilometer in 2021 (CBS, 2023). In conclusion, rail and road infrastructure networks developed significantly in the Netherlands.

To create a seamless transport system across European borders, the EU's trans-European transport network (TEN-T) policy focusses on an improved infrastructure network (European Commission, 2024). This concerns roads, railways, inland waterways and short sea shipping routes. This is done with the intent of improving the links between nodes. For example, linkages between maritime ports and inland ports are improved.

1.1 Problem Definition

The interaction between seaports and the hinterland plays an increasingly important role in the global supply chain (Notteboom, 2008). Constructing new infrastructure and improving current infrastructure integrates seaports and the hinterland further. As a result, the connection to the hinterland improves, which has a significant effect on the port's competitiveness and attractiveness (Makhecha, 2016). Container throughput is the most crucial factor to evaluate the competitive strength of a port (Liu & Park, 2011). Therefore, the port's connection to the hinterland has a significant effect on port container throughput. Additionally, the construction and maintenance of transportation routes improves the existing infrastructure network and is therefore a determinant of transportation costs.

However, capital intensive investments are required to construct new infrastructure and improve the existing infrastructure networks. Therefore, infrastructure investments are a determinant of performance in the transport sector (OECD, 2024).

In short, infrastructure investments improve the port's connectivity and accessibility, which has a significant effect on port container throughput.

1.2 Main Research Question

Therefore, it is interesting to investigate to what extent different types of inland infrastructure investments influence port container throughput in sea bordering European Union (EU) countries. Consequently, the main research question is formulated as follows:

What are the effects of rail, road, and inland waterway infrastructure investments on port container throughput in sea bordering European Union countries?

Therefore, the effects of rail infrastructure investments, road infrastructure investments, and inland waterway (IWW) infrastructure investments on port container throughput are investigated. Additionally, it is investigated whether the effects of rail and road infrastructure investments on port container throughput are influenced by inland waterway container transport. Because of the available data, the years 2007 until 2018 are covered in this research.

The effect of rail infrastructure investments on port container throughput is investigated in the following seventeen countries: Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Poland, the Netherlands, Romania, Slovenia, Spain and Sweden. This sample is also used to investigate the effect of road infrastructure investments on port container throughput.

Containers are in Belgium, France, Germany, the Netherlands and Romania also transported via inland waterways to the hinterland and to inland ports, next to rail and road transport (Pastori, 2015). Therefore, the effect of inland waterway infrastructure investments on port container throughput is investigated in these five countries.

1.3 Previous Research

Despite the fact that inland infrastructure investments and port container throughput are related, there has hardly been done any quantitative research on this topic. To the best of my knowledge, only Fachouridis (2018) investigated the direct effect of inland infrastructure investments on port container throughput. The Hamburg-Le Havre range (Belgium, France, Germany and the Netherlands) and Mediterranean range (Croatia, Greece, Italy, Portugal, Slovenia and Spain) are included in his research. Fachouridis included the following types of inland infrastructure investments: road transport, rail transport, maritime port and air transport. Moreover, the effect of transport equipment investments on port container throughput is investigated. His research covers the years 1987 until 2015.

It is important to mention that inland waterway infrastructure investments are not included in this research, because Fachouridis stated that inland waterways are only present in the Hamburg-Le Havre range. Consequently, he stated that comparing the two regions would be unequal.

The methodology and obtained results of his research are included in the Literature Review section.

1.4 Contributions to Previous Research

This research contributes to previous research in several ways.

First, this research provides insights into the effect of inland waterway infrastructure investments on port container throughput. There is a gap in the existing literature, because researchers have not investigated whether inland waterway infrastructure investments influence port container throughput. While the presence of inland waterways allows transportation of containers from seaports to the hinterland and to inland ports via inland waterways, inland waterway infrastructure investments are ignored in Fachouridis' research. Therefore, it is interesting to investigate the effect of inland waterway infrastructure investments on port container throughput.

Second, this research provides insights into whether inland waterway container transport influences the effects of rail and road infrastructure investments on port container throughput. This research will therefore contribute to existing literature by including interaction terms to investigate whether the effects of rail and road infrastructure investments on port container throughput are influenced by the transportation of containers via inland waterways.

Third, this research provides more precise estimates of the effects of rail and road infrastructure investments on port container throughput by controlling for additional variables which influence port container throughput. Therefore, this research advances previous research of Fachouridis by including control variables in the estimated models.

Fourth, the effects of rail and road infrastructure investments on port container throughput are investigated for a different sample compared to Fachouridis' research. The following countries are

included in this research while they were not included in Fachouridis' research: Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Romania and Sweden. However, Fachouridis included Portugal in the sample while this country is not included in this research because of missing data after 2013.

Lastly, this research covers the years 2007 until 2018, while Fachouridis covers the years 1987 until 2015 in his research. Since the development of the variables changed after 2015, it is relevant from an academic point of view to provide more recent insights into the effect of inland infrastructure investments on port container throughput. This is also relevant from a managerial perspective, because policy makers could formulate more efficient strategies.

1.5 Relevance

This research is relevant from an academic and managerial point of view.

First, this research is relevant from an academic perspective because of the contributions to previous research. Therefore, this research provides new and hopefully valuable insights into the influence of rail, road, and inland waterway infrastructure investments on port container throughput. Furthermore, it is researched whether the effects of rail and road infrastructure investments on port container throughput are influenced by inland waterway container transport, which contributes to existing literature.

Second, this research is potentially relevant from a managerial perspective. Policy makers could use the results of this research to reconsider their strategy regarding infrastructure investments. For example, governments could adjust their policies based on the estimated effects of rail, road, and inland waterway infrastructure investments on port container throughput. However, this research is only relevant from a managerial perspective when we can say with certainty that the estimated effects are unbiased and causal.

1.6 Research approach

In the following sections, we will delve deeper into the effects of rail, road, and inland waterway infrastructure investments on port container throughput in sea bordering EU countries. First, the current literature about the effect of inland infrastructure investments on port container throughput is investigated in the Literature Review section. Additionally, other determinants of port container throughput are highlighted and the hypotheses are stated in this section. Afterwards, the methodology and used data are explained. Subsequently, the results of the main analysis are displayed in the Results section, and the results of the robustness checks are displayed. Lastly, limitations of this research including recommendations for future researchers are provided in the Discussion section, and the research question is answered in the conclusion.

2. Literature Review

It is frequently mentioned in existing literature that the connectivity of ports influences port container throughput. For example, Ho et al (2008) argued that a port's connectivity influences the port's competitiveness, which is evaluated by container throughput volumes (Liu & Park, 2011). As mentioned by the authors, ports can not become competitive if they do not have a comprehensive connectivity. Moreover, Grossman et al (2006) argued that infrastructure links (air, pipeline, rail, road and waterways) have a highly significant effect on the port's competitiveness. Furthermore, Makhecha (2016) argued that the accessibility to the hinterland plays a crucial role in the performance of ports. Since the performance of ports is measured in terms of container throughput volumes, the accessibility of the port determines port container throughput.

Now, other studies are discussed which highlight the relevance of the port's connectivity and accessibility for the port's performance.

Tongzon (2009) investigated port choices from a freight forwarder perspective and concluded that adequate infrastructure is the third most principal factor in the port selection process of forwarders. Since infrastructure is a matter of choice, this factor is more important compared to the location of the port. Besides, Felicio et al (2015) investigated the influence of port characteristics and container terminal characteristics on the performance of container terminals by sending a survey to twelve container terminals in Spain and Portugal. The respondents rate the distance to the center of Europe and road access as the most principal factors. Besides, rail access to the hinterland is an important factor. Based on the obtained results, the authors concluded that five factors, including sea and land access, influence the performance of container terminals. As mentioned by the authors, greater accessibility of inland transport makes it possible to spread further. Therefore, integration within logistics networks influences the performance of container terminals.

2.1 Infrastructure Investments

Infrastructure investments are a form of investments in real assets (CFI, 2024). Infrastructure investments cover spending on the construction of new transportation routes and the improvement of the existing infrastructure network (OECD, 2024). More specifically, inland infrastructure investments cover investments in rail infrastructure, road infrastructure, inland waterway infrastructure, maritime port infrastructure and airport infrastructure. For example, this includes investments in bridges, tunnels and highways.

It is important to note that inland infrastructure maintenance covers only maintenance expenditures and entails therefore a different type of expenditure.

Infrastructure investments are partly financed by governments. However, governments are not able to finance the need for new infrastructure alone (PWC, 2024). Therefore, multilateral development banks, international financial institutions and private finance play an essential role in financing infrastructure.

For example, the Dutch government makes additional infrastructure investments to reduce the increasing pressure on railways, roads, inland waterways and airports (Rijksoverheid, 2024). Therefore, the Dutch government is planning to widen the highway A4 with the intent of improving the traffic flow connection between the port of Rotterdam, Amsterdam and The Hague (Rijkswaterstaat, 2024).

2.2 Direct Effect

There has hardly been done any quantitative research on the effect of inland infrastructure investments on port container throughput. As mentioned before, only Fachouridis (2018) investigated the direct effect of inland infrastructure investments on port container throughput within the Hamburg-Le Havre range and Mediterranean range.

Besides, Rodrigue and Notteboom (2020) stated that it is expected that port infrastructure investments have a positive influence on port throughput effects. In addition, Talley (1996) argued that infrastructure investments expand and/or improve infrastructure linkages and decrease transportation costs. Moreover, congestion reduces and the time accessibility of transportation services improves. Consequently, the volume of transportation movements increases.

Furthermore, Acik and Ayaz (2021) investigated the effect of transportation mode investments on cargo traffic in Turkish ports from 2004 until 2018. The authors consider whether the transport investments are used efficiently to prevent misleading results arising from observing only transport investments. In this research, efficiency scores are measured based on the comparison of input and output. The input is measured in terms of the length of lines in kilometers, and the output is measured by the transport performance of the lines in tons per kilometer. Their analysis shows that, for rail transport, a one percent change in mode efficiency causes a 1.97 percent change in port throughput. For road transport, a one percent change in mode efficiency causes a 1.58 percent change in port throughput.

Now, the used methodology and obtained results of Fachouridis' research are presented.

2.2.1 Methodology Fachouridis

First, he conducted a unit root test in order to test stationarity. The researchers decided to conduct the Im-Pesaran-Shin test for the level and first difference of the variables. All variables are included in this test.

Afterwards, Fixed Effects and Random Effects models are estimated to analyze the relationship between different types of inland infrastructure investments and port container throughput. The author did not include any control variables in these models. Consequently, it is stated that the estimated models are

expected to suffer from omitted variable bias. The selected models, which are used to interpret the estimated coefficients, are the models where the lagged effects have the highest R-squared.

Lastly, Hausman tests are conducted separately for all hypotheses to test whether the Fixed Effects or Random Effects model is most appropriate. Subsequently, the coefficient of the most appropriate model is interpreted for every hypothesis.

2.2.2 Results Fachouridis

The Im-Pesaran-Shin test shows that all variables are non-stationary on the level and stationary on the first differences. Consequently, the variables in the panel data regressions are based on first differences. However, the author states that first differencing ignores the long-term relationship between the independent variables and dependent variable. Therefore, a co-integration test is used.

Based on the Hausman test, Fachouridis concluded for both port ranges that the Fixed Effects model is most appropriate for rail infrastructure investments, and the Random Effects model is most appropriate for road infrastructure investments. The estimation of the most appropriate models reveals that the effects of rail infrastructure investments and road infrastructure investments on port container throughput vary per port range.

For ports located within the Hamburg-Le Havre range, rail infrastructure investments have a positive and significant effect on port container throughput after seven years at a five percent significance level. However, the effect is negative and significant at a one percent significance level after three years for ports within the Mediterranean range. For ports located within the Hamburg-Le Havre range, road infrastructure investments have a positive and insignificant effect on port container throughput after four years (at a ten percent significance level). On the other hand, road infrastructure investments have a positive and significant effect on port container throughput after three years at a one percent significance level for ports located in the Mediterranean range.

In conclusion, rail and road infrastructure investments have a direct effect on port container throughput.

Additionally, the authors found that maritime port infrastructure investments have a positive and significant effect on TEU throughput at a one percent significance level for both port ranges. It is essential to note that the terms TEU throughput and port container throughput are used interchangeably. The effect is visible after five years for the Hamburg-Le Havre range, and after two years for ports in the Mediterranean range. The effects of air transport infrastructure investments and transport equipment investments on port container throughput are also positive and significant (at a five percent significance level). The difference in lags between the two regions applies also to air transport infrastructure investments.

2.3 Indirect Effect

Infrastructure investments could also have an indirect effect on port container throughput.

Research is done about the effect of infrastructure investments on Gross Domestic Product (GDP), and the effect of GDP on port container throughput. Sturm et al (1999) found that infrastructure investments have a positive and significant effect on GDP (at a 1% significance level). Moreover, GDP influences trade flows and consequently the volume of port throughput (Intihar et al, 2017). Based on these results, it could be argued that infrastructure investments have an indirect effect on port container throughput.

In other words, infrastructure investments have an indirect effect on port container throughput via economic growth, which is most often measured in terms of GDP. Wigren and Wilhelmsson (2007) also argued that infrastructure investments have an effect on short-run economic growth in Western-Europe. This is confirmed by Crescenzi and Rodriguez-Pose (2012), who found that being surrounded by good transport infrastructure has a significant impact on regional economic growth.

In conclusion, infrastructure investments have an indirect effect on port container throughput via economic growth (measured in terms of GDP).

2.4 Determinants Port Container Throughput

Various researchers endeavor to forecast annual throughput volumes with the intent of increasing the reliability and precision of their forecasting models. In these forecasting models, variables are included which are (directly) related to port container throughput. A large number of factors influences port container throughput (Meersman et al, 2014).

Port throughput forecasting models are important because of several reasons. First, port throughput forecasting plays an essential role in the capacity planning and management of ports (Eskafi et al, 2021). For example, terminal operators could optimize the container handling process by adapting their strategy to throughput forecasts. Second, capacity shortages cause congestion and increase waiting times, which adversely affects the port's performance. On the other hand, overcapacity provides growth opportunities. However, capital intensive investments are required to increase the capacity. Therefore, having reliable throughput forecasts is important for the performance of ports. Third, forecasting models could influence the strategy of port authorities regarding the port's development and infrastructure investments (Intihar et al, 2015). Accurate forecasts can meaningfully influence the strategy of port development, infrastructure-based investments, and efficient daily operations management (Zhang et al, 2013).

Now, existing literature is reviewed to explore which factors influence port container throughput. These factors are divided in the following two categories: Macroeconomic Variables and Port Characteristics.

2.4.1 Macroeconomic Variables

International trade indicates port container throughput. Therefore, Eskafi et al (2020) included the following six macroeconomic variables in their analysis to increase the precision of the port container throughput forecast: national GDP, world GDP, consumer price index, export volume, import volume and national population. Based on later research in which these six macroeconomic variables are included, the authors concluded that port throughput is influenced by all six macroeconomic variables (Eskafi et al, 2021).

Liu and Park (2011) found that transshipment (positive effect) and port tariffs (negative effect) are the strongest determinants of port container throughput in Korea. On the other hand, the hinterland's GDP (positive effect), hinterland's import and export volume (positive effect), and investments made by the government (positive effect) are the strongest determinants of port container throughput in China. For the whole sample of ports in China and Korea; GDP of the hinterland, import and export volume of the hinterland, free trade zone area, and investments made by the government have a positive and significant influence on port container throughput at a five percent significance level.

Intihar et al (2015) included the following macroeconomic variables in their analysis to forecast the container throughput of Adriatic ports (Port of Koper): GDP, Purchasing Power Parity, Export and Import value, trade balance and unemployment rate. The authors concluded that the GDP and value of export and import have the most significant effect on port container throughput.

According to Intihar et al (2017); GDP, GNP, inflation rate, consumer price index and unemployment rate are typical indicators of container throughput. The authors included the following five macroeconomic indicators in their forecasting models: GDP per capita, Import volume, Export volume, Unemployment rate and Purchasing Power Parity. Based on the estimated models, the authors believe that the predictions are promising.

The Bangkok Port Authority applies a linear regression method to forecast the number of containers in the port. The following factors are used in these forecasting models: GDP, exchange rate and world GDP. In this research, the exchange rate is compared to US dollars. Additionally, the population size and fuel price are included in their research. However, Gosang et al (2011) believe that other important macroeconomic factors, such as the interest rate and inflation rate, should also be included. Their analysis demonstrates that all factors influence export and/or import volumes, and are therefore also likely to influence the container throughput of the port of Bangkok.

Portugal-Perez and Wilson (2012) investigated the impact of infrastructure on the export performance of developing countries. Their analysis shows that improvements in infrastructure quality increase export growth. Since export volumes are related to port container throughput, it is likely that infrastructure quality is also related to port container throughput.

In conclusion, a diverse set of macroeconomic variables influences port container throughput. Table 2.1 below presents an overview of the macroeconomic variables.

Table 2.1 Overview macroeconomic determinants port container throughput

Number	Macroeconomic variable
1	Consumer Price Index
2	Exchange rate
3	Free trade zone area
4	Fuel price
5	Inflation rate
6	Infrastructure quality
7	Interest rate
8	Investments made by government
9	National Export Volume & Hinterland's Export Volume
10	National GDP & Hinterland's GDP & World GDP
11	National GDP per capita
12	National GNP
13	National Import Volume & Hinterland's Import Volume
14	Population
15	Purchasing Power Parity
16	Trade balance
17	Unemployment rate
18	World GDP

Notes: This table shows the macroeconomic variables which determine port container throughput. The variables are selected based on the investigated literature. These variables are presented in alphabetic order.

2.4.2 Port Characteristics

First of all, the available capacity of a port influences port container throughput (Meersman et al, 1997). The capacity determines the upper limit of throughput the port can handle, which is known as the physical capacity. Therefore, the weakest link in the port determines the physical capacity.

However, it is not only about having a sufficient capacity. Ports need to find ways to use their capacity in an efficient and optimal way. The efficiency of ports and terminals is also a determinant of TEU throughput (Makhecha, 2016). Since port infrastructure investments could improve the port's efficiency, port infrastructure investments also determine port container throughput. He found that investments in port infrastructure have a positive and insignificant effect on port container throughput. This applies to the port of Antwerp, port of Hamburg and port of Le Havre.

Handling costs are related to efficiency. Kammoun & Abdennadher (2022) found that the handling costs are the most important determinant of port competitiveness. Container throughput could grow through increased port competition (Meersman et al, 1997). Since the competitive strength of ports is evaluated by container throughput (Liu & Park, 2011), handling costs determine port container throughput. Besides, the authors concluded that barriers to accessibility, liner shipping connectivity, port infrastructure quality, port's logistic performance and technical efficiency are key determinants.

Another factor which is related to the port infrastructure quality is congestion. Congestion influences price premiums (Ho et al, 2008). Since price premiums influence port container throughput, congestion is also a factor related to port container throughput. Port related costs, cargo handlings costs, and cargo storage costs also influence a port's competitiveness (Meersman et al, 1997).

Besides, the geographical location of ports influences port container throughput (Makhecha, 2016). For example, the presence of industrial clusters influences the country's import and export volume. Therefore, the distance to these industrial centers influences port container throughput. Moreover, the distance to rival ports influences port container throughput (Sun & Bunamo, 1973). When the distance between ports is smaller, it is likely that these ports service the same hinterland. In other words, the distance between ports influences the competition between ports. Therefore, the distance between rival ports influences port container throughput.

Furthermore, the draft determines the competitiveness of seaports (Makhecha, 2016). A deeper draft does not constraint large ships to visit a specific seaport. Instead, a deeper draft allows large container vessels to enter the port, which influences the port's performance. For example, the port of Rotterdam is currently the only port in Europe that can handle the largest container vessels (EUR, 2023). Since the performance of ports is evaluated by the volume of container throughput, the draft influences the port container throughput.

Wagner et al (2022) also argued that maritime access is an essential determinant of port competitiveness. Previous research shows that the following factors determine the competitiveness of ports: hinterland proximity and (maritime) connectivity, nautical accessibility, port infrastructure and facilities, quality of port services, the geographical location of a port, and the operational efficiency. Container throughput is the most crucial factor to evaluate the competitive strength of a port (Liu & Park, 2011). Therefore, these factors are all determinants of port container throughput. Wagner et al (2022) researched the effect of fairway deepening on the benefits of cargo shippers in ports in Poland and concluded that an increase in draft by 2.5 meters decreases transportation costs up to 25 percent. This is beneficial, because lower transportation costs increase the port's interest of shippers.

Research from Liu and Park (2011) shows that terminal storage capacity, berth length and transshipment have a positive and significant influence on port container throughput in China and Korea at a five

percent significance level. On the other hand, port tariffs negatively influence port container throughput. The effect is statistically significant at a ten percent significance level.

In conclusion, a large number of port characteristics influences container throughput volumes in ports. Table 2.2 below summarizes port characteristics which influence port container throughput.

Table 2.2 Overview port specific determinants port container throughput

Number	Port characteristic
1	Accessibility of hinterland / Hinterland connectivity
2	Berth length
3	Congestion
4	Draft
5	Geographical location
6	Handling costs
7	Liner shipping connectivity
8	Physical capacity
9	Port and terminal efficiency
10	Port infrastructure investments
11	Port infrastructure quality
12	Port's logistic performance
13	Port tariffs
14	Technical efficiency
15	Transshipment

Notes: This table shows characteristics of ports which determine port container throughput. The variables are selected based on the investigated literature. These variables are presented in alphabetic order.

2.5 Hypotheses

Based on the researched literature, it is concluded that constructing new transportation routes improves the infrastructure network, and integrates seaports and the hinterland further. As a result, the port's connectivity and accessibility improve. In addition, transportation costs decrease and the port's competitiveness improves. The port's connectivity has a significant effect on the port's competitiveness (Makhecha, 2016). As mentioned before, container throughput is the most crucial factor to evaluate the competitive strength of ports (Liu & Park, 2011). Therefore, constructing new infrastructure and improving the existing infrastructure network influence port container throughput.

2.5.1 Hypothesis 1

Since rail infrastructure investments are required to expand and improve the country's existing rail network, it is likely that rail infrastructure improve the connectivity between the country's ports and

hinterland areas. As a result, the competitiveness of ports improves and the port container throughput is likely to increase. Consequently, the first hypothesis is formulated.

Hypothesis 1: Rail infrastructure investments have a positive and significant effect on port container throughput in sea bordering EU countries.

2.5.2 Hypothesis 2

Road infrastructure investments expand and improve the country's existing network of roads (e.g. highways), and the connectivity between ports and the hinterland areas is likely to improve. As a result, the port's performance improves, and port container throughput increases. Therefore, the second hypothesis is formulated.

Hypothesis 2: Road infrastructure investments have a positive and significant effect on port container throughput in sea bordering EU countries.

2.5.3 Hypothesis 3

In several EU countries, seaports are located on the estuary of rivers. For example, the river Rhine connects the port of Rotterdam with the hinterland and inland ports. It is therefore also possible to transport containers from the seaport to the hinterland via inland waterways. As a result, containers are transported from the seaport to the hinterland by using a combination of rail, road, and inland waterway networks.

The modal share for seaports within the EU exists only partially of inland waterway container transport for the following five EU countries and corresponding seaports: Belgium (Antwerp & Zeebrugge), France (Le Havre & Marseille), Germany (Bremen & Hamburg), the Netherlands (Rotterdam) and Romania (Constanta) (Pastori, 2015). The modal shares of hinterland container transport for these ports in 2007 are displayed in Table A1, and for 2018 in Table A2. These tables are displayed in Appendix A and illustrate that the modal shares of inland waterway container transport in 2007 and 2018 are comparable (Notteboom et al, 2022; BSL Transportation Consultants, 2019). It is therefore assumed that the modal shares of hinterland container transport remained constant during this time period.

For seaports in all other EU countries, containers are only transported to the hinterland via rail and road networks (Pastori, 2015).

Inland waterway infrastructure investments improve and expand a country's inland waterway infrastructure network, and improve the connectivity between ports and hinterland areas. As a result, the port's performance improves. Therefore, the third hypothesis is formulated.

Hypothesis 3: Inland waterway infrastructure investments have a positive and significant effect on port container throughput in sea bordering EU countries.

2.5.4 Hypothesis 4

As mentioned before, containers are transported to the hinterland and to inland ports by using a combination of railways, roads and inland waterways in five sea bordering EU countries.

Taking advantage of the presence of inland waterways could reduce congestion. Since congestion negatively affects the port's performance (Ho et al, 2008), inland waterway container transport is likely to have a positive impact on port container throughput. Congestion is already reduced by the transportation of containers via inland waterways. Therefore, it is expected that rail and road infrastructure investment have a smaller effect on port container throughput in countries where containers are also transported via inland waterways compared to other countries.

On the other hand, the opportunity to transport containers via inland waterways improves a country's logistics network. For example, containers are transported from seaports to inland ports via inland waterways. Rail and road infrastructure investments could improve the connectivity to inland ports, which has a positive effect on port container throughput. Therefore, it is expected that the transportation of containers via inland waterways positively influences the effects of rail and road infrastructure investments on port container throughput.

There is no literature which discusses whether the effects of rail and road infrastructure investments on port container throughput are influenced by inland waterway container transport.

Despite that it is expected that there is an effect, it is not possible to argue whether the effect is larger or smaller in sea bordering EU countries where containers are transported via inland waterways compared to other sea bordering EU countries. Consequently, the fourth hypothesis is formulated.

Hypothesis 4: The effects of rail and road infrastructure investments on port container throughput are significantly affected by inland waterway container transport in sea bordering EU countries.

3. Methodology

We are interested in measuring the effects of different types of inland infrastructure investments on port container throughput in sea bordering EU countries. The following steps are taken to achieve this.

First of all, we look at the availability of data for sea bordering EU countries to select the sample. Therefore, attention is paid to the dependent variable and independent variables. Afterwards, the independent variables, which are expressed in current euros, are converted to millions constant 2015 euros by using a GDP deflator. The GDP deflator is calculated by dividing a country's Nominal GDP by the Real GDP (Wall Street Prep, 2024). Dividing the values of the independent variables by the GDP deflator allows to compare the amount of infrastructure investments accurately over time.

The GDP deflator measures changes in the overall price levels of goods and services that contribute to GDP (Chowdhury, 2008). It is decided to use a GDP deflator, because it is a broad measure of inflation which reflects price changes in all aspects of the economy. Therefore, household spending and government spending are included. On the other hand, the consumer price index only measures changes in consumer prices (Chowdhury, 2008). Since infrastructure investments are partly financed by governments (PWC, 2024), using the GDP deflator provides a more comprehensive overview of price changes compared to the consumer price index.

The trends of the GDP deflator and consumer price index are similar (Chowdhury, 2008). Therefore, it is not required to include inflation in the estimated models as a control variable.

Thereafter, it is observed whether there is sufficient variation in the dependent variable and independent variables for the selected sample. Figures are plotted separately for every country to gain detailed insights into the variation per country. This is essential for the analysis, because it allows for more precise estimates.

Third, a unit-root test is conducted to test for stationarity. Stationarity means that the statistical properties remain constant (Affek, 2019). In other words, the way the variable changes, does not change over time. Testing for stationarity is important, because the relationship between the independent variables and the dependent variable should be stationary in order to prevent forecasting errors (Chou et al, 2008). There are multiple unit-root tests for panel data. The Levin-Lin-Chu, Harris-Tsavalis and Breitung tests assume that the parameter is the same for all panels, while other tests allow panel-specific parameters (Stata, 2023). Because it is not expected that the parameter is the same for all panels, we should look for another unit-root test. The Im-Pesaran-Shin (IPS) test is valid when the number of panels and time-periods is fixed (Stata, 2023). Therefore, the IPS test is conducted to test for stationarity.

Fourth, available data of control variables, which are selected as determinants of port container throughput based on researched literature, are obtained and included in the dataset. Control variables which are expressed in current euros or current dollars are also converted to constant 2015 values by using the GDP deflator.

Subsequently, it is investigated whether these control variables are correlated with the independent variables. Therefore, a correlation table is constructed to observe the correlation between the independent variables and control variables, and the correlation among control variables. According to Mukaka (2012), correlation coefficients above 0.7 indicate high correlation. Multicollinearity arises when multiple predictive variables in a model are highly related (Thompson et al, 2017). Therefore, the correlation table is used to detect multicollinearity.

Multicollinearity is an issue because of several reasons. First, the magnitude of the coefficient of the parameter is not consistent with the expectations. Second, multicollinearity increases standard errors which has a negative impact on the precision of the estimates (Thompson et al, 2017). As a consequence, it is possible that the coefficient of the independent variable will not be statistically significant. Furthermore, small adjustments to the dataset may change the estimated coefficient of the parameter of interest.

Afterwards, Variance Inflation Factor (VIF) scores are calculated to address multicollinearity into more detail. Increasing VIF scores reflect a stronger dependence between predictors, and indicate multicollinearity. Therefore, multiple researchers argue that the VIF scores should be below ten to prevent multicollinearity.

3.1 Model Choice

Panel data analysis is most appropriate, because we are interested in measuring causal effects of rail, road, and inland waterway infrastructure investments on port container throughput. Therefore, panel data models are required. In the following sections, the most appropriate panel data model is selected.

3.1.1 Pooled OLS, Fixed Effects and Random Effects

The Pooled OLS model is the Best Linear Unbiased Estimator when the Zero Conditional Mean (ZCM) assumption holds (Riumalló Herl, 2023). In other words, the error term should be uncorrelated with the independent variable (exogeneity assumption). The Pooled OLS model uses both between and within variation. Therefore, the time-invariant and time-variant part of the error should both be uncorrelated with the independent variable. Besides, the Pooled OLS model is inefficient when serial correlation occurs between the error terms.

However, the ZCM assumption is not likely to hold because it is expected that there are factors in the error term which are correlated with the independent variable. Moreover, it is likely that serial correlation exists between the error terms.

Despite the fact that the Pooled OLS model is the Best Linear Unbiased Estimator, other models are used to measure an unbiased effect of inland infrastructure investments on port container throughput. Fixed Effects (FE) and Random Effects (RE) models are used, because the FE model relaxes the exogeneity assumption and the RE model accounts for serial correlation.

The Fixed Effects (FE) model relaxes the exogeneity assumption by eliminating the time-invariant part of the error term. Therefore, all between variation is eliminated and there is only within variation left to estimate the coefficient of the parameter of interest. The FE model assumes that the time-variant part of the error term is uncorrelated with the independent variable (strict exogeneity assumption). When this assumption holds, the FE model is unbiased.

The Random Effects (RE) model accounts for serial correlation. The RE model uses both between and within variation to estimate the coefficient of the parameter of interest, and assumes that the error term is uncorrelated with the independent variable (exogeneity assumption). Therefore, the time-variant and time-invariant component of the error term should both be uncorrelated with the independent variable. In short, both Pooled OLS and RE models assume exogeneity but the difference is that the RE model accounts for serial correlation.

3.1.2 Hausman Test

Since the assumptions of the Pooled OLS model are not likely to hold, it is required to choose between the FE and RE model. This is done by conducting the Hausman test in Stata.

3.2 Lags

The effect of inland infrastructure investments on port container throughput is likely to be lagged, because it takes time until infrastructure projects are finished. For example, it takes time before the construction of new roads is finished. Since trucks are not able to drive on unfinished roads, it is not expected that infrastructure investments influence port container throughput in the same year. This expectation is confirmed by Ramey (2021), who concluded that infrastructure projects have time-to-build delays. Besides, it is expected that it will take time before an effect on port container throughput could be measured after finishing the infrastructure project.

Fachouridis (2018) found that the effects of rail and road infrastructure investments on port container throughput are lagged. The results are described in Section 2.2.2. It is based on the estimated effects in his research likely that the effects are visible after about three years. However, it could be the case that it deviates. Therefore, it is decided to lag the independent and control variables by a maximum of four years. Consequently, models are estimated for lags of one, two, three and four years. For example, a lag of one year means that the independent variable and all control variables are lagged by one year. Additionally, the models are estimated without lags to understand the relationship between the variables.

3.3 Main Analysis

3.3.1 Hypothesis 1

To test the first hypothesis, different FE and RE models are estimated for rail infrastructure investments. Model 1 includes only the amount of rail infrastructure investments as the independent variable, while Model 2 also includes all control variables which have correlation coefficients below 0.7. In the third model, control variables are included which have correlation coefficients below 0.7, and which have VIF scores below ten. However, the coefficient which measures the correlation between rail infrastructure investments and export volume is slightly above 0.7. Model 4 includes control variables which have correlation coefficients below 0.7, and which have VIF scores below ten. Lastly, Model 5 includes all control variables. For example, the regression of Model 4 looks as follows:

$$TEU_{it} = \alpha_i + B1 * Rail\ inv_{it} + B2 * GDP\ Per\ Capita_{it} + B2 * Unemployment\ Rate_{it} + U_{it}$$

In this formula, alpha (α_i) is the constant and U_{it} is the error term.

The optimal number of lags is selected based on the significance of the estimated coefficient of rail infrastructure investments in the estimated models. Therefore, the FE and RE models are selected where the estimated coefficients of rail infrastructure investments are consistently significant. In other words, the coefficient should not be coincidentally significant in one of the five estimated models. In short, the significance of the estimated coefficient of interest should not be sensitive to including regressors.

After selecting the optimal number of lags, the optimal model is selected by observing the correlation coefficients and VIF scores. Thereafter, the Hausman test is conducted for the optimal model to see whether the FE or RE model is most appropriate. Finally, the results of the optimal model are interpreted.

3.3.2 Hypothesis 2

The method which is used to test the first hypothesis is also used to estimate the effect of road infrastructure investments on port container throughput. The only difference is that the amount of road infrastructure investments is in these models the independent variable, and the amount of rail infrastructure investments could be added as a control variable.

3.3.3 Hypothesis 3

The third hypothesis is tested by estimating different FE and RE models for inland waterway infrastructure investments. Model 1 includes only the amount of inland waterway infrastructure investments as the independent variable, while Model 2 also includes all control variables which have correlation coefficients below 0.7. In the third and fourth model, control variables are included which have correlation coefficients below 0.7, and which have VIF scores below ten. Lastly, Model 5 includes all control variables.

Other than that, the third hypothesis is tested in the same way as the first and second hypothesis.

3.3.4 Hypothesis 4

In the fourth hypothesis, it is tested whether the effects of rail infrastructure investments and road infrastructure investments on port container throughput are influenced by inland waterway container transport. Therefore, an interaction term is added to the optimal models which are used to test Hypothesis 1 and Hypothesis 2.

For rail infrastructure investments, the interaction term is an interaction of the amount of rail infrastructure investments and a dummy variable which indicates whether containers are transported via inland waterways (IWW dummy). For road infrastructure investments, the interaction term is an interaction of the amount of road infrastructure investments and the IWW dummy.

Additionally, the IWW dummy is included in the models. However, this dummy is time-invariant and is therefore omitted.

Based on the significance of the coefficients of the independent variable and interaction term, it is argued whether inland waterway container transport influences the effects of rail and road infrastructure investments on port container throughput. Afterwards, the sign of both coefficients is used to observe the direction of the estimated effect.

3.4 Robustness Checks

After estimating the models to test the four hypotheses, three robustness checks are conducted to validate the robustness of the main findings. First of all, it is based on the descriptive statistics tables concluded whether the samples of the robustness check and main analysis are comparable. Subsequently, the models which are optimal in the main analysis are estimated again to test the hypotheses. By comparing the sign and significance of the estimated coefficients of the robustness check and main analysis, it is concluded whether the findings are robust.

For the first robustness check, it is tested whether the results are robust to excluding countries. This analysis also covers the years 2007 until 2018. For the first, second and fourth hypothesis, a sub-sample of countries located in the Hamburg – Le Havre range and Mediterranean range is selected. Belgium, France, Germany and the Netherlands are located in the Hamburg – Le Havre range. Besides, Croatia, Greece, Italy, Portugal, Slovenia and Spain are located within the Mediterranean range. Since Portugal is also located in the Mediterranean range but not present in our dataset, the sample of the first robustness check consists of the following nine countries: Belgium, Croatia, France, Germany, Greece, Italy, the Netherlands, Slovenia and Spain. For the third hypothesis, the sub-sample consists of the four countries located in the Hamburg-Le Havre range.

The second robustness check covers merely the years 2009 until 2018 to see whether the results are robust to excluding years. These years are selected, because port container throughput decreased between 2008 and 2009 for the majority of the seventeen countries (see Appendix B). Therefore, this

robustness check is used to see whether the decrease in port container throughput influenced the estimated effects. The sample for the first, second and fourth hypothesis consists of seventeen countries, and the sample for the third hypothesis consists of five countries.

Lastly, the third robustness check covers a larger timeframe to see whether the results are robust to the inclusion of years. Since a larger amount of data on infrastructure investments is only available for twelve countries, these countries are selected. Therefore, the analysis covers the years 2004 until 2018. For the first, second and fourth hypothesis, the sub-sample consists of the following twelve countries: Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Romania, Spain and Sweden. For the third hypothesis, the sample consists of the following five countries: Belgium, France, Germany, the Netherlands and Romania.

3.5 Remarks Methodology

There is no ideal model to conduct this research. Therefore, it is assumed that the used methodology in this research is most appropriate to investigate the effects of rail, road, and inland waterway infrastructure investments on port container throughput.

3.6 Comparison Methodology Fachouridis

Overall, the methodology to test the effect of inland infrastructure investments on port container throughput is comparable to the methodology used in Fachouridis' research. However, Fachouridis selected the optimal model where the lagged effect has the highest R-squared. The optimal number of lags is in this research selected by observing whether the estimated coefficient of the independent variable is consistently significant in the five estimated models. Thereafter, the optimal model is selected by observing the correlation coefficients and VIF scores. Fachouridis does not create correlation tables and calculate VIF scores because he does not include control variables in the models. Lastly, Fachouridis does not conduct robustness checks to validate the robustness of the findings.

4. Data

4.1 Data Background

The sample consists of sea bordering EU countries which have at least one container port. This sample is selected because of the following three reasons. First, all countries are member of the European Union (EU). Since the EU operates as a single market in a free-trade zone area, there are no tariffs or other trade restrictions which could influence a country's port container throughput. Second, all countries border the sea and have at least one seaport where containers are handled. As mentioned before, ninety percent of the world's good were transported by sea in 2021 (Nagurney, 2021). Therefore, it is assumed that it is only interesting to estimate the effects of different types of inland infrastructure investments on port container throughput for EU countries bordering the sea. Third, it is assumed that it is only interesting to research the effects of rail and road infrastructure investments on port container traffic when railways and roads connect at least one seaport in a country to the hinterland. Therefore, the inland infrastructure network allows transportation of containers from the seaport(s) to the hinterland.

However, Portugal is not included because of missing infrastructure investment data after 2013. Additionally, Cyprus, Malta and Ireland are excluded because these countries are located on islands. As mentioned in the Literature Review section, the geographical location of ports influences port container throughput (Makhecha, 2016). Moreover, the distance to rival ports influences port container throughput (Sun & Bunamo, 1973). Seaports in these three countries are located further away from rival seaports. Because these factors influence port container throughput, these countries are excluded from the sample.

All other sea bordering EU countries are high-income countries, except for Bulgaria which is classified as an upper-middle income country (World Bank, 2023b). There are substantial differences between high-income and upper-middle income countries (Global Infrastructure Hub, 2024). For example, the score for the regulatory framework is substantially higher in high-income countries compared to middle-income countries. The regulatory framework involves customs declarations, which is a determinant of port container throughput (Makhecha, 2016). Since streamlined customs procedures minimize delays and increase port container throughput, Bulgaria is excluded from the sample.

Consequently, the sample includes the following seventeen countries: Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Poland, the Netherlands, Romania, Slovenia, Spain and Sweden. The countries included in the sample are highlighted in green in Figure 1 below. The other EU countries are marked in grey, and non-EU countries are displayed with stripes.

The following countries are included in the sample which is used to test the third hypothesis: Belgium, France, Germany, the Netherlands and Romania. These countries are selected, because containers are in

these countries also transported from seaports to the hinterland and to inland ports via inland waterways (Pastori, 2015). It is important to note here that the presence of inland waterways does not necessarily mean that containers are transported via inland waterways. Since it is assumed that it is only interesting to research the effect of inland waterway infrastructure investments on port container traffic when containers are transported via inland waterways, the sample consists of only five countries.



Figure 1 Geographical map of sample

Some countries have more data available compared to other countries. For example, data is available from 2000 until 2021 for France and Germany. On the other hand, data for Romania is only available from 2004 until 2018, and data for Latvia from 2007 until 2021. Data is available for all countries within the sample from 2007 until 2018. Therefore, this research covers this timeframe.

4.2 Variables

In the analyzed models, the dependent variable is a country’s port container throughput in a specific year. This variable is measured in terms of the number of TEUs, and the data are obtained from the World Bank (World Bank, 2024a). The World Bank dataset is called “Container port traffic (TEU: 20 foot equivalent units)”. In this dataset, port container traffic is measured in terms of the number of TEUs that flow from sea to land transport modes, and from land transport modes to sea. Since port container throughput measures the number of containers the port handles over time (BTS, 2017), it is concluded that the obtained data reflect port container throughput.

The independent variables are rail infrastructure investments, road infrastructure investments and inland waterway infrastructure investments. Infrastructure investments cover spending on the construction of new transportation routes, and the improvement of the existing infrastructure network (OECD, 2024).

All sources of financing are taken into account. These variables are measured in millions constant 2015 euros. The data for all countries is obtained from the OECD dataset, except for the Netherlands (OECD, 2024). Since there are missing values for the Netherlands in the OECD dataset, it is decided to obtain the data from the Dutch Ministry of Finance (Rijksfinanciën, 2018).

For the selected sample, the figures which illustrate the variation in the dependent variable from 2007 until 2018 are displayed in Appendix B. For the independent variables, these figures show the variation from 2003 until 2018 because the number of lagged years has a maximum of four. The figures of rail infrastructure investments per country are shown in Appendix C, for road infrastructure investments in Appendix D, and for inland waterway infrastructure investments in Appendix E. Based on these figures, it can be observed that there is no clear trend for these three variables. Therefore, it is concluded that there is sufficient variation in the dependent variable and independent variables.

The variable “IWW dummy” is a dummy variable which indicates whether containers are also transported to the hinterland or to inland ports via inland waterways. This time-invariant variable is equal to one if containers are transported via inland waterways, and zero otherwise.

The variable “Rail_iww” is an interaction of rail infrastructure investments and IWW dummy, and the variable “Road_iww” is an interaction term of road infrastructure investments and IWW dummy.

Now, the control variables are explained which are included to increase the precision of the estimates and prevent possible omitted variable bias. The first control variable is GDP, which is measured in millions constant 2015 US dollars (World Bank, 2024c). Second, GDP per capita is calculated by dividing a country’s GDP by its midyear population and is measured in constant 2015 US dollars (World Bank, 2024d). The third control variable is government expenditures transport, which measures the government’s expenditures to transport in millions constant 2015 US dollars (UNCTAD, 2023). Fourth, the variable population reflects the size of a country’s total population in millions of people (World Bank, 2024f). The fifth and sixth control variable are export volume and import volume, measured in millions constant 2015 US dollars (World Bank, 2024b & World Bank, 2024e). The seventh control variable is the overall infrastructure quality, which indicates the quality of a country’s overall infrastructure on a scale from one to one hundred. This indicates among other things the quality of road infrastructure, efficiency of train services, railroad density and liner shipping connectivity. The data are obtained from multiple sources. The scores of 2002, 2004 and 2006 are obtained from Global Competitiveness Reports from the World Economic Forum (Porter & Schwab, 2002; Porter et al, 2004; Augusto Lopez-Claros, 2006). The scores from 2007 until 2017 are obtained from a World Bank dataset (World Bank, 2023a), and the scores for 2018 are obtained from The Global Competitiveness Report 2018 (Schwab, 2018). Since it is not possible to access the scores of 2003 and 2005, the value of 2003 is determined by taking the average of the values from 2002 and 2004, and the value of 2005 is

determined by taking the average of the values from 2004 and 2006. Lastly, the variable unemployment indicates a country's unemployment as a percentage of the total labor force (World Bank, 2024g).

The dataset is a balanced panel dataset, which means that there is data for seventeen countries during the period 2007 until 2018. Table 4.1 below shows the descriptive statistics of variables for the sample which consists of seventeen countries. This sample is used to test the first, second and fourth hypothesis. Besides, Table 4.2 demonstrates the descriptive statistics of the variables which are used in the models to test the third hypothesis. This sample consists of five countries.

Table 4.1 Descriptive statistics Hypothesis 1, 2 and 4

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	204	4537774	5340561	130740	1.72e+07
Rail infrastructure inv. (millions 2015 euros)	204	1509.073	2243.906	12.80381	9468.645
Road infrastructure inv. (millions 2015 euros)	204	2682.889	3508.368	88.15524	14157.56
Rail_iww (millions 2015 euros)	204	797.2515	2014.502	0	9468.645
Road_iww (millions 2015 euros)	204	1500.329	3503.224	0	14157.56
IWW dummy	204	0.2941176	0.456766	0	1
Gov. exp. transport (millions 2015 US dollars)	204	14328.37	15884.14	212.63	56244.3
Population size (millions)	204	22.58038	25.06004	1.314545	82.90578
Export volume (millions 2015 US dollars)	204	284438.5	361611.5	10548.35	1731054
Import volume (millions 2015 US dollars)	204	263887.9	316781.4	9602.584	1509730
GDP (millions 2015 US dollars)	204	706274.7	923858.7	18957.31	3559041
GDP per capita (2015 US dollars)	204	28466.92	14676.43	7480.581	56563.49
Overall infrastructure quality (score from 0 to 100)	204	74.15518	14.56734	33	94.71429
Unemployment rate (%)	204	9.533441	4.971475	3.384	27.686

Notes: This table presents the descriptive statistics of the dependent variable, independent variables and control variables.

Table 4.2 Descriptive statistics Hypothesis 3

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	60	8574503	5337364	556694	1.72e+07
Rail infrastructure inv. (millions 2015 euros)	60	2710.655	2947.634	108.5799	9468.645
Road infrastructure inv. (millions 2015 euros)	60	5101.12	4852.484	129.6739	14157.56
IWW infrastructure inv. (millions 2015 euros)	60	433.6956	285.3304	34.07733	1016.624
Gov. exp. transport (millions 2015 US dollars)	60	27070.84	18820.86	4769.651	56244.3
Population size (millions)	60	39.06472	29.11871	10.6257	82.90578
Export volume (millions 2015 US dollars)	60	622344.6	474681.4	38251.42	1731054
Import volume (millions 2015 US dollars)	60	566231.3	399398.2	48003.18	1509730
GDP (millions 2015 US dollars)	60	1409184	1221016	155041.3	3559041
GDP per capita (2015 US dollars)	60	34176.37	13235.47	7480.581	47826.82
Overall infrastructure quality (score from 0 to 100)	60	78.21857	18.53909	33	94.71429
Unemployment rate (%)	60	6.859167	1.856554	3.384	10.354

Notes: This table presents the descriptive statistics of the dependent variable, independent variables and control variables.

4.3 Measurement Variables

It is decided to use the actual values of the variables, because it allows to add control variables to the models without having multicollinearity issues. Consequently, it is possible to include GDP per capita as a control variable to account for the indirect effect of infrastructure investments on port container throughput via GDP. In this way, this research contributes significantly to existing literature on this topic.

On the contrary, including control variables in the models where logarithmic transformations are applied to all variables ensures that the VIF scores are above the threshold value. This is investigated by estimating models in which a log transformation is performed on all variables. As a result, it is not possible to add control variables to these models because of multicollinearity issues.

Applying logarithmic transformations could be valuable, because we are not sure whether the relationship between inland infrastructure investments and port container throughput is linear.

However, it is assumed that it is essential to add control variables to the models to increase the precision of the estimates, prevent possible omitted variable bias, and account for the indirect effect via GDP. Therefore, it is decided to use the actual values of the variables in the regression analyses.

4.4 Im-Pesaran-Shin Test

Table 4.3 below shows the results of the Im-Pesaran-Shin (IPS) test. Based on the P-values, it is concluded that all variables are non-stationary on the level because it is not possible to reject the null hypothesis at a five percent significance level. However, the variables are stationary when including time trends (at a one percent significance level). Besides, the variables are stationary on the first differences (at a one percent significance level).

Since the number of observations decreases by using first differences, which decreases the statistical power of the models, it is decided to make the data stationary by accounting for time-trends. Year fixed effects are added to the models to account for time-trends, because it is not assumed that the time trend is linear. In the regression tables, Year fixed effects are included as “Year dummies”.

Table 4.3 IPS test

Variable	Level		Time-trend		First differences	
	P-value		P-value		P-value	
Port container throughput	0.9999	Non-stationary	0.0157	Stationary	0.0000	Stationary
Rail infrastructure investments	0.0657	Non-stationary	0.0045	Stationary	0.0000	Stationary
Road infrastructure investments	0.6229	Non-stationary	0.0050	Stationary	0.0000	Stationary
IWW infrastructure investments	0.0514	Non-stationary	0.0144	Stationary	0.0013	Stationary

Notes: This table presents the results of the IPS tests. The variable is stationary when the null hypothesis is rejected. Based on a five percent significance level, it is determined whether the null hypothesis can be rejected. The number of observations for port container throughput, rail infrastructure investments, and road infrastructure investments is equal to 204. Sixty observations are used to test stationarity for IWW infrastructure investments.

4.5 Correlation Tables

The correlation tables are displayed below. Table 4.4 includes the correlation coefficients for the whole sample, and reveals that rail infrastructure investments and road infrastructure investments are not highly correlated with the following variables: GDP per capita, Overall infrastructure quality and Unemployment rate. These control variables are also not highly correlated with each other, except for

infrastructure quality which is highly correlated with GDP per capita. This suggests that it is possible to include these variables in the models to improve the precision of the estimates without suffering from multicollinearity. Besides, it is important to note that the correlation between rail infrastructure investments and export is 0.7173, which is slightly above the threshold value of 0.7.

Table 4.5 includes the correlation coefficients for the sample which consists of the five countries where containers are also transported via inland waterways. This table reveals that none of the control variables is highly correlated with inland waterway infrastructure investments. However, multiple control variables are highly correlated with each other.

For both samples, it is important to recognize that GDP is highly correlated with the independent variables and the majority of the control variables. Therefore, controlling for GDP causes multicollinearity. As mentioned in the Literature Review section, infrastructure investments have an indirect effect on port container throughput via GDP. It is therefore essential to control for the GDP per capita, which is calculated by dividing a country's GDP by its midyear population size, to account for this indirect effect.

Table 4.4 Correlation table Hypothesis 1, 2 and 4 - 204 observations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Rail infr. inv.	1									
(2) Road infr. inv.	0.8448	1								
(3) Gov. exp. transport	0.8840	0.9122	1							
(4) Population	0.8272	0.9094	0.9533	1						
(5) Export	0.7173	0.7929	0.9032	0.8434	1					
(6) Import	0.7649	0.8209	0.9315	0.8667	0.9953	1				
(7) GDP	0.8554	0.9055	0.9782	0.9471	0.9375	0.9528	1			
(8) GDP per capita	0.3179	0.2014	0.3861	0.1735	0.4501	0.4515	0.3698	1		
(9) Infr. quality	0.2749	0.1802	0.2989	0.1146	0.3970	0.3927	0.3290	0.7309	1	
(10) Unemployment	0.0206	-0.0539	-0.1103	-0.0063	-0.2092	-0.2013	-0.0954	-0.3396	-0.0868	1

Notes: This table displays the correlation coefficients.

Table 4.5 Correlation table Hypothesis 3 - 60 observations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Rail infr. inv.	1										
(2) Road infr. inv.	0.8340	1									
(3) IWW infr. inv.	-0.0750	0.1448	1								
(4) Gov. exp. transport	0.8813	0.9250	0.2661	1							
(5) Population	0.8336	0.9698	0.2681	0.9582	1						
(6) Export	0.6555	0.7286	0.5638	0.8682	0.8278	1					
(7) Import	0.7193	0.7645	0.5017	0.9052	0.8517	0.9943	1				
(8) GDP	0.8358	0.9257	0.3371	0.9860	0.9747	0.9166	0.9393	1			
(9) GDP per capita	0.2904	0.1178	0.3103	0.4409	0.1955	0.5623	0.5817	0.3999	1		
(10) Infr. quality	0.4608	0.3631	0.2253	0.6245	0.4220	0.6126	0.6459	0.5742	0.8901	1	
(11) Unemployment	0.3725	0.2021	-0.5261	0.1831	0.1459	-0.2016	-0.1314	0.0827	-0.0301	0.1481	1

Notes: This table displays the correlation coefficients.

4.6 Variance Inflation Factor Scores

The VIF scores of the optimal models are displayed in Appendix F. The VIF scores in the selected models are below the threshold value, which is mentioned in the Methodology section.

4.7 Robustness Checks

The tables in Appendix K demonstrate the descriptive statistics of the samples of the three robustness checks. By comparing Table 4.1 and Table 4.2, and the descriptive statistics tables in Appendix K, it is concluded that there are substantial differences in the descriptive statistics.

The differences in the descriptive statistics of the samples could lead to a variation in the estimated effects. In other words, the estimated effects in the robustness check could deviate from the estimated effects in the main analysis because of the differences in descriptive statistics.

5. Results

5.1 Hypothesis 1 – Rail Infrastructure Investments

The estimated FE and RE models displayed in Appendix G reveal that the effect of rail infrastructure investments on port container throughput is statistically significant in the models where one year is lagged. However, the effect is statistically insignificant in the FE model including all control variables (see Table G4), and in Model 2 of Table G5. Additionally, the effect of rail infrastructure investments on port container throughput is consistently significant in the models without lags. Again, the effect is statistically insignificant in the FE model including all control variables (see Table G2).

As described in Section 3.2, it is plausible that the effect of rail infrastructure investments on port container throughput is lagged. Therefore, the models where one year is lagged are selected. Subsequently, Model 4 is selected because all correlation coefficients of the variables included in this model are below 0.7, and the VIF scores are below ten (see Figure F1 in Appendix F). Therefore, there is no multicollinearity in this model.

After conducting the Hausman test for the selected model, it is concluded that the FE model is most appropriate (see Figure J1 in Appendix J). The estimated FE models are shown below in Table 5.1. The fourth model is used to interpret the estimated effect. In addition, the other models are displayed in this table to give an overview of the impact of including control variables on the magnitude and significance of the estimated coefficient of rail infrastructure investments. However, it is important to note here that multicollinearity is a concern in Model 2, Model 3 and Model 5 because of the high correlation among predictors and/or high VIF scores.

Based on the estimated coefficient of rail infrastructure investments displayed in Model 4, it is concluded that the effect of rail infrastructure investments on port container throughput is negative after one year. This effect is statistically significant at a ten percent significance level. On average, one additional million euros of rail infrastructure investments decreases port container throughput in sea bordering EU countries after one year by 76 TEU, *ceteris paribus*.

In conclusion, there is a negative and statistically significant effect of rail infrastructure investments on port container throughput after one year in sea bordering EU countries. Consequently, the first hypothesis is not accepted.

Table 5.1 Rail infrastructure investments relating to TEU throughput – Fixed Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-152.9171***	-87.79354*	-126.9402***	-76.94789*	-131.3544
Road infr. inv.					55.18205
GDP					-0.9272308
GDP per capita			-117.7432**	-71.19579	-166.6907***
Gov. exp. transport					39.83278
Population					-126626.2
Exports			3.812951***		11.56103***
Imports					-8.002077**
Infrastructure quality		1366.976			4532.498
Unemployment		83088.35***	55842.29***	63328.72***	37372.08*
Year dummies	Included	Included	Included	Included	Included
Constant	4712302***	3865429***	6588757***	6074633***	1.04e+07***
N	204	204	204	204	204
Overall	0.1102	0.0083	0.0210	0.1252	0.3566
R-squared					

Notes: *** P<0.01 ** P<0.05 * P<0.10

5.2 Hypothesis 2 – Road Infrastructure Investments

The estimated FE and RE models demonstrate that the effect of road infrastructure investments on port container throughput is not consistently significant in the estimated models displayed in Appendix H. However, the estimated effect is most often significant in the models where two periods are lagged (see Tabel H6 and Table H7). Therefore, the models where two years are lagged are selected.

Thereafter, Model 4 is selected because all correlation coefficients are below 0.7 and the VIF scores are below the threshold value (see Figure F2 in Appendix F).

Based on the conducted Hausman test, it is concluded that the FE model is most appropriate (see Figure J2 in Appendix J). The estimated FE models are shown below in Table 5.2. The fourth model is used to interpret the estimated coefficient, and other models are also displayed to give an overview of the impact of including control variables on the magnitude and significance of the estimated coefficient of road infrastructure investments. It is also essential to note that multicollinearity is a concern in Model 2, Model 3 and Model 5 because of the high correlation among predictors and/or high VIF scores.

The estimated coefficient in Model 4 indicates that the effect of road infrastructure investment on port container throughput is positive after two years. This effect is statistically insignificant at a ten percent significance level, because the P-value is equal to 0.105. On average, one additional million euros of road infrastructure investments increases port container throughput in sea bordering EU countries after two years by 59 TEU, *ceteris paribus*.

In conclusion, there is a positive and insignificant effect of road infrastructure investments on port container throughput after two years. Consequently, the second hypothesis is not accepted.

Table 5.2 Road infrastructure investments relating to TEU throughput – Fixed Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	3.828014	45.15587	62.93905*	59.59287	115.6741**
Rail infr. inv.					-36.01389
GDP					-6.08761**
GDP per capita			-117.1669**	-98.40403*	-53.91056
Gov. exp. transport					11.6087
Population					33946.59
Exports			1.23569		8.823185***
Imports					-3.596806
Infrastructure quality		3621.705			-83.05057
Unemployment		84045.62***	57616.01***	58395.88***	44481.52**
Year dummies	Included	Included	Included	Included	Included
Constant	4455734***	3320781***	6613004***	6388322***	7086902**
N	204	204	204	204	204
Overall	0.0081	0.0788	0.0111	0.0661	0.3759
R-squared					

Notes: *** P<0.01 ** P<0.05 * P<0.10

5.3 Hypothesis 3 – Inland Waterway Infrastructure Investments

The estimated FE and RE models demonstrate that the effect of inland waterway (IWW) infrastructure investments on port container throughput is consistently significant in the estimated models where one, two, three and four years are lagged (see Appendix I). The estimated coefficients are most significant in the FE and RE models where two years are lagged. In the models one to four where two years are lagged, all P-values are equal to 0.000. Therefore, the models where two years are lagged are selected.

The correlation coefficients and VIF scores are below the threshold values for Model 2, Model 3 and Model 4. Therefore, it is also required to observe the overall R-squared to select the optimal model. The average overall R-squared of the estimated FE and RE models is highest for the third model. Therefore, the third model is used to interpret the estimated coefficient.

Based on the conducted Hausman test, it is concluded that the RE model is most appropriate (see Figure J3 in Appendix J). The estimated RE models are shown below in Table 5.3. The VIF scores of the third model, which is used to interpret the estimated coefficient, are displayed in Figure F3 in Appendix F. Again, other models are displayed in Table 5.3 to give an overview of the impact of including control variables on the magnitude and significance of the estimated coefficient of inland waterway infrastructure investments. It is also essential to note that multicollinearity is a concern in Model 5, because the predictors are highly correlated with each other and the VIF scores are larger than ten.

Table 5.3 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	4912.59***	7927.523***	5732.436***	5254.308***	-1239.777
Rail infr. inv.					-539.6663**
Road infr. inv.					-246.5259
GDP					-20.69342**
GDP per capita		249.7293***	219.8669***		399.6227***
Gov. exp. transport					3.028077
Population					584107.5**
Exports		1.475794		3.387564**	21.93175**
Imports					5.331283
Infrastructure quality					-17053.89
Unemployment		-172075		114817	447847***
Year dummies	Included	Included	Included	Included	Included
Constant	7063916***	-1209228	-170027.4	4374632**	-1.23e+07***
N	60	60	60	60	60
Overall R-squared	0.4336	0.8665	0.8482	0.5901	0.9815

Notes: *** P<0.01 ** P<0.05 * P<0.10

The estimated coefficient in Model 3 indicates that the effect of inland waterway infrastructure investment on port container throughput is positive after two years. This effect is statistically significant at a one percent significance level. On average, one additional million euros of inland waterway

infrastructure investments increases port container throughput in sea bordering EU countries after two years by 5732 TEU, *ceteris paribus*.

In conclusion, there is a positive and significant effect of inland waterway infrastructure investments on port container throughput after two years. Consequently, the third hypothesis is accepted.

5.4 Hypothesis 4 – Influence of Inland Waterway Container Transport

5.4.1 Rail Infrastructure Investments

The effect of rail infrastructure investments on port container throughput is investigated for the FE models with one lagged period. Since the fourth model is used to test Hypothesis 1, this model is also used to investigate whether the estimated effect is significantly different for countries where containers are transported via inland waterways compared to other countries.

It is evident in Table 5.4.1 below that the coefficient of rail infrastructure investments is negative and significant at a ten percent significance level. Nevertheless, the interaction term is positive and statistically insignificant. On average, the effect of rail infrastructure investments on port container throughput after one year is smaller in sea bordering EU countries where containers are transported via inland waterway compared to other sea bordering EU countries, *ceteris paribus*. The effect is statistically insignificant at a ten percent significance level.

Table 5.4.1 Rail infrastructure investments relating to TEU throughput Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-111.806*
IWW dummy	Omitted
Rail*IWW	75.97981
GDP per capita	-70.31542
Unemployment	62844.31***
Year dummies	Included
Constant	6066628***
N	204
Overall R-squared	0.1258

Notes: *** P<0.01 ** P<0.05 * P<0.10

5.4.2 Road Infrastructure Investments

The effect of road infrastructure investments on port container throughput is investigated by using the FE model with two lagged periods. Therefore, Model 4 is also used to investigate whether the estimated

effect of road infrastructure investments on port container throughput is significantly different for countries where containers are transported via inland waterways compared to other countries.

It is illustrated in Table 5.4.2 below that the coefficient of road infrastructure investments is positive and insignificant. The interaction term is also positive and statistically insignificant at a ten percent significance level. On average, the effect of road infrastructure investments on port container throughput after two years is higher in sea bordering EU countries where containers are transported via inland waterway compared to other sea bordering EU countries, *ceteris paribus*. The effect is statistically insignificant at a ten percent significance level.

Table 5.4.2 Road infrastructure investments relating to TEU throughput Fixed Effects Lag 2

	Model 4
Road infr. inv.	50.88002
IWW dummy	Omitted
Road*IWW	93.39142
GDP per capita	-96.39495*
Unemployment	58900.48***
Year dummies	Included
Constant	6214750***
N	204
Overall R-squared	0.0362

Notes: *** P<0.01 ** P<0.05 * P<0.10

In conclusion, inland waterway container transport has a positive and statistically insignificant influence on the effects of rail infrastructure investments and road infrastructure investments on port container throughput. Consequently, the fourth hypothesis is not accepted.

5.5 Discussion Results

In Hypothesis 1, it was stated that rail infrastructure investments have a positive effect on port container throughput. Contrary to the expected positive effect, the analysis revealed that the effect is negative after one year. Fachouridis (2018) found a negative and significant effect after three years for ports within the Mediterranean range (at a one percent significance level). However, an explanation of why the effect is negative is missing.

There is currently no literature which provides a rational explanation for a negative effect of rail infrastructure investments on port container throughput. Therefore, it is not possible to provide a detailed explanation of why the estimated effect could be negative.

A potential reason for the unexpected sign of the effect is omitted variable bias (Wilms et al, 2021). The correlation tables indicate that multiple variables, which determine port container throughput but are not included in the fourth model, are highly correlated with rail infrastructure investments. For example, the variable which measures the government’s expenditures to transport is highly correlated with rail infrastructure investments and is a determinant of port container throughput. Consequently, the estimated coefficient of rail infrastructure investments is biased (and not causal), which could lead to this unexpected result.

Another potential explanation for the negative effect of rail infrastructure investments on port container throughput is based on the scatterplot displayed in Figure 2 below. In this scatterplot, the mean values of port container throughput (Y) and rail infrastructure investments (X) are displayed by year. This figure indicates that the negative effect is driven by the strong decline in rail infrastructure investments between 2012 and 2013, and between 2015 and 2016. However, the volume of port container throughput increased in these timeframes. Since the independent variable is only lagged by one year, these declines are also included in the analysis. Therefore, it is possible that the negative effect is driven by these datapoints.

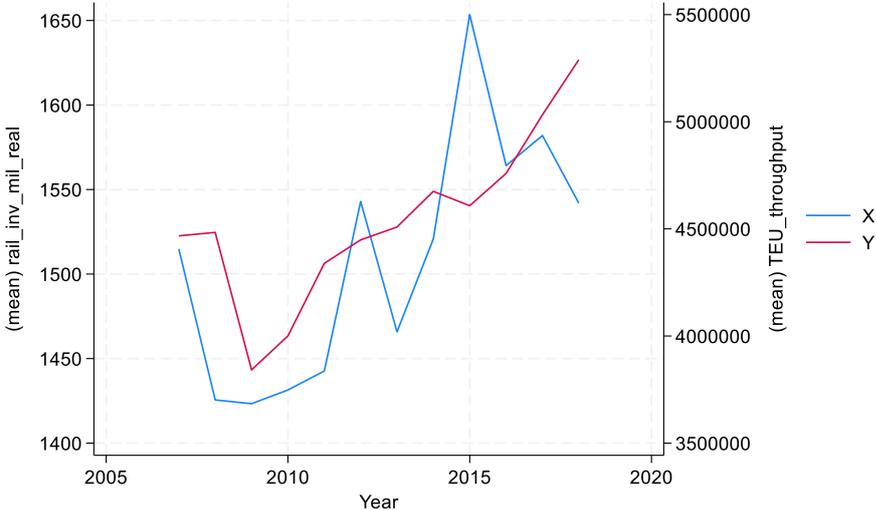


Figure 2 Scatterplot port container throughput and rail infrastructure investments

For the second hypothesis, the sign of the estimated effect is similar to the expectations. However, the estimated effect is insignificant. Repeatedly, it is likely that the estimated effect suffers from omitted variable bias for the same reason as in Hypothesis 1. It is likely that there are multiple variables which

are highly correlated with road infrastructure investments and determine port container throughput. Omitted variable bias ensures that the estimated effect is over- or underestimated (Wilms et al, 2021). Therefore, the estimation is unreliable and biased. Consequently, the estimated effect is not causal.

The estimated effect of inland waterway infrastructure investments on port container throughput is similar to the expectations. However, the estimated effect is again likely to suffer from omitted variable bias. As a result, the estimated effect is biased and not causal.

Lastly, the analysis of the fourth hypothesis indicates that inland waterway container transport does not statistically significantly influence the effects of rail infrastructure investments and road infrastructure investments on port container throughput. Therefore, the obtained results of the fourth hypothesis are contrary to the expectations. Despite it is not possible to compare the obtained results to other research, it is again expected that the estimated model suffers from omitted variable bias.

In conclusion, the estimated models suffer from omitted variable bias, and the estimated effects are therefore not causal.

There is no research providing insights into the effect of port container throughput on inland infrastructure investments. However, it could be the case that the amount of inland infrastructure investments is partially determined by throughput forecasts. Adjusting the amount of inland infrastructure investments to throughput forecasts does not necessarily mean that there is an effect of port container throughput on inland infrastructure investments. Therefore, it is expected that there is no reversed causality.

Besides, it is principal to note that the results are highly sensitive to applying logarithmic transformations to the variables. In multiple cases, the sign and significance of the coefficient of the parameter of interest change after applying logarithmic transformations to the dependent variable and independent variable. Therefore, the results are not robust to applying logarithmic transformations to the variables. Consequently, the results should be interpreted more carefully.

6. Robustness Checks

6.1 Robustness Check 1

The estimated coefficient of rail infrastructure investments is negative and statistically insignificant at a ten percent significance level (see Table K3 in Appendix K). However, the coefficient is negative and statistically significant at a ten percent significance level in the main analysis. Therefore, it is concluded that the findings are not robust.

The estimated effect of road infrastructure investments on port container throughput is shown in Table K4. The estimated coefficient of road infrastructure investments is positive and statistically insignificant at a ten percent significance level. In the main analysis, the estimated effect is also positive and statistically insignificant at a ten percent significance level. Therefore, the robustness check reveals that the findings corresponding to the second hypothesis are robust.

The estimated coefficient of inland waterway infrastructure investments displayed in Table K5 illustrates that the effect on port container throughput is positive and statistically significant at a one percent significance level. This is also the case in the main analysis. Therefore, the first robustness check reveals that the findings corresponding to the third hypothesis are robust.

For Hypothesis 4, the main analysis shows that the coefficient of rail infrastructure investments is negative and insignificant at a ten percent significance level, and the coefficient of the interaction term is positive and insignificant at a ten percent significance level. However, this is different in the robustness check, which is displayed in Table K6. The estimated coefficient of rail infrastructure investments is negative and statistically insignificant, and the coefficient of the interaction term is negative and insignificant at a ten percent significance level. Therefore, the findings of Hypothesis 4 are not robust. For the second part of Hypothesis 4, the coefficient of road infrastructure investments is positive and insignificant (at a ten percent significance level), and the coefficient of the interaction term is positive and statistically insignificant in the main analysis. This is also the case in the robustness check (see Table K7). Therefore, the findings of the second part of the third hypothesis are robust.

Since the findings of the first part of the fourth hypothesis are not robust, it is concluded that the findings of Hypothesis 4 are not robust.

6.2 Robustness Check 2

Table K10 demonstrates the estimated effect of rail infrastructure investments on port container throughput. The coefficient indicates that the effect is negative and statistically significant at a five percent significance level. However, the estimated coefficient is negative and statistically significant at a ten percent significance level in the main analysis. While the significance level is different, the

conclusion at a ten percent significance level remains constant. Therefore, this robustness check indicates that the findings of the first hypothesis are robust.

The estimated coefficient of road infrastructure investments is positive and statistically insignificant at a ten percent significance level (see Table K11). This applies also to the main analysis. Therefore, this robustness check indicates that the findings for Hypothesis 2 are robust.

The estimated coefficient of inland waterway infrastructure investments, displayed in Table K12, illustrates that the effect on port container throughput is positive and statistically significant at a one percent significance level. This is also the case in the main analysis. Therefore, the second robustness check reveals that the findings corresponding to the third hypothesis are also robust.

For the main analysis, the coefficient of rail infrastructure investments is negative and significant at a ten percent significance level, and the coefficient of the interaction term is positive and insignificant at a ten percent significance level. However, this is different in the second robustness check (see Table K13). The estimated coefficient of rail infrastructure investments is negative and statistically significant at a one percent significance level, and the coefficient of the interaction term is positive and significant at a one percent significance level. Therefore, these findings indicate that the results of first part of Hypothesis 4 are not robust.

In the main analysis, the coefficient of road infrastructure investments is positive and insignificant, and the coefficient of the interaction term is positive and statistically significant at a ten percent significance level. This is different in the robustness check which is displayed in Table K14. The estimated coefficient of road infrastructure investments is negative and insignificant at a ten percent significance level, and the coefficient of the interaction term is positive and insignificant. Therefore, the findings of the second part of the fourth hypothesis are also not robust.

Since both parts of the fourth hypothesis are not robust, it is concluded that the findings of Hypothesis 4 are not robust.

6.3 Robustness Check 3

The estimated effect of rail infrastructure investments on container throughput in EU ports is displayed in Table K17. The estimated coefficient of rail infrastructure investments is negative and statistically insignificant at a ten percent significance level. However, the coefficient is negative and statistically significant in the main analysis. Therefore, this robustness check indicates that the findings are not robust.

The estimated coefficient of road infrastructure investments is negative and statistically insignificant at a ten percent significance level (see Table K18), while the estimated effect is positive and statistically insignificant at a ten percent significance level in the main analysis. Therefore, this robustness check indicates that the findings corresponding to the second hypothesis are not robust.

The estimated effect of inland waterway infrastructure investments on port container throughput is displayed in Table K19. The coefficient illustrates that the effect is positive and statistically significant at a five percent significance level. While the significance is different compared to the main analysis, the conclusion at a five percent significance level remains constant. Therefore, the third robustness check reveals that the findings corresponding to the third hypothesis are robust.

For the main analysis, the coefficient of rail infrastructure investments is negative and significant at a ten percent significance level, and the coefficient of the interaction term is positive and insignificant at a ten percent significance level. However, this is completely different in the third robustness check (see Table K20). The estimated coefficient of rail infrastructure investments is negative and statistically insignificant, and the coefficient of the interaction term is negative and insignificant at a ten percent significance level. Therefore, the findings of the first part of Hypothesis 4 are not robust.

For the main analysis, the coefficient of road infrastructure investments is positive and insignificant (at a ten percent significance level), and the coefficient of the interaction term is positive and statistically insignificant. Again, this is completely different in the robustness check which is displayed in Table K21. The estimated coefficient of road infrastructure investments is negative and insignificant, and the coefficient of the interaction term is negative and insignificant at a ten percent significance level. This indicates therefore that the findings of the fourth hypothesis are also not robust.

In conclusion, the findings of Hypothesis 4 are not robust because the findings of both parts are not robust.

6.4 Discussion Robustness Checks

The robustness checks demonstrate that the results are sensitive to the composition of the sample and to the selected timeframe. Therefore, the main findings for Hypothesis 1, 2 and 4 are not generalizable. However, the findings of Hypothesis 3 are robust.

For causal inference, it is necessary that the results are robust (Lu & White, 2014). Consequently, the coefficients of the main analysis should be interpreted more careful.

The findings may be non-robust because of several reasons. First, the composition of the sample is different for the first and third robustness check. Second, the analysis covers a smaller timeframe for the second robustness check compared to the main analysis, and a broader range of years for the third hypothesis. The global economic crisis exploded in 2008 (Brancaccio & Fontana, 2011). The second hypothesis covers only years after the strong decline in port container throughput between 2008 and 2009, and the analysis of the third robustness check also covers several years before the crisis. In short, the different selected timeframes could cause non-robust results.

7. Discussion

This study has several limitations, which provide opportunities for future researchers.

First, the estimated effects are not causal because of omitted variable bias. There are multiple variables, such as government expenditures to transport, which are correlated with infrastructure investments and determine port container throughput. Consequently, the estimated effects are biased and not causal.

Second, the statistical power is low because of the limited number of observations. Since this research focusses only on sea bordering EU countries, the sample size is small. Additionally, this research covers a short timeframe. Future researchers could increase the statistical power by using data on a larger timeframe. Besides, future researchers could increase the statistical power by selecting a larger sample.

Third, the sample is not representative for sea bordering EU countries. This is a limitation, because this influences the validity and reliability of this research. Future researchers could therefore decide to include all sea bordering EU countries to provide more comprehensive insights.

Fourth, this study does not capture long-term effects because of the short timeframe. This could lead to misleading conclusions. Additionally, the timespan covers the global financial crisis. Based on the observed decline in port container throughput between 2008 and 2009, it is likely that the financial crisis influenced port container throughput. To make more convincing conclusions, future researchers should pay more attention to the potential influence of the global financial crisis on the estimated effects.

Fifth, the estimated effects in the first and second hypothesis are not completely robust to selecting different timeframes and samples. This applies also to the results of the fourth hypothesis. Consequently, the obtained results are not generalizable which is seen as a limitation.

Sixth, it is unknown how the infrastructure investments are spent. For example, infrastructure investments could be used for the construction of highways which improves the connection to the port. On the other hand, infrastructure investments could also be used to construct roads in areas where no container ports are present, which is not expected to influence port container throughput. Acik and Ayaz (2021) argued that infrastructure investments do not indicate that the infrastructure parts are used effectively. Therefore, the results of this research are misleading. Future researchers should therefore take the effectiveness of infrastructure investments into account.

Seventh, maritime port infrastructure investments are not included in this research because of the limited availability of data. As mentioned in Section 2.4.2, maritime port infrastructure investments determine port container throughput. Since the effect is currently not researched for sea bordering EU countries, it is interesting for future researchers to use available data to investigate the effect of maritime port infrastructure investments on port container throughput.

8. Conclusion

In this research, the effects of rail, road and inland waterway infrastructure investments on port container throughput are investigated in sea bordering EU countries. Based on the quantitative analysis, it is concluded that the effect of rail infrastructure investments on port container throughput after one year is negative and statistically significant. This is contrary to the expected positive result. Besides, road infrastructure investments have a positive and insignificant effect on port container throughput after two years. Therefore, the first and second hypothesis are not accepted. However, the third hypothesis is accepted because inland waterway infrastructure investments have a positive and significant effect on port container throughput after two years.

Additionally, it is researched whether the effects of rail and road infrastructure investments on port container throughput are influenced by inland waterway container transport. Based on the estimated models, it is concluded that transporting containers via inland waterways does not have a statistically significant influence on the effects. Consequently, the fourth hypothesis is not accepted.

It is essential to note that the estimated effects are not causal because of omitted variable bias. Therefore, it is not possible to say whether policy makers should change the country's level of infrastructure investments. Despite the fact that this research is not relevant from a managerial perspective, this research is definitely relevant from an academic point of view because of the substantial contributions to existing literature.

In conclusion, this research advances our understanding of determinants of port container throughput, highlighting the effects of rail, road, and inland waterway infrastructure investments on port container throughput in sea bordering EU countries.

References

- Acik, A. & Ayaz, I.S. (2021). *Impact of Transport Infrastructure Investments on Port Throughputs: An Efficiency Approach*. Accessed through <https://dergipark.org.tr/en/download/article-file/1162478>
- Affek, S.P. (2019). *Stationarity in time series analysis*. Accessed through <https://towardsdatascience.com/stationarity-in-time-series-analysis-90c94f27322>
- Augusto Lopez-Claros (2006). The Global Competitiveness Report 2006-2007. *World Economic Forum*. Accessed through https://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2006-07.pdf
- Brancaccio, E. & Fontana, G. (2011). The Global Economic Crisis – New perspectives on the critique of economic theory and policy. London: Routledge.
- BSL Transportation Consultants (2019). 2018 report on Combined Transport in Europe. *International Union of Railways*. Accessed through https://uic.org/IMG/pdf/2018_report_on_combined_transport_in_europe.pdf
- BTS (2017). *3 Measures of Throughput and Capacity*. Accessed through https://www.bts.gov/archive/publications/port_performance_freight_statistics_annual_report/2016/ch3
- CBS (2023). *Lengte van spoortrajecten; spoortrajectkenmerken, provincie*. Accessed through <https://opendata.cbs.nl/statline/#/CBS/nl/dataset/71024ned/table?dl=8F916>
- CFI (2024). *Infrastructure Investments*. Accessed through <https://corporatefinanceinstitute.com/resources/career-map/sell-side/capital-markets/infrastructure-investments/>
- Chou, C.C., Chu, C.C. & Liang, G.S. (2008). A modified regression model for forecasting the volumes of Taiwan's import containers. *Mathematical and Computer Modelling*, 47(9-10), 797-807. <https://doi.org/10.1016/j.mcm.2007.05.005>
- Chowdhury, A. (2008). The GDP implied deflator. *Economic & Labour Market Review*, 2(6), 53-56. Accessed through <https://link.springer.com/content/pdf/10.1057/elmr.2008.91.pdf>
- CLO (2022). Aanbod, gebruik en reistijdverlies hoofdwegennet, 2000-2021. *Compendium voor de Leefomgeving*. Accessed through <https://www.clo.nl/indicatoren/nl213706-aanbod-gebruik-en-reistijdverlies-hoofdwegennet-2000-2021#:~:text=Tussen%202000%20en%202021%20is,aan%20de%20provincies%20is%20overgedragen.>

- Crescenzi, A. & Rodriguez-Pose, A. (2012). Infrastructure and regional growth in the European Union. *Papers in regional science*, 91(3), 487-513. Accessed through https://rsaiconnect.onlinelibrary.wiley.com/doi/pdfdirect/10.1111/j.1435-5957.2012.00439.x?casa_token=5MY-Z32OabsAAAAA:RtGZJyW7mQWimyc56HsezF-aRzN4aLxSZWHuv_QkroroWH2R4y8d59x9jH0AI407hQNGVZvCniENQ
- Du, T. (2015). AHP Analysis for Evaluation of European Container Port Performance. *Erasmus University Rotterdam*.
- Eskafi, M., Kowsari, M., Dastgheib, A., Ulfarsson, G.F., Taneja, P. & Thorarinsdottir, R.I. (2020). Mutual information analysis of the factors influencing port throughput. *Maritime Business Review*, 6(2), 129-146. Accessed through <https://shippingdigest.tw/wp-content/uploads/2022/08/202131-Vol.-6-No.-2-2021.pdf>
- Eskafi, M., Kowari, M., Dastgheib, A., Ulfarsson, G.F., Stefansson, G., Teneja, P. & Thorarinsdottir, R.I. (2021). A model for port throughput forecasting using Bayesian estimation. *Maritime Economics & Logistics*, 23, 348-368. <https://doi.org/10.1057/s41278-021-00190-x>
- EUR (2023). Colossal container ships pose major logistical challenges. *Erasmus University Rotterdam*. Accessed through <https://www.eur.nl/en/news/colossal-container-ships-pose-major-logistical-challenges>
- European Commission (2014). *Infrastructure in the EU: Developments and Impact on Growth*. Accessed through https://ec.europa.eu/economy_finance/publications/occasional_paper/2014/pdf/ocp203_en.pdf
- European Commission (2024). *Trans-European Transport Network (TEN-T)*. Accessed through https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en
- Fachouridis, A. (2018). Determinants of seaports container throughput between the Hamburg-Le-Havre range and the Mediterranean ports: Infrastructure investments and their returns on TEU. *Erasmus University Rotterdam*.
- Felicio, J.A., Caldeirinha, V. & Dionisio, A. (2015). The effect of port and container terminal characteristics on terminal performance. *Maritime Economics & Logistics*, 17, 493-514. <https://doi.org/10.1057/mel.2014.33>
- Global Infrastructure Hub (2024). *Compare countries*. Accessed through <https://infracompass.gihub.org/compare-countries/?country=High%2cUpperMiddle>

- Gosang, V., Chandraprakaikul, W. & Kiattisin, S. (2011). A Comparison of Traditional and Neural Networks Forecasting Techniques for Container Throughput at Bangkok Port. *The Asian Journal of Shipping and Logistics*, 27(3), 463-482.
- Grossman, H., Otto, A., Stiller, S. & Weidemeier, J. (2006). Maritime Trade and Transport Logistics. HWWI (Part A): Perspectives for maritime trade – Cargo shipping and port economics. *Wealth and Life in the Next Generation*, No. 4, Berenberg Bank und Hamburgisches WeltWirtschaftsinstitut (HWWI). Accessed through <https://www.econstor.eu/bitstream/10419/102539/1/728791528.pdf>
- Ho, K.H.D., Ho, M.W. & Hui, C.M.E. (2008). Structural Dynamics in the Policy Planning of Large Infrastructure Investment under the Competitive Environment: Context of Port Throughput and Capacity. *Journal of Urban Planning and Development*, 134(1), 9-20. [https://doi.org/10.1061/\(ASCE\)0733-9488\(2008\)134:1\(9\)](https://doi.org/10.1061/(ASCE)0733-9488(2008)134:1(9))
- Intihar, M., Kramberger, T. & Dragan, D. (2015). The relationship between the economic indicators and the accuracy of container throughput forecasting. *IAME 2015 Conference Kuala Lumpur*, 64.
- Intihar, M., Kramberger, T. & Dragan, D. (2017). Container Throughput Forecasting using Dynamic Factor Analysis and Arimax Model. *Promet – Traffic & Transportation*, 29(5), 529-542. Accessed through <https://hrcak.srce.hr/file/278240>
- Kammoun, R. & Abdennadher, C. (2022). Seaport efficiency and competitiveness in European seaports. *Transport Policy*, 121, 113-124. <https://doi.org/10.1016/j.tranpol.2022.04.003>
- Langen, P. de, Nijdam, M. & Horst, M. van der (2006). New indicators to measure port performance. *Erasmus University Rotterdam*. Accessed through <https://www.jmr.unicon.es/index.php/jmr/article/view/40/38>
- Liu, L. & Park, G. (2011). Empirical analysis of Influence Factors to Container Throughput in Korea and China Ports. *The Asian Journal of Shipping and Logistics*, 27(2), 279-303.
- Lu, X. & White, H. (2014). Robustness checks and robustness tests in applied economics. *Journal of Econometrics*, 178(1), 194-206. <https://doi.org/10.1016/j.jeconom.2013.08.016>
- Makhecha, A. (2016). Analysis of the determinants of container throughput of the major ports in the Hamburg Le Havre range. *Erasmus University Rotterdam*.
- Meersman, H., Steenssens, C. and Voorde, E. Van de (1997). Container Throughput, Port Capacity and Investment. *Universitaire Faculteiten St.- Ignatius*. Accessed through <https://repository.uantwerpen.be/docman/irua/33b638/18140.pdf>

- Meersman, H., Voorde, E. Van de & Vanelslander, T. (2014). *Port Infrastructure Finance*. New York: Routledge. Accessed through https://books.google.nl/books?hl=nl&lr=&id=R6PcAwAAQBAJ&oi=fnd&pg=PA33&dq=effect+of+infrastructure+investments+on+port+container+throughput&ots=hl1Ehq0iof&sig=lhNMu43StVOaK6RuJYJqrSk-Tvg&redir_esc=y#v=onepage&q=effect%20of%20infrastructure%20investments%20on%20port%20container%20throughput&f=false
- Mukaka, M.M. (2012). Statistics Corner: A guide to appropriate use of Correlation coefficient in medical research. *Malawi Medical Journal*, 24(3), 69-71.
- Nagurney, A. (2021). Our economy relies on shipping containers. This is what happens when they're "stuck in the mud". *World Economic Forum*. Accessed through <https://www.weforum.org/agenda/2021/10/global-shortagof-shipping-containers/>
- Notteboom, T. (2008). The relationship between seaports and the intermodal hinterland in light of global supply chains: European challenges. *International Transport Forum*. Accessed through <https://www.itf-oecd.org/sites/default/files/docs/dp200810.pdf>
- Notteboom, T., Lugt, L. van der, Saasse, N. van, Sel, S. & Neyens, K. (2020). The Role of Seaports in Green Supply Chain Management: Initiatives, Attitudes, and Perspectives in Rotterdam, Antwerp, North Sea Port, and Zeebrugge. *Sustainability*, 12(4), 1688. <https://doi.org/10.3390/su12041688>
- Notteboom, T., Pallis, A. & Rodrigue, J.P. (2022). *Port Economics, Management and Policy*. New York: Routledge. Accessed through <https://porteconomicsmanagement.org/pemp/contents/part2/port-hinterlands-regionalization/modal-split-selected-ports-europe/>
- OECD (2024). *Infrastructure investment (indicator)*. doi: 10.1787/b06ce3ad-en (Accessed on 12 February 2024)
- Pastori, E. (2015). Modal Share of Freight Transport to and from EU Ports. *European Parliament*. Accessed through [https://www.europarl.europa.eu/RegData/etudes/STUD/2015/540350/IPOL_STU\(2015\)540350_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2015/540350/IPOL_STU(2015)540350_EN.pdf)
- Porter, M.E. & Schwab, K. (2002). *The Global Competitiveness Report 2002-2003*. New York: Oxford University Press 2003.
- Porter, M.E., Schwab, K., Sala-i-Martin & Augusto Lopez-Claros (2004). *The Global Competitiveness Report 2004-2005*. New York: Palgrave Macmillan.

- Portugal-Perez, A. & Wilson, J.S. (2012). Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure. *World Development*, 40(7), 1295-1307.
<https://doi.org/10.1016/j.worlddev.2011.12.002>
- PWC (2024). *Global infrastructure trends – Part 2: Development in financing*. Accessed through <https://www.pwc.com/gx/en/industries/capital-projects-infrastructure/publications/infrastructure-trends/global-infrastructure-trends-financing.html>
- Ramey, V.A. (2021). The Macroeconomic Consequences of Infrastructure Investment. *National Bureau of Economic Research*. Accessed through https://www.nber.org/system/files/working_papers/w27625/w27625.pdf
- Rijksfinanciën (2018). *Jaarverslag – A Infrastructuurfonds*. Accessed through <https://www.rijksfinancien.nl/jaarverslag/2018/A>
- Rijksoverheid (2024). *Infrastructuur*. Accessed through <https://www.rijksoverheid.nl/regering/coalitieakkoord-omzien-naar-elkaar-vooruitkijken-naar-de-toekomst/2.-duurzaam-land/infrastructuur>
- Rijkswaterstaat (2024). *A4: verbeteren doorstroming A4 Haaglanden-N14*. Accessed through <https://www.rijkswaterstaat.nl/wegen/projectenoverzicht/a4-verbeteren-doorstroming-a4-haaglanden-n14>
- Riumalló Herl, C. (2023). Applied Microeconometrics – Panel data: Introduction (Lecture Week 4). *Erasmus School of Economics*. Erasmus University Rotterdam.
- Rodrigue, J.P. & Notteboom, T. (2020). Chapter 7.2 – Ports and Economic Development. *Port Economics, Management and Policy*. Accessed through <https://porteconomicsmanagement.org/pemp/contents/part7/port-and-economic-development/>
- Schwab, K. (2018). The Global Competitiveness Report 2018. *World Economic Forum*. Accessed through <https://www3.weforum.org/docs/GCR2018/05FullReport/TheGlobalCompetitivenessReport2018.pdf>
- Song, D. & Panayides, P.M. (2008). Global supply chain and port/terminal: integration and competitiveness. *Maritime Policy & Management*, 35(1), 73-87.
<https://doi.org/10.1080/03088830701848953>
- Stata (2023). *Xtunitroot – Panel-data unit-root tests*. Accessed through <https://www.stata.com/manuals/xtxtunitroot.pdf>

- Sturm, J.E., Jacobs, J. & Groote, P. (1999). Output Effects of Infrastructure Investment in the Netherlands, 1853-1913. *Journal of Macroeconomics*, 21(2), 355-380. Accessed through <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=8f60e785e5433b9edba70d863039d4acf09ae8c0>
- Sun, N. & Bunamo, M.C. (1973). Competition for Handling US Foreign Trade Cargoes: The Port of New York's Experience. *Economic Geography*, 49(2), 156-162. Accessed through https://www.tandfonline.com/doi/pdf/10.2307/143084?casa_token=U-Tqjw1fe3cAAAAA:mQuzqTzn2Ssz9rBB8SUDFEhzDRUNsp3evWQtrC5sEBHNLkIAAN1DxUouXK7-R4Ds249C7HZBESEE
- Talley, W.K. (1996). Linkages between transportation infrastructure investment and economic production. *Logistics and Transportation Review*, 32(1), 145-154. Accessed through <https://www.proquest.com/docview/197435991/fulltext/B28C840271DC4BD0PQ/1?accountid=13598&sourcetype=Scholarly%20Journals>
- Talley, W.K. (2006). Port Performance: An Economics Perspective. *Research in Transportation economics*, 17, 499-516. Accessed through [https://doi.org/10.1016/S0739-8859\(06\)17022-5](https://doi.org/10.1016/S0739-8859(06)17022-5)
- Thompson, C.G., Kim, R.S., Aloe, A.M. & Becker, B.J. (2017). Extracting the Variance Inflation Factor and Other Multicollinearity Diagnostics from Typical Regression Results. *Basic and Applied Psychology*, 39(2), 81-90. <https://doi.org/10.1080/01973533.2016.1277529>
- Tongzon, J.L. (2009). Port choice and freight forwarders. *Transportation Research Part E: Logistics and Transportation Review*, 45(1), 186-195. <https://doi.org/10.1016/j.tre.2008.02.004>
- UNCTAD (2023). *Government expenditures – Transport*. Accessed through <https://unctadstat.unctad.org/datacentre/dataviewer/US.GovExpenditures>
- Wagner, N., Kotowska, I. & Plucinski, M. (2022). The Impact of Improving the Quality of the Port's Infrastructure on the Shippers' Decisions. *Sustainability*, 14(10), 6255. <https://doi.org/10.3390/su14106255>
- Wall Street Prep (2024). *GDP Deflator*. Accessed through <https://www.wallstreetprep.com/knowledge/gdp-deflator/>
- Wigren, R. & Wilhelmsson M. (2007). Construction investments and economic growth in Western Europe. *Journal of Policy Modeling*, 29(3), 439-451. Accessed through https://www.sciencedirect.com/science/article/pii/S0161893806001335?casa_token=4JnuHsLKeDcAAAAA:Y5oH5IO2Z4Oek1e8aFSgovJeDR56L61cpVMNmBpyKAAItqe2T0WTAA2goih eiqidVa52JsZ9sw#sec5

- Wilms, R., Mäthner, E., Winnen, L. & Lanwehr, R. (2021). Omitted variable bias: A threat to estimating causal relationships. *Methods in Psychology*, 5, 2590-2601.
<https://doi.org/10.1016/j.metip.2021.100075>
- World Bank (2023a). WEF Global Competitiveness Index – Historical Dataset. *World Economic Forum*. Accessed through
<https://prosperitydata360.worldbank.org/en/indicator/WEF+GCIHH+EOSQ056>
- World Bank (2023b). *World Bank Group country classification by income level*. Accessed through
<https://blogs.worldbank.org/en/opendata/new-world-bank-group-country-classifications-income-level-fy24>
- World Bank (2024a). *Container port traffic (TEU: 20 feet equivalent units)*. Accessed through
<https://data.worldbank.org/indicator/IS.SHP.GOOD.TU>
- World Bank (2024b). *Exports of goods and services (constant 2015 US\$)*. Accessed through
<https://data-worldbank-org.eur.idm.oclc.org/indicator/NE.EXP.GNFS.KD?view=chart>
- World Bank (2024c). *GDP (constant 2015 US\$)*. Accessed through
<https://data.worldbank.org/indicator/NY.GDP.MKTP.KD>
- World Bank (2024d). *GDP per capita (constant 2015 US\$)*. Accessed through
<https://data.worldbank.org/indicator/NY.GDP.PCAP.KD?locations>
- World Bank (2024e). *Imports of goods and services (constant 2015 US\$)*. Accessed through
<https://data-worldbank-org.eur.idm.oclc.org/indicator/NE.IMP.GNFS.KD?view=chart>
- World Bank (2024f). *Population, total*. Accessed through <https://data-worldbank-org.eur.idm.oclc.org/indicator/SP.POP.TOTL>
- World Bank (2024g). *Unemployment, total (% of total labor force) (national estimate)*. Accessed through
<https://data-worldbank-org.eur.idm.oclc.org/indicator/SL.UEM.TOTL.NE.ZS>
- Zhang, Y., Wang, X. & Chen, K. (2013). Growth and distributive effects of public infrastructure investments in China. *Springer International Publishing*, 87-116. Accessed through
<https://library.oapen.org/bitstream/handle/20.500.12657/28053/1001941.pdf#page=96>

Appendices

Appendix A: Modal Split TEU European ports

Table A1 Modal split container ports 2007

	Rail	Road	Inland waterways
Antwerp	8	60	32
Zeebrugge	45	55	1
Le Havre	84	7	9
Marseille	12	82	6
Bremen	59	37	4
Hamburg	32	66	2
Rotterdam	9	60	31
Constanta	47	48	5

Notes: Modal share (%) containers per port in 2007 (Notteboom et al, 2022). Therefore, 8% of the TEUs from the port of Antwerp is transported to the hinterland via railways.

Table A2 Modal split container ports 2018

	Rail	Road	Inland waterways
Antwerp	6.9	55.1	39.0
Zeebrugge			
Le Havre			
Marseille	10.9	82.9	6.2
Bremen	46.0	51.2	2.8
Hamburg	42.8	55.0	2.2
Rotterdam	10.4	56.2	33.4
Constanta			

Notes: Modal share (%) of TEU in 2018 for the ports (BSL Transportation Consultants, 2019). The data for the port of Zeebrugge, port of Le Havre and port of Constanta are missing in 2017.

Appendix B: Figures Port Container Throughput

The port container throughput in number of TEUs is displayed on the Y-axis, and the Year is displayed on the X-axis.

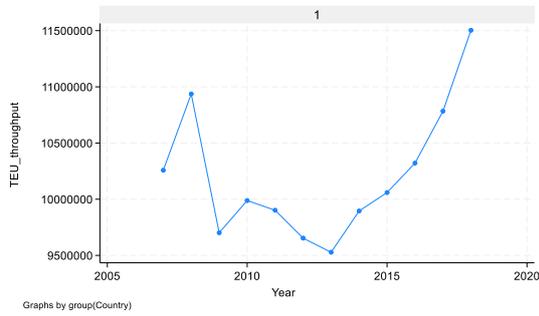


Figure B1 Port container throughput Belgium

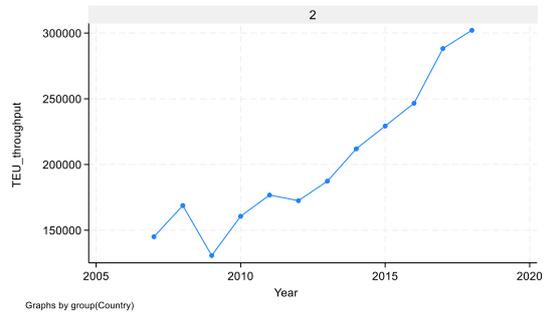


Figure B2 Port container throughput Croatia

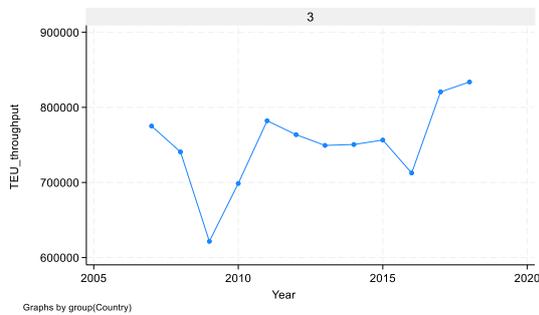


Figure B3 Port container throughput Denmark

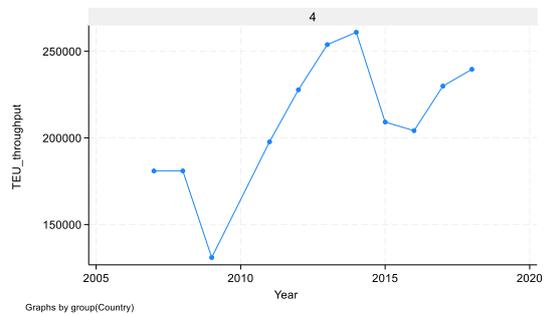


Figure B4 Port container throughput Estonia

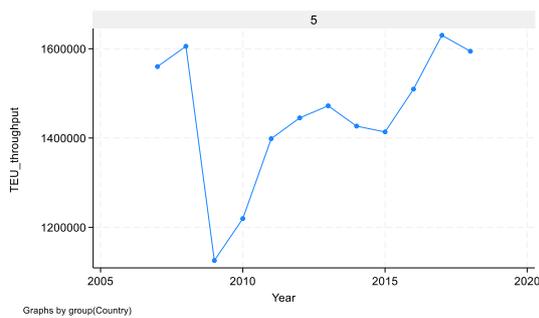


Figure B5 Port container throughput Finland

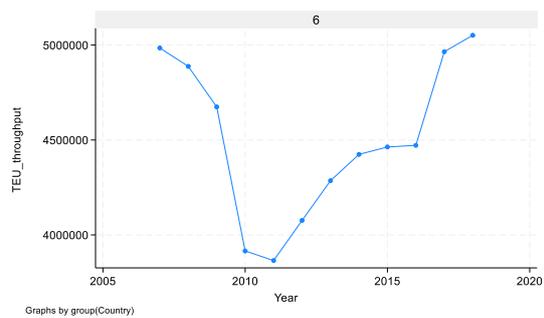


Figure B6 Port container throughput France

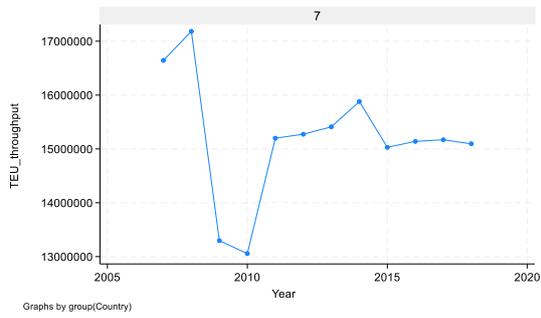


Figure B7 Port container throughput Germany

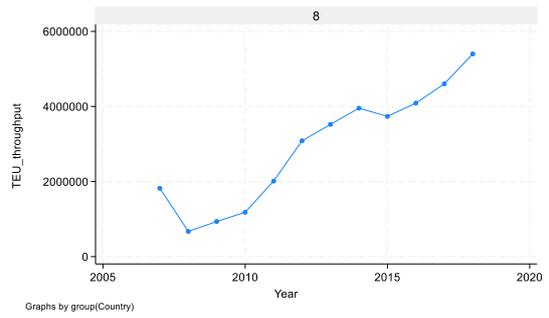


Figure B8 Port container throughput Greece

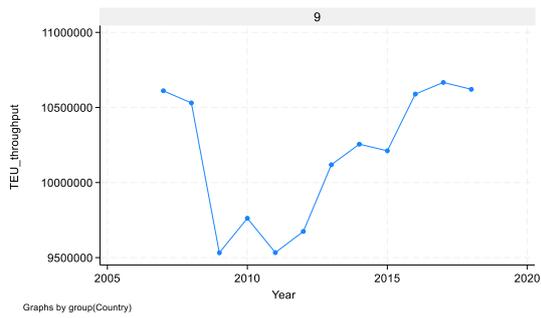


Figure B9 Port container throughput Italy

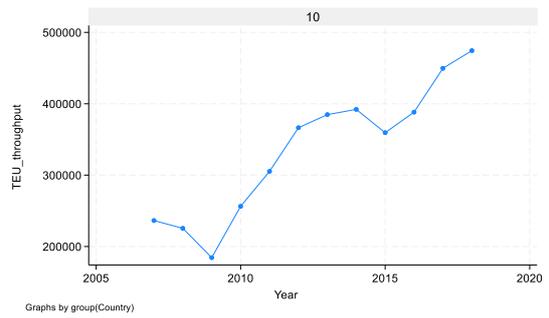


Figure B10 Port container throughput Latvia

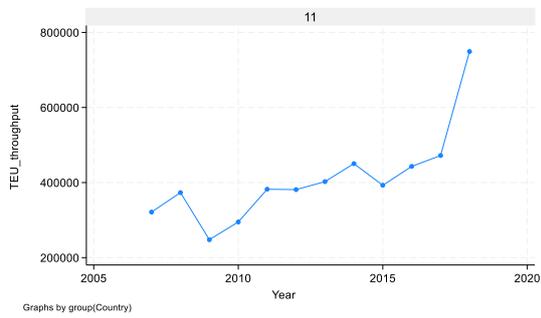


Figure B11 Port container throughput Lithuania

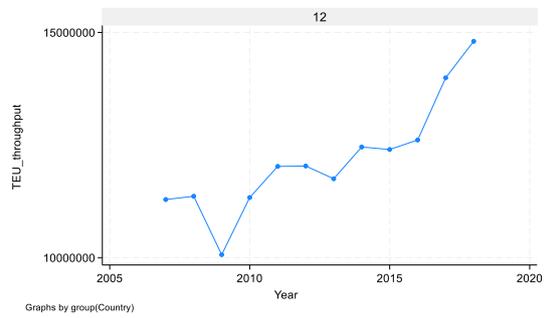


Figure B12 Port container throughput the Netherlands

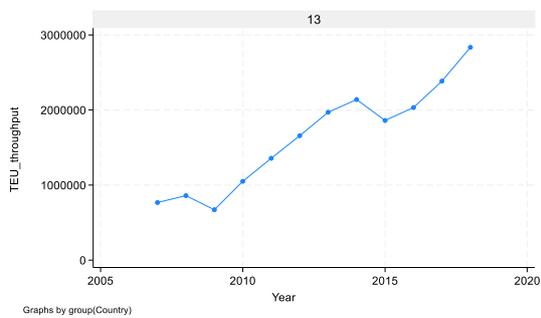


Figure B13 Port container throughput Poland

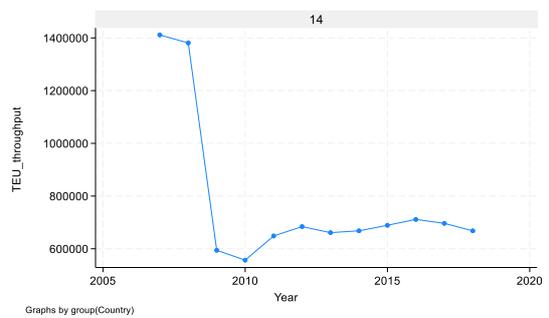


Figure B14 Port container throughput Romania

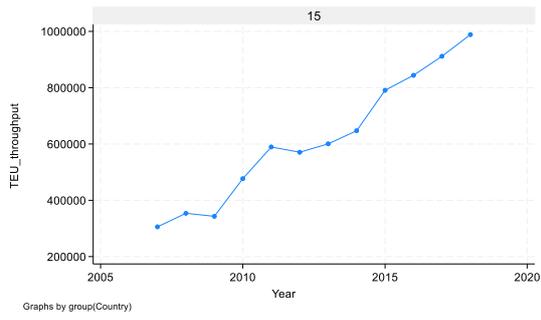


Figure B15 Port container throughput Slovenia

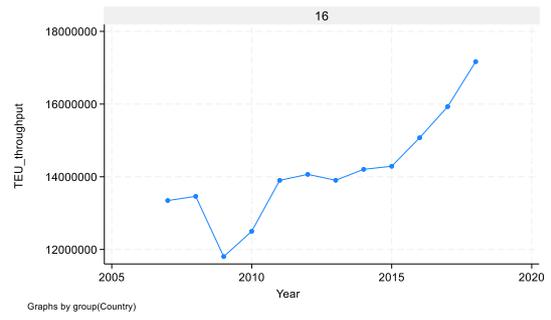


Figure B16 Port container throughput Spain

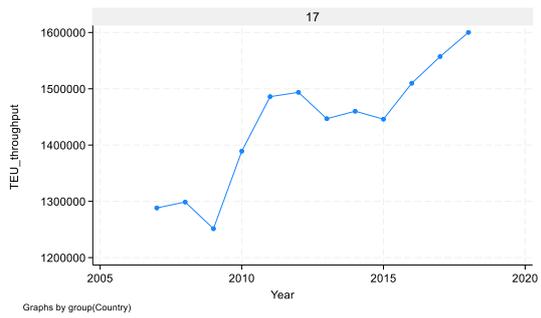


Figure B17 Port container throughput Sweden

Appendix C: Figures Rail Infrastructure Investments

Rail infrastructure investments in millions constant 2015 euros are displayed on the Y-axis, and the Year is displayed on the X-axis.

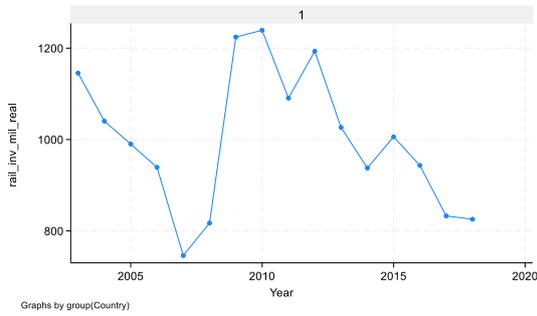


Figure C1 Rail infrastructure investments
Belgium

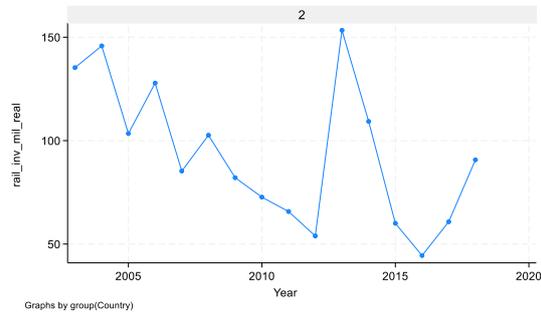


Figure C2 Rail infrastructure investments
Croatia

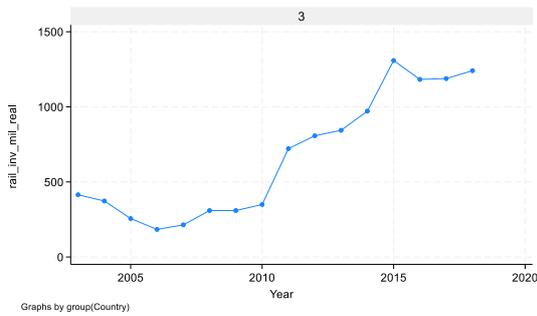


Figure C3 Rail infrastructure investments
Denmark

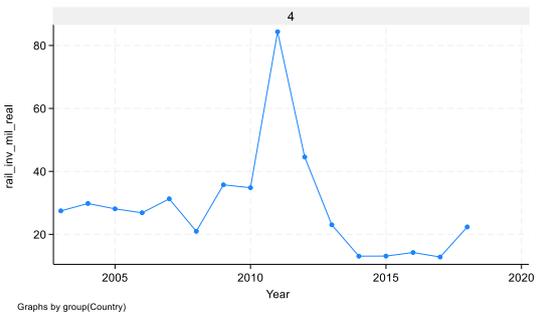


Figure C4 Rail infrastructure investments
Estonia

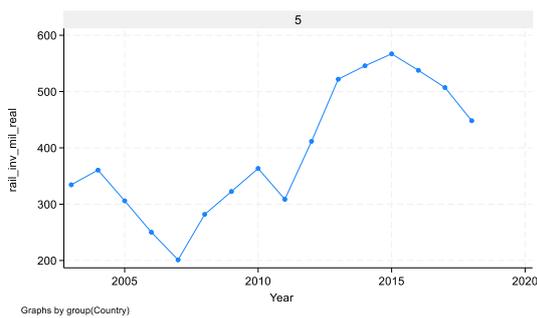


Figure C5 Rail infrastructure investments
Finland

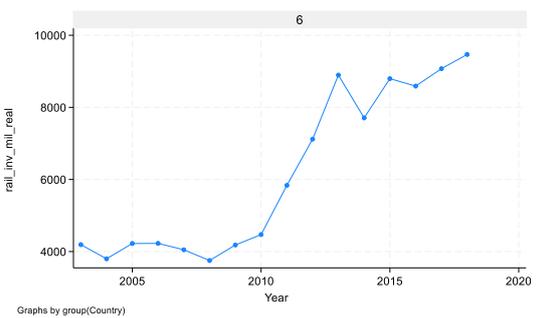


Figure C6 Rail infrastructure investments
France

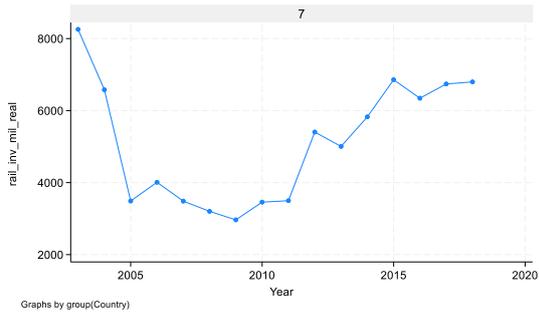


Figure C7 Rail infrastructure investments
Germany

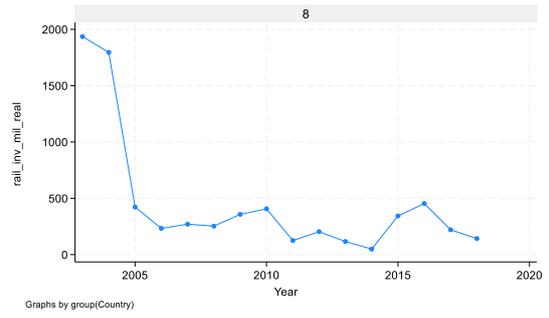


Figure C8 Rail infrastructure investments
Greece

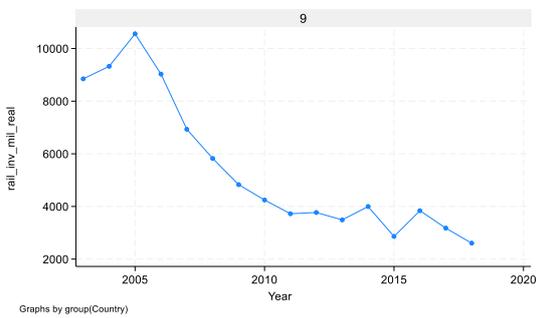


Figure C9 Rail infrastructure investments
Italy

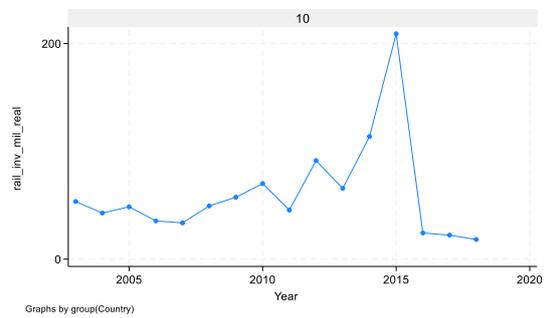


Figure C10 Rail infrastructure investments
Latvia

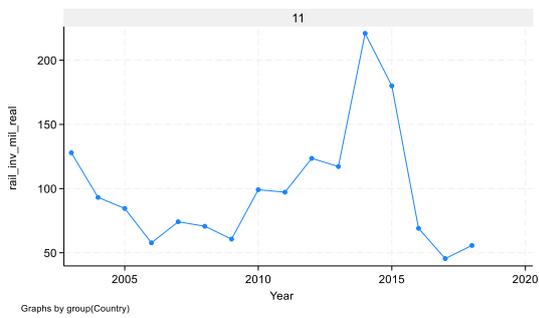


Figure C11 Rail infrastructure investments
Lithuania

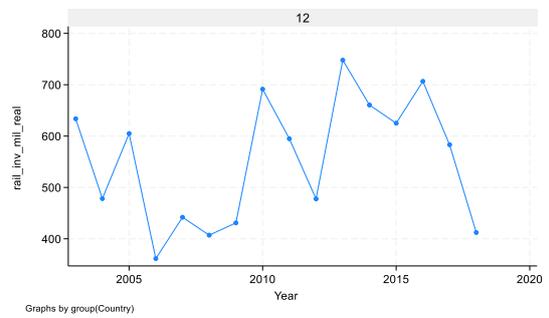
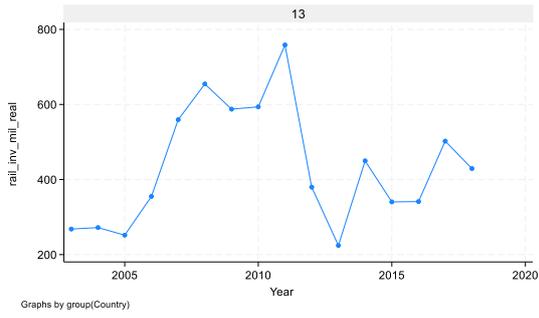
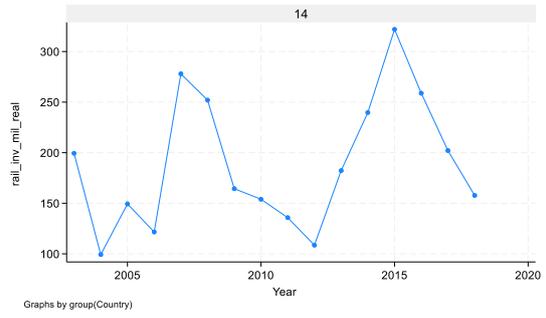


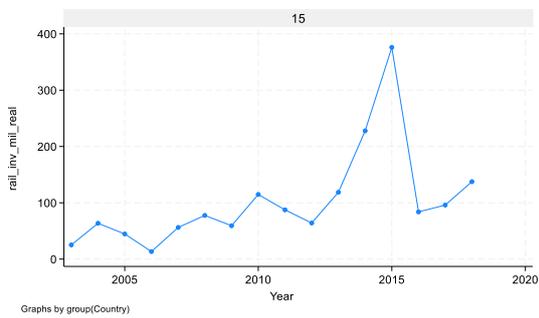
Figure C12 Rail infrastructure investments
the Netherlands



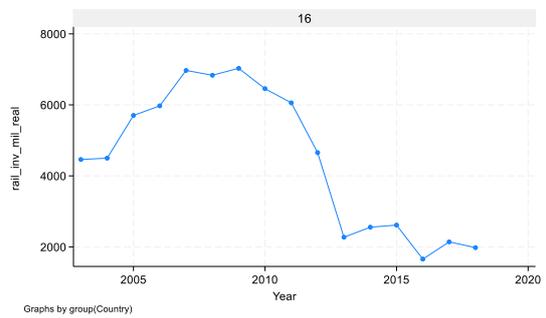
*Figure C13 Rail infrastructure investments
Poland*



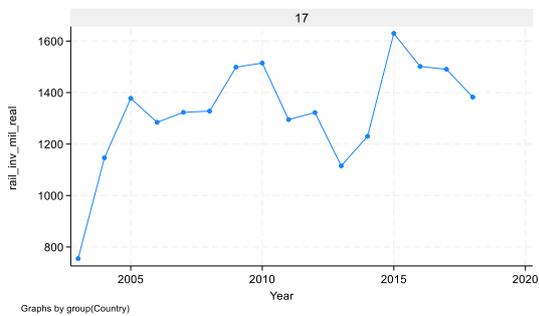
*Figure C14 Rail infrastructure investments
Romania*



*Figure C15 Rail infrastructure investments
Slovenia*



*Figure C16 Rail infrastructure investments
Spain*



*Figure C17 Rail infrastructure investments
Sweden*

Appendix D: Figures Road Infrastructure Investments

Road infrastructure investments in millions constant 2015 euros are displayed on the Y-axis, and the Year is displayed on the X-axis.

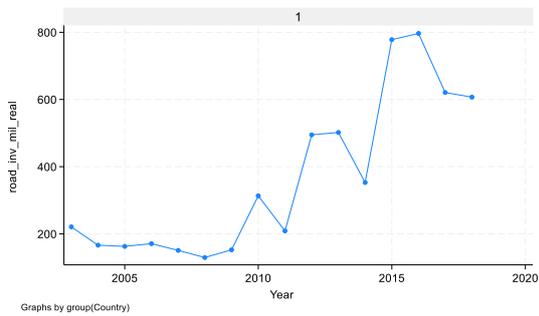


Figure D1 Road infrastructure investments
Belgium

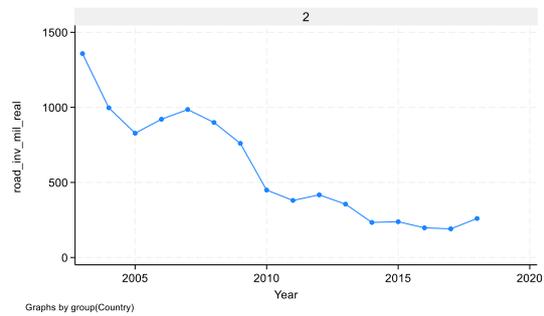


Figure D2 Road infrastructure investments
Croatia

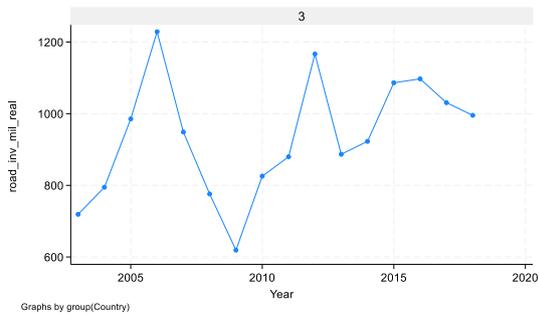


Figure D3 Road infrastructure investments
Denmark

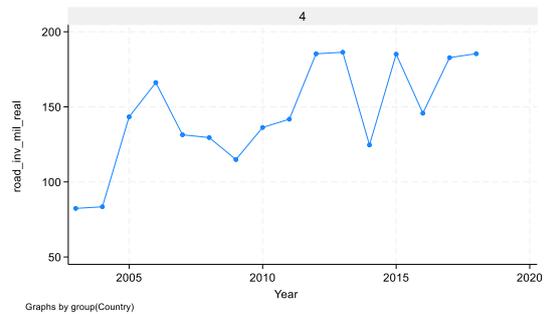


Figure D4 Road infrastructure investments
Estonia

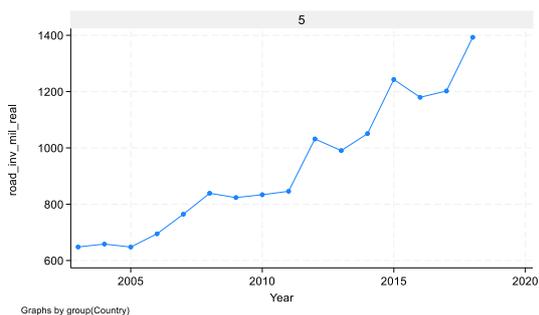


Figure D5 Road infrastructure investments
Finland

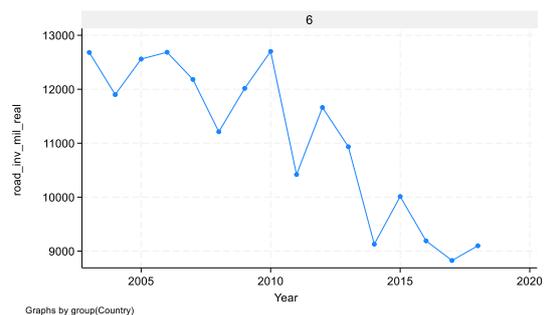


Figure D6 Road infrastructure investments
France

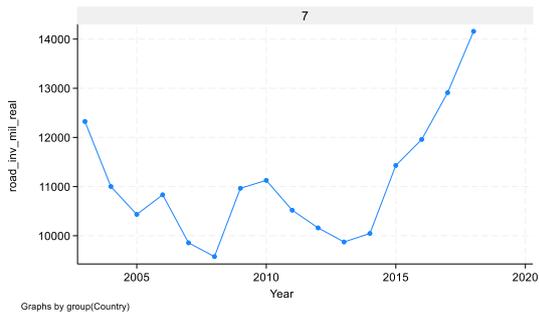


Figure D7 Road infrastructure investments
Germany

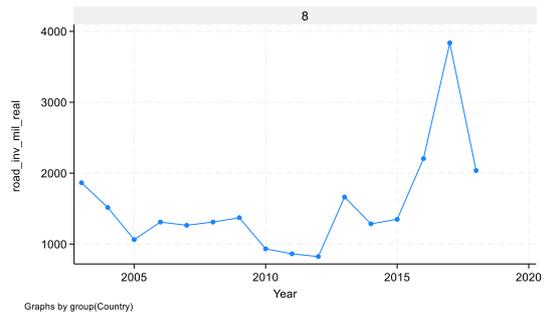


Figure D8 Road infrastructure investments
Greece

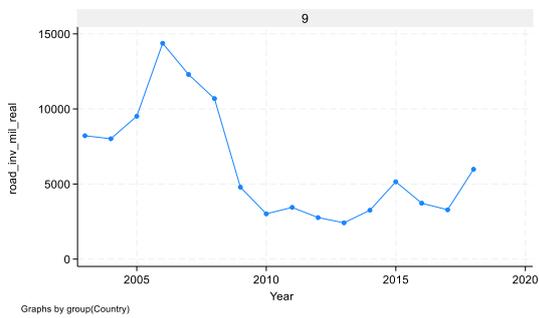


Figure D9 Road infrastructure investments
Italy

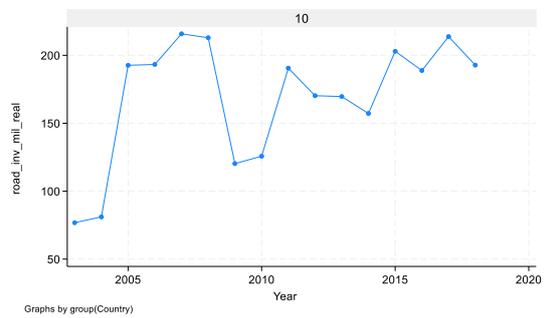


Figure D10 Road infrastructure investments
Latvia

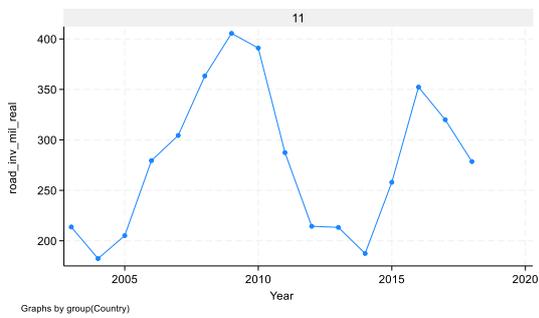


Figure D11 Road infrastructure investments
Italy

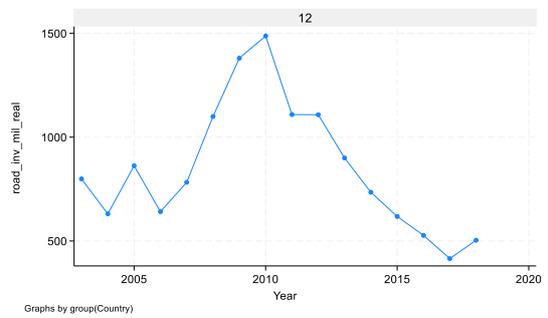


Figure D12 Road infrastructure investments the
Netherlands

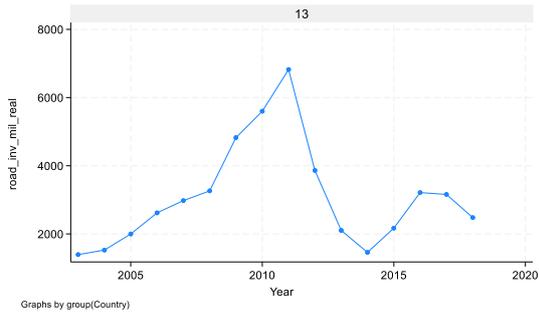


Figure D13 Road infrastructure investments
Poland

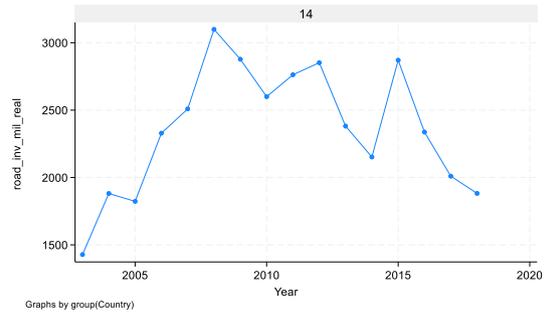


Figure D14 Road infrastructure investments
Romania

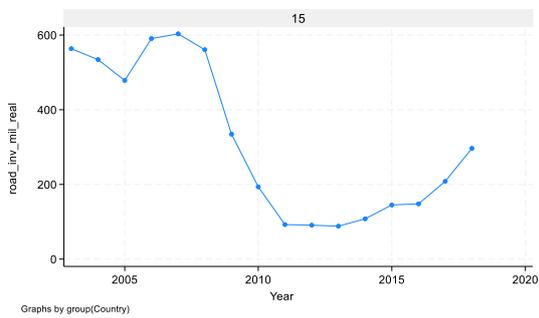


Figure D15 Road infrastructure investments
Slovenia

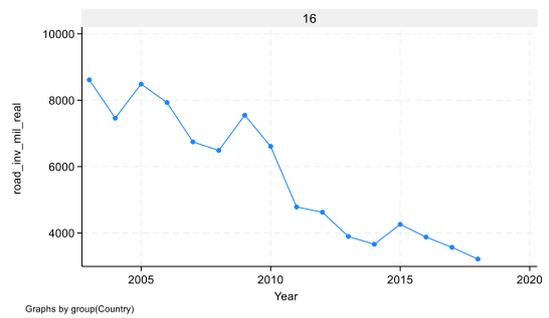


Figure D16 Road infrastructure investments
Spain

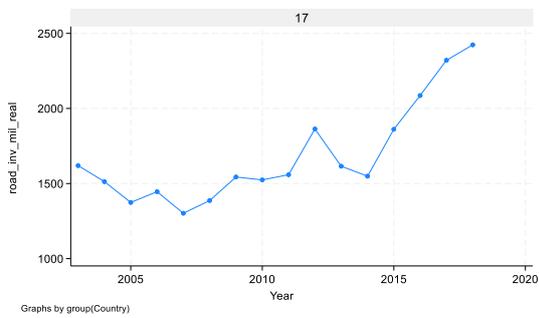


Figure D17 Road infrastructure investments
Sweden

Appendix E: Figures Inland Waterway Infrastructure Investments

Inland waterway infrastructure investments in millions constant 2015 euros are displayed on the Y-axis, and the Year is displayed on the X-axis.

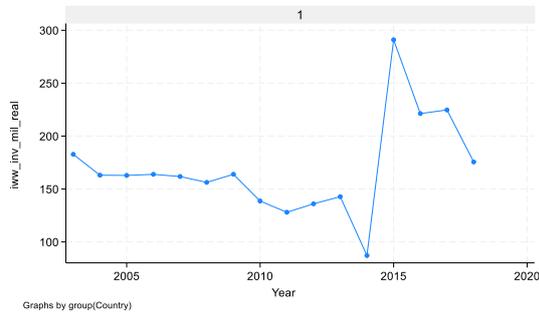


Figure E1 IWW infrastructure investments
Belgium

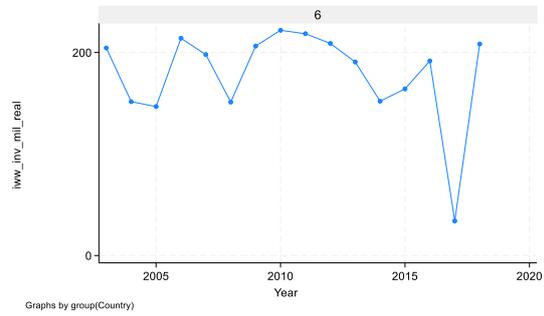


Figure E2 IWW infrastructure investments
France

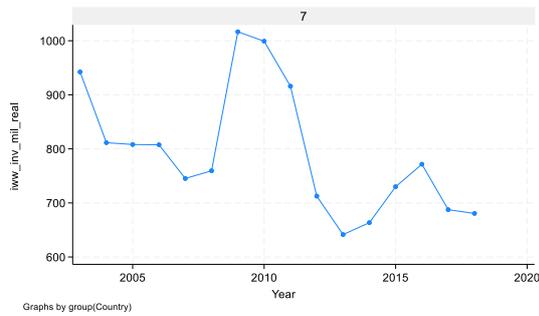


Figure E3 IWW infrastructure investments
Germany

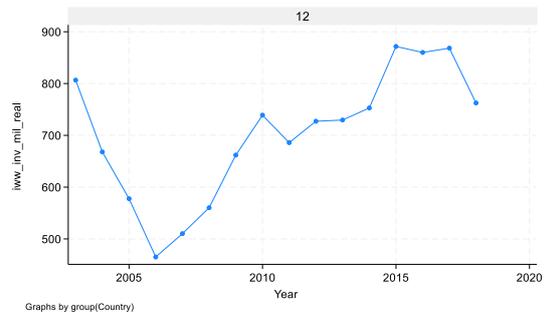


Figure E4 IWW infrastructure investments the
Netherlands

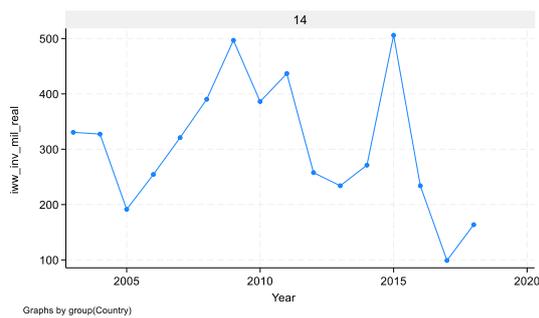


Figure E5 IWW infrastructure investments
Romania

Appendix F: Variance Inflation Factor Scores

Hypothesis 1: Rail Infrastructure Investments

Model 4 of Table G4 (Rail infrastructure investments – Fixed Effects – Lag 1)

```
. vif, uncentered
```

Variable	VIF	1/VIF
rail_inv_m~1	1.64	0.608105
GDP_per_ca~1	4.25	0.235332
unemployme~1	4.60	0.217566
Year		
2008	1.42	0.703071
2009	1.42	0.703624
2010	1.56	0.641683
2011	1.66	0.602153
2012	1.65	0.605416
2013	1.70	0.589177
2014	1.72	0.580608
2015	1.69	0.590193
2016	1.64	0.608249
2017	1.59	0.627137
2018	1.55	0.646692
Mean VIF	2.01	

Figure F1 VIF scores Hypothesis 1

Hypothesis 2: Road Infrastructure Investments

Model 4 of Table H6 (Road infrastructure investments – Fixed Effects – Lag 2)

```
. vif, uncentered
```

Variable	VIF	1/VIF
road_inv_m~2	1.65	0.604803
GDP_per_ca~2	4.00	0.250205
unemployme~2	4.42	0.226021
Year		
2008	1.46	0.687107
2009	1.42	0.705584
2010	1.41	0.707238
2011	1.54	0.649145
2012	1.64	0.611257
2013	1.63	0.614426
2014	1.67	0.597786
2015	1.70	0.589621
2016	1.67	0.598146
2017	1.62	0.615604
2018	1.58	0.634403
Mean VIF	1.96	

Figure F2 VIF scores Hypothesis 2

Hypothesis 3: Inland Waterway Infrastructure Investments

Model 3 of Table I7 (IWW infrastructure investments – Random Effects – Lag 2)

. vif, uncentered

Variable	VIF	1/VIF
iwv_inv_mi~2	3.74	0.267025
GDP_per_ca~2	6.20	0.161284
Year		
2008	1.37	0.731233
2009	1.39	0.719876
2010	1.40	0.713458
2011	1.43	0.700344
2012	1.43	0.699029
2013	1.43	0.697684
2014	1.40	0.713235
2015	1.39	0.716866
2016	1.40	0.712744
2017	1.47	0.681595
2018	1.45	0.691391
Mean VIF	1.96	

Figure F3 VIF scores Hypothesis 3

Appendix G: Models Rail Infrastructure Investments

Model 1: Only rail infrastructure investments included as independent variable.

Model 2: Rail infrastructure investments and control variables which have correlation coefficients below 0.7. However, some VIF scores are above 10.

Model 3: Rail infrastructure investments and control variables which have VIF scores below 10. All correlation coefficients are below 0.7, except for the correlation between rail infrastructure investments and export volume which is equal to 0.7173.

Model 4: Rail infrastructure investments and other control variables which have correlation coefficients below 0.7, and which have VIF scores below 10.

Model 5: Rail infrastructure investments and all control variables.

Table G1 below presents an overview of the number of observations per model.

Table G1 Number of observations models rail infrastructure investments

	Without Lags	Lag 1	Lag 2	Lag 3	Lag 4
Model 1	204	204	204	204	204
Model 2	204	204	204	204	204
Model 3	204	204	204	204	204
Model 4	204	204	204	204	204
Model 5	204	204	204	204	204

Notes: Number of observations per estimated model. 204 observations means that every country has twelve observations (17 countries * 12 years = 204 observations).

Table G2 Rail infrastructure investments relating to TEU throughput – Fixed Effects – No lags

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-191.6361***	-119.9096**	-196.872***	-125.795***	-115.3731
Road infr. inv.					-37.50933
GDP					3.899791
GDP per capita			-127.7176**	-73.17971	-192.4457***
Gov. exp. transport					14.50737
Population					-318003.9***
Exports			4.21012***		10.96404***
Imports					-10.96439***
Infrastructure quality		9756.303			3285.716
Unemployment		86529.44***	50632.07**	65553.68***	44723.19**
Year dummies	Included	Included	Included	Included	Included
Constant	4757682***	3383885***	7019358***	6323680***	1.38e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G3 Rail infrastructure investments relating to TEU throughput – Random Effects – No lags

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-177.0482***	-105.0137**	-215.8179***	-127.1598***	-192.2901**
Road infr. inv.					-13.85902
GDP					1.199794
GDP per capita			-28.20336	-1.169457	12.38831
Gov. exp. transport					34.66066
Population					48832.36
Exports			5.020442***		10.43086**
Imports					-8.213608*
Infrastructure quality		11745.14			11421.12
Unemployment		87362.56***	80905.48***	87097.48***	90858.43***
Year dummies	Included	Included	Included	Included	Included
Constant	4735584***	3215524**	3778663**	4112628**	-31692.39

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G4 Rail infrastructure investments relating to TEU throughput – Fixed Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-152.9171***	-87.79354*	-126.9402***	-76.94789*	-131.3544
Road infr. inv.					55.18205
GDP					-0.9272308
GDP per capita			-117.7432**	-71.19579	-166.6907***
Gov. exp. transport					39.83278
Population					-126626.2
Exports			3.812951***		11.56103***
Imports					-8.002077**
Infrastructure quality		1366.976			4532.498
Unemployment		83088.35***	55842.29***	63328.72***	37372.08*
Year dummies	Included	Included	Included	Included	Included
Constant	4712302***	3865429***	6588757***	6074633***	1.04e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G5 Rail infrastructure investments relating to TEU throughput – Random Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-137.7731***	-71.06168	-143.6636***	-78.16304*	-226.0316**
Road infr. inv.					62.22654
GDP					-2.652673
GDP per capita			-23.67489	2.301614	32.23891
Gov. exp. transport					59.41402
Population					119285.7**
Exports			4.738969***		9.679438***
Imports					-3.348515
Infrastructure quality		4240.804			10755.7
Unemployment		83990.35***	84944.95***	84857.96***	92712.27***
Year dummies	Included	Included	Included	Included	Included
Constant	4688048***	3627558***	3556174**	3869444**	-1056478

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G6 Rail infrastructure investments relating to TEU throughput – Fixed Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-122.6783***	-67.61547	-61.97457	-48.89196	-36.01389
Road infr. inv.					115.6741**
GDP					-6.08761**
GDP per capita			-77.5999	-61.67085	-53.91056
Gov. exp. transport					11.6087
Population					33946.59
Exports			1.400362		8.823185***
Imports					-3.596806
Infrastructure quality		-3307.436			-83.05057
Unemployment		76335.74***	59227.64***	60038.77***	44481.52**
Year dummies	Included	Included	Included	Included	Included
Constant	4674067***	4130137***	5802350***	5657138***	7086902**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G7 Rail infrastructure investments relating to TEU throughput – Random Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-107.6742**	-50.33107	-78.92611	-52.42367	-137.2695*
Road infr. inv.					108.4725*
GDP					-5.038923**
GDP per capita			8.695953	11.59171	84.4594**
Gov. exp. transport					31.38768
Population					199058.4***
Exports			2.682089**		5.840144
Imports					1.403416
Infrastructure quality		-124.6446			8935.874
Unemployment		77162.05***	86462.51***	80229.02***	95882.76***
Year dummies	Included	Included	Included	Included	Included
Constant	4648789***	3869072***	3000827**	3526968**	-2516403*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G8 Rail infrastructure investments relating to TEU throughput – Fixed Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-99.02269**	-47.10819	-34.39704	-33.49491	31.59807
Road infr. inv.					50.33407
GDP					-7.025144**
GDP per capita			-62.08233	-58.47536	-18.00572
Gov. exp. transport					28.57064
Population					93001.02
Exports			0.3040404		8.601952**
Imports					-4.334992
Infrastructure quality		1193.28			1100.404
Unemployment		67995.22***	54127.84***	54053.52***	41045.88*
Year dummies	Included	Included	Included	Included	Included
Constant	4642965***	3816920***	5563958***	5532773***	5409195*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G9 Rail infrastructure investments relating to TEU throughput – Random Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-82.53704*	-29.22553	-44.42625	-38.70465	-51.03295
Road infr. inv.					37.99567
GDP					-5.42144**
GDP per capita			19.15287	15.11018	97.61677***
Gov. exp. transport					43.17391
Population					220060.9***
Exports			1.610834		5.208428
Imports					0.9847465
Infrastructure quality		4234.189			11737.38
Unemployment		68641.47***	79351.01***	72865.5***	86820.08***
Year dummies	Included	Included	Included	Included	Included
Constant	4613734***	3565911***	2951121**	3445516**	-2964363**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G10 Rail infrastructure investments relating to TEU throughput – Fixed Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-40.45737	2.614597	25.29934	25.03188	119.374*
Road infr. inv.					39.41869
GDP					-4.515978
GDP per capita			-104.1779*	-103.7152**	-81.52361
Gov. exp. transport					10.51957
Population					137283.2
Exports			0.0331566		11.09621***
Imports					-9.894537*
Infrastructure quality		5754.266			3336.186
Unemployment		62255.55***	40594.93**	40575.31**	11813.25
Year dummies	Included	Included	Included	Included	Included
Constant	4543096***	3455542***	6656243***	6651678***	5164943*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table G11 Rail infrastructure investments relating to TEU throughput – Random Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
Rail infr. inv.	-21.63159	20.48148	24.73631	16.75208	76.05624
Road infr. inv.					-4.695886
GDP					-5.100709**
GDP per capita			-7.366043	-14.52206	94.36359***
Gov. exp. transport					31.41549
Population					223185.5***
Exports			1.189839		7.728206*
Imports					-2.57487
Infrastructure quality		8173.979			13004.13
Unemployment		62499.25***	67053.62***	60844.38***	67637.29***
Year dummies	Included	Included	Included	Included	Included
Constant	4507868***	3226557**	3735365**	4221104***	-2768566**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Appendix H: Models Road Infrastructure Investments

Model 1: Only road infrastructure investments included as independent variable.

Model 2: Road infrastructure investments and control variables which have correlation coefficients below 0.7. However, some VIF scores are above 10.

Model 3: Road infrastructure investments and control variables which have VIF scores below 10. All correlation coefficients are below 0.7, except for the correlation between road infrastructure investments and export volume which is equal to 0.7929.

Model 4: Road infrastructure investments and other control variables which have correlation coefficients below 0.7, and which have VIF scores below 10.

Model 5: Road infrastructure investments and all control variables.

Table H1 below presents an overview of the number of observations per model.

Table H1 Number of observations models road infrastructure investments

	Without Lags	Lag 1	Lag 2	Lag 3	Lag 4
Model 1	204	204	204	204	204
Model 2	204	204	204	204	204
Model 3	204	204	204	204	204
Model 4	204	204	204	204	204
Model 5	204	204	204	204	204

Notes: Number of observations per estimated model. 204 observations means that every country has twelve observations (17 countries * 12 years = 204 observations).

Table H2 Road infrastructure investments relating to TEU throughput – Fixed Effects – No lags

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-66.33126	-31.8152	-46.33077	-38.54114	-37.50933
Rail infr. inv.					-115.3731
GDP					3.899791
GDP per capita			-143.4386***	-94.66932*	-192.4457***
Gov. exp. transport					14.50737
Population					-318003.9***
Exports			2.9776***		10.96404***
Imports					-10.96439***
Infrastructure quality		15133.13*			3285.716
Unemployment		93837.23***	57401.03***	67466.94***	44723.19**
Year dummies	Included	Included	Included	Included	Included
Constant	4678167***	2875461***	7590816***	6860395***	1.38e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H3 Road infrastructure investments relating to TEU throughput – Random Effects – No lags

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-51.79746	-18.91137	-47.22432	-35.35786	-13.85902
Rail infr. inv.					-192.2901**
GDP					1.199794
GDP per capita			-10.88381	-17.26232	12.38831
Gov. exp. transport					34.66066
Population					48832.36
Exports			4.151195***		10.43086**
Imports					-8.213608*
Infrastructure quality		16772.07**			11421.12
Unemployment		93932.82***	99640.07***	90721.1***	90858.43***
Year dummies	Included	Included	Included	Included	Included
Constant	4631984***	2718253**	3201848**	4470661**	-31692.39

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H4 Road infrastructure investments relating to TEU throughput – Fixed Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-5.307562	29.88507	40.68867	37.59174	55.18205
Rail infr. inv.					-131.3544
GDP					-0.9272308
GDP per capita			-150.8153***	-102.558*	-166.6907***
Gov. exp. transport					39.83278
Population					-126626.2
Exports			3.071749***		11.56103***
Imports					-8.002077**
Infrastructure quality		9102.375			4532.498
Unemployment		90704.56***	57055.06***	62658.16***	37372.08*
Year dummies	Included	Included	Included	Included	Included
Constant	4485625***	3013685***	7332178***	6697877***	1.04e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H5 Road infrastructure investments relating to TEU throughput – Random Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	5.566069	39.92813	32.46604	34.62949	62.22654
Rail infr. inv.					-226.0316**
GDP					-2.652673
GDP per capita			-21.86122	-23.2836	32.23891
Gov. exp. transport					59.41402
Population					119285.7**
Exports			4.162361***		9.679438***
Imports					-3.348515
Infrastructure quality		11142.31			10755.7
Unemployment		90859.96***	97798.34***	85722.15***	92712.27***
Year dummies	Included	Included	Included	Included	Included
Constant	4448263***	2833118**	3202855**	4328659**	-1056478

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H6 Road infrastructure investments relating to TEU throughput – Fixed Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	3.828014	45.15587	62.93905*	59.59287	115.6741**
Rail infr. inv.					-36.01389
GDP					-6.08761**
GDP per capita			-117.1669**	-98.40403*	-53.91056
Gov. exp. transport					11.6087
Population					33946.59
Exports			1.23569		8.823185***
Imports					-3.596806
Infrastructure quality		3621.705			-83.05057
Unemployment		84045.62***	57616.01***	58395.88***	44481.52**
Year dummies	Included	Included	Included	Included	Included
Constant	4455734***	3320781***	6613004***	6388322***	7086902**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H7 Road infrastructure investments relating to TEU throughput – Random Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	15.20247	55.79495	59.18766	55.62673	108.4725*
Rail infr. inv.					-137.2695*
GDP					-5.038923**
GDP per capita			-2.725939	-20.14681	84.4594**
Gov. exp. transport					31.38768
Population					199058.4***
Exports			2.593778**		5.840144
Imports					1.403416
Infrastructure quality		5780.444			-8935.874
Unemployment		84351.11***	94073.09***	79874.77***	95882.76***
Year dummies	Included	Included	Included	Included	Included
Constant	4421103***	3133358**	2943714**	4119436**	-2516403*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H8 Road infrastructure investments relating to TEU throughput – Fixed Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-29.32608	12.85244	24.88666	23.6564	50.33407
Rail infr. inv.					31.59807
GDP					-7.025144**
GDP per capita			-82.3069	-77.73821	-18.00572
Gov. exp. transport					28.57064
Population					93001.02
Exports			0.3229875		8.601952**
Imports					-4.334992
Infrastructure quality		4282.684			1100.404
Unemployment		71974.74***	53579.56***	53519.98***	41045.88*
Year dummies	Included	Included	Included	Included	Included
Constant	4551819***	3441808***	5959353***	5912086***	5409195*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H9 Road infrastructure investments relating to TEU throughput – Random Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-16.69755	24.7377	29.48239	22.38206	37.99567
Rail infr. inv.					-51.03295
GDP					-5.42144**
GDP per capita			13.24199	-6.796341	97.61677***
Gov. exp. transport					43.17391
Population					220060.9***
Exports			1.802263*		5.208428
Imports					0.9847465
Infrastructure quality		6408.802			11737.38
Unemployment		72398.29***	84263.46***	71858.06***	86820.08***
Year dummies	Included	Included	Included	Included	Included
Constant	4515461***	3254532**	2854358**	3892649**	-2964363**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H10 Road infrastructure investments relating to TEU throughput – Fixed Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-44.44408	-4.633764	10.29323	10.35403	39.41869
Rail infr. inv.					119.374*
GDP					-4.515978
GDP per capita			-98.86512*	-98.99067*	-81.52361
Gov. exp. transport					10.51957
Population					137283.2
Exports			-0.0093021		11.09621***
Imports					-9.894537*
Infrastructure quality		5551.419			3336.186
Unemployment		61734.37***	41124.01**	41131.53**	11813.25
Year dummies	Included	Included	Included	Included	Included
Constant	4605483***	3494803***	6540621***	6541726***	5164943*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table H11 Road infrastructure investments relating to TEU throughput – Random Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
Road infr. inv.	-31.36452	7.07812	18.02596	8.558978	-4.695886
Rail infr. inv.					76.05624
GDP					-5.100709**
GDP per capita			1.919608	-23.16964	94.36359***
Gov. exp. transport					31.41549
Population					223185.5***
Exports			1.347073		7.728206*
Imports					-2.57487
Infrastructure quality		7277.333			13004.13
Unemployment		62201.86***	69971.51***	58594.37***	67637.29***
Year dummies	Included	Included	Included	Included	Included
Constant	4564843***	3310861**	3432779**	4465735***	-2768566**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Appendix I: Models IWW Infrastructure Investments

Model 1: Only IWW infrastructure investments included as independent variable.

Model 2: IWW infrastructure investments and all control variables which have correlation coefficients below 0.7. However, some VIF scores are above 10.

Model 3: IWW infrastructure investments and control variables which have correlation coefficients below 0.7, and which have VIF scores below 10.

Model 4: IWW infrastructure investments and other control variables which have correlation coefficients below 0.7, and which have VIF scores below 10.

Model 5: IWW infrastructure investments and all control variables.

Table I1 below presents an overview of the number of observations per model.

Table I1 Number of observations models inland waterway infrastructure investments

	Without Lags	Lag 1	Lag 2	Lag 3	Lag 4
Model 1	60	60	60	60	60
Model 2	60	60	60	60	60
Model 3	60	60	60	60	60
Model 4	60	60	60	60	60
Model 5	60	60	60	60	60

Notes: Number of observations per estimated model. 60 observations means that every country has twelve observations (5 countries * 12 years = 60 observations).

Table 12 IWW infrastructure investments relating to TEU throughput – Fixed Effects – Lag 0

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	2103.228*	1132.273	2329.71*	1182.292	-1089.158
Rail infr. inv.					-352.1677**
Road infr. inv.					-343.8043***
GDP					-15.74701***
GDP per capita		611.8512*	81.86567		243.4765
Gov. exp. transport					173.7981*
Population					302797.2
Exports		0.4174395		3.077289*	44.36033***
Imports					-30.37138***
Infr. quality					-13606.62
Unemployment		495806.1**		244982.1*	244668.7*
Year dummies	Included	Included	Included	Included	Included
Constant	8103242***	-1.57e+07	5277688	5065444***	-1215661

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 13 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 0

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	2308.595**	4612.381***	3077.987***	1306.039	-3595.062***
Rail infr. inv.					-510.6082***
Road infr. inv.					-361.2312***
GDP					-15.16976***
GDP per capita		247.0844***	247.3557***		347.6409***
Gov. exp. transport					92.22891
Population					421818.3***
Exports		2.296038***		3.349768**	43.14338***
Imports					-26.72662***
Infr. quality					-22149.46
Unemployment		-566836.7***		244148.3**	449742.6***
Year dummies	Included	Included	Included	Included	Included
Constant	8023727***	1536971	-546577.4	4873268	-8600004***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 14 IWW infrastructure investments relating to TEU throughput – Fixed Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	3550.314***	2940.998***	3782.173***	3039.558***	1556.996
Rail infr. inv.					-124.1454
Road infr. inv.					-280.4266*
GDP					-13.05664
GDP per capita		420.1302	91.95633		418.7897
Gov. exp. transport					76.88702
Population					152640.5
Exports		1.46278		3.298163*	24.57028**
Imports					-13.88525
Infr. quality					-12236.77
Unemployment		339325.3**		179475.3	238581.1
Year dummies	Included	Included	Included	Included	Included
Constant	7564926***	-9270155	4494720	4633164***	-1384975

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 15 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 1

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	3688.157***	6352.994***	4344.699***	3118.719***	-2119.458
Rail infr. inv.					-470.255***
Road infr. inv.					-339.7682**
GDP					-15.13215**
GDP per capita		244.6284***	231.8025***		363.5424***
Gov. exp. transport					17.14605
Population					445593.2**
Exports		1.991758**		3.590267**	34.21912***
Imports					-15.81358
Infr. quality					-20073.67
Unemployment		-345463.5*		183893.1*	447478.9***
Year dummies	Included	Included	Included	Included	Included
Constant	7512409***	271116.2	-254393.4	4417020	-9484421**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 16 IWW infrastructure investments relating to TEU throughput – Fixed Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	4788.012***	4530.681***	5107.626***	4605.442***	3061.329*
Rail infr. inv.					126.2182
Road infr. inv.					-18.75106
GDP					-17.31573**
GDP per capita		446.1253*	92.99987		713.8529**
Gov. exp. transport					-54.09707
Population					67371.57
Exports		-0.9733028		0.7300082	-5.520555
Imports					20.76644*
Infr. quality					-6898.849
Unemployment		216455.2		50571.37	216904.7
Year dummies	Included	Included	Included	Included	Included
Constant	7110922***	-8179012	4061340	6413502***	-1532340

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 17 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 2

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	4912.59***	7927.523***	5732.436***	5254.308***	-1239.777
Rail infr. inv.					-539.6663**
Road infr. inv.					-246.5259
GDP					-20.69342**
GDP per capita		249.7293***	219.8669***		399.6227***
Gov. exp. transport					3.028077
Population					584107.5**
Exports		1.475794		3.387564**	21.93175**
Imports					5.331283
Infr. quality					-17053.89
Unemployment		-172075		114817	447847***
Year dummies	Included	Included	Included	Included	Included
Constant	7063916***	-1209228	-170027.4	4374632**	-1.23e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 18 IWW infrastructure investments relating to TEU throughput – Fixed Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	4338.214***	4042.902***	4728.178***	3699.541***	3181.824*
Rail infr. inv.					-47.64717
Road infr. inv.					-11.98143
GDP					-15.55055**
GDP per capita		551.4801**	97.40638		796.2808***
Gov. exp. transport					-24.599
Population					313475.1
Exports		-1.041751		0.9950634	-6.2991
Imports					19.72581*
Infr. quality					-18383.62
Unemployment		299256.1**		127098.2	190723
Year dummies	Included	Included	Included	Included	Included
Constant	7077062***	-1.18e+07	3889190	5900926***	-1.42e+07

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 19 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 3

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	4502.328***	8856.02***	5529.707***	4184.78***	257.6366
Rail infr. inv.					-270.3196
Road infr. inv.					-238.9116
GDP					-20.82398**
GDP per capita		256.4427***	231.6543***		476.0082***
Gov. exp. transport					-86.00447
Population					641690.2**
Exports		1.105173		2.587146	23.44941**
Imports					0.7502064
Infr. quality					-20982.94
Unemployment		-31948.08		168860.5	464467.3**
Year dummies	Included	Included	Included	Included	Included
Constant	7007435***	-3041010	-616448.1	4652078**	-1.36e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 110 IWW infrastructure investments relating to TEU throughput – Fixed Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	2746.412*	2602.333*	2983.742*	1768.572	1368.375
Rail infr. inv.					202.1012
Road infr. inv.					344.8208
GDP					-16.60624**
GDP per capita		465.9307**	53.16815		344.1767
Gov. exp. transport					4.66121
Population					489390
Exports		-0.4761252		0.9913038	10.38118
Imports					3.648272
Infr. quality					12683.74
Unemployment		318168.6**		192043.1	50137.26
Year dummies	Included	Included	Included	Included	Included
Constant	7562706***	-8608496	5833421	6241418***	-1.03e+07

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table 111 IWW infrastructure investments relating to TEU throughput – Random Effects – Lag 4

	Model 1	Model 2	Model 3	Model 4	Model 5
IWW infr. inv.	3036.872**	9412.179***	4271.825***	2116.364	2141.065
Rail infr. inv.					449.6484**
Road infr. inv.					84.13386
GDP					-27.00946***
GDP per capita		260.7837***	234.8037***		422.3475***
Gov. exp. transport					-132.4735
Population					701407.9***
Exports		0.542091		1.772212	26.56187**
Imports					5.692576
Infr. quality					46306.95
Unemployment		89357.14		212659.1*	367398.5*
Year dummies	Included	Included	Included	Included	Included
Constant	7419415***	-4505970*	-309708.6	5597860**	-1.69e+07***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Appendix J: Hausman Tests

Hypothesis 1:

	Coefficients		(b-B) Difference	sqrt(diag(V _b -V _B)) Std. err.
	(b) fe_rail_mo~4	(B) re_rail_mo~4		
rail_inv_m~1	-76.94789	-78.16304	1.21515	6.113462
GDP_per_ca~1	-71.19579	2.301614	-73.49741	30.18176
unemploye~1	63328.72	84857.96	-21529.25	8307.065
Year				
2008	149115.6	100385.3	48730.3	21050.4
2009	-493105.4	-543020.5	49915.1	21972.83
2010	-640597.8	-629979.5	-10618.26	4783.309
2011	-355178.3	-403794.2	48615.89	19029.61
2012	-199678.5	-275104.8	75426.31	30059.28
2013	-189269.4	-263926.1	74656.69	29000.67
2014	-50316.73	-128868.8	78552.06	30751.85
2015	-61202.54	-156735.1	95532.53	37691.43
2016	184930.6	68176.55	116754	46250.94
2017	546655.8	408518.6	138137.2	55875.91
2018	924310.3	749502.2	174808.1	71419.45

b = Consistent under H₀ and H_a; obtained from xtreg.
 B = Inconsistent under H_a, efficient under H₀; obtained from xtreg.

Test of H₀: Difference in coefficients not systematic

chi2(3) = (b-B)'[(V_b-V_B)⁻¹](b-B)
 = 13.11
 Prob > chi2 = 0.0044
 (V_b-V_B is not positive definite)

Figure J1 Hausman test Hypothesis 1

The P-value is equal to 0.0044. Therefore, we reject the null hypothesis at a one percent significance level and prefer the FE model.

Hypothesis 2:

	Coefficients		(b-B) Difference	sqrt(diag(V _b -V _B)) Std. err.
	(b) fe_road_mo~4	(B) re_road_mo~4		
road_inv_m~2	59.59287	55.62673	3.966147	6.301532
GDP_per_ca~2	-98.40403	-20.14681	-78.25722	30.21501
unemploye~2	58395.88	79874.77	-21478.89	7908.691
Year				
2008	168014.9	111678.9	56335.97	20970.12
2009	-297511.9	-408232.9	110721	43271.11
2010	-124946.2	-237370.8	112424.5	44356.11
2011	-118657.7	-162704.9	44047.23	16990.4
2012	-38714.6	-144350.9	105636.3	40588.13
2013	89587.15	-45767.18	135354.3	52860.54
2014	202665.5	68552.59	134112.9	52472.67
2015	129466.3	-9267.866	138734.1	55013.5
2016	349633.8	191491.8	158142	63246.56
2017	692562.3	512285.3	180277	70580.79
2018	1057369	853016.2	204353.1	80370.61

b = Consistent under H₀ and H_a; obtained from xtreg.
 B = Inconsistent under H_a, efficient under H₀; obtained from xtreg.

Test of H₀: Difference in coefficients not systematic

chi2(3) = (b-B)'[(V_b-V_B)⁻¹](b-B)
 = 11.69
 Prob > chi2 = 0.0085
 (V_b-V_B is not positive definite)

Figure J2 Hausman test Hypothesis 2

The P-value is equal to 0.0085. Therefore, we reject the null hypothesis at a one percent significance level and prefer the FE model.

Hypothesis 3:

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
	(b) fe_iww_mod~3	(B) re_iww_mod~3		
iww_inv_mi~2	5107.626	5732.436	-624.8093	440.9525
GDP_per_ca~2	92.99987	219.8669	-126.867	104.9708
2009	-1482632	-1736039	253407.3	208537.9
2010	-1496144	-1805964	309819.2	253361.4
2011	-1352375	-1557044	204669	155962.6
2012	-1328430	-1599873	271442.5	211878.2
2013	-1314822	-1671175	356353.6	283897.5
2014	-620922.4	-925395.9	304473.4	248379.4
2015	-650057.9	-940173.2	290115.3	238851.6
2016	-555657.9	-899696.2	344038.3	283736.7
2017	-774323.9	-1251140	476815.8	379672.6
2018	-223384.2	-721721.2	498337	403506.7

b = Consistent under H0 and Ha; obtained from xtreg.
 B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
 = 2.05
 Prob > chi2 = 0.3596
 (V_b-V_B is not positive definite)

Figure J3 Hausman test Hypothesis 3

The P-value is equal to 0.3596. Therefore, we can not reject the null hypothesis at a ten percent significance level and prefer the RE model.

Appendix K: Robustness Checks

Robustness Check 1

Table K1 Descriptive statistics sample Robustness Check 1 – Hypothesis 1, 2 and 4

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	108	7793550	5573539	130740	1.72e+07
Rail infrastructure inv. (millions 2015 euros)	108	2464.033	2721.166	44.46115	9468.645
Road infrastructure inv. (millions 2015 euros)	108	3916.539	4317.97	88.15524	14157.56
Rail_iww (millions 2015 euros)	108	1483.187	2585.639	0	9468.645
Road_iww (millions 2015 euros)	108	2553.104	4501.578	0	14157.56
IWW dummy	108	0.4444444	0.4992206	0	1
GDP per capita (2015 US dollars)	108	30366.7	10634.29	11703.98	47826.82
Unemployment rate (%)	108	10.61781	5.948006	3.384	27.686

Notes: Descriptive statistics of the sample of the first Robustness Check to test Hypothesis 1, 2 and 4.

Table K2 Descriptive statistics sample Robustness Check 1 – Hypothesis 3

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	48	1.05e+07	4044195	3865087	1.72e+07
IWW infr. inv.	48	463.0303	306.4517	34.07733	1016.624
GDP per capita (2015 US dollars)	48	40559.06	3412.552	35129.36	47826.82

Notes: Descriptive statistics of the sample of the first Robustness Check to test Hypothesis 3.

Table K3 Robustness Check 1 - Hypothesis 1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-70.50414
Road infr. inv.	
GDP	
GDP per capita	30.63162
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	119352.6***
Year dummies	Included
Constant	6007187*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K4 Robustness Check 1 – Hypothesis 2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	79.91508
Rail infr. inv.	
GDP	
GDP per capita	-4.797641
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	121801.2***
Year dummies	Included
Constant	6369494**

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K5 Robustness Check 1 – Hypothesis 3 - Random Effects Lag 2

	Model 3
IWW infr. inv.	6299.628***
Road infr. inv.	
Rail infr. inv.	
GDP	
GDP per capita	176.3023
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	
Year dummies	Included
Constant	1462254

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K6 Robustness Check 1 – Hypothesis 4.1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-49.47213
IWW dummy	Omitted
Rail*IWW	-49.42619
GDP per capita	34.11713
Unemployment	118935.2***
Year dummies	Included
Constant	5899593*

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K7 Robustness Check 1 – Hypothesis 4.2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	70.97889
IWW dummy	Omitted
Road*IWW	82.2606
GDP per capita	-0.1580972
Unemployment	122550.3***
Year dummies	Included
Constant	6051513*

Notes: *** P<0.01 ** P<0.05 * P<0.10

Robustness Check 2

Table K8 Descriptive statistics sample Robustness Check 2 – Hypothesis 1, 2 and 4

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	170	4550228	5310668	130740	1.72e+07
Rail infrastructure inv. (millions 2015 euros)	170	1516.85	2254.546	12.80381	9468.644
Road infrastructure inv. (millions 2015 euros)	170	2595.643	3402.009	88.15524	14157.56
Rail_iww (millions 2015 euros)	170	854.1569	2141.226	0	9468.644
Road_iww (millions 2015 euros)	170	1502.776	3513.241	0	14157.56
IWW dummy	170	0.2941176	0.4569912	0	1
GDP per capita (2015 US dollars)	170	28409.41	14665.4	7657.542	56563.49
Unemployment rate (%)	170	10.11245	5.194853	3.384	27.686

Notes: Descriptive statistics of the sample of the second Robustness Check to test Hypothesis 1, 2 and 4.

Table K9 Descriptive statistics sample Robustness Check 2 – Hypothesis 3

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	50	8482627	5322291	556694	1.59e+07
IWW infr. inv.	50	441.3658	295.3561	34.07733	1016.624
GDP per capita (2015 US dollars)	50	34286.54	13233.76	7657.542	47826.82

Notes: Descriptive statistics of the sample of the second Robustness Check to test Hypothesis 3.

Table K10 Robustness Check 2 – Hypothesis 1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-118.4528**
Road infr. inv.	
GDP	
GDP per capita	-80.13895
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	45627.75*
Year dummies	Included
Constant	6014936***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K11 Robustness Check 2 – Hypothesis 2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	1.944576
Rail infr. inv.	
GDP	
GDP per capita	-66.49725
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	54223.72**
Year dummies	Included
Constant	5384900***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K12 Robustness Check 2 – Hypothesis 3 - Random Effects Lag 2

	Model 3
IWW infr. inv.	5549.057***
Road infr. inv.	
Rail infr. inv.	
GDP	
GDP per capita	311.88***
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	
Year dummies	Included
Constant	-4912294

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K13 Robustness Check 2 – Hypothesis 4.1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-317.5285***
IWW dummy	Omitted
Rail*IWW	375.5193***
GDP per capita	-87.58064
Unemployment	38896.47
Year dummies	Included
Constant	6371099***

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K14 Robustness Check 2 – Hypothesis 4.2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	-10.9789
IWW dummy	Omitted
Road*IWW	107.96
GDP per capita	-62.9899
Unemployment	55754.26**
Year dummies	Included
Constant	5153149***

Notes: *** P<0.01 ** P<0.05 * P<0.10

Robustness Check 3

Table K15 Descriptive statistics sample Robustness Check 3 – Hypothesis 1, 2 and 4

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container traffic (number of TEUs)	180	5929855	5412076	76550	1.72e+07
Rail infrastructure inv. (millions 2015 euros)	180	2126.273	2558.727	44.46115	10556.76
Road infrastructure inv. (millions 2015 euros)	180	3581.961	4006.353	129.6739	14374.54
Rail_iww (millions 2015 euros)	180	1076.391	2205.011	0	9468.644
Road_iww (millions 2015 euros)	180	2134.146	4061.076	0	14157.56
IWW dummy	180	0.4166667	0.4943818	0	1
GDP per capita (2015 US dollars)	180	33736.44	13847.25	6005.916	56563.49
Unemployment rate (%)	180	9.414389	4.972414	3.384	27.686

Notes: Descriptive statistics of the sample of the third Robustness Check to test Hypothesis 1, 2 and 4.

Table K16 Descriptive statistics sample Robustness Check 3 – Hypothesis 3

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Port container throughput (number of TEUs)	75	8291108	5208659	373702	1.72e+07
IWW infr. inv.	75	425.7953	280.6789	34.07733	1016.624
GDP per capita (2015 US dollars)	75	33671.13	13205.91	6005.916	47826.82

Notes: Descriptive statistics of the sample of the third Robustness Check to test Hypothesis 3.

Table K17 Robustness Check 3 – Hypothesis 1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-64.79809
Road infr. inv.	
GDP	
GDP per capita	100.0181
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	176384.2***
Year dummies	Included
Constant	230650.1

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K18 Robustness Check 3 – Hypothesis 2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	-52.40591
Rail infr. inv.	
GDP	
GDP per capita	77.62766
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	177311.7***
Year dummies	Included
Constant	975384.1

Notes: *** P<0.01 ** P<0.05 * P<0.10

Table K19 Robustness Check 3 – Hypothesis 3 - Random Effects Lag 2

	Model 3
IWW infr. inv.	2901.11**
Road infr. inv.	
Rail infr. inv.	
GDP	
GDP per capita	270.472***
Gov. exp. transport	
Population	
Exports	
Imports	
Infrastructure quality	
Unemployment	
Year dummies	Included
Constant	-3325151

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K20 Robustness Check 3 – Hypothesis 4.1 - Fixed Effects Lag 1

	Model 4
Rail infr. inv.	-7.142449
IWW dummy	Omitted
Rail*IWW	-131.6676
GDP per capita	83.63241
Unemployment	172022.5***
Year dummies	Included
Constant	786231.4

Notes. *** P<0.01 ** P<0.05 * P<0.10

Table K21 Robustness Check 3 – Hypothesis 4.2 - Fixed Effects Lag 2

	Model 4
Road infr. inv.	-50.94069
IWW dummy	Omitted
Road*IWW	-6.493829
GDP per capita	77.23789
Unemployment	177373.9***
Year dummies	Included
Constant	997894.8

Notes: *** P<0.01 ** P<0.05 * P<0.10