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# Econometric Insights into LNG Carrier Port Congestion and Energy Inflation: A Data-Driven Approach

**Stavros Karamperidis [1], Konstantinos D. Melas [2,3,4,*] and Nektarios A. Michail [5]**

[1] Plymouth Business School, University of Plymouth, Plymouth PL4 8AA, UK; stavros.karamperidis@plymouth.ac.uk
[2] Department of Economics, University of Western Macedonia, 521 00 Kastoria, Greece
[3] Faculty of Business and Economics, Metropolitan College, 546 24 Thessaloniki, Greece
[4] Department of Economics, University of Macedonia, 546 36 Thessaloniki, Greece
[5] Economic Analysis and Research Department, Central Bank of Cyprus, Nicosia 1076, Cyprus; nektariosmichail@centralbank.cy
* Correspondence: mkonstantinos@mitropolitiko.edu.gr

**Abstract:** We examine how LNG carrier port congestion in European ports, measured via detailed vessel-level AIS data, affects euro area energy inflation. As energy inflation significantly affects headline inflation, this study provides an additional factor that can contribute to inflationary pressures. Overall, the results show that higher port congestion increases natural gas prices with the latter having an impact on energy inflation. The reaction stands at 0.1% per 1% shock in port congestion. These findings underline the relationship between the shipping industry and the real economy and support the view that shipping developments can potentially be used as leading indicators.

**Keywords:** liquified natural gas; energy inflation; European Union; maritime economics

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## 1. Introduction

An earlier part of the current research was presented in the International Conference of Applied Economics 2023, in Brno, Czech Republic and published in the International Conference on Applied Economics proceedings 2023 (pp. 531–536). Cham: Springer Nature Switzerland [1].

The shipping industry, while often overlooked, serves as a backbone of the global economy, as it consistently transports around 85% of international trade [2]. The sector, which typically operates behind the scenes as the transport of goods is rarely seen by the end-consumers, has recently been thrust into the spotlight due to a confluence of external factors that have disrupted its normal operations. In particular, the surge in shipping costs that followed the COVID-19 pandemic [3] has had a direct effect on inflation across the world. At the same time, geopolitical tensions, most notably those stemming from the Russia–Ukraine conflict, have caused significant disruptions to global supply chains, compelling governments to adopt various regulatory and other protective measures that have had profound implications for the shipping industry [4]. These cumulative pressures have exacerbated port congestion, a problem that has gained increasing attention in recent years [5,6].

Port congestion generally refers to the delays that vessels encounter between their arrival at a port's anchorage points and the moment they finally berth for loading or unloading cargo—a phenomenon commonly referred to as berth-related congestion [7]. Congestion results in lost productivity within the shipping industry but also carries widespread economic consequences for all other sectors involved, as they experience delays in obtaining their goods. The effects of congestion will thus ripple from shipowners and vessel charters to manufacturers and consumers, contributing to higher product costs and inefficiencies across supply chains. Previous studies highlight the severe economic impacts of port congestion, with research showing that the U.S. alone suffered export losses amounting to $15.7 billion from May to November 2021 due to port congestion [5].

A growing body of literature explores the broader implications of port congestion on global trade [6], the U.S. economy [5], and specific sectors like petroleum by-products [8]. However, despite the energy crisis, most pronounced at the start of the Russia–Ukraine war in 2022, there remains a surprising dearth of research focused on how port congestion of Liquefied Natural Gas (LNG) carriers can affect the economy. This is particularly important given that LNG has emerged as a critical commodity as the majority of the electricity generation of the developed world relies on this fuel. As a result, its price is also heavily impacted by economic and geopolitical developments [9]. This gap in the literature is particularly significant in the context of the European Union's green energy transition, which necessitates increased reliance on natural gas to meet its environmental targets. Natural gas offers a better environmental profile compared to oil products [10] and provides a more stable energy source amid the fluctuating landscape of energy supply [11].

To bridge this gap, this study, and an earlier part of it [1], aims to shed insights into the broader economic consequences of port congestion and investigates the relationship between port congestion of LNG carriers at European ports and energy inflation in the euro area. We employ vessel-level data encompassing all LNG vessels that were discharged at euro area ports, accounting for a total of 3254 voyages over the period from January 2018 to December 2022. The data, sourced from the AXSMarine database, allows us to construct a detailed port congestion index. This index is calculated by summing the discharge wait duration multiplied by vessel size over the total vessel size and the total number of trading days in the month within the specified period. To further analyze the data, we estimate a structural vector autoregression (SVAR) model, incorporating the main macroeconomic variables usually employed. In particular, we use the Harmonized Index of Consumer Prices (HICP) to measure inflation, natural gas prices to account for the cost of energy, the Eurostoxx stock market index to capture the developments in the macroeconomic environment, and the newly created port congestion index. The results derived from the SVAR model suggest a significant influence of port congestion on both natural gas prices and energy inflation, with the latter experiencing a 0.1% increase per 1% shock in port congestion.

Given the profound impact of energy inflation on businesses [12] and households [13], the findings of this study underscore the importance of considering port congestion as a critical variable in economic analyses, especially with regard to inflation. This research also highlights the intricate relationship between the shipping industry and the real economy, echoing earlier work by Kilian [14] and Michail et al. [15], and supports the argument that the shipping industry can function as a leading economic indicator [16]. More precisely, port congestion acts as an additional factor when the price of transportation is considered. Put simply, the more a vessel waits in the anchorage due to the lack of available space and inconsistent port management, the higher the price of the final products (in our case the LNG fuel). Of course, inflation is not only affected by transportation per se, but on the policy front, actions should be taken so as to minimize the unnecessary rise in prices both for the businesses and for the households. Noticeably, the use of the new technology of AIS in the shipping industry and its connection with the port authorities [17,18] can potentially minimize the latter problem, which also echoes in importing countries' economies.

The remainder of this paper is structured as follows: Section 2 provides a comprehensive review of the relevant literature, Section 3 outlines the data and methodology employed, Section 4 presents the empirical results, and Section 5 concludes with a discussion of the findings and their implications.

## 2. Literature Review

While the existing literature comprehensively covers congestion in land and air transport, maritime congestion receives much less attention [19]. This disparity is likely due to the maritime industry's tendency to operate "in the shadows", with its critical role in global trade and daily operations largely ignored by the public unless a major disaster occurs [20]. A notable example of this was the grounding of the mega-container carrier Evergiven in the Suez Canal on 23 March 2021. This incident caused severe congestion in the canal, resulting in significant disruptions to global supply chains and costing approximately USD 9 billion per day over the seven days the vessel remained grounded [21].

According to Bolat et al. [22], port congestion is one of the most crucial factors in assessing port performance, significantly affecting port efficiency and productivity. Congestion can lead to lower service levels, extended waiting times, reduced income, increased debt risk, potential bankruptcy, and diminished competitiveness [23]. In a recent study in 2024, Zhang et al. [24] showed that port congestion status contributes significantly to determining port time and makes it fluctuate by up to nearly 50 h. Additionally, port congestion creates tensions within the transportation system that can have spillover effects throughout the supply chain. If these tensions become chronic, they may alter shippers' ordering and shipment strategies, potentially reshaping broader business strategies [25]. Furthermore, port congestion can increase transportation costs and emissions as vessels idling at ports burn additional fuel. This also negatively impacts vessels' Carbon Intensity Indicator (CII) ratings, reflecting higher environmental costs [1]. In 2024, Li et al. [26] showed that emissions first decrease with the outbreak of congestion, but it then turns increases after a few days in large ports.

In a nutshell, port congestion can cause significant time loss, additional fuel consumption, greater inconvenience and even accidents to shippers, and influential disruption to the maritime supply chain, while inventory costs also increase. Bai et al. [27] showed that the direct economic impact on cargo owners is generally unfavorable, making them the ones who bear the brunt of port congestion, while for shipowners, the impact can be either beneficial (with reduced costs) or detrimental, depending on the prevailing market conditions.

Thus, economies of scale can be achieved only if ports and ships operate on an efficient level with optimized procedure, while if ports fail to deliver efficient vessel turnaround, efficiency is compromised, cost savings are not achieved, and the important role of ports in maritime supply chains is undermined [28–30].

Although port congestion was analyzed at the aggregate level, vessel-specific studies are scarce. The only notable example is Bai et al. [31], who developed a port congestion index for LPG carriers using AIS data. Moreover, the literature lacks studies examining how port congestion impacts the broader economy. The sole exception is the study by Michail and Melas [31], which investigated the effect of congestion on shipping freight rates. Consequently, our study is the first to not only measure LNG carrier port congestion but also explore how it transmits effects to the broader economy. To this end, the following section provides more details with regard to the data and the methodology employed.

## 3. Data and Methodology

Limited by data availability, we collected Automatic Identification System (AIS) data from January 2018 until December 2022 for all LNG vessels trading around the world (29,468 voyages in total) from the AXSMarine database. The variables collected include the discharge wait duration (in days), the size of the vessel (in deadweight tons—DWT), and the country of discharge. Based on the country of discharge, we narrowed our selection to vessels trading within the euro area waters, leading to an examination of 3254 voyages from January 2018 until December 2022, with the data in monthly frequency.

In brief, AIS data provide information specific to each ship's voyage at fixed time intervals. In the literature, AIS data for capturing port congestion was firstly used by AbuAlhaol et al. [32] to monitor the ports of Halifax, Hong Kong, and Singapore. However, the data covered only a short period of time (a year). Since then, studies that examine port congestion have increased their coverage [8]. As the authors also note, monitoring has to take place for a longer period of time (at least a couple of years) to avoid any seasonality bias and one-off events (e.g., COVID-19). At the same time, bias could also be introduced by aggregating all traffic flows; thus, to identify causal effects on economic aspects, researchers need to focus on one homogeneous cargo segment. For this reason, as Peng et al. [19] noted that port congestion measures based on AIS are not often found in the literature. To address all of the above issues, our study uses AIS data from January 2018 until December 2022, covering five years of flows, while we also focus only on LNG carriers to avoid aggregation issues.

To obtain a metric of port congestion, we used the sum of the discharge wait duration multiplied by the vessel size, over the total vessel size multiplied by the total days of trading in the month over that particular period. This allows us to create a port congestion index for LNG carriers, presented as a share of all vessels, weighted by their size and number of days in wait. This intuitive measure offers us insights into how port issues as well as increased demand can potentially affect the flow of LNG in the euro area.

Figure 1 depicts the port congestion index. As expected, and as suggested by the literature [23], port congestion rose during the pandemic as a result of the lockdowns and social distancing protocols, which constricted port traffic. Following the first pandemic wave in 2020, congestion eased but started to climb up again in early 2022 when Europe started distancing itself from Russia and cut down on pipeline imports, focusing on imports using LNG carriers. This increase in demand resulted in a larger amount of vessels in the euro area ports and thus contributed to higher port congestion.

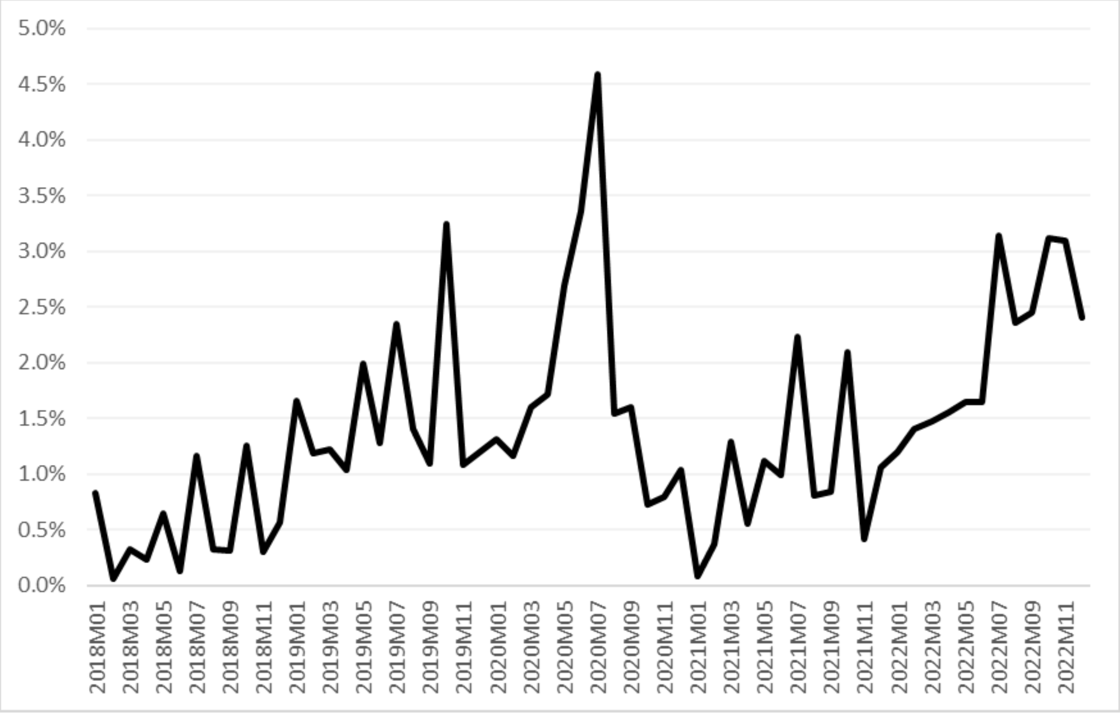

**Figure 1.** The euro area LNG port congestion index.

While the index itself does provide an intuitive view on how port congestion is affected by macroeconomic and geopolitical developments, our main point of interest is how congestion can potentially affect the euro area economy. To assess this, we propose the use of a structural vector autoregression (SVAR) model [33] with euro area variables and the port congestion index. Formally, the SVAR model can be expressed by the following system of linear equations:

$$X_t = a_0 + \sum_{i=1}^{k} \beta_i X_{t-i} + u_t$$

where $X_t$ is a matrix of endogenous variables, which were selected to test the relevant hypothesis. $a_0$ is a vector of constants and $\beta_i$ is a vector of coefficients at the relevant lag length, $i$. Finally, $t$ represents the time period.

The primary variable of interest in this analysis is energy inflation over the specified period. However, to avoid distortions caused by value added tax reductions implemented during the COVID-19 pandemic, we utilize the constant tax series. This approach ensures that the effects of taxation easing or the return to standard taxation practices do not confound our analysis. To isolate the impact of port congestion on energy inflation, we controlled for fluctuations in energy prices. Given that natural gas is the predominant fuel used for electricity generation in Europe, we used the Dutch TTF price as a proxy for natural gas price increases (oil is also an important determinant, given its use as a transport fuel. However, natural gas and oil have a very strong positive correlation (higher than 80%) thus the use of both is redundant. In a robustness check, using the oil price made no qualitative difference in the conclusions reached). Additionally, to account for macroeconomic developments and economic expectations, we include the Eurostoxx index, which measures the performance of the 50 largest European companies, in our model. In robustness checks, the euro area unemployment rate was also included to capture the prevailing labor market conditions and the associated domestic price pressures. The results were qualitatively similar.

Regarding the data sources, the Eurostoxx index was sourced from the European Central Bank's Statistical Data Warehouse, while the other variables, including the constant tax series and natural gas prices, were obtained from Eurostat. The data covers the period from January 2018 to December 2022, constrained by the availability of vessel-specific data.

For the identification scheme, a standard Cholesky (lower triangular) decomposition was employed. The variables were ordered in a sequence that reflects their influence and response to external shocks. In particular, the order places natural gas prices first as they are determined internationally and are not immediately influenced by any developments within the euro area. Port congestion is ordered next, reflecting its dependence on natural gas prices and overall demand for fuel. The stock market variable, represented by the Eurostoxx index, is ordered third. All these variables are presumed to influence energy inflation, which is therefore ordered last in the decomposition. Similar ordering structures can be found in related literature in the shipping sector [3,4,31].

The estimated VAR model employs two lags, determined based on the Akaike and Schwarz information criteria. The model successfully passes all diagnostic tests, including tests for normality, autocorrelation, and heteroscedasticity; the results of these tests are available upon request (while the graph may appear to indicate that a broken trend exists in the congestion series, this is captured in the model via the lags, as well as the appropriate dummies. As a result, all VAR components have iid residuals, with no autocorrelation or heteroscedasticity issues detected). Stability and lag length test results can be found in Appendix A, where we also include a table of variable sources and measurement values. Additionally, dummy variables were incorporated to capture the effects of port openings and closures due to COVID-19 restrictions, as well as a dummy to capture the start of the Russian invasion in Ukraine, ensuring that these disruptions do not skew the analysis (we note that the dummy for the Russian invasion in Ukraine takes place in March 2022 instead of at the end of February, which is when the markets showed a response to it. Separating the sample in pre- and post-invasion using a dummy variable did not affect the results).

As previously indicated, the focus of this study is on the impact of port congestion—specifically discharge delays—on inflation and energy prices. Therefore, the presentation of the results is concentrated on these effects, which are depicted through impulse response functions (IRFs) in the subsequent section. Detailed analyses of other impacts are available upon request.

## 4. Empirical Estimates

Figure 2 illustrates the impulse response functions derived from the SVAR model, as described in the preceding section. As is standard in the literature, the shocks are defined to equal one standard deviation of the errors of each equation/variable. For the sake of brevity, only the most pertinent responses are presented, while the full set of results is available upon request. The responses clearly demonstrate that following a 15% shock in discharge delay (disch_delay), there is a corresponding increase in energy inflation of approximately 1.5% occurring around three months after the shock (equivalent to 0.1% per 1% shock). This rise in energy inflation is primarily driven by a significant increase in natural gas (natgas) prices, which escalate by approximately 9% during the same period. It is important to note that while a 15% standard deviation shock may initially appear substantial, the standard deviation of the discharge delay series is 28%, and with a mean of 42%, this suggests that a 66% change is plausible at just the one standard deviation level. Naturally, the extent of such changes is contingent on prevailing circumstances, which, as recent events have shown, can lead to much higher levels of congestion.

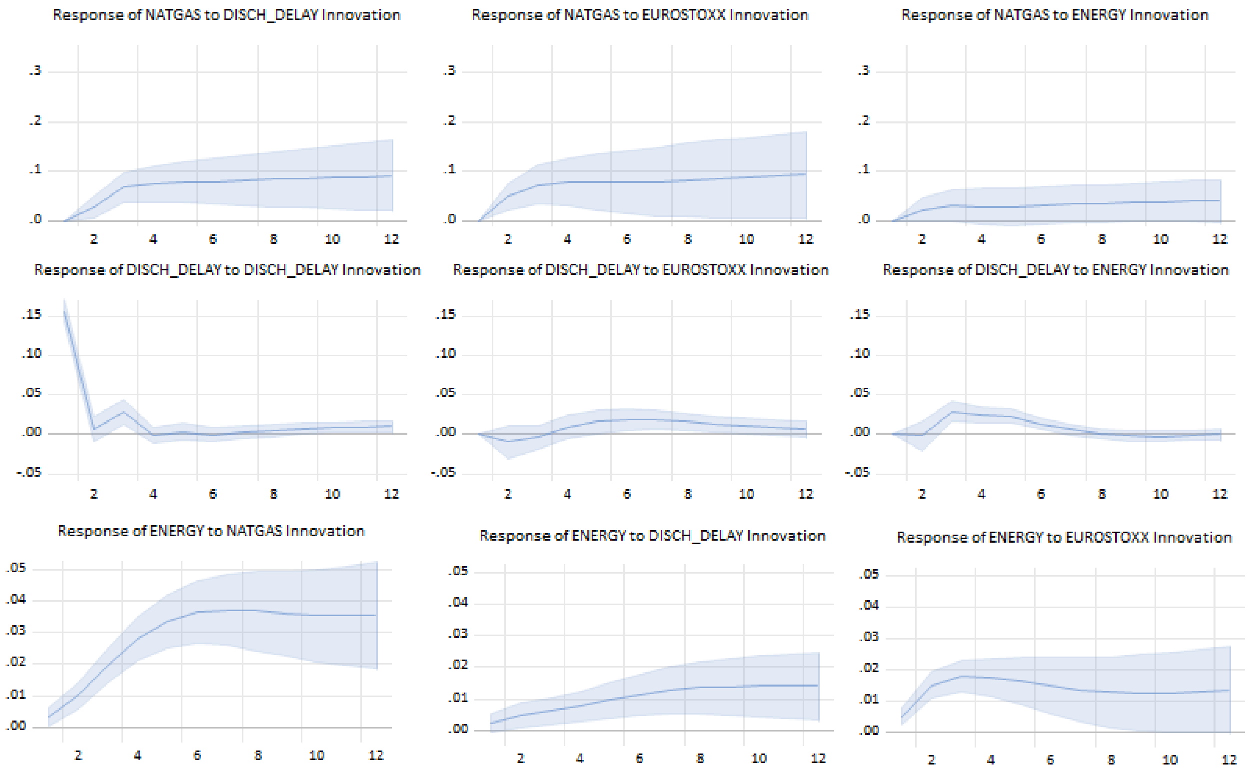

**Figure 2.** SVAR impulse response functions. Notes: Figure shows impulse responses from SVAR model with two lags. Shaded areas represent 68% confidence interval. For example, "Response of ENERGY to DISCH_DELAY" shows how energy inflation is expected to react following shock that increases port congestion (discharge delay).

Although the above analysis may seem straightforward, the policy implications it uncovers are quite profound. Specifically, the results underscore the fact that delays in vessel discharge, referred to as "port congestion", can exert a significant and economically meaningful impact on energy prices. Given that the pass-through of energy prices to headline inflation was around 60% during the first nine months of 2022 [8], these findings suggest that the substantial rise in inflation observed throughout the year can at least partly be also attributed to port-related issues.

Furthermore, a variance decomposition of our VAR model reveals that approximately 70% of the variance in energy inflation is attributable to fluctuations in natural gas prices, while another 10% is directly linked to discharge delays. Considering the ongoing efforts to reduce reliance on Russian gas imports via pipelines and the increased utilization of LNG carriers to supply gas to Europe, it is plausible to anticipate that, during a particularly harsh winter, port congestion is likely to intensify. Such an increase in congestion could have a pronounced and potentially significant effect on energy inflation, further complicating the economic landscape.

These insights highlight the critical need for policymakers to consider the indirect effects of port congestion on broader economic variables, particularly in the context of energy security and inflation control. Given that the usual central bank mandate is the control of price development, via its growth rate, inflation, then any factor that can have a meaningful impact, even if this is indirect, merits inclusion in the policymaking watchlist. This will become particularly important in the near future given that Europe continues to navigate the complexities of securing a stable energy supply of LNG in a changing geopolitical environment. Thus, understanding and mitigating the impacts of port congestion can be crucial not only with regard to inflation but also for maintaining economic stability.

## 5. Conclusions

We provide the first study that elaborates on how port congestion in the case of LNG carriers can potentially affect euro area energy inflation. Our measure of port congestion, created using AIS data from the AXSMarine database, covers all LNG vessels that were discharged in euro area ports over the January 2018–December 2022 period. The resulting port congestion index registers increases when demand rises or when port issues occur. To provide a more formal estimate of the effect, we use a structural VAR (SVAR) model, which shows that port congestion appears to have an effect on energy inflation indirectly, i.e., via an increase in natural gas prices. The extent of the shock is meaningful as energy inflation rises by (the equivalent of) 0.1% following a 1% shock in port congestion. For comparison purposes, we note that a one standard deviation shock in port congestion would imply an increase of 66% in congestion, or 6.6% in energy inflation.

Our results are of particular importance not only for the shipping world but for the broader cluster of decision makers, and, in particular, for central banks. Given the fact that energy inflation affects both households and businesses, higher energy prices will ultimately affect the economy and harm purchasing power [34,35]. At the same time, these are likely to influence monetary policy decisions, given that higher inflation is likely to prolong higher interest rates. Other important implications also include increasing LNG storage in the EU, but most importantly, securing the efficient operation of the continent's ports, which will be paramount to supporting economic growth [36–38].

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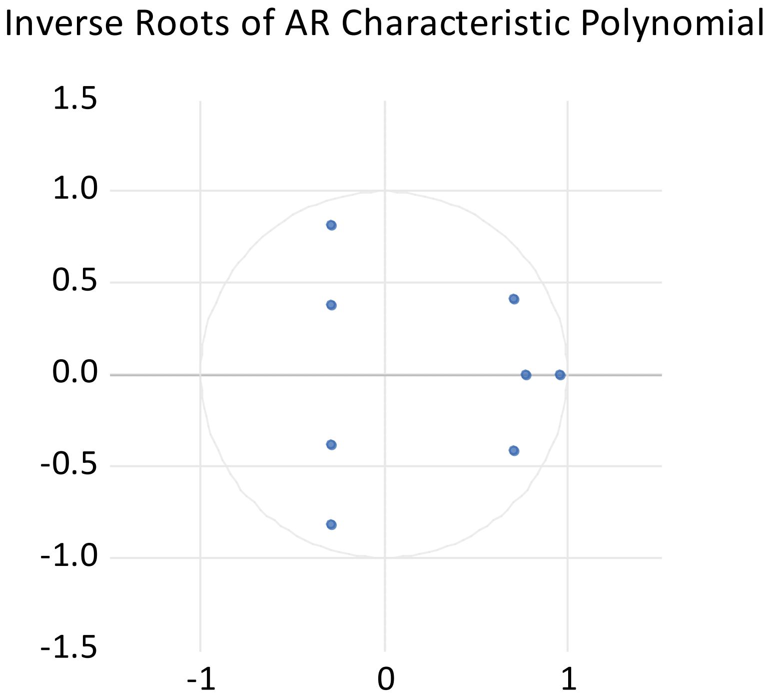
**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

1. Stability test—inverse roots of characteristic polynomial.



2. Lag length criteria—Akaike and Schwarz information criteria.

| Lag | Akaike Criterion | Schwarz Criterion |
|---|---|---|
| 0 | 7.313046 | 8.938778 |
| 1 | 1.467808 *** | 3.452673 *** |
| 2 | 1.608305 | 3.951302 |
| 3 | 1.876819 | 4.578050 |
| 4 | 2.173683 | 5.232946 |
| 5 | 1.979905 | 5.397301 |
| *** refers to the optimal lag length | | |

3. Variable definitions and sources.

| Name | Variable | Source | Units |
|---|---|---|---|
| Disch_Delay | Discharge delay of LNG vessels | AXSMarine | Days |
| NatGas | Dutch TTF Natural Gas Prices | Eurostat | Euros |
| Energy | Energy component of the Harmonized Index of Consumer Prices (HICP) at constant tax levels | Eurostat | Index |
| Eurostoxx | Eurostoxx 50 index | ECB SDW | Index |

## References

1. Karamperidis, S.; Michail, N.A.; Melas, K.D. LNG Carriers Discharge Waiting Time and Energy Inflation. In *International Conference of Applied Economics*; Springer Nature: Cham, Switzerland, 2023; pp. 531–536.
2. UNCTAD. *Review of Maritime Transport 2023*; UNCTAD: New York, NY, USA, 2023.
3. Michail, N.A.; Melas, K.D. Shipping Markets in Turmoil: An Analysis of the COVID-19 Outbreak and Its Implications. *Transp. Res. Interdiscip. Perspect.* **2020**, *7*, 100178. [CrossRef]
4. Michail, N.A.; Melas, K.D. Geopolitical Risk and the LNG-LPG Trade. *Peace Econ. Peace Sci. Public Policy* **2022**, *28*, 243–265. [CrossRef]
5. Steinbach, S. Port Congestion, Container Shortages, and U.S. Foreign Trade. *Econ. Lett.* **2022**, *213*, 110392. [CrossRef]
6. Komaromi, A.; Cerdeiro, D.; Liu, Y. *Supply Chains and Port Congestion Around the World*; International Monetary Fund: Washington, DC, USA, 2022.
7. Takebayashi, M.; Hanaoka, S. Efficient Inter-Port Cooperation Considering Port Congestion and Port Charge. *Marit. Transp. Res.* **2021**, *2*, 100011. [CrossRef]
8. Bai, X.; Jia, H.; Xu, M. Port Congestion and the Economics of LPG Seaborne Transportation. *Marit. Policy Manag.* **2021**, *49*, 913–929. [CrossRef]
9. Hudecova, K.; Rajacaniova, M. Geopolitical Risk and Energy Market. *Peace Econ. Peace Sci. Public Policy* **2023**, *29*, 171–187. [CrossRef]
10. Zachmann, G. Electricity Wholesale Market Prices in Europe: Convergence? *Energy Econ.* **2008**, *30*, 1659–1671. [CrossRef]
11. Al-Yafei, H.; Aseel, S.; Kucukvar, M.; Onat, N.C.; Al-Sulaiti, A.; Al-Hajri, A. A Systematic Review for Sustainability of Global Liquified Natural Gas Industry: A 10-Year Update. *Energy Strategy Rev.* **2021**, *38*, 100768. [CrossRef]
12. Bean, C.R. *Globalisation and Inflation*; Bank of England Quarterly Bulletin 2006-Q4; Bank of England: London, UK, 2006.
13. Breitenfellner, A.; Crespo Cuaresma, J.; Mayer, P. Energy Inflation and House Price Corrections. *Energy Econ.* **2015**, *48*, 109–116. [CrossRef]
14. Kilian, L. Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *Am. Econ. Rev.* **2009**, *99*, 1053–1069. [CrossRef]
15. Michail, N.A.; Melas, K.D.; Cleanthous, L. The Relationship between Shipping Freight Rates and Inflation in the Euro Area. *Int. Econ.* **2022**, *172*, 40–49. [CrossRef]
16. Kilian, L. Measuring Global Real Economic Activity: Do Recent Critiques Hold up to Scrutiny? *Econ. Lett.* **2019**, *178*, 106–110. [CrossRef]
17. Kao, S.L.; Chung, W.H.; Chen, C.W. AIS-Based Scenario Simulation for the Control and Improvement of Ship Emissions in Ports. *J. Mar. Sci. Eng.* **2022**, *10*, 129. [CrossRef]
18. Liu, D.; Rong, H.; Guedes Soares, C. Shipping Route Modelling of AIS Maritime Traffic Data at the Approach to Ports. *Ocean Eng.* **2023**, *289*, 115868. [CrossRef]
19. Peng, W.; Bai, X.; Yang, D.; Yuen, K.F.; Wu, J. A Deep Learning Approach for Port Congestion Estimation and Prediction. *Marit. Policy Manag.* **2022**, *50*, 835–860. [CrossRef]
20. Stopford, M. *Maritime Economics*, 3rd ed.; Routledge: New York, NY, USA, 2013; ISBN 9781134742677.
21. Notteboom, T. Global Trends in Maritime Supply Chains and Ports in 2021. In *Annual Report of Valencia Containerized Freight Index (VCFI)*; Valenciaport: Valenica, Spain, 2021.
22. Bolat, P.; KayïŞoğlu, G.; Güneş, E.; Kizilay, F.E.; Özsöğüt, S. Weighting Key Factors for Port Congestion by AHP Method. *J. ETA Marit. Sci.* **2020**, *8*, 252–273. [CrossRef]
23. Gui, D.; Wang, H.; Yu, M.; Ferrari, C.; Gui, D.; Wang, H.; Yu, M. Risk Assessment of Port Congestion Risk during the COVID-19 Pandemic. *J. Mar. Sci. Eng.* **2022**, *10*, 150. [CrossRef]
24. Zhang, T.; Yin, J.; Wang, X.; Min, J. Prediction of Container Port Congestion Status and Its Impact on Ship's Time in Port Based on AIS Data. *Marit. Policy Manag.* **2024**, *51*, 669–697. [CrossRef]
25. Notteboom, T.E. The Time Factor in Liner Shipping Services. *Marit. Econ. Logist.* **2006**, *8*, 19–39. [CrossRef]
26. Li, X.; Zhao, Y.; Cariou, P.; Sun, Z. The Impact of Port Congestion on Shipping Emissions in Chinese Ports. *Transp. Res. D Transp. Env.* **2024**, *128*, 104091. [CrossRef]
27. Bai, X.; Jia, H.; Xu, M. Identifying Port Congestion and Evaluating Its Impact on Maritime Logistics. *Marit. Policy Manag.* **2024**, *51*, 345–362. [CrossRef]
28. Brooks, M.R.; Pallis, A.A. Assessing Port Governance Models: Process and Performance Components. *Marit. Policy Manag.* **2008**, *35*, 411–432. [CrossRef]
29. Saeed, N.; Song, D.W.; Andersen, O. Governance Mode for Port Congestion Mitigation: A Transaction Cost Perspective. *Netnomics Econ. Res. Electron. Netw.* **2018**, *19*, 159–178. [CrossRef]
30. Liu, J.; Wang, X.; Chen, J. Port Congestion under the COVID-19 Pandemic: The Simulation-Based Countermeasures. *Comput. Ind. Eng.* **2023**, *183*, 109474. [CrossRef]
31. Michail, N.; Melas, K. Measuring the Impact of Port Congestion on Containership Freight Rates. *SSRN Electron. J.* **2023**. [CrossRef]
32. AbuAlhaol, I.; Falcon, R.; Abielmona, R.; Petriu, E. Mining Port Congestion Indicators from Big AIS Data. In Proceedings of the International Joint Conference on Neural Networks (IJCNN), Rio de Janeiro, Brazil, 8–13 July 2018; IEEE: Piscataway, NJ, USA, 2018; pp. 1–8.

33. Sims, C.A. Macroeconomics and Reality. *Econometrica* **1980**, *48*, 1–48. [CrossRef]
34. Herriford, T.; Johnson, E.M.; Sly, N.; Smith, A.L. How Does a Rise in International Shipping Costs Affect U.S. Inflation? Federal Reserve Bank of Kansas City: Kansas City, MO, USA, 2016.
35. Carriere-Swallow, Y.; Deb, P.; Furceri, D.; Jiménez, D.; Ostry, J.D. Shipping Costs and Inflation. *J. Int. Money Financ.* **2023**, *130*, 102771. [CrossRef] [PubMed]
36. Notteboom, T.; Pallis, A.; Rodrigue, J.-P. *Port Economics, Management and Policy*; Routledge: London, UK, 2021; ISBN 9780429318184.
37. Mudronja, G.; Jugović, A.; Škalamera-Alilović, D. Seaports and Economic Growth: Panel Data Analysis of Eu Port Regions. *J. Mar. Sci. Eng.* **2020**, *8*, 17. [CrossRef]
38. Ayesu, E.K.; Sakyi, D.; Darku, A.B. Seaport Efficiency, Port Throughput, and Economic Growth in Africa. *Marit. Econ. Logist.* **2023**, *25*, 479–498. [CrossRef]