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The Emergence of Marine Freight Rate Bubbles Following the COVID-19 Outbreak

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Abstract

This research analyzes the formation and growth of price bubbles in the marine freight industry by using the Supremum Augmented Dickey-Fuller (SADF) and Generalized Supremum Augmented Dickey-Fuller (GSADF) econometric methods, utilizing data from the Baltic Dry Index (BDI). The study covers the timeframe from the 47th week of 2019 to the 51st week of 2023. Research indicates the presence of eight separate pricing bubbles in the marine industry worldwide during this period. Quarterly, the distribution of bubbles was as follows: one in Q1 2020, one in Q2 2021, two in Q4 2021, one in Q1 2022, and one each in Q1, Q3, and Q4 of 2023. Significantly, six of these bubbles appeared before the World Health Organization declared that COVID-19 no longer represented a worldwide public health emergency. The emergence of these first bubbles is intricately linked to pandemic-related events, including heightened demand for raw materials, interruptions from lockdowns, impacts of economic recovery, and shortages of vessels. The latter two bubbles, seen after COVID, may be ascribed to logistical constraints at Brazilian ports and heightened cargo quantities of coal, iron ore, and bauxite.

Key words: Shipping freight, Price bubbles, Baltic Dry Index, COVID-19

JEL Code: C22, L91, R40

1. Introduction

The phenomenon of freight shipment rate bubbles has attracted considerable attention from industry professionals and researchers due to their profound influence on the real economy and the global supply chain. Assessing the presence of bubbles is crucial for effectively evaluating the effectiveness of supply chain management. Over several years, the phrase "bubble formation" has been subjected to various meanings, none directly oppose one another. A rational bubble indicates a self-validating conviction that a price is determined by a combination of intrinsically irrelevant variables or by genuinely relevant variables that entail

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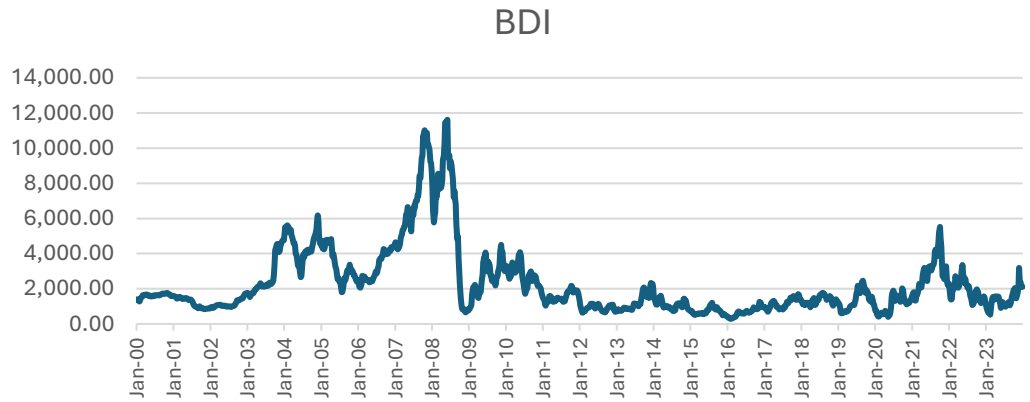
parameters that are not fundamental to the market (Diba & Grossman, 1988, p. 520). Most crises consist of two stages. During the initial stage of crises, bubbles and imbalances arise. The following period refers to the point at which the previously building risk becomes evident, and the crisis breaks out (Brunnermeier & Oehmke, 2013, p. 1222).

Literature on bubbles is classified into four distinct categories. The first two classifications of models analyze bubbles within the rational expectations framework but differ in their assumptions on the homogeneity of knowledge among investors or the existence of asymmetric information among investors. Another category of models focuses on the interplay between rational and behavioral investors. The final set of models indicates the presence of varied investor opinions and acknowledges the occurrence of deviation from the fundamental price (Brunnermeier, 2016, p. 28). The world economy has seen significant historical bubbles, including the Dutch Tulipmania (1634-38), the Mississippi Bubble (1719-20), and the South Sea Bubble (1720). The internet bubble, which sprang from the dot-com disaster of 2001, the US housing bubble primarily caused by the subprime catastrophe of 2006, and the global financial crisis of 2008 are significant events that have occurred in this millennium (Taskinsoy, 2021, p. 2). A thorough analysis was undertaken to examine the presence of a price bubble in 16 distinct real-time daily commodity closing prices spanning from 2015 to 2019 in the energy, meat, metal, and plant categories. The results indicate that timber and beef cattle are the only commodities experiencing a price bubble. These commodities have shown that real-time price movements are influenced by core values (Yildirim, 2021, p. 1).

The 2008 financial crisis, the 2015 migrant crisis, the COVID-19 pandemic, and the ongoing worldwide climate crisis are among the significant challenges of the 21st century affecting all types of transportation modes, including maritime (Borca et al., 2021, p. 1). The weekly BDI data for this century is depicted in Graph 1. The research period is the critical time frame, and the significant fluctuations are clearly delineated within it. The review below indicates that the most substantial price fluctuation occurred during the 2008 financial crisis. A notable period of volatility in BDI values occurred between August 2002 and December 2005. Initially, at 1000, the index fluctuated to about 2500 in the subsequent month. During the specified timeframe, the index attained a value of 5540 in February 2004. The index, which reached 2900 in August of the same year, escalated to 5450 in December 2004, a Graph that may be characterized as a record for the relevant time. By the conclusion of the second quarter of 2005, the value decreased to 2900. A specific sequence of events, such as the necessity to dispatch cargo or congestion in specific ports, is the primary cause of the remarkable fluctuations in the BDI (Geman & Smith, 2012, pp. 10–11). The index's most volatile period in the relevant period is abruptly preceding and following the onset of COVID-19. The primary objective of the research is to identify bubbles during this period.

Graph 1. BDI Trend: 2000-2023.



Source: https://tr.investing.com/indices/baltic-dry-historical-data

A significant variation in freight prices has been reported since the initial confirmed case of COVID-19 was reported in China on November 17th, 2019, which has affected global networks of supply chains, logistics, and transportation (Kpozehouen et al., 2020, p. 1). On January 30th, 2020, WHO formally declared a public health emergency of worldwide concern, and on March 11th, 2020, it assessed that COVID-19 may be classified as a pandemic (Coronavirus Disease-COVID-19 Pandemic, 2024). The COVID-19 phase terminated on May 5th, 2023, after the WHO declared the conclusion of the COVID-19 emergency phase (Sarker et al., 2023, p. 2851). More studies are needed to determine if there is a bubble in the shipping sector between the beginning of COVID-19 and the most recent date when most transmissions have stopped. The early identification of a bubble during COVID-19 is of the utmost importance for policymakers, industry experts, and academics due to the far-reaching consequences on the real and financial sectors.

The fluctuations in shipping freight outside the expected range could affect most products traded globally. Since the onset of COVID-19, price instability has negatively affected households and local businesses expanded all actors within the global economy. This research makes a scholarly contribution by examining the explosive characteristics of shipping cargoes as quantified by BDI, commencing with COVID-19. We utilized the weekly BDI data for our research. Data collection commenced during the week commencing November 18th, 2019, and concluded on December 22nd, 2023. This study selects the SADF and GSADF as the techniques for analyzing bubbles (Acharya, 2024, p. 1). Since this study aims to detect price bubbles, no model was constructed to determine which would better predict volatility. In this context, we statistically test whether the selected variable contains price bubbles and, if so, on which dates they deflate using the SADF and GSADF unit root tests with tails. In particular, the GSADF test was applied to detect the formation of multiple price bubbles. As a result of the research, multiple bubbles have formed in the BDI over the specified period. This study adds significantly to the current understanding by identifying many instances of bubbles over the

relevant time frame. This study begins with a comprehensive literature review, followed by an explanation of methodology. The data is then outlined, leading to the empirical analysis. Finally, the study concludes with a summary of key findings and outcomes.

The COVID-19 has been observed to cause significant fluctuations in several markets, particularly in the short term, with global maritime transport being one of them. In addition to the factors mentioned above, significant changes have been observed in several processes in maritime transportation, particularly in port operations, as well as in the supply chain structure, during the relevant period. The volatility in freight prices has fundamentally had significant effects on transportation costs. This situation has the potential to cause significant changes in a number of factors, primarily commodity flow and global trade. Detection of freight price bubbles has become an increasingly critical area of research for both maritime sector stakeholders and macroeconomic policymakers. The topic of freight market bubbles is among the subjects that have been studied to a certain extent in academia. From the start of the COVID-19 period to the end of the normalization process, a limited number of studies have been conducted on freight price bubbles in maritime. It has been observed that the number of studies investigating price bubbles using high-frequency data has remained relatively limited. This study uses weekly BDI data and employs SADF and GSADF techniques for analysis. It aims to analyze marine freight rate bubbles during and after the pandemic, thereby providing a current and complementary contribution to the literature on maritime finance and logistics.

2. Literature Review

The maritime freight industry is characterized by its seasonality, cyclical nature, volatility, and capital-intensive operations. Additionally, it is very vulnerable to the impacts of the global economic conditions. Shipowners and charterers face significant risk due to unpredictable fluctuations in freight rates, petroleum prices, interest rates, foreign currency exchange rates, and vessel values. These factors directly impact their income and costs (Kavussanos & Visvikis, 2006, p. 233). Commercial factors governing freight market demand and supply have influenced Marine Freight rates. Freight rate volatility constitutes the primary source of market risk for transportation industry participants. (Angelidis & Skiadopoulos, 2008, p. 448). Shipping market cycles also exist consistently with the cyclical character of the global economy. Economic cycles exert a substantial impact on shipping cycles. Significant evidence of the impact of economic cycles on the maritime sector can be found in the correlation between bulker demand and economic conditions (Tsioumas et al., 2021, p. 1). Economic conditions have significantly influenced the shipping freight market throughout the history of the marine sector. One significant event that has profoundly impacted the maritime industry is The Wall Street Crash of October 1929. The crisis and subsequent recession in global commerce caused a significant downturn in the maritime sector until the late 1930s. From 1931 to 1934, the volume of maritime commerce decreased by 26% (Goulielmos, 2009, p. 330).

According to empirical analysis, economic activity cycles were the primary determinants of the short-term behavior of maritime freight rates between 1850 and the First World War. A robust temporal relationship is typically observed between the highest moments of the business cycle, commodity prices, and freight rates. This relationship has been especially evident during the peak years of 1873, 1889, 1900, and 1912 (Klovland, 2002, p. 17).

The world has seen at least nine major wars, two of which were World Wars, since 1741. Wars have both positive and negative impacts on global shipping. Ships are necessary for transporting supplies during battles and for rehabilitation efforts afterward. Wars led to increased seaborne demand and decreased supply due to lost ships in the conflict (Goulielmos, 2020, p. 1672). Wars are among the significant factors that contribute to fluctuations in maritime pricing. Supply and demand contingencies may also influence freight rates, including but not limited to the financial crisis and COVID-19(Chen et al., 2021, p. 2). The mortgage crisis and Lehman Brothers' bankruptcy, which originated in the United States in 2007 and 2008, rapidly escalated into worldwide crises. Many vessels are documented to be sent in for demolition during periods of crisis due to fleet downsizing. This circumstance results in a decline in the sector's capacity (Dursun & Sercan, 2012, p. 374). The international shipping freight industry has distinct characteristics that differentiate it from other markets. The primary distinguishing element is the extreme volatility of transporting freight.

The yearly volatility of the maritime freight index was at least double that of the Morgan Stanley Capital International World Stock Market Index from 1999 to 2011, illustrating this influence. The second feature is the various seasonal influences that come with the items sent via shipping fleets (Su et al., 2019, p. 819). The study analyzed the relationship between spot and forward freight in the dry bulk shipping market and discovered a lasting and reciprocal causal link between spot and FFA pricing on the Baltic Panamax Index (BPI) Time Charter and Baltic Capesize Index (BCI) C7 routes (Yin et al., 2017, p. 271). The study examined the interplay and dynamics of BDI about the prevailing pricing of iron ore. Significant spillover interactions between BDI and the iron ore market were identified (Gu et al., 2019, p. 3855).

Several studies have been conducted to analyze the freight volatility and price bubbles in the global transportation businesses. Research on the dry bulk business from 2005 to 2010 revealed significant volatility and a boom-and-bust cycle in freight prices driven by speculation (Cocconcelli & Medda, 2016, p. 295). Eight main factors—climatic, cultural, political, operational, production, adjacent market, and sentiment—have been identified as significant in the research analyzing the causes of minor bubbles in the BDI (Açık & Başer, 2018, p. 364). The research utilizing the Baltic Freight Capesize Index (BCI), Baltic Freight Panamax Index (BPI), and JE HydeShipping Index (JE HydeShipping Index) demonstrated that variations in the bulk shipping market impact the volatility of different vessel types in unique ways, owing to the vessels' unique degrees of flexibility (Jing et al., 2008, p. 249). The analysis of monthly BDI data from October 1988 to February 2018 identified four bubbles in the marine freight

industry, with three potentially stemming from strong demand, supply capacity, crude oil prices, and US currency swings. The 2008 global financial crisis was the primary factor in the final bubble (Su et al., 2019, p. 818). The research analyzed possible bubbles in shipping freight rates by utilizing daily values of the BDI and Baltic Clean Tanker Index (BCTI) as data sources from September 2019 to December 2021, revealing several bubbles in both indexes (Khan et al., 2023, p. 1). Two significant findings emerged from the research examining the role of geopolitical risk in the correlation between oil prices and BDI: first that oil prices can induce BDI in the short term even in the absence of geopolitical risk, and second, that increased geopolitical uncertainty stimulates the correlation between oil prices and BDI (Khan et al., 2021, p. 8).

The findings of the study examining the impact of fluctuations in the Baltic Dirty Tanker Index(BDTI) on the likelihood of price bubbles in second-hand VLCC, SUEZMAX and AFRAMAX vessels indicate that a one-unit increase in freight rates on the dirty tanker market corresponds to an 80%, 70%, and 55% higher probability of a price bubble in the vessels mentioned above, respectively(Açık & Başer, 2020, p. 13).

A varied performance was observed when freight rates for 2018, representing a period close to the period covered by the research, were analyzed. The primary factors contributing to the pressure on freight rates during the first two quarters of 2018 include a slowdown in trade growth and the continuing rollout of mega container ships. The temporary rise in freight rates during the subsequent period was attributed to increased shipments from China to the USA (UNCTAD, 2019). The COVID-19 outbreak and the subsequent conflict between Russia and Ukraine have exacerbated the situation impacting the global supply chain. Numerous studies have been undertaken on the volatility of freight prices in the marine sector due to the COVID-19 outbreak and the ongoing conflict between Russia and Ukraine (Rožić et al., 2022, p. 1). The research studies the impact of external influences on the shipping sector by using data from the current COVID-19 epidemic. It analyses the reactions of freight rates for dry bulk, clean, and filthy tankers. GARCH (1,1) and VAR models indicated that such occurrences directly influenced the dry bulk and dirty tanker sectors. Moreover, the results revealed substantial secondary effects, primarily due to the decline in oil prices. Although results were obtained using both GARCH (1,1) and VAR specifications in the study, they did not include price bubbles in their research. (Michail & Melas, 2020, p. 1).

The research using the market-model event study methodology to assess the effect of COVID-19 on dry bulk, clean, and dirty tankers, as well as the maritime stock market, yielded significant findings. Excluding the tanker market, which demonstrated a pandemic-resistant response, the dry and stock markets responded adversely to the WHO statement on January 30th, 2020, as shown by the first findings of the research. The second fielding pertains to the significant date of March 11th, 2020, where evidence indicated negative abnormal returns in both the

dry and stock markets, suggesting that the announcement of the COVID-19 pandemic was perceived as a severe external shock, forecasting the collapse of global trade due to national restrictions(Gavalas et al., 2022, pp. 161–162). Data from the BDI, Global Stock Market Indicator (MSCI), and Investor Sentiment Index(VIX) were evaluated using LSTAR-GARCH and LSTAR-APGARCH models. The model results indicated a substantial improvement in prediction and forecasting accuracy for LSTAR-APGARCH, in which LSTAR-GARCH models closely succeeded. The overall findings validate the need for models that include nonlinearity and volatility dynamics to use the BDI, VIX, and MSCI indices as reliable leading economic indicators for forecasting the trajectory of the global economy (M. Bildirici et al., 2023, p. 1).

Bubble entities were analyzed using the GSADF test for Baltic stock market indexes from March 1st, 2019, to December 29th, 2023. Six times in the Baltic Supramax Index (BSI), five times in the BHSI on the Baltic Stock Exchange, and once in BCI and BPI. Three times from the BCTI and five times from the BDTI were bubble assets acquired (Tarkun, 2024, p. 14). The wavelet quantile-on-quantile approach was employed to analyze the impact of COVID-19 on shipping freight. The results of the study not only demonstrated that the pandemic has indeed affected shipping freight costs, primarily due to the unavailability of vessels and the reduced demand for energy and raw materials but also indicated that the spread of COVID-19 has had a positive impact on the Baltic Dry Index in the high quantiles. The Baltic Dry Tanker Index and the BCTI have been adversely affected by the COVID-19 infection, particularly in the short and medium term, in the medium to high quantiles. In the high quantiles, the long-term positive impact of COVID-19 on the BCTI has been acknowledged (Khan et al., 2022, p. 1). The study by Memişoğlu and Sigalı (2023) analyzed the volatility transition between container and dry bulk freight markets during the COVID-19 pandemic using an asymmetric BEKK-GARCH (1,1) model. The findings indicate that there was bidirectional volatility transmission between them.

The literature review reveals that a substantial proportion of the research focuses on geopolitical concerns, oil prices, and financial crises as the fundamental factors contributing to the emergence of bubbles. Upon analyzing the period under research, it becomes evident that the analyses include the periods before the onset of the COVID-19 epidemic. While the amount of research conducted during the epidemic era was restricted, a small subset of studies that covered a portion of the pandemic period were discovered. Research conducted from the first detection of the COVID-19 case until the time when the significance of COVID-19 diminished creates a void in the existing body of literature.

The literature review conducted within the scope of this study shows that the focus of studies is freight volatility, price bubbles, and macroeconomic relationships. The review revealed that research focusing on freight price bubbles across multiple periods—the pandemic onset, the pandemic period, and the normalization period—is not among the extensively researched topics. This indicates that there is a significant gap in academic research in this area. Based on this gap, this study aims to examine the formation and growth of price bubbles in

the maritime transport sector using weekly BDI data with SADF and GSADF econometric methods.

3. Methodology

In the initial research stage, we used the SADF test, which has become widely accepted as a right-side unit root test. Phillips et al. (2011) suggested employing the SADF method to identify price bubbles. Recursive execution of a right-side unit root test and a sup test constitute the method. The test procedure demonstrates discriminatory capability in detecting bubbles that undergo periodic collapses. The right-hand SADF process is formulated as follows (Phillips et al., 2011, p. 207).

$$b_t = \mu_b + \delta b_{t-1} + \sum_{l=1}^{d} \phi_i \Delta b_{t-d} + \in_{b,t} \qquad \in_{b,t} \sim ND\ (\mu, \sigma_b^2) \tag{1}$$

In the equation above, it represents the index value, d represents the value of the lag parameter, and ND represents an independent and normal distribution. The ADF test is calculated by dividing the coefficient of bt-1, denoted as δ, by the standard error of the corresponding coefficient in the provided equation(Akdag & İskenderoğlu, 2019, p. 1089).

$$\mathrm{ADF}_{\mathrm{d1,d2}} = \frac{\delta_{\mathrm{d1,d2}}}{\mathrm{se}(\delta_{\mathrm{d1,d2}})} \tag{2}$$

To calculate the GSADF test, the aforementioned iterative regression equation will be retroactively applied to numerous subsamples, and repeated right-tailed ADF tests will be acquired for every iteration. In this scenario, distinct from the SADF test, sub-subsamples are generated where the samples' beginning points(d1) and endpoints(d2) dynamically alter and deviate from the zero point. Considering the whole sample interval as (0, 1), the initial points of the subsamples will vary within the range (0, d2-d0), while the final points will vary within the range (d0, 1). The minimal estimate window length is denoted as d0(Mandaci & Çağli, 2018, pp. 96–97)

The equations required to perform SADF and GSADF tests are as follows (Phillips et al., 2015a, pp. 1048-1049.):

$$SADF_{d_2}(d_0) = sup_{d_1 \in [0, d_2 - d_0]} ADF_{d_1}^{d_2} \tag{3}$$

$$GSADF\ (d_0) = sup_{d_2 \in [d_0, 1]} SADF_{d_2}\ (d_0) \tag{4}$$

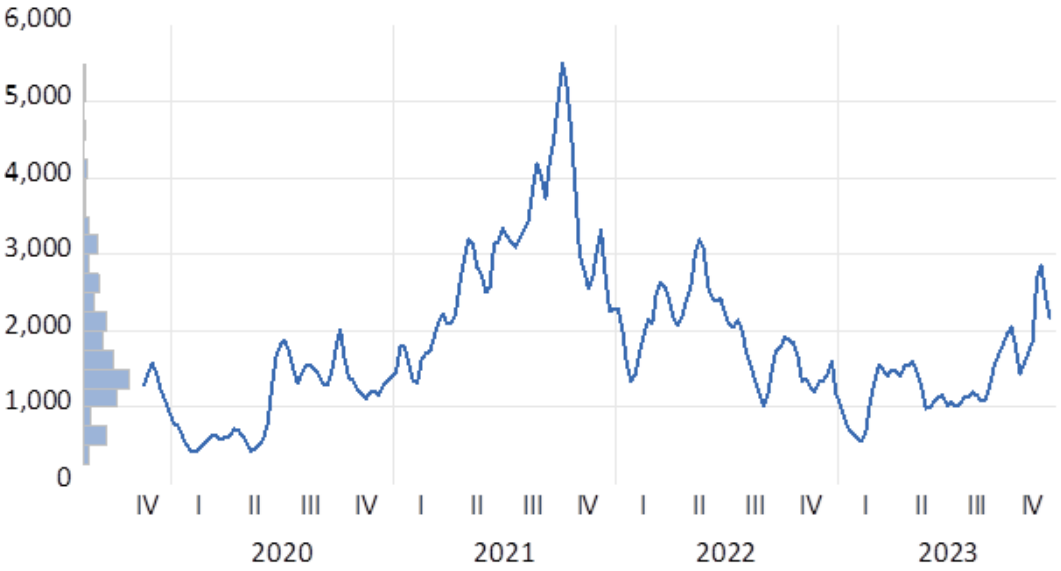
The SADF and GSADF unit root tests evaluate the null hypothesis H0: δ = 1, against the alternative hypothesis H1: δ > 1 (Phillips et al., 2015b).

4. Data

BDI, founded by the London-based Baltic Exchange, serves as a significant indicator of shipping costs and can also serve as a leading indicator for worldwide supply and demand (Ruan et al., 2016, p. 278). BDI is a composite index that is derived by taking the average of BCI, BPI, the Baltic Supramax Index (BSI), and the Baltic Handysize Index (BHSI) (Tsouknidis, 2016, p. 95). BDI measures the average daily cost of shipping raw materials globally used in production. It includes aspects of future economic activity and is thus considered a prominent economic indicator. Endogeneity and supply lag are two common issues that hamper this market's dynamics (Papailias et al., 2017, p. 256). The beginning of the outbreak of COVID-19 had a substantial influence on the pricing of commodities, resulting in reductions across several commodities, notably crude oil. COVID-19 containment measures have significantly curtailed travel, leading to a substantial decrease in oil consumption (Implication of COVID-19 for Commodities, 2024, p. 8). Since the first verified incidence of COVID-19 in China was reported on November 17th, 2019, there have been significant variations in freight prices, which have had a significant impact on supply chains, logistics, and transportation networks all across the world (Allam, 2020, p. 2; Kwon, 2020, p. 107; Roberts et al., 2021, p. 4).

The weekly BDI data was used in our research to identify any bubbles in the shipping freight industry. The sampling started on the week started on November 18th, 2019, and terminated on December 22nd, 2023. The analysis was completed on 213 weekly data in the relevant date range. The data is obtained from https://tr.investing.com/indices/baltic-dry-historical-data and evaluated using the E-views software.

Graph 2. Change in BDI

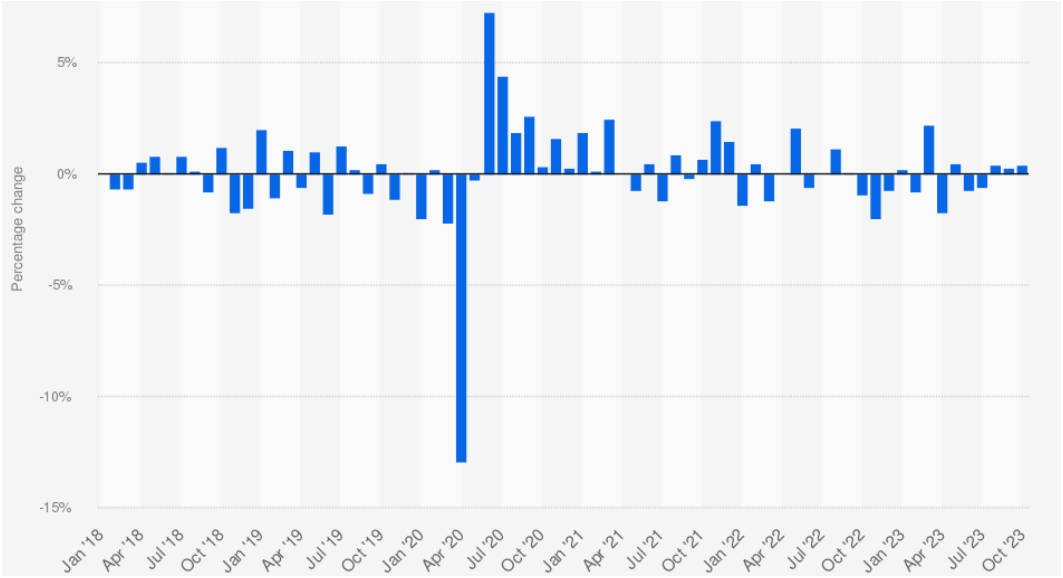


Source: https://tr.investing.com/indices/baltic-dry-historical-data

Graph 2 depicts the progression of the BDI over the research period. A decrease in the demand for shipping was observed up to the first part of 2020. The main factors contributing to the significant impact of COVID-19 on global trade are restrictions on movement, border closures, and prolonged customs procedures. Many measures were implemented during the worldwide COVID-19 epidemic, increasing customs charges and transportation expenses. Consequently, this has resulted in increased costs for international commerce and a decrease in the expected period(Vo & Tran, 2021, p. 6).

Graph 3 illustrates the fluctuation in global goods trade volume. The data illustrates a substantial decline in worldwide trade volume from the initial confirmed case of COVID-19.

Graph 3. Change in Global Goods Trade Volume



Source: Netherlands Bureau for Economic Policy Analysis. (December 22nd, 2023). Global goods trade volume change from January 2018 to October 2023 (Graph). In Statista. Retrieved January 29th, 2024, from https://www.statista.com/statistics/1032180/global-growth-goods-trade/

Global trade experienced a substantial resurgence in 2021, followed by a precipitous decline in 2020 due to the economic upheavals induced by COVID-19. In 2020, the proportion of global output to world trade decreased from 28 percent in 2019 to approximately 25 percent. 2021 attained roughly 30%. The relative importance of Intraregional and Interregional trade flows in most developing country areas remained relatively steady in 2020 compared to 2019 (Key Statistics 2021, 2024, p. 1:11). The contraction in worldwide commerce in 2020 was on par with the global financial crisis in 2008 and notably more severe than the decrease

triggered by the global recession in 2015. The global trade value had a swift comeback in 2021, propelled by a robust rebound in global demand and increased commodity prices. Trade growth has consistently maintained a favorable trend from late 2020 to mid-2022(Key Statistics 2022, 2024, p. 1).

Table 1. The Descriptive Statistics of BDI

	BDI
Mean	1812.197
Median	1553.250
Maximum	5499.800
Minimum	419.2000
Std. Dev.	959.4361
Skewness	1.177106
Kurtosis	4.641979
Jarque-Bera	73.11589
Probability	0.000000
Sum	385997.9
Sum Sq. Dev.	1.95E+08
Observations	213

Source: Authors' calculations

Table 1 provides the descriptive statistics about BDI. As indicated in the table, the median and mean values are nearby. Deviation of the meaning from the media arises when outliers are present, leading to skewed distribution (Livingston, 2004, p. 118). The disparity between the maximum and minimum values indicates that BDI exhibits the most significant volatility from the onset of the pandemic to the conclusion of the investigated time frame, a fact supported by the standard deviation.

A positively skewed value has been identified for BDI. This indicates values with a long tail to the right, meaning that the variables are positively skewed (Doane

& Seward, 2011, pp. 1–7. The kurtosis value shown in Table 1 is larger than 3, indicating that the series follows a leptokurtic distribution. Leptokurtic distributions have a greater degree of Kurtosis, characterized by longer tails and a higher peak in the center (Larasati et al., 2018, pp. 1–2).

Table 2. Results of the SADF and GSADF Test

		SADF	GSADF
BDI		1.860627*	1.958267*
Critical Values:	99% level	1.072375	1.952427
	95% level	0.542361	1.366383
	90% level	0.268334	1.152434

Source: Authors' calculations

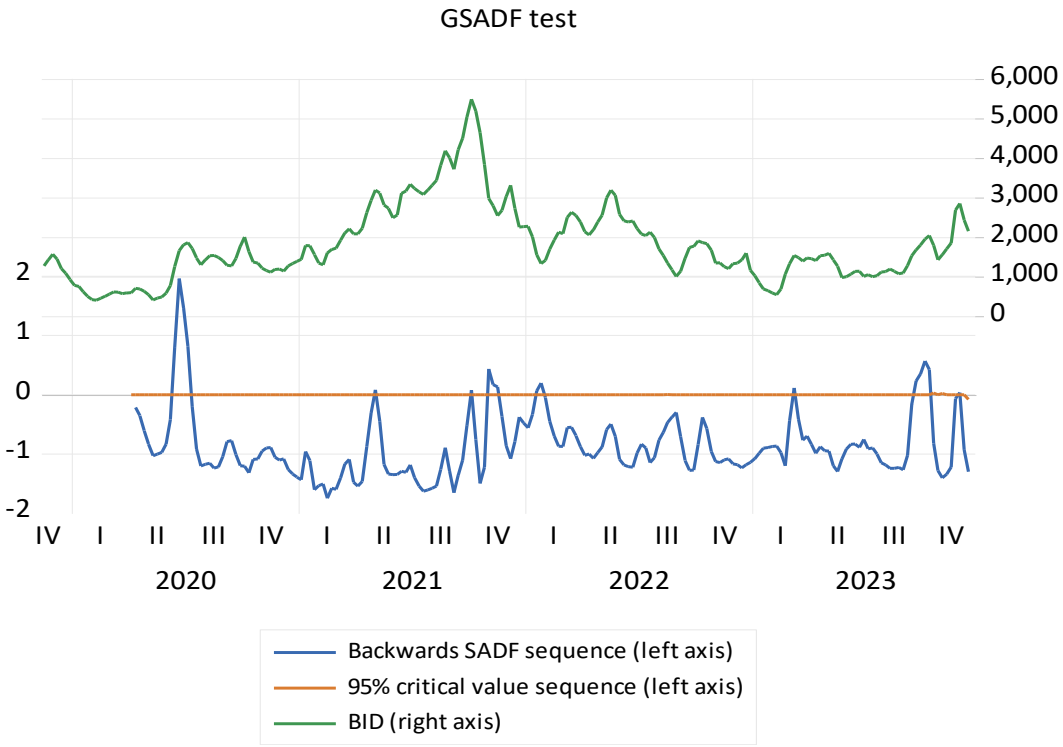
Table 2 displays the statistical value and threshold for SADF and GSADF. The results are obtained by the execution of 1.000 Monte Carlo simulations. The statistical values of the SADF and the GSADF of BDI are 1.86 and 1.95, respectively, and both are >99% of the threshold.

5. Empirical Results

The results presented in Table 2 indicate that BDI contains price bubbles, as the test statistics show the critical values. The findings presented in Table 2 highlight the explosive characteristics of marine transportation and emphasize the importance of detecting bubbles.

Graphs 4 provide graphical representations of the test findings. The green line represents the original series, while the yellow line indicates the crucial values of the tests. Price bubbles appear at the points when the blue line crosses over global catastrophes, like COVID-19, commonly lead to volatility in shipping freight rates. In the long run, exchange rate returns negatively correlate with changes in the BDI (Han et al., 2020, p. 11). Apparent supply and demand factors are the primary drivers of the BDI. (Bildirici et al., 2015, p. 417).

Graph 4. GSADF test of BDI.



Source: Authors' calculations

As seen in Graph 4, the BDI has several instances of bubbles. Considering the test, findings have contributed to the formation of each bubble. In 2020: W25, the first bubble initially emerged, bursting at the end of 2020: W28. The percentage change in global goods trade volume was 7.3% in June 2020 and 4.42% in July 2020. These values represent the most significant percentage change from January 2018 to October 2023, illustrated in Graph 2. The primary factors that will lead to an increase in freight charges throughout the specified time are the changes occurring in the worldwide market for iron ore. The surge in demand from the crucial Chinese market for steel, where iron ore is a fundamental ingredient for steel production, has resulted in a substantial strain on the demand for maritime transportation, as well as a 10-month peak in iron ore prices as of June 2020 (Iron Ore CBS June 2020 — Iron Ore Prices Hit 10-Month High, 2024). Significant increases in freight rating have been noted in the Capesize market. Iron ore is the primary catalyst and critical determinant for the formation of the bubble, which is intricately linked to replenishing and augmented infrastructure expenditures in China.

Additionally, prices increased throughout the Panamax market. In the Atlantic, supply issues have been identified as a factor in the price increase. Evidence suggests that favorable developments in the grain market, such as the introduction of grain from the Black Sea, have substantially contributed to the surge in freight rates (Shipping Costs Soaring | World Grain, 2024). Analyzing the BCI, BPI, BSI, and BHSI, which constitute the components of the BDI, and BDTI and

BCTI, which transport crude oil and petroleum byproducts, both in the period when the bubble was detected and in the neighboring bubble periods, will provide enlightening elements in the analysis process. A bubble was found in the BSI from July 13th to July 23rd, 2020, while no bubbles were detected in any other specified above during the same period (Tarkun, 2024, p. 20). A price bubble was detected for BCTI between April 15th, 2020, and May 1st, 2020, when we examined the periods close to when the bubble was detected (Khan et al., 2023, p. 6). VLCC market experienced a surge of activity in W28:2020, with rates increasing by approximately 40% following a period of inactivity. In the same week, the Suezmax market experienced a surge, primarily due to the US Gulf and West African markets. The Aframax segment has experienced a close to low point level of rates in the North Sea and Baltic during the same time frame (Fearnley Weekly Report - Week 28, 2020, 2024). The conclusion can be drawn that the end of the relevant bubble aligns with the restrictions imposed during the second wave of COVID-19, demonstrating a connection between the conclusion of the relevant bubble and the significance attributed to it within the context of the COVID-19 second wave (Cacciapaglia et al., 2020).

The second bubble occurred in 2021: W18. The upward movement in freight prices has become attributed to the increase in demand that drives maximal iron ore production, particularly from Western Australia and Brazil, because of commodity prices reaching historical levels (Brightmore, 2024). The operational efficiency of shipping companies experienced a notable decrease due to substantial congestion at specific critical ports, ongoing staff shortages, and quarantine restrictions. This decline in efficiency further intensified the upward trend in freight rates throughout the period examined. The link between the blockage of the Suez Canal in March 2021, the consequent increase in freight costs within a short timeframe, and the formation of a price bubble is remarkable (Lee & Wong, 2021). Economic recovery is one of the critical possible causes of the second bubble. In Tarkun (2024) research, a bubble was identified in BHI from February 16th to March 29th, 2021; in BSI from March 3rd to March 24th, 2021; and in BDTI from March 9th to March 30th, 2021. In the research conducted by Khan et al. (2023), another bubble was identified in the BCTI from March 19th to May 1st, 2021. While the duration of the second bubble identified in the research does not precisely align with the periods during which the bubbles in the studies emerged, assessing the temporal closeness of the relevant intervals is valuable.

The occurrence of the following bubble is in the timeframe of 2021: W40. It is crucial to acknowledge that the index captured its highest point ever recorded at 5,650 points in October of 2021 (InterCapital, 2024). The primary factors contributing to the increase are the Atlantic basin and backhaul segment. A potential linkage exists between the substantial decline observed in the FFA curve and the inclination of owners to opt for extended maturity due to diminished confidence in the futures market. An increase in freight costs is attributed to the rising demand for coal. At the time of bubble development, the VLCC market had rate escalations propelled by the Atlantic market. At the same time, the Aframax segment valued

notable enhancements in the Baltic routes for both crude and fuel oil (Fearnleys Weekly Report Week 40 2021, 2024).

Similarly, the fourth bubble bursts at 2021: W46, having come into being at 2021: W44. According to the BDI weekly data, comparing the 3-week period during which the bubble occurred to the preceding three-week periods, there was a fall of more than 37%. One of the reasons for the decline in the relevant time is an adjustment made to counteract the overheating in the freight prices for big ships in October, together with the impact of a decline in demand. The substantial shift in iron ore and coal demand is one of the primary factors contributing to the decrease in freight rates (Enrico Dela Cruz, 2024; "The Coal Hub," 2024; Sivaramakrishnan, 2024). The price bubble identified for BDTI, which started on October 11th, 2021, and persisted until November 15th, 2021, encompasses the duration of the third and fourth BDI bubbles in the analysis (Tarkun, 2024, p. 20).

In the third and fourth weeks of 2022, the fifth bubble emerged and remained intact for two weeks until collapsing. The partial decrease in freight charges has been attributed to demand-based contraction resulting from weather circumstances impacting iron ore mining (Iron Ore Shipments, 2024). The imminent Chinese New Year has been identified as an element influencing the scenario (Impact of Chinese New Year, 2024). During the specified period, tensions have risen in the border dispute between Ukraine and Russia (Ukraine-Russia Border Crisis, 2024). In this given time frame, Suezmax sector rates exhibited positive trends, particularly from the Black Sea to Augusta, Nigeria to the UK, and Basrah to the West Mediterranean markets. The rates in the VLCC sector exhibited a downward trend for significant routes, specifically from the Middle East Gulf to China and from West Africa to China (Baltic Exchange Tanker Report – Week 3:2022, 2024). No additional bubbles were identified in 2022; the sixth bubble occurred within one week, commencing in the tenth week of 2023, and ultimately perished. The upward trend in freight rates, which were comparatively diminished during the preceding period, can be primarily ascribed to two factors: the escalation in transportation volume associated with key commodity groups that rely on maritime transportation, namely iron ore, coal, and bauxite; and the favorable shift in supply/demand ratios. During the time frame, the VLCC market significantly enhanced rates across all routes, including the Middle East Gulf to China, the Middle East Gulf to the US Gulf, West Africa to China, and the US Gulf to China. In the Suezmax market, rates for most routes exhibited a declining trend, while Middle Eastern routes, mainly Basrah/Lavera, had a stable rate (Baltic Exchange Tanker Report – Week 10:2023, 2024).

A bubble of four weeks, which emerged twenty-eight weeks after its predecessor, has been identified within the context of the relevant analysis. The commencement and conclusion of this bubble occurred between the 38th and 41st weeks of 2023. It is significant to note that the bubble mentioned above is the initial detected bubble observed after the WHO's declaration on May 5th, 2023, that COVID-19 has concluded as a public health emergency (WHO Declaration, 2024). The rates on several routes in the VLCC segment, including the Middle East Gulf to China, Middle East Gulf to US Gulf, and West Africa to China routes,

experienced an upward trend during the first week of the bubble's detection. In the Aframax category, despite a notable gain in the Ceyhan/Lavera route, other markets saw declines, particularly the East Coast Mexico/US Gulf and Covenas/US Gulf routes (Baltic Exchange Tanker Report – Week 38 :2023, 2024).

One of the causes for the increase is the failure of supply to meet demand, which can be explained by the ongoing problem of high congestion in Brazil, the growth of the FFA market, and the positive changes in the regional coal supply situation, most notably in Indonesia (SGX Group Reports, 2024). The research period concluded with identifying the eighth and final bubble in the forty-eighth week of 2023. One factor worthy of attention pertains to the BDI value's increase of over 40% during the relevant week compared to the prior week. Increasing cargo demand and tonnage supply have been the primary causes of the condition. The significant trend in iron ore and bauxite transportation appears to have an essential share in explaining the increase in demand (Hellenic Shipping News Worldwide - Baltic Dry Bulk Index Doubles, 2024). The authorization granted by the United States for transactions about oil, gas, and gold in Venezuela has been a significant factor in the substantial escalation of maritime transportation charges (Circular, 2024).

An analysis of price bubbles and the periods in which they occur reveals that the findings are economically consistent when temporary demand constraints and sudden changes in demand in the market are considered. It can be said that the market reactions to excessive supply-demand imbalances in the specified bubbles are among the possible interpretations and topics that need to be researched in the future. The results obtained are substantially consistent with the existing literature, as indicated in the relevant sections. The study specifically demonstrates the dynamic development of prices and the formation of price bubbles in the post-pandemic period, which can be described as a normalization period. The relevant results serve as important indicators that the extreme price volatility experienced during the pandemic continued in the post-pandemic period as well.

6. Conclusion

This study examines the assessment of price bubbles in the maritime freight market utilizing the SADF and GSADF econometric techniques, concentrating on weekly BDI data from the 47th week of 2019 to the 51st week of 2023, encompassing the onset of the COVID-19 pandemic and afterward. For the duration of this analysis, the pandemic period, which included both the time during which there was a significant reduction in limitations and the period during which there was a significant increase in fluctuation in prices, was included. It was important for the study that the period between 24.02.2022 and the following period, a watershed moment in the ongoing tension between Russia and Ukraine, two countries with significant roles in global energy and grain production, fell within the time frame covered by the research. The implications of the Russia-Ukraine conflict, a significant occurrence that has had a profound impact on international trade, and

the results of international sanctions imposed on countries impacted by freight price bubbles have been unquestionably vital topics that warrant more research. Such research has been undertaken in the current research, and the research period commenced in the 47th week of 2019, coinciding with the initial occurrence of the pandemic. Given the final BDI data for 2023, which corresponds to the 51st week of that year, this value was established as the study's endpoint. Freight rates are established based on the balance between the supply and demand. The power dynamics between the shipowner and the charterer are key factors affecting freight prices. The main reason for sudden swings in freight pricing is due to factors that disturb the balance between supply and demand. Numerous instances are documented in the literature where upward price movements were precipitated primarily by unanticipated demand disruptions and carrying capacity shortages. During the research period, notable occurrences impacted the global transportation industry, including a pandemic and increasing geopolitical tensions that resulted in armed conflicts. The primary result demonstrated that the international shipping sector experienced eight bubbles during the relevant period. Two of these bubbles occurred for four weeks, a single bubble occurred for three weeks, one bubble lasted for two weeks, and the other four bubbles lasted for one week altogether. Price fluctuations during the period, including the price inflation identified in the second quarter of 2020, could have been attributed to the repercussions of the COVID-19 initial recovery period. From the start of the research until May 5th, 2023, when the WHO declared the conclusion of COVID-19 as a global health emergency, it can be shown that the primary reason for fluctuations in shipping freight is COVID-19 and related factors. Regional armed conflicts, stranded ships, and containers should be included on the list of occurrences that impacted freight rates during the specified period, in addition to COVID-19. Beyond the elements mentioned above that generate uncertainty, challenges arising from the mismatch between supply and demand and contango's occurrence could also be considered contributing factors to fluctuations in freight rates. The impact of the substantial surge in inflation Graphs documented in the United States during 2020 on the escalation of freight rates is an additional aspect that warrants emphasis. Using data from the Baltic Dirty Ship Index (BDTI), BCTI, and BDI, Khan et al. (2023) examined the development of freight price bubbles during COVID-19. They reached similar conclusions regarding the causes of bubble formation, including high raw material demand and uncertainty induced by COVID-19 restrictions as significant contributors. Additionally, the analysis reveals that inadequate floating storage capacity and oil price fluctuations contribute to bubble formations on the BDTI side.

Upon examination of the last two bubbles, it becomes evident that they serve as a sign that the force majeure situation caused by COVID-19 has been overcome, and the process of returning to normalcy has commenced. The primary factor behind the presence of these bubbles is the uneven demand for land, particularly for coal and iron ore.

A literature review indicates that detecting bubbles formed on BDI data is a subject of significant interest. This represents a significant barrier to thoroughly comparing the results obtained from prior studies. The literature review indicates that Khan et al. (2023) represents a significant intersection of research periods in

the study of bubbles formed on BDI data, allowing for a comparative analysis of results to a certain extent. Khan et al. (2023) analyzed the period range from September 2019 to December 2021. Our investigation spans November 18th, 2019, to December 22nd, 2023, as the time interval. The variance in the research period is among the leading causes of the expected variations in the results. Khan et al. (2023) utilized daily data in their research, whereas the current study employed weekly data, contributing to the discrepancies in the findings. The initial bubble identified in the study was recorded between 2020:25 and 2020:28. Khan et al. (2023) demonstrated that the formation phase of the bubble identified in their investigation occurred between June 12th, 2020, and July 20th, 2020. The bubble identified in the study by Khan et al. (2023) persisted for two weeks overall. The bubble detected during research was recorded in 2021:18. Khan et al. (2023) indicated that the creation phase of the bubble discovered in their analysis happened between April 21st, 2020, and May 13th, 2020, emphasizing a slight temporal discrepancy. The third bubble noted in the search has been recorded at 2021:40. Khan et al. (2023) confirmed that the formation phase of the bubble observed in their study transpired between August 18th, 2021, and October 20th, 2021, including the time span of the bubble in our research. Another bubble identified in our study was spotted during weeks 2021:44 and 2021:46 but was not discovered in the associated study. The disparity in the research duration constitutes one of the primary explanations identified. The dates associated with the other bubbles identified in our research fall beyond the date range stated by Khan et al. (2023), precluding any chance of comparison.

The research allows for furnishing policymakers with a variety of information along with suggestions for policy. The research revealed several instances of price bubbles in freight rates during the duration of the pandemic till the conclusion of 2023. These price bubbles were the result of an extensive variety of factors. The findings derived from the search into the precise attributes and origins of price bubbles furnish valuable insights that could be applied to surmount the factors that contribute to their formation during periods of crisis and beyond, mainly if a force majeure comparable to COVID-19 materializes in the future. In addition to providing policymakers with information that can enhance the early warning system for price bubbles, the research will also improve this system. The applicable system is among the many critical components when identifying elements that may harm a global maritime industry and developing preventative measures. Contributions to assist in the timely identification of price bubbles and the development of preventive measures are precious for all stakeholders in the maritime transportation industry, with particular significance for policymakers and regulators. Future research on price bubbles in the post-COVID-19 era should include the analysis of BCI, BPI, BSI, BHSI, BCT, and BDTI data, in addition to the BDI data. This study can also be expanded by analyzing the impact of COVID-19 on the BCI, BPI, BSI, and the BHSI, as well as the BCTI and BDTI in relation to oil price fluctuations. These studies will provide industry stakeholders and academic researchers with valuable information and insights.

From a policy perspective, the research findings once again emphasize the important role of regulators and market participants in closely monitoring high-frequency fundamental freight indicators, including but not limited to the BDI. Research has shown that econometric methods, including but not limited to SADF and GSADF, can help industry professionals and policymakers manage risk during periods of extreme supply-demand disequilibrium. Econometric methods capable of performing an early warning role, including but not limited to SADF and GSADF, have been shown to be among the methods that can help relevant parties, primarily industry professionals and policymakers, to manage risk during periods of excessive supply-demand imbalances.

The inclusion of a single index in the study, the use of weekly data as the time interval, and the use of economic models that only detect price bubbles in the analysis are among the main limitations of the study. The use of multiple indices related to the subject is among the top recommendations for future studies. In addition, the use of higher-frequency data sets within the scope of the research is another recommended item. Conducting research on longer-interval data sets is another recommended issue. Finally, the application of alternative econometric methods could strengthen future research.

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