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MODELING DYNAMICS OF DRY BULK FREIGHT RATES AND MARKET CAPITALIZATION OF DRY BULK SHIPPING COMPANIES

The majority of international trade is carried by sea. In shipping, the dry bulk sector handles the largest portion of international cargo transportation. **Objective.** This paper examines the influence of various economic indicators on the Baltic Exchange Dry Index (BDI), which is known as the leading indicator of the dry bulk freight market. Furthermore, the study also investigates the factors which predetermined dynamics of the stock market capitalization of five public-listed pure-play dry bulk shipping companies within the period of 2005–2023. **Methods.** By applying OLS (ordinary least squares) regressions on structural market data, the effects of prices of dry bulk commodities, oil, and money (interest rates) on the freight market are estimated. Similarly, the effects of prices of dry bulk cargoes and oil, the S&P 500 index, interest rates and freight rates on stock market capitalization of dry bulk shipping companies are assessed. The **results** suggest that interest rates are a useful predictor of changes in the dry bulk freight rates. As to stock market capitalization, each shipping company exhibited dependence on different factors, with the behavioral pattern of only two of them, Star Bulk and Golden Ocean, being similar. The models for these companies display a comparable power to explain variation in market capitalization and indicate a robust positive relationship with the S&P 500 index and price of aluminium. The prices of oil and iron ore influenced Genco's market capitalization. The BDI and S&P 500 were the primary drivers of the market capitalization of Eagle bulk. Seanergy, holding the lowest market capitalization among companies under analysis, demonstrated dependence on the BDI only, which is consistent with expectations. The prices of other commodities did not demonstrate significance for modeling purposes. Above constitutes **scientific novelty** of the paper. **Practical significance.** The paper presents a modeling instrument which offers equivalent usefulness for both shipping industry participants and investors which consider adding shipping stocks to their portfolios.

Keywords: transport, maritime transport, shipping, shipping companies, fleet, international cargo transportation, seaborne trade, dry bulk trade, freight rates, freight market, BDI, interest rates, oil price, S&P 500 index, stock market, market capitalization, structural market data, regression analysis.

Problem statement. In the world economy, the role of the shipping industry cannot be underestimated since more than 80% of goods traded worldwide are transported by sea [1]. As any other form of the international economic relations, the shipping industry has been affected recently due to the covid-19 pandemic and the Ukrainian war outbreak. The volume of the seaborne trade dropped on a year-on-year basis, however, in 2023 it recovered and exceeded pre-covid (2019) levels. Overall, seaborne trade follows a clear upward trend over several decades [1].

In terms of both trade volumes and existing vessels' cargo carrying capacity, the dry bulk sector accounts for almost half of the shipping industry [1]. Moreover, this is the most significant shipping sector for Ukraine. The dry bulk segment is engaged with transportation of dry bulk cargoes which are subdivided into major bulk (iron ore, coal, grain) and minor bulk (steel products, forest products, fertilizer, bauxite, cement, petcoke,

sugar, etc.). Iron ore is a key steel component and is mainly consumed in construction industries. Coal is used for steelmaking and fueling power stations. Grain is an agricultural commodity used for baking and factory farming [2, p. 445–446].

Out of four markets providing maritime transport services, three are supportive while the freight market is the leading one as it essentially trades vessels' space and establishes the equilibrium price of transportation – freight rate [2, p. 177–179]. The maritime economics theory suggests that co-movements between different types of freight rates or indices are inherent to each sector of shipping, as such, each type of rate can be scrutinized with the similar level of relevance as a proxy of specific freight market [3, p. 46–47]. For the sake of dry bulk sector analysis, the Baltic Exchange Dry Index (BDI) produced and published by the Baltic Exchange perfectly represents the freight market. It is a composite index calculated as a weighted average of the four vessel-specific indices classified by tonnage of associated dry bulk carriers – BCI (Capesize), BPI (Panamax), BSI (Supramax), BHI (Handysize) indices [4]. Introduced in 1999, it is considered as a 'barometer' of dry bulk shipping by all stakeholders, so fits for the two purposes of this research.

The inherent cyclicality of freight market [2, p. 96–98] makes it rather unpredictable while an ability to forecast the development of freight market is crucial to successful and more informed decision-making processes in shipping. Thus, there is a continuous need for advancement existing and development new modeling techniques for more effective prediction of the freight market cycles. Concurrently, market capitalization of shipping companies remains underexplored, albeit for existing shareholders and potential investors it reflects the corporate health of a company.

Analysis of recent research and publications. Extensive earlier research on the factors influencing the BDI or other proxies for dry bulk shipping freight market is available in existing literature. Regarding commodity prices, they were significant the most during negative price growth regimes providing a roadblock to any perspective freight rate uplift while during positive growth regime no impact of commodity prices on freight rates was noticed as opposed to the impact of oil, as N. Michail and K. Melas note [5, 6]. Later W. Drobetz et al. [7] confirmed that dry bulk shipping freight rates were positively impacted by geopolitical risk shocks. In addition, S. Park, H. Kim and J. Kwon [8] ascertained that when dry bulk freight rates exceeded the expected range, this was dictated by specific demand rather than actual interception of supply and demand curves.

Concurrently, significantly less attention has been devoted to shipping stock market indicators so far. Changes in commodity prices, including oil, were found to result in shipping stock prices increasing, according to N. Michail and K. Melas [9]. Another research by K. Grammenos and A. Arkoulis [10] indicates that while industrial production and inflation do not influence stock returns of the shipping companies, exchange rates positively affect it while oil prices and laid-up tonnage negatively. In containership segment, stock market capitalization of the leading market player (Maersk) proved significant to impact charter rates, as G. Zaidman et al. point out [11].

Research methodology. With the aim to contribute to the pertinent literature by adding stock market indicators into shipping analysis as well as modeling dependence of shipping stock market performance on different variables, stepwise regressions are performed by OLS (ordinary least squares) technique to determine respective regression equations. The best equation is the one that minimizes the sum of the squares of the errors between each year's real observation and each year's theoretical equation. To this end, IBM SPSS Statistics software is utilized.

Two types of opposing hypotheses are formulated: the null hypothesis (purports insignificant relationship between response and each explanatory variable) and the alternative hypothesis. The level of confidence of 95% about results is aimed at. Hypotheses are checked against p-value, Student's t distribution and standard error. Thereafter the coefficient of determination (R-squared) is verified to assess the degree of goodness of fit of each model, i.e. to which extent the regression equation can predict the variation. F-statistic and its significance are examined to evaluate the quality and adequacy of the model. As a diagnostic test for autocorrelation, the Durbin–Watson statistic is examined.

The set of structural market data used for analysis and modeling contains annual time-series data for the period from 2005 to 2023 captured from various open-access sources, such as Companies Market Cap [12], Macrotrends [13], Trading Economics [14], the Federal Reserve Bank of St. Louis [15]. The set of structural market data includes the following indicators (acronym assigned to each variable for the sake of regression analysis is nearby each variable name in brackets in italics): Eagle Bulk market capitalization (*EAGLE_MARCAP*); Genco market capitalization (*GENCO_MARCAP*); Golden Ocean market capitalization

(*GOLDEN_OCEAN_MARCAP*); Seanergy market capitalization (*SEANERGY_MARCAP*); Star Bulk Carriers market capitalization (*STAR_BULK_MARCAP*); the Baltic Exchange Dry Index (*BDI*); LIBOR 1-year interest rate (LIBOR); the S&P 500 index (*SP500*); price of Brent crude oil (*P_OIL*); price of iron ore (*P_IRON_ORE*); price of coal (*P_COAL*); price of wheat (*P_WHEAT*); price of corn (*P_CORN*); price of rice (*P_RICE*); price of aluminium (*P_ALUM*).

The purpose of the article is to offer a modeling mechanism of dry bulk freight market and market capitalization of dry bulk shipping companies. In this regard, the first research objective is to determine the factors which influenced the BDI within 2005–2023. The second research objective is to model the relationship between stock market capitalization of the five active dry bulk shipping companies and various macroeconomic and dry bulk trade specific indicators. This allows to figure out commonalities and differences to eventually issue recommendations for market practitioners and shipping investors.

Summary of the main research material.

1. Analysis of BDI

To satisfy the first research objective, a stepwise regression is run for the following model:

$$BDI = \beta 0 + \beta 1 * LIBOR + \beta 2 * P\_OIL + \\ + \beta 3 * P\_IRON\_ORE + \beta 4 * P\_COAL + \\ + \beta 5 * P\_WHEAT + \beta 6 * P\_CORN + \\ + \beta 7 * P\_RICE + \beta 8 * P\_ALUM \quad (1)$$

Stepwise regression analysis suggests that the null hypothesis cannot be rejected for prices of oil and seven dry bulk cargoes under examination, as such, they are made redundant and not included into regression equation while LIBOR proved significant.

$$BDI = 594.602 + 602.029 * LIBOR \quad (2)$$

To explore in depth and check the nature of the revealed relationship between the BDI and LIBOR and the strength of it, the regression model was reconstructed to ascertain which equation (linear, quadratic, or cubic) better explains the relationship.

According to the models summary presented in Tab. 1 and Tab. 2, cubic equation has the highest R-squared value which means that the cubic function is the most robust to reflect the relationship.

$$BDI = 2362.848 - 1768.671 * LIBOR + \\ + 628.400 * LIBOR^2 - 41.350 * LIBOR^3 \quad (3)$$

Equation (3) explains 47.7% of the variation in the BDI within 2005–2023 by changes in LIBOR with 98.2% probability. Statistical significance is proved by F-statistic value (4.563) exceeding the critical value (3.287 at 5% significance). The actual significance level of F is 0.018 (fall under less than 0.050). Fig. 1 illustrates the observation.

As opposed to prices of seven considered dry bulk cargoes which do not influence the development of the BDI, the price of money (LIBOR) impacts the cost of transportation in the dry bulk shipping. This model's observation has practical application as it indicates that monetary policy of the major regulators affected the global dry bulk shipping industry through interest rate over the period under examination.

As far as relatively low interest rates were concerned, with the increase of LIBOR, the BDI

Table 1

'BDI (LIBOR)' regression models' summary

Equation	Model summary		
	R-squared	F	Significance
Linear	0.349	9.116	0.008
Quadratic	0.473	7.187	0.006
Cubic	0.477	4.563	0.018

Source: compiled by the authors on regression analysis performed in IBM SPSS Statistics

Table 2

'BDI (LIBOR)' regression models' parameter estimates

Equation	Parameter estimates			
	Constant	β1	β2	β3
Linear	594.602	602.029		
Quadratic	1,923.315	-939.842	269.956	
Cubic	2,362.848	-1,768.671	628.400	-41.350

Source: compiled by the authors on regression analysis performed in IBM SPSS Statistics.

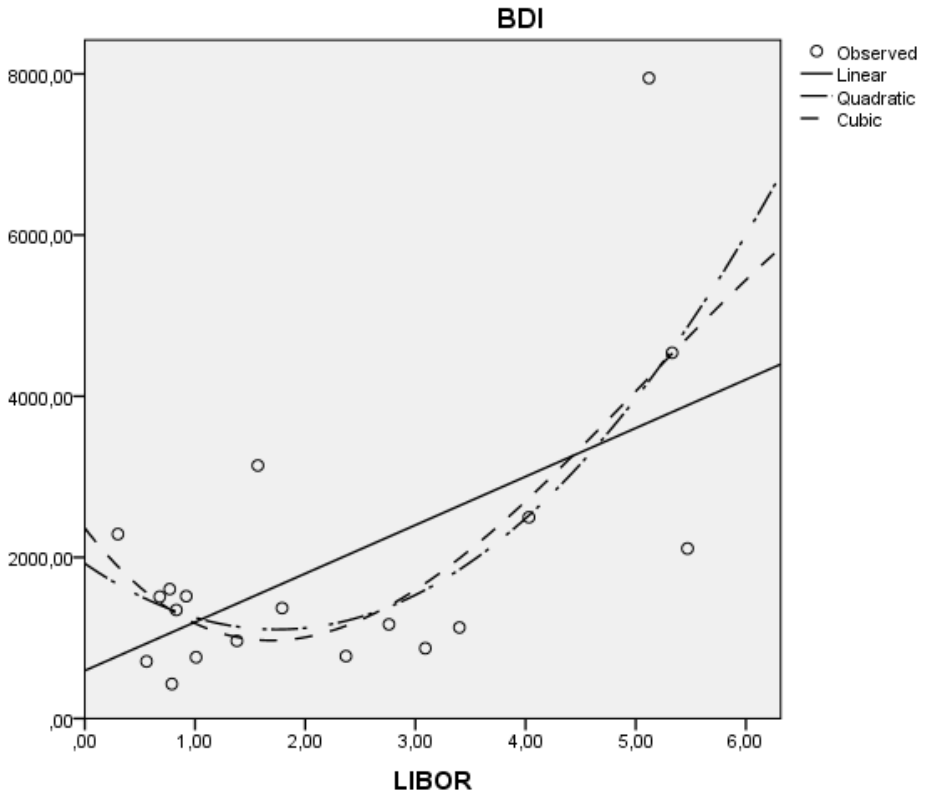

Fig. 1. Graphs of linear, quadratic and cubic equations of relationship between BDI and LIBOR

Source: compiled by the authors on regression analysis performed in IBM SPSS Statistics.

decreased. This was valid till the extremum of the cubic function was reached (BDI=968.984). After the extremum value, further increase of LIBOR stimulated the growth of the BDI. This is apparently due to a time lag as the increase in operations financing costs driven by the increase in interest rates takes a period of time to actually occur which in the given case amounted to 4–6 months.

2. Analysis of stock market capitalization of five dry bulk shipping companies

To satisfy the second research objective, five dry bulk shipping companies are considered. Although selected randomly, all of them satisfy two selection criteria, being a) pure-play dry bulk carriers' owners, and b) public listed. Each shipping company is examined independently, and a stepwise regression is run for each company for the following general model:

$$MARCAP = \beta 0 + \beta 1 * SP500 + \beta 2 * BDI + \\ + \beta 3 * LIBOR + \beta 4 * P\_OIL + \\ + \beta 5 * P\_IRON\_ORE + \beta 6 * P\_COAL + \\ + \beta 7 * P\_WHEAT + \beta 8 * P\_CORN + \\ \beta 9 * P\_RICE + \beta 10 * P\_ALUM \quad (4)$$

Tab. 3 and Tab. 4 present the statistical outcome of the regression analysis. Statistically insignificant factors are made redundant while statistically significant variables which demonstrate relationship with the respective stock market capitalization indicators are presented in the relevant column.

For Eagle Bulk stock market capitalization (shipowner focused exclusively on Handymax/Ultramax tonnage), neither LIBOR nor price of oil nor price of dry bulk commodities passed the test for significance whilst the BDI and the S&P 500 index did – both positively impact the response variable which is consistent with the current economic theory. Expectedly, Eagle Bulk, being a US-based public listed company, demonstrated connection with the S&P 500 index which represents the stock performance of the 500 largest companies listed in the USA.

The coefficient of determination (0.720) suggests that 72% of Eagle Bulk marcap variation can be explained by changes in BDI and S&P 500. The F-statistic is 20.609 which comfortably exceeds the critical value of 3.634 (at 5% significance). The actual significance level of F is effectively zero and certainly less than 5%. Durbin-Watson statistic (2.414) falls within the 1.536–2.464 range suggesting no errors autocorrelation observed. Both t-statistic exceed the threshold value (2.120).

For Genco Shipping market capitalization, the outcome of the regression analysis is completely different – only prices of oil and iron ore

Table 3

Summary of regression analysis of dry bulk shipping companies' market capitalization on various economic indicators

Dependent variable	Model summary			
	R-squared	DW	F	F prob.
EAGLE_BULK_MARCAP	0.720	2.414	20.609	0.000
GENCO_MARCAP	0.841	2.616	18.545	0.002
GOLDEN_OCEAN_ MARCAP	0.886	1.384	62.294	0.000
SEANERGY_MARCAP	0.467	1.193	12.265	0.004
STAR_BULK_MARCAP	0.928	2.480	96.210	0.000

Source: compiled by the authors on regression analysis performed in IBM SPSS Statistics

Table 4

Summary of parameter estimates of regression models of dry bulk shipping companies' market capitalization on various economic indicators

Dependent variable	Parameter estimates			
	Significant independent variables	Std. coef.	t statistic	Prob.
EAGLE_BULK_MARCAP	BDI	0.844	6.252	0.000
	SP500	0.361	2.678	0.017
	_cons	-0.077[a]	-0.763	0.457
GENCO_ MARCAP	P_OIL	0.655	3.849	0.006
	P_IRON_ORE	0.405	2.379	0.049
	_cons	-0.424[a]	-2.859	0.024
GOLDEN_OCEAN_ MARCAP	SP500	0.890	10.442	0.000
	P_ALUM	0.201	2.356	0.032
	_cons	-0.983[a]	-3.373	0.004
SEANERGY_ MARCAP	BDI	0.683	3.502	0.004
	_cons	-0.001[a]	-0.059	0.954
STAR_BULK_ MARCAP	SP500	0.920	13.147	0.000
	P_ALUM	0.194	2.771	0.014
	_cons	-1.356[a]	-4.780	0.000

[a] Unstandardized coefficients are used for constants

Source: compiled by the authors on regression analysis performed in IBM SPSS Statistics

demonstrated statistically significant relationship with the response variable. Unexpectedly, the S&P 500 index was made redundant. The R-squared value (0.841) suggests that 84.1% of Genco marcap variation can be explained by changes in prices of oil and iron ore. Iron ore is mainly transported by Panamax and Capesize tonnage. Over the last years, Genco was not reported to operate any Panamax vessel while Capesize fleet accounts for 37% of company's fleet in vessel units and for 64% of company's cargo carrying capacity [16]. It may be concluded that the company is more dependent on the trade of its Capesize part of the fleet rather than Handymax/ Ultramax.

The F-statistic (18.545) is in considerable excess of the threshold value of 3.634 (at 5% significance). The actual significance level of F is effectively zero and certainly less than 5%. Durbin-Watson statistic (2.616) falls into the uncertainty region, and the evidence for autocorrelation is very mild. Both t-statistic exceed the critical value (2.120) with the corresponding p-values being less than the specified level of significance.

For Golden Ocean stock market capitalization, the statistical significance was proven for the S&P 500 index and price of aluminium. Although shipping firms do not dominate the S&P 500 as opposed to IT and financial companies, Golden Ocean, as all other companies examined in the current paper, is listed on NASDAQ, therefore the connection between its capitalization and overall stock market capitalization trends is reasonable.

The coefficient of determination (0.886) suggests the high forecasting accuracy of the model as 88.6% of Golden Ocean marcap variation can be explained by changes in the S&P 500 and price

of aluminium. The F-statistic is 62.294 which by far exceeds the critical value with confident significance level (effectively zero). Durbin-Watson statistic (1.384) falls in the middle of the uncertainty range, so minor autocorrelation may occur if any. Both t-statistic exceed the threshold value (2.120), it is extremely strong (10.442) especially in case of the S&P 500.

Among the five models, the one constructed for Seanergy market capitalization appeared to have the lowest predictive capability (coefficient of determination is 0.467) with only one variable (BDI) proved significant. While F-statistic (12.265) exceeds the threshold value (4.451) with p-value below 0.05 and t-statistic for the BDI (3.502) is over the critical value (2.110), Durbin-Watson statistic (1.193) factually falls within the region of uncertainty, although by insignificant margin, being effectively nearby the range pinpointing the positive autocorrelation of errors (1.180–1.401).

For Star Bulk Carriers market capitalization (which announced merger with Eagle bulk [17] after the commencement of the current research), the produced regression model is the most robust and qualified. The coefficient of determination is the highest out of all (0.928) and the F-statistic (96.210) is the highest as well.

Having said that, 92.8% of the variations in Star Bulk Carriers marcap can be explained by variations in the two explanatory variables – the S&P 500 index and price of aluminium whose t-statistic values (13.147 and 2.771) exceed the threshold (2.120). Durbin-Watson statistic (2.480) falls within uncertainty region and beyond the 'no autocorrelation range' (1.536–2.464) with insignificant margin allowing to conclude low probability of errors autocorrelation.

Findings and recommendations. Interestingly, modeling results were the most credible for the two dry bulk shipping companies whose market capitalization in absolute terms has been the highest out of all considered shipowners since 2017 (Golden Ocean and Star Bulk Carriers). Both shipowners appeared to be dependent on similar factors – the S&P 500 and price of aluminium. The latter is especially worthwhile further investigation since aluminium is not the major dry bulk commodity in terms of volumes transported by sea. In respect of relationship with the S&P 500 index, it is abundantly clear that the US-listed shipping companies with the highest market capitalization follow the general trend of the largest world companies operating in various spheres.

In turn, Seanergy, whose stock market capitalization is the lowest out of the companies under examination, did not demonstrate relationship with considered variables apart from the BDI which, although consistent with basic maritime economics, does not allow for more sophisticated method of modeling and forecasting company's marcap development.

Eagle Bulk is the third company whose marcap is dependent on the S&P 500 index, which is a rather straightforward observation for the company originated from the USA. Future research may focus on examining whether this observation holds true once Eagle Bulk and Star Bulk Carriers complete the merger and start acting as one entity – the world's largest publicly-listed bulker owner [17]. As to the BDI, the connection is apparent – when the freight rates increase, ceteris paribus so does market capitalization. The same applies to negative growth regime.

Despite also being the US-headquartered company, Genco is the only shipping company whose market capitalization changes are explained solely by prices of goods – iron ore and oil. Volumes of iron ore seaborne trade exceed volumes of all other dry bulk cargoes and account for approximately 13% of overall seaborne trade volumes [1]. The assumption can be made that Genco's vessels were actively engaged in iron ore trade over the period under consideration, although this is subject to further verification through available information about vessels' employment track record in the past. On another note, earlier research [11] confirmed that price of steel (produced out of iron ore) impacted the containership charter rates development.

As to the price of oil, the assumption can be made that the impact on Genco's marcap is stipulated by vessels' efficient oil consumption, so further look at fleet's profile and vessels' energy efficiency indicators is preferable before taking investment decisions. Another reason for this observation may be that Genco's vessels were mainly employed under time-charter agreements since such contracts prescribe bunker costs to be under charterer's (not owner's) responsibility.

The conducted research based on structural market data suggests that price of coal and grains (wheat, corn, rice) should not be primarily analyzed for the modeling and forecasting market capitalization of considered dry bulk shipping companies. As regards LIBOR, although it was excluded from all five regression equations for respective companies, as a predictor it proved a strong connection with the BDI when all commodity prices did not, and BDI (as a proxy for freight rate) is in essence the main variable of focus for all shipping industry participants.

Therefore, LIBOR should be attentively examined once there is a need to predict freight market developments. After a major interest rate drop in 2020 and 2021 caused by the attempt to support the world economy and slowed down

economic growth due to covid-19 pandemic, the main world regulators increased interest rates in 2022 and 2023 [13] to tackle the inflation. With the expectation that interest rates are supposed to decrease in the forthcoming future, the prediction can be made that dry bulk freight rates may subsequently decrease. In some time, further research may attempt to find a new extremum point when negative impact of LIBOR on the BDI turns to positive. Another suggestion for future research is to verify applicability of this observation to containership and wet bulk shipping segments.

Conclusions. Despite the limitations of the study, the above modeling findings may be of interest to said companies' owners and shareholders as well as stock market participants and third-party shipping investors as soon as with the high level of credibility observations will remain valid for the future.

Based on the analysis of structural market data, the following useful predictors for dry bulk shipping modeling were ascertained. Fluctuations in commodity prices did not turn to influence stock market capitalization of dry bulk shipping companies much except for aluminium and iron ore. The price of oil has a profound effect only on the market capitalization of one considered company (Genco). There are certain commonalities in the behavior of market capitalization indicators – companies with the largest market capitalization in absolute terms (Star Bulk Carriers and Golden Ocean) appeared to be dependent on the S&P 500 and price of aluminium while among the two US-based shipowners only one (Eagle Bulk) demonstrated the causal relationship with the S&P 500. The BDI proved to impact marcap of only two considered companies.

While LIBOR does not directly impact marcap, it is the most powerful explanatory factor for the BDI modeling. This allows to infer that regulatory authorities influence the dry bulk shipping market, and this influence is channeled through interest rates as a monetary measure. For the current unstable state of the world economy when LIBOR in 2023 was 18 times higher than in 2021, this observation has a direct practical implication and forecasting sense for all stakeholders of the shipping market.

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МОДЕЛЮВАННЯ ДИНАМІКИ ФРАХТОВИХ СТАВОК НА СУХОВАНТАЖНІ ПЕРЕВЕЗЕННЯ ТА РИНКОВОЇ КАПІТАЛІЗАЦІЇ СУХОВАНТАЖНИХ СУДНОПЛАВНИХ КОМПАНІЙ

У судноплавстві на суховантажний сегмент припадає найбільша частина міжнародних вантажних перевезень. Стаття досліджує вплив різних економічних показників на Балтійський індекс суховантажних перевезень (BDI), який відомий як провідний індикатор ринку суховантажних морських перевезень. Крім того, у статті також досліджуються фактори, які визначили динаміку ринкової капіталізації п'яти суховантажних судноплавних компаній, які котируються на фондовій біржі, протягом періоду з 2005 до 2023 року. Проводячи регресійний аналіз структурних ринкових даних із використанням методу найменших квадратів, дослідження оцінює вплив цін на сухі вантажі, нафту та гроші (процентні ставки) на фрахтовий ринок. Подібним чином також оцінюється вплив цін на насипні вантажі та нафту, індексу S&P 500, процентних ставок і фрахтових ставок на ринкову капіталізацію суховантажних судноплавних компаній. Результати свідчать про те, що процентні ставки є значущим прогностичним фактором змін у ставках фрахтового ринку суховантажного тоннажу. Що стосується ринокової капіталізації, то кожна судноплавна компанія демонструє залежність від різних факторів, і моделі лише для двох з них, Star Bulk і Golden Ocean, подібні. Моделі для цих компаній демонструють порівняльно високу здатність пояснювати коливання ринкової капіталізації та вказують на сильний позитивний зв'язок з індексом S&P 500 і ціною на алюміній. Ціни на нафту та залізну руду впливають на ринкову капіталізацію компанії Genco. Ціни на інші товари не продемонстрували значущості для моделювання. Ці висновки однаково корисні як для учасників судноплавної галузі, так і для інвесторів, які розглядають можливість додавання акцій судноплавних компаній до своїх портфелів.

Ключові слова: транспорт, морський транспорт, судноплавство, підприємства морського транспорту, флот, міжнародні вантажні перевезення, морська торгівля, суховантажна торгівля, фрахтові ставки, фрахтовий ринок, BDI, процентні ставки, ціна нафти, індекс S&P 500, фондовий ринок, ринкова капіталізація, структурні ринкові дані, регресійний аналіз.