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Başlıca Ticari Gemi Tiplerinin Ortalama Filo Hızlarının Modellenmesi ve Analizi

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ÖZET

Bu çalışmada, deniz taşımacılığında ana piyasa türleri olan konteyner, kuru yük ve ham petrol filolarının ortalama hızlarını navlun oranı, yakıt fiyatı, filo büyüklüğü ve faiz oranı gibi dış faktörleri kullanarak tahmin ve analiz edilmiştir. Teorik çerçeveye uygun olarak, navlun ve faiz oranları ortalama hızları olumlu yönde etkilerken, yakıt fiyatı ve filo büyüklüğü olumsuz yönde etkilemektedir. Navlun oranı en çok konteyner filosunun ortalama hızını etkilerken, yakıt fiyatı, filo büyüklüğü ve faiz oranı en çok ham petrol filosunun ortalama hızını etkilemektedir; kuru yük filosunun ortalama hızı yakıt fiyatından ve filo büyüklüğünden en az etkilenmektedir; ve konteyner filosunun ortalama hızı faiz oranından en az etkilenmektedir. Genel olarak, faktörler arasındaki katsayı büyüklükleri göz önüne alındığında, üç pazarın ortalama hızlarında en etkili faktör filo büyüklükleridir. Böylece navlun ve yakıt fiyatı çerçevesinde sıkışmış olan ampirik literatüre yeni boyutlar eklenmiştir.

Anahtar kelimeler: Gemi hızı, yakıt fiyatı, navlun oranı, faiz oranı.

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Research Article

Modeling and Analyzing the Average Fleet Speed of Major Commercial Ship Types

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ABSTRACT

In this study, the average speeds of container, dry bulk and crude oil fleets, which are the main market types in maritime transportation, are estimated and analyzed by using external factors such as freight rate, bunker price, fleet size and interest rate. Freight and interest rates affect the average speeds positively, while bunker price and fleet size negatively affect in accordance with the theoretical justifications. The freight rate mostly affects the average speed of the container fleet, while bunker price, fleet size and interest rate mostly affect the average speed of the crude oil fleet; the average speed of the dry bulk fleet is least affected by the fuel price and fleet size; and the average speed of the container fleet is least affected by the interest rate. In general, when the coefficient sizes between the factors are considered, the most effective factor in average speeds of the three market is their fleet size. Thus, new dimensions have been added to the empirical literature stuck in the framework of freight rate and bunker price.

Keywords: Vessel speed, bunker price, freight rate, interest rate

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1. Introduction

The speed of the ship is the most important factor affecting the productivity of the ship. With faster sail times, more cargo can be transported in a given period (Alderton, 2008:45). However, since the ship's speed increase directly affects the voyage costs (Lui, 2012:391), different speed choices can be observed in every market and voyage conditions. Therefore, the speed that maximizes profitability can vary.

A concept emerging from the relationship between speed and cost is slow steaming. It is a concept that emerged after some unexpected market conditions occurred in the early 2000s. With the simultaneous occurrence of factors such as high fuel prices, oversupply in the market and low freight rates, ship owners reduced their speed to maintain their profitability and followed a slow steam strategy (Cariou, 2019:150). Keeping the speeds low is beneficial, especially in terms of fuel savings. Additionally, the damage caused by ships to the environment is also reduced. However, there are also negative effects on services such as delays and longer transit time. For this reason, the concept of optimum speed has begun gaining more importance.

Optimum speed is the speed level that maximizes the current profitability over the effect of many external factors on maritime transportation. In other words, the optimum speed may be high or low in different market conditions and at different times (Crist, 2012:195). In addition, because the markets of each cargo type are partly different from each other, the effects of external factors on the speeds in each market may differ. For example, while some cargoes are low in value, other cargoes have much higher values. Or, while the competition is low in some markets, the features of a perfectly competitive market may prevail in some markets. Generally, ships increase their speed if the benefit gained by increasing the speed of the ship is greater than the cost of the increase in the speed (Adland, 2021:327).

In studies examining the speed of ships in the literature, ship speeds are often modeled on the basis of bunker price and freight rates. Interest rates, which are the most important factor determining the capital cost of the cargo and the ship, are not included in the empirical models. Additionally, there is no doubt that the size of the fleet, which represents the supply in the market, will affect the competition and be decisive in the speed of the ships. Not including these important variables in the empirical models reduces the inclusiveness of the results. The empirical modeling of these variables, which are stated in some sources as theoretically affecting ship speeds, together with bunker price and freight rate is the first distinguishing point of our study from the literature. Furthermore, possible differences according to market conditions have not been taken into account sufficiently. Because the structures and mechanisms of the markets may differ from each other according to the type of cargo and the type of ship. In some markets, competition is very high, while in others it is quite low. This situation may cause differentiation in the concerns of delivering the cargo quickly. Accordingly, in this study, it is aimed to model the average speed values in the container, dry bulk and crude oil transportation markets, which are the main markets in maritime, with some external factors. The factors included are freight rate, bunker price, fleet capacity and real interest rate. The findings obtained using regression models revealed that the effects of the factors are significant, and the effect levels differ according to the market types. Freight and interest rates have a positive effect on the average fleet speed, while the effect of fuel price and fleet size is negative. Thus, results in accordance with the theoretical expectations were obtained and new dimensions were added to the limited empirical models in the literature.

In the second part of the study, the possible effects of the factors that are included in the model are examined by considering the ship speed theoretically. Literature is reviewed and current study is positioned in the third part. The method and data set used are introduced in the research model in the fourth part. The results of the research and discussions about these results are presented in the fifth part. In the last part, our findings are presented, and recommendations are made for further studies.

2. Theoretical Framework

One of the most basic of the models developed based on the question of which ship speed increases the profitability for the ship owner in which situation has been developed by Evens and Marlow (1990) and presented in Equation 1. The factors affecting the optimum speed (S) in this equation are voyage freight rate (R), bunker price (p), distance (d) and fuel constant (k).

$$S = \sqrt{\frac{R}{3pkd}} \tag{1}$$

According to this equation, it is possible to make inferences about the effects of some variables on the optimum speed assuming other variables are constant. Since the voyage revenue (R) is at the top of the fraction, the increase in the value also increases the optimum speed (S). The main reason for this is the effort to complete the current voyage faster and get another new cargo at high freight rates. However, the bunker price (p) is at the bottom of the fraction, and an increase in this value decreases the optimum speed (S). The main reasons for this are the cubic relationship between speed and fuel consumption, and the high share of bunker cost in total voyage costs. Finally, since the distance (d) is at the bottom of the fraction, an increase in this value decreases the optimum speed (S). The reason for this is that the fuel consumption is higher in the long distance, and the extra fuel consumption resulting from the higher speed can cause a huge cost increase in the long distance.

Meaning of optimum speed may differ according to ship owners and cargo owners. For ship owners, optimum speed can be achieved by profit maximization, while for cargo owners, it can be achieved by cost minimization. Freight and time costs are the main items that form costs for cargo owners. The time cost is the inventory cost for the cargo due to interest rates. In this respect, the level of freight that the cargo owner can bear is very effective in determining the optimum speed for the ship owner (Ma, 2020:148). Therefore, the inclusion of interest rates in the above model would be more inclusive.

In this study, it is aimed to model the validity of these and similar theories and the effect of some other macroeconomic variables on ship speed. To test this, average speed statistics for ship types are compiled from various data sources. Then, the models are developed by adding the variables that are likely to affect the speed value in this macro dimension. Unlike previous studies, we also added the interest rate variable to this model. Because the maritime market is considered a market that interacts with itself. However, this market is also affected by the global economy and macroeconomic variables. The model we set up is presented in Equation 2.

$$Speed\ of\ Vessel = f(Freight(+), Bunker\ Price(-), Vessel\ Supply(-), Interest\ Rate(+)) \tag{2}$$

In this model, ship speed is correlated with the freight rate, bunker price, fleet size and interest rate due to both the theoretical background and data availability. According to the expectations, while freight and interest rates affect optimum speed positively, fleet size and bunker price affect negatively. Now, the theoretical impact of each factor is considered under subheadings.

2.1. Impact of Freight Rate

One of the most important factors determining ship speeds is freight rates. The level of freight in the market directly determines the profitability of ships (Alizadeh and Nomikos, 2009:3). Additionally, a general feature of the maritime market is that the supply is inelastic in the short run due to the time to build effect (Bendall and Stent, 2005). Therefore, the only way to increase the transport capacity supply in the short run is to increase the speed of the ship (Sturmey, 1975:66). In this way, the amount of cargo carried per unit time increases. For this reason, there is a positive relationship between freights and ship speeds. In depressed market conditions, ships tend to sail at a slow steam, and in boom market conditions, ships tend to sail at a faster speed (Wen et al., 2017). Additionally, pirate attacks on ships may increase during periods of high freight rates (Erginer et al., 2019). For this reason, ships can increase their speed more while passing through dangerous areas. Generally, the effect of freights on ship speeds is positive.

2.2. Impact of Bunker Price

In addition to freight rates, the other most important factor affecting the profitability of ships is cost. The cost item that constitutes the largest share of the total cost of the ship is fuel cost. Fuel consumption is directly related to the speed and fuel consumption profile of the ship (Andersson at al., 2015), so it may constitute between 30% and 80% of the total voyage costs (Mietzner, 2015:109). As the ship speed increases, the fuel consumption does not increase at the same rate, but much more (Doudnikoff et al., 2014). When freight rates are high, the fuel price becomes less important, and shipowners increase ship speeds. However, fuel price is one of the important factors in determining ship speed as it greatly affects profitability. Therefore, there is a negative relationship between ship speed and fuel price (Cariou, 2019:143). On the one hand, increasing ship speed makes it possible to carry more spot cargo. On the other hand, reducing the speed reduces costs as it causes to consume less fuel (Norstad et al., 2011). So, there is a trade-off between carrying more cargo by sailing faster and lowering the cost of fuel by sailing slower. Additionally, the effect of fuel price may vary depending on whether the maritime transport organizational structure is liner or tramp (Ronen, 1982). Also, there may be variations in fuel consumption according to the engine technology and efficiency of the ships (Crist, 2012:192). Finally, since factors other than bunker price are also very influential, the relationship between ship speed and bunker price may be nonlinear and asymmetrical (Açık and Başer, 2018). Therefore, impact of bunker price on ship speed may vary.

2.3. Impact of Vessel Supply

The size of the ship fleet in the market constitutes the supply side of the maritime transport market. At any point in time, some ships trade, some are docked, and some are used as warehouses (Stopford, 2003:115). In this respect, the fleet utilization rate has a significant impact on the level of freight. As this rate increases, freights tend to increase, but if the rate is low, freight rates remain low. It emerges as a situation arising from the classical supply and demand relationship. Therefore, as the fleet utilization rate increases, the speed of the ships is expected to increase as well, because the freight rates are also higher at a high utilization rate (Lorange, 2009:40). As a result, when freight rates are high, the productivity of the fleet increases and the cargo per unit increases (Açık and Kayıran, 2018). However, if the fleet grows while freight rates are stable, productivity drops, and ships slow down their speeds to minimize costs. Also, when the demand increases, the speed of the ship increases, but when the idle or laid-up ships are put into service again, the speed of the ships gets slower (Faber et al., 2017). Therefore, other factors being constant, a negative relationship between fleet size and average speed rates can be expected.

2.4. Impact of Interest Rate

The effect of interest rates on the speed of ships has not attracted sufficient attention in the literature. However, interest rates are an important factor affecting the cost of capital for both the ship owners and the cargo owners (Ma, 2020:145). The increase in the time the ship spends in the port increases the capital cost because it misses out cargo transportation. For cargo owners, the time taken until the delivery of the cargo increases the capital cost (Wen et al., 2017). In this respect, since capital costs are an important item for both parties, it is likely that interest rates will affect the speed of the ships. In a market with higher interest rates, ships can accelerate to higher speed levels (Song, 2021). Therefore, the relationship between interest rate and average ship speed is expected to be positive.

3. Literature Review

The possible effects of factors affecting ship speeds are mentioned in many reference sources as described in the theoretical part. However, empirical studies modeling ship speeds and the factors affecting these speed increase or decrease decisions are very rare in the literature.

A study examining the effect of bunker prices on average fleet speeds was conducted by Açık and Başer (2018). In the study, the effect of changes in fuel prices on the average speed of dry bulk carriers was tested with asymmetric causality analysis. This method separates the shocks of the variables as positive and negative and analyzes the relationships with 4 possible combinations. The results revealed that positive shocks in fuel prices cause negative shocks in ship speeds. However, negative shocks in prices do not cause an increase in ship speeds. Researchers explain this situation with the conditions of perfect competition in the dry bulk market.

In addition to econometric studies like these ones, studies focused on reducing costs by optimizing speed based on the relationship between bunker price and bunker consumption have also attracted great interest in the literature (e.g. Wang et al., 2013; Sheng et al., 2014; Aydin et al., 2017; Wang et al., 2019; Medina et al., 2020). These studies have developed and proposed optimization models using various bunker price and speed scenario, which includes bunker cost minimization and freight income maximization. There are also studies examining and modeling the theoretical relationship between fuel consumption and speeds of the vessels (e.g. Ronen, 1982; Evens and Marlow, 1990; von Westarp, 2020). These studies aimed to develop coefficient models using some important variables. Furthermore, the average speed of ships is also a determining factor for their carrying capacity. When ships increase their speed, the amount of cargo they carry per unit time also increases. In this direction, there are studies on making the right choice between making the ships sail at low speed and putting extra ships into service in liner shipping transportation and increasing the speed of existing ships (Ng, 2019).

While bunker prices are one of the most important factors affecting speed, there are of course other variables as well. In another study using VLCC ship types conducted by (Aßmann, 2012), the effect of fuel prices and freight rates on ship speeds was examined by regression analysis. However, significant results could not be obtained in this study. It has been revealed that other factors other than these factors have a great effect on determining the speed. While ship speeds were high in some high bunker prices and low freight rates, ships' speeds remained low in some low bunker prices and high freight rates. The determining factor in these variable results is likely to be changes in demand for oil. Another study in which bunker prices were modeled together with other factors that could affect speed was conducted by Adland and Jia (2018). In the study, which models the speed of the ships through VLCC ship types, analyzes were applied by including variables such as bunker price, freight rate, ship draft rate, designed speeds of ships and whether the ships are in ballast or laden. As a result of the regression analyzes applied as a panel dataset, it was determined that the variables were significant in the model that included all the variables. The increase in bunker prices causes a decrease in the speed of ships. The increase in spot freight rates naturally causes an increase in the speed of the ships. Due to increasing freight rates, the costs incurred by increasing speed lose their importance and the chance of making more profits increases. When the draft ratio, which indicates the load status of the ships, increases, the speed of the ships increases. Because this situation, which means more cargo, shows that the demand for ships is high and a profitable operation is being carried out. Finally, as the designed speed of ships increases, their sailing speed also increases. This is directly related to optimum fuel consumption rates of the ships.

Interest rates, another variable used in the current research, is a concept directly related to the inventory costs of goods. At the same time, it is in a position that affects the situation in the world economy and is affected by the situation in the world economy. It is therefore likely to have a direct effect on the demand for transport and an indirect effect on the speed of ships. Empirical studies examining the effect of interest rates on the speed of ships have not received enough attention in the literature. Theoretically, the interest rate is included among the factors that affect the optimum speed of the ships by Ma (2020:148) and it is placed in a profit maximizing model. However, an empirical study examining the effect of interest rates on the speed by using historical data has not been found in the literature. On the other hand, since interest rates determine the inventory costs, they can be decisive in choosing different combinations, taking into account the delivery times offered by the modes in multi-modal transports. In this framework, it was included as a variable in the models in the study conducted by Sahin et al. (2014) and its significant effects were determined.

When the studies in the literature are examined, studies investigating ship speed can be generalized as empirical studies, theoretical studies and optimization studies. By examining ship speeds for three ship types empirically, we aimed to determine how well the market behavior fits the theoretical framework and whether these relationships differ according to the ship type. In empirical studies, freight rates and bunker prices were mostly used, and analyzes were applied on a single type of ship. Our study differs from the empirical studies in the literature in 2 ways: including the interest rate and fleet size by adding them in the model and questioning possible differentiations by including more than one ship type in the analysis.

4. Methodology and Data

To determine statistical relationships between variables, multiple linear logarithmic regression analysis is used in the study. The advantage of this analysis is that it makes it possible to detect how much the dependent variable changes considering the percental change in the independent variables (Gujarati, 2004:176). Thus, unitary differences between the coefficients in terms of effect disappear and comparisons can be made more easily. Additionally, logarithmic data show better distribution properties and become linearized (Asteriou and Hall, 2011:24).

In the research, average fleet speeds are included as dependent variables, while freight rate, bunker price, fleet size and interest rate are included as independent variables. First, significance of the models and coefficients were checked by estimating each regression model for the container, dry bulk and crude oil markets. Then, the sizes of the significant independent variables were compared in different market types with each other. Thus, we determined how the effects of each independent variable differ in each market. The regression model estimated for each ship market is presented in Equation 3:

$$VesselSpeed_t = \beta_1 + \beta_2 Freight_t + \beta_3 Bunker_t + \beta_4 Fleet_t + \beta_4 Interest_t + \varepsilon_t \quad (3)$$

For the container, dry bulk and crude oil markets, 3 different models have been estimated using the unique variables of each market. Then, the assumptions of the model were tested by applying Ljung-Box Q-statistics for autocorrelation (Ljung and Box, 1979), ARCH for heteroscedasticity (Engle, 1982), and Jarque-Bera for normal distribution to the residuals of the estimated models (Pagan and Hall, 1983). In case of detection of any of these assumptions, the standard errors were recalculated by applying covariance correction methods. Thus, reliable coefficients were obtained. In regression models, Huber-White (White, 1980) corrections are applied in case of heteroscedasticity, and HAC (Newey and West, 1987) corrections are applied in case of autocorrelation or autocorrelation & heteroscedasticity.

The data were collected from various sources. The definition and the source of the variables are presented in Table 1. Data from Bloomberg (2018) were used for average fleet speeds. These data consist of the average values of the fleet in the sea mile. For freight rates, Baltic Dry Index for the dry bulk market, the Baltic Dirty Tanker Index for the tanker market, and the Container Ship Time Charter Assessment Index for the container market were used. Each of these indices are used as leading indices in their own markets and represents their markets very well. For the bunker price, Los Angeles Long Beach 380 cst price (Bloomberg, 2018) was chosen as the representative price. Of course, bunker prices can vary a lot depending on the region and fuel quality. The main reason why this price was chosen as a representative is data accessibility. In addition, considering the high correlation between fuel prices, it is thought that choosing a representative price does not cause a situation that hinders the research. For the fleet statistics variable, Fleet Deployment Rate (Braemar, 2021) statistics waspublished for each market by Braemar, which has a prestigious position in the maritime industry, were used. Finally, it was found appropriate to use the macro data of the United States of America for real interest rates, because the economic power that most influences and directs the global economy is in this country. The real interest rates were obtained by subtracting the USA inflation rate from the FED interest rates and included them in our model for all ship market types.

Table 1. Definitions of the Variables

	Bulk	Tanker	Container
Average Speed	Average Bulk Fleet Statistics (Bloomberg, 2018)	Average Tanker Fleet Statistics (Bloomberg, 2018)	Average Container Fleet Statistics (Bloomberg, 2018)
Freight Rate	Baltic Dry Index (Bloomberg, 2018)	Baltic Dirty Tanker Index (Bloomberg, 2018)	Container Ship Time Charter Assessment Index (Bloomberg, 2018)
Bunker Price	Los Angeles Long Beach 380 cst prices (Bloomberg, 2018)	Los Angeles Long Beach 380 cst prices (Bloomberg, 2018)	Los Angeles Long Beach 380 cst prices (Bloomberg, 2018)
Fleet	Bulk Fleet Deployment Rate (Braemar, 2021).	Tanker Fleet Deployment Rate (Braemar, 2021).	Container Fleet Deployment Rate (Braemar, 2021).
Real Interest Rate	Fed Interest Rate – USA Inflation Rate (FRED, 2021)	Fed Interest Rate – USA Inflation Rate (FRED, 2021)	Fed Interest Rate – USA Inflation Rate (FRED, 2021)

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Descriptive statistics of the data set for the dry bulk market are presented in Table 2. This data set covers the 2009 M1 and 2018 M6 periods and consists of 114 observations. According to its fleet value, it has a much larger volume than tanker and container fleets. According to the average fleet speed, it has the lowest average speed. The volatility (standard deviation/mean) of the freight index is 58% and represents a much higher value than the volatility of other markets. The main reason for this can be cited as the perfect competitiveness of the dry bulk cargo market. Since the competition is high, imbalances between supply and demand can be felt directly in freight levels. On the other hand, it can be said that they reduce the average speed of the ships for cost minimization.

Table 2. Bulk Descriptive Statistics

	DWT	N380	REALIN	BDI	BULKSPEED
Mean	652,000,000	485.3876	0.166634	1,406.541	8.092148
Median	689,000,000	455.4979	0.113780	1,122.929	7.611631
Maximum	798,000,000	742.4091	1.660612	3,940.571	10.25500
Minimum	428,000,000	249.5682	-0.835107	306.9048	7.135000
Std. Dev.	1,101.349	145.0622	0.478791	823.6671	1.027407
Skewness	-0.613105	0.129113	0.769406	1.340630	1.037912
Kurtosis	2.001276	1.629192	3.596685	4.144764	2.560905
Jarque-Bera	11.87995	9.242527	12.93888	40.37330	21.38377
Probability	0.002632	0.009840	0.001550	0.000000	0.000023
Observations	114	114	114	114	114

Source: Bloomberg (2018); Braemar (2021); FRED (2021).

Descriptive statistics of the dataset used for the tanker market, which covers the periods between 2009 M1 and 2018 M6 and consists of 114 observations, are presented in Table 3. Tankers have a smaller volume than the dry bulk cargo fleet, but larger than the container fleet, according to the fleet size. Considering the average speed, it is faster than the dry bulk cargo fleet but slower than the container fleet. The volatility of freights is the lowest in this market, which is 17%. This shows that a more stable course is observed compared to the dry cargo and container markets.

Table 3. Tanker Descriptive Statistics

	DWT	N380	REALIN	BDTI	CRUDSPEED
Mean	473,000,000	485.3876	0.166634	745.9270	8.590197
Median	481,000,000	455.4979	0.113780	739.2619	8.185000
Maximum	564,000,000	742.4091	1.660612	1125.700	10.43500
Minimum	355,000,000	249.5682	-0.835107	477.8421	7.781429
Std. Dev.	54,784,340	145.0622	0.478791	131.6397	0.787882
Skewness	-0.210500	0.129113	0.769406	0.453363	1.189886
Kurtosis	2.304929	1.629192	3.596685	3.239717	2.906016
Jarque-Bera	3.136738	9.242527	12.93888	4.178184	26.94272
Probability	0.208385	0.009840	0.001550	0.123799	0.000001
Observations	114	114	114	114	114

Source: Bloomberg (2018); Braemar (2021); FRED (2021).

Our descriptive statistics on the container market are presented in Table 4. This data set covers the 2010 M11 and 2018 M6 periods and consists of 92 observations. The reason why it is shorter than the dry bulk and tanker data set is that the previous values of the CTEXIDEX variable could not be reached. When the average values are examined, it is seen that the fleet size is smaller than other markets. However, it has been determined that the average fleet speed is the highest compared to other markets. Here, it may be effective that the cargoes transported are much more valuable than other markets. When the volatility (standard deviation/mean) of the freight index is examined, it can be said that it has a value of 23%, lower than the bulk cargo but higher than the tanker.

Table 4. Container Descriptive Statistics

	DWT	BUNKER	INTEREST	CTEXIDEX	CONSPEED
Mean	222,000,000	503.7469	0.209907	416.6430	9.986656
Median	223,000,000	533.7391	0.164662	381.1970	9.738439
Maximum	258,000,000	742.4091	1.660612	707.7143	11.64500
Minimum	182,000,000	265.5238	-0.835107	294.5455	9.222727
Std. Dev.	22,353,721	151.4726	0.512877	97.23825	0.627021
Skewness	-0.190405	-0.061731	0.598858	1.450967	0.999815
Kurtosis	1.719521	1.408322	3.056940	4.432615	2.896206
Jarque-Bera	6.841128	9.769947	5.511442	40.14884	15.36895
Probability	0.032694	0.007559	0.063563	0.000000	0.000460
Observations	92	92	92	92	92

Source: Bloomberg (2018); Braemar (2021); FRED (2021).

5. Findings

Before implementation of the time series analysis, unit roots in the series should be checked in order to obtain consistent results. Series containing unit root carry the shocks to which they are exposed. This makes it impossible to predict future values using their past values. For this reason, unit root tests are first applied in time series analyzes such as linear regression. If the series contains a unit root, the analysis is continued by taking the first difference of the series.

On the other hand, data sets covering a long period may experience structural breaks over time. This may cause erroneous results in unit root tests. It is inevitable that a sector such as maritime, which contains a lot of uncertainty and is affected by many events, large and small, will experience a structural break. For this reason, analyzes were applied that consider possible structural breaks in the series in unit root analyses. One break ADF test developed by Zivot and Andrews (1992) and two break ADF test developed by Narayan and Popp (2010) were selected. These tests can detect breaks in level and both in level and trend. Analysis results obtained by applying GAUSS software are presented in Table 4 and Table 5. Analysis results for 1 and 2 breaks in level are presented in Table 5. According to the results obtained for 1 structural break, the unit root null hypothesis was rejected for the average speed and fleet size variables for dry bulk market and for the fleet size and interest rate variables for the container market. According to the test results with 2 structural breaks, the unit root null hypothesis was rejected for average speed, bunker price and fleet size for dry bulk market, average speed, bunker price, fleet size and interest rate for container market, and average speed, freight rate, bunker price and fleet size for tanker market. Considering the level breaks in these results, there are series containing unit roots. However, these breaks may have occurred not only in the level but also in the trend. For this reason, test results that also consider trend breaks should be examined to obtain better results.

Table 5. Results of the ADF Test with Structural Breaks in Level

	One Break ADF	Break Date	Decision	Two Break ADF	Break Date	Decision
	Zivot and Andrews (1992)			Narayan and Popp (2010)		
B_Speed	-5.878***	22	H0 Rejected	-6.588***	22, 63	H0 Rejected
B_Freight	-2.755	91	H0 Accepted	-3.528	21, 97	H0 Accepted
B_Bunker	-3.629	68	H0 Accepted	-4.401**	20, 68	H0 Rejected
B_Fleet	-5.727***	32	H0 Rejected	-6.577***	32, 54	H0 Rejected
B_Interest	-1.691	97	H0 Accepted	-2.663	23, 99	H0 Accepted
C_Speed	-4.267	56	H0 Accepted	-4.901**	56, 75	H0 Rejected
C_ Freight	-3.487	80	H0 Accepted	-3.677	44, 75	H0 Accepted
C_Bunker	-3.474	46	H0 Accepted	-4.084*	46, 77	H0 Rejected
C_Fleet	-5.913***	68	H0 Rejected	-7.165***	49, 68	H0 Rejected
C_Interest	-5.900***	79	H0 Rejected	-6.380***	25, 49	H0 Rejected
T_Speed	-3.559	22	H0 Accepted	-6.517***	23, 72	H0 Rejected
T_ Freight	-4.330	65	H0 Accepted	-5.327***	58, 71	H0 Rejected
T_Bunker	-3.629	68	H0 Accepted	-4.401**	20, 68	H0 Rejected
T_Fleet	-4.545	24	H0 Accepted	-5.775***	24, 53	H0 Rejected
T_Interest	-1.691	97	H0 Accepted	-2.663	23, 99	H0 Accepted

Null of unit root is rejected at *10%, **5%, ***1%. B refers to dry bulk ships, C refers to container ships, T refers to tanker ships.

The unit root test results, which consider both the level and trend breaks in the series, are presented in Table 6. According to the test results applied for 1 structural break, the null hypothesis of unit root was rejected in the variables of fleet size for dry bulk market, average speed, fleet size and interest rate for container market, and freight rate and fleet size for tanker. According to the test results applied for 2 structural breaks, the null hypothesis of unit root was rejected in freight rate, fleet size and interest rate for dry bulk market, all variables for container market, average speed, freight rate, fleet size and interest rate for tanker market. When the results presented in Table 5 and Table 6 are considered together, it is seen that the unit root null hypothesis was rejected at least once, considering breaks in either level or trend for each series. Here, the level values of the series can be used in the analysis without applying the difference taking process.

Table 6. Results of the ADF Test with Structural Breaks in Level and Trend

	One Break ADF	Break Date	Decision	Two Break ADF	Break Date	Decision
	Zivot and Andrews (1992)			Narayan and Popp (2010)		
B_Speed	-5.746	22	H0 Accepted	-7.371	22, 71	H0 Accepted
B_ Freight	-3.363	81	H0 Accepted	-6.624***	52, 89	H0 Rejected
B_Bunker	-2.522	20	H0 Accepted	-4.386	33, 77	H0 Accepted
B_Fleet	-5.182***	32	H0 Rejected	-6.662***	41, 64	H0 Rejected
B_Interest	-3.316	90	H0 Accepted	-7.885***	23, 96	H0 Rejected
C_Speed	-4.285*	43	H0 Rejected	-6.101***	25, 59	H0 Rejected
C_ Freight	-3.824	66	H0 Accepted	-6.619***	52, 66	H0 Rejected
C_Bunker	-3.652	55	H0 Accepted	-5.439**	36, 58	H0 Rejected
C_Fleet	-6.578***	55	H0 Rejected	-7.059***	34, 55	H0 Rejected
C_Interest	-7.122***	74	H0 Rejected	-8.524***	35, 74	H0 Rejected
T_Speed	-4.069	22	H0 Accepted	-5.521**	26, 72	H0 Rejected
T_ Freight	-5.566***	58	H0 Rejected	-6.462***	58, 86	H0 Rejected
T_Bunker	-2.522	20	H0 Accepted	-4.386	33, 77	H0 Accepted
T_Fleet	-4.277*	24	H0 Rejected	-4.672*	34, 53	H0 Rejected
T_Interest	-3.316	90	H0 Accepted	-7.885***	23, 96	H0 Rejected

Null of unit root is rejected at *10%, **5%, ***1%. B refers to dry bulk ships, C refers to container ships, T refers to tanker ships.

The regression model estimated for each ship market using the variables is shown in Equation 4. Average fleet speed was included in the model as the dependent variable while freight rate, bunker price, fleet size and real interest rate were included as independent variables. Results of the estimated models were presented in Table 7.

$$VesselSpeed_t = \beta_1 + \beta_2 Freight_t + \beta_3 Bunker_t + \beta_4 Fleet_t + \beta_4 Interest_t + \varepsilon_t \qquad (4)$$

The model estimated for the dry bulk market is significant according to the F statistic. All independent variables have significant effects on the average fleet speed at the 1% confidence level. The explanatory power of the model was determined as 98%. According to the tests applied to the residuals of the model, it has been determined that there is an autocorrelation problem in the model. The results obtained by applying the HAC correction showed that all independent variables have a significant effect on the dependent one. Freight and interest rates have a positive effect on fleet speed, while bunker price and fleet size have a negative effect.

The significance of the regression model estimated for the container market was confirmed by the F statistic. All independent variables have significant effects on the dependent variable at the 1% confidence level. The explanatory power of the model is approximately 92%. However, autocorrelation and heteroscedasticity were detected in the residuals of the model. Therefore, the model was re-estimated by applying the HAC correction. In the new model, the interest rate is significant at 5% and all other variables are significant at the 1% confidence level. The effects of freight rate and interest rate on fleet speed are positive, while the effects of fuel price and fleet size are negative.

Finally, the regression model estimated for the tanker market is significant according to the F statistic. The freight rate has a significant effect on fleet speed at the 5% confidence level, while all other independent variables have significant effects at the 1% confidence level. The explanatory power of the model is approximately 91%. However, auto correlation and heteroscedasticity were detected in the residuals of the model. Therefore, according to the results obtained by applying the HAC correction, the effect of freight rate became insignificant. Other independent variables are significant at the 1% confidence level. While the effect of interest rate on fleet speed is positive, the effect of fuel price and fleet size is negative.

Table 7. Results of Regression Model

Model	Bulk	Bulk Robust	Container	Container Robust	Tanker	Tanker Robust
Freight	0.029***	0.029***	0.037***	0.037***	0.026*	0.026
Bunker	-0.023***	-0.023***	-0.055***	-0.055***	-0.066***	-0.066***
Fleet	-0.569***	-0.569***	-0.712***	-0.712***	-0.789***	-0.789***
Interest	0.017***	0.017***	0.013***	0.013**	0.038***	0.038***
C	13.556***	13.556***	16.106***	16.106***	18.138***	18.138***
F Stat.	2289***	2289	270***	270***	276***	276***
R-Squared	0.98	0.98	0.92	0.92	0.91	0.91
Adj. R-Squared	0.98	0.98	0.92	0.92	0.90	0.90
Durbin-Watson	0.95	0.95	0.36	0.36	0.35	0.35
Autocorrelation	Yes	-	Yes	-	Yes	-
Heterosc.	No	-	Yes	-	Yes	-
Normality (JB)	2.799	-	8.840**	-	10.929***	-
Wald F Stat.	-	906***	-	192***	-	85***

Null hypothesis is rejected at *10%, **5%, ***1%.

The interpretation becomes easier by showing the coefficients obtained from all regression estimates graphically. Accordingly, a, b, c, and d parts of Figure 1, the effect of each independent variable on the average fleet speed was presented graphically for all ship types.

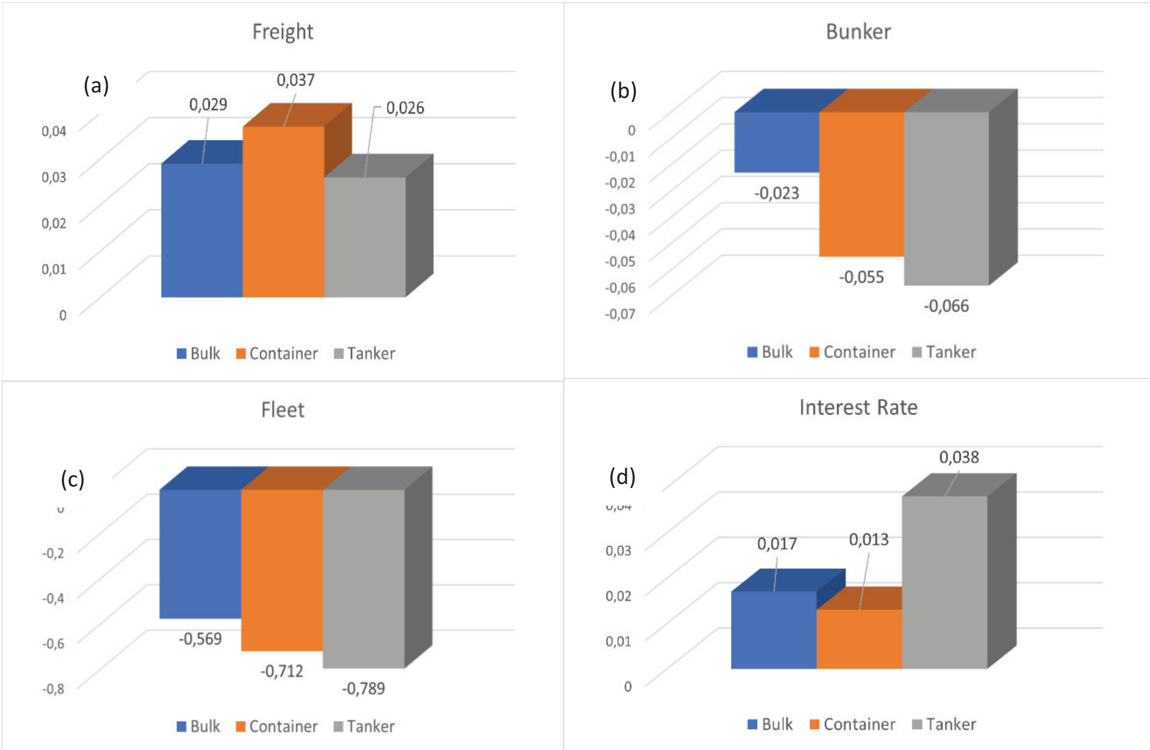

Figure 1. Coefficients Obtained from Models

When the effect of freight on average fleet speed was examined (Figure 1a), it is seen that the effect is positive as expected. When the freights increase due to the increasing demand, the optimum speeds of the ships also increase. By increasing the speed of the ship, fleet productivity increases, and more cargo can be transported per unit time. Thus, the income gained by increasing the speed of the ship exceeds the cost incurred and this speed increase decision can turn into a profitable situation. According to the results obtained, it is seen that the freight rate affects the average speed of the container fleet the most. This may be related to the container fleet having the smallest fleet volume. One of the main reasons for this is the market structure. Container shipping is not a competitive market in the short run. Therefore, average ship speeds may have responded more to higher freight rates, as supply was relatively limited. After the container market, the speed of the dry bulk fleet is most affected by freight rates. The dry bulk market has the characteristics of a perfectly competitive market. It also has the largest fleet volume, as can be seen from the descriptive statistics. The extreme increase in freight rates before 2008 also led to an extreme increase in ship orders. Since this situation has caused excess supply in the market for a long time, ship speeds may have responded less than the container fleet to increase freight rate. Finally, the effect of freight on the average speed of the tanker fleet is minimal and statistically insignificant. The main reason for this may be the close relationship between crude oil tankers and crude oil prices. While the variety of cargoes is relatively large in the container and dry bulk markets, there is only one type of cargo in crude oil transportation, it is the crude oil. This situation causes it to be immediately affected by the developments in the crude oil markets. In this respect, the demand for tankers is related to the price and supply of oil. Additionally, sometimes tankers can be used as a storage unit for crude oil to get benefit from low oil prices or be prevented from volatility in crude oil supply and price. This does not require that the cargo be delivered in a limited time frame. Thus, the effect of freights on ship speeds may be meaningless.

Second, the effect of bunker prices on speeds was examined (Figure 1b), it was found that all effects are significant and negative. Bunker prices have a decisive effect on the optimum speed of the ships, as they constitute a very large part of the voyage costs. As the increase in bunker prices increases the voyage costs of the ships, the ships can reduce their fuel consumption by slow steaming. Thus, they maintain their profitability by reducing fuel-related costs in a competitive environment. It has been observed that the response of the dry bulk cargo fleet to bunker prices is the lowest. This may be because the new tonnage delivered after 2008 was very large and the fleet was relatively young. Thus, because the fleet consists of highly fuel-efficient ships and competition is very high due to excess supply, fleet speeds may have less response to bunker price changes. Since there are so many ships and the contracts are usually voyage-based, it is more difficult to find a new cargo when the voyage is completed than with other types of ships. Therefore, decreases in bunker prices may not provide sufficient motivation to complete the voyage faster. The response of the speed of the container fleet to the price of the bunker is about twice that of the dry bulk cargo fleet. The main reason for this may also be related to the market structure. Because the competition is very low, most cargo owners are confined to specific liner shipping companies. For this reason, it may not hurt the competitive power to go a little early or late to its destination. For this reason, the increase in bunker prices may have been responded to with a significant speed reduction to increase profitability. Again, the decrease in fuel prices may have been responded to by increasing the speed to increase profitability. Finally, the most responsive ship type to the change in bunker prices was determined as the crude oil tanker. The tanker market should be interpreted quite differently from the others. Because oil is both a cost and a cargo. The decrease in crude oil prices may increase the demand for the cargo they carry while reducing the voyage costs of the ships. This may result in an asymmetrical relationship. In this respect, the increasing oil demand due to the decrease in oil prices may provide an extra motivation for ships to complete their voyages in a shorter time. Therefore, the response of the tanker fleet to bunker prices may be at the highest level.

The size of the fleet in the market constitutes the supply of maritime transport. New ships produced in the shipbuilding industry and ships dismantled in the shipbreaking industry determine the fleet size in the market. In this respect, it can be expected that the growth in the fleet will have a negative effect on the average fleet speeds. Assuming demand constant, an increase in supply will decrease the equilibrium freight rate. Here, shipowners may decide to reduce their speed to reduce their costs. According to our estimation results, fleet size has the highest coefficients compared to the others (Figure 1c), indicating that the most influential factor in average fleet speeds is the carrying capacity in the market. In the dry bulk market, the effect of the increase in the fleet on ship speeds is the lowest. This may be due to the already high fleet size and perfectly competitive market conditions. As can be seen from the descriptive statistics, the market with the lowest average speed is the dry bulk market. Additionally, freight rates on the market have been at relatively low levels for a long time, causing many ships to carry freight rates that are slightly above the cost.

The effect of the interest rate is a situation related to the inventory cost of the goods being transported. However, it also affects the capital cost of the ship and equipment. Since the price of higher value cargoes is much higher than the transportation cost, they are largely unaffected by changes in transportation costs to a certain extent. However, since time is invaluable for expensive cargoes, cargo owners can afford higher freight rates for shorter delivery times. This can also affect the speed of ships. As expected in this respect, the effect of interest rates on fleet speeds is positive for all ship markets (Figure 1d). According to the results, the market in which the interest rate affects the fleet speed the most is the crude oil market, and the container market is the least affected. Cargoes transported by container transport are more valuable cargoes, so it could be expected that the most impact would be in this market. The reason why this expectation was not met may be related to the market structure. On some routes, it may not be a concern to sail faster to gain a competitive advantage for the liner-shipping companies, which gain monopolistic powers through mergers. When the container fleet speed average is also examined, it is seen that the standard deviation has the lowest value although the average is the highest. This shows that the speed change decisions are taken within a certain range of speed limits. The effect of the interest rate on the speed of the crude oil fleet may be due to the extreme fluctuations in crude oil prices. In addition to the supply and demand balance, political decisions are also effective in the course of oil prices. For this reason, the inventory cost of petroleum crude oil also fluctuates a lot. To avoid this, ships can be expected to deliver their cargo more quickly during periods of high interest rates. Also, crude oil is a critical commodity for the world economy. The periods with high interest rates are the periods when the economy is lively and therefore the demand for oil is high. It can be said that this high demand environment also contributes to the faster delivery of crude oil. The fact that the dry bulk cargo fleet is less affected by interest can also be explained by the concept of competition. The prices of dry bulk cargoes are also fluctuating and are directly affected by the economic situation. However, since the fleet size is very large, profitability is at low levels, and this makes it not a profitable decision to increase the ship speed to generate a competitive difference. In this way, the speed of the fleet is less affected by the developments in interest rates compared to the crude oil market.

6. Conclusion

In the study, the average fleet speeds in the container, dry bulk and crude oil markets, which are the main freight markets in maritime transportation, were modeled. Then, it was determined whether factors affecting ship speeds are significant and whether there is a difference between the degree of impact. For modeling, the most commonly used freight indices and fleet utilization rates for each market were used in that model. Bunker price and interest rate were used as common variables in each model. Of course, these variables may not be exactly realistic since they are USA interest rate and Los Angles bunker prices, but representative variables can be used based on some assumptions for modeling. The results obtained presented theoretical and statistically significant findings. Freight and interest rates have a positive effect on the average fleet speed, while the effect of fuel price and fleet size is negative. There are also differences between the coefficients. The main source of differentiation is the degree of competition of the market structure and the characteristics of the cargoes carried.

These results can be used in deciding which types of ships should be designed to fuel efficient and which types of ships should investors consider taking the future macroeconomic environment into account, to reveal which fleet is most affected by which factor. For instance, bunker prices may decrease in the future as demand for fossil energy sources decreases due to the developments in the alternative energy sources. This may reveal new developments regarding the optimum speed levels of ships. High-tech engines can be ignored for a while for the ship market, which is only slightly affected by the price of fuel, as each design and production stage of ships generates extra costs for investors. Also, the biggest impact of alternative energy could be on demand for crude oil tankers. Second, the speed of ships also affects port traffic and competitiveness. Because by completing the faster ship voyage in a shorter time, it can make more port visits in a unit time. However, in the opposite case, a slower navigating ship will have fewer port visits. In this respect, ports can shape their competitive strategies by considering the future values of our macroeconomic variables. Additionally, port and equipment investments according to ship types can be shaped by taking these indicators into account. Finally, the results of our research can be used to control both freight rates for ship owners and transportation safety for cargo owners by ensuring sustainable transportation capacity for policy makers. Since slower or faster sailing will affect the total fleet capacity in the market negatively or positively, this will affect the freight rate levels and cargo owners' access to the available vessels in the market.

Our study had to do the modeling at the macro-level using some representative variables. Because data accessibility required it. If vessel speed statistics on a route basis can be obtained and freight rates and fuel prices on that route can be used in the analysis, much more detailed findings can be revealed. In addition, an interest rate variable to be used based on financial centers mostly preferred by ship investors may obtain healthier results. Finally, similar models for other ship markets such as LNG, LPG, RORO can be estimated in future studies.

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