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THE DRY-BULK SHIPPING MARKET: A SMALL ECONOMETRIC MODEL

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ABSTRACT

Dry-bulk shipping is of paramount importance for the safe and efficient transportation of goods around the world. This paper introduces a small econometric model describing the main dynamics and interactions within this sector. In addition, we have efficiently integrated the influence of global trade demand on freight rates, addressing a limitation that has persisted in many similar models. We consider that our model could assist market participants to take more educated decisions in chartering and investing.

JEL Classification: C32, E17, F47

Keywords: International shipping, freight rates, seaborne trade, econometric model, forecasting,

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1. Introduction

Dry-bulk shipping stands out as one the most efficient means of transporting large quantities of cargo in international trade. Historically, dry-bulk freight rates have exhibited pronounced volatility. As a result, shipping cycles emerge over time, alternating periods of euphoria and distress. Stopford (2009) distinguishes into long cycles and short cycles. He further analyses the stages of each cycle into trough, recovery, peak, and collapse. He demonstrates the unpredictable nature of the shipping cycles and their huge volatility provoking periods of skyrocketing profits to be followed by periods of complete financial distress.

Within the various shipping sectors, dry-bulk vessels carry large quantities of dry cargo in bulk, on a “one-ship, one-cargo” basis. Owners are tramp operators executing voyages everywhere in the world in response to demand. The freight market, in which freight rates for the employment of the vessels are determined, functions under conditions of perfect competition, featuring limited barriers to entry and exit, a homogenous product, easy access to customers and rapid dissemination of information. Product development and promotion activities are typically unnecessary (Lun and Quaddus, 2009). Within this context, both vessel owners and charterers are price takers (Stopford, 2009), contrary to other shipping sectors like the one of container transportation (Sys, 2009; Wu and Huang, 2018).

Dry-bulk vessels are classified based on vessel size and the existence of self-loading equipment (gear), as illustrated in Table 1. Larger vessels carry heavier cargoes like iron ore and coal, whereas smaller ones specialize in commodities like wheat, soybean, cotton and other minor bulk (Clarksons, 2023). Smaller vessels are equipped with self-loading capacity as they need to call at small, more remote ports with lower drafts which occasionally lack loading infrastructure.

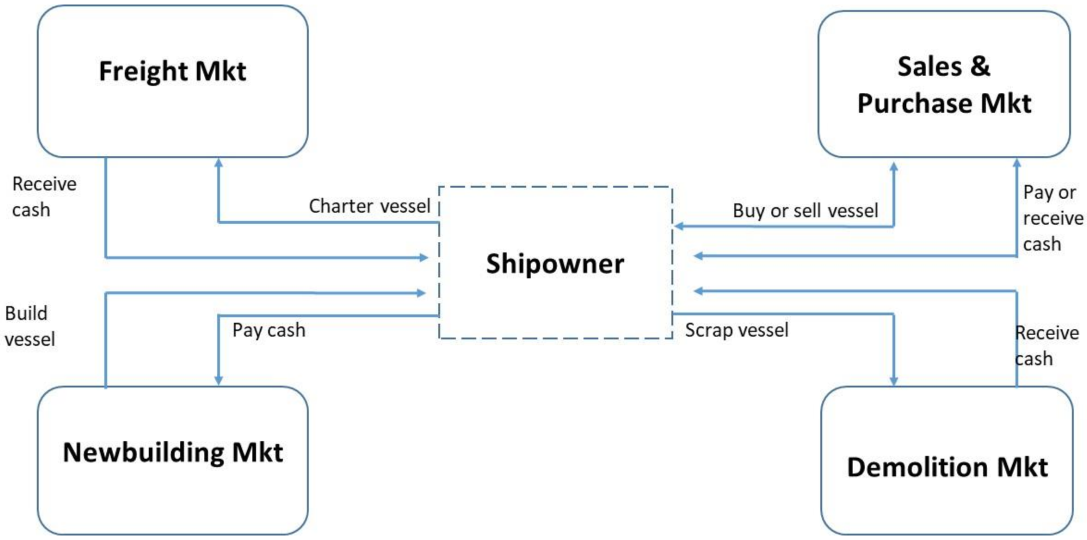
Table 1: Types of dry-bulk vessels

Vessel	Deadweight (tons)	Geared
Capesize	120,000 – 200,000	No
Panamax	65,000 – 82,500	No
Supramax	50,000 – 66,000	Yes
Handysize	20,000 -35,000	Yes

Source: The Baltic Exchange (2020)

The dry-bulk shipping sector, similarly to any other shipping sector, is structured along four separate, yet highly interrelated sub-market, as illustrated in Figure 1 (Stopford, 2009; Lun and Quaddus, 2009; Luo et al., 2009).

Figure 1: The four Shipping Markets

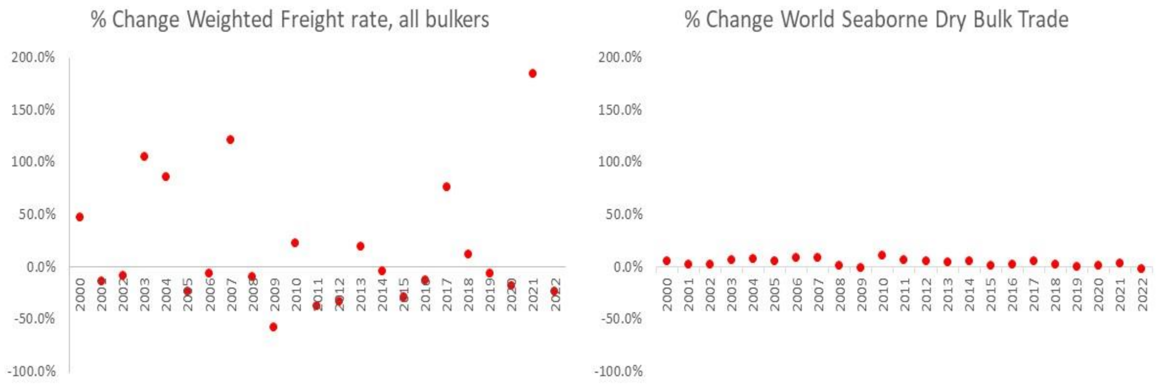


Source: Authors' own development

The freight market is the most important among the four, as the interaction between demand and supply for freight tonnage determines the freight rates. These, in turn, serve as the main input of the other three markets, influencing the participants' decision to invest in ships. Sales & Purchase is the market at which shipowners engage in buying and selling second-hand vessels. The overall supply of vessels is determined by the activity in the newbuilding market where new ships are constructed, and the demolition market where existing older ship are scraped.

Demand in the freight market is described as highly (almost perfect) inelastic to price changes mainly because it is considered a *derived demand,* driven by the underlying need for transporting specific commodities. There are very limited substitutes to ocean transportation, whereas freight cost typically represents a very small fraction of the overall commodity cost, allowing the shippers to accept higher freight rates in order to effect the transportation. Actually, this is why some researchers argue that for the shipping demand curve to become more elastic, freight rates need to be so high as to significantly impact the cargo's overall price (Koopmans, 1939). Our data suggest that the average estimated price elasticity of demand in the dry-bulk market for the period 2000 - 2022 is only -0.13, underscoring its highly inelastic nature, as further visualized in Figure 2, presenting year-on-year changes in freight rates vis a vis world seaborn dry-bulk volumes[1]. Within this context, shipping demand is determined by the developments in the global demand for dry-bulk commodities, along with geographical production and consumption patterns, as well as geopolitical events (Scarsi, 2007; Stopford, 2009). Geopolitical risks and a rise in international uncertainty are found to also impact the shipping markets (Qi et al., 2023).

Figure 2: Price Elasticity of Demand in dry-bulk 2000 – 2020



Source: https://sin.clarksons.net/

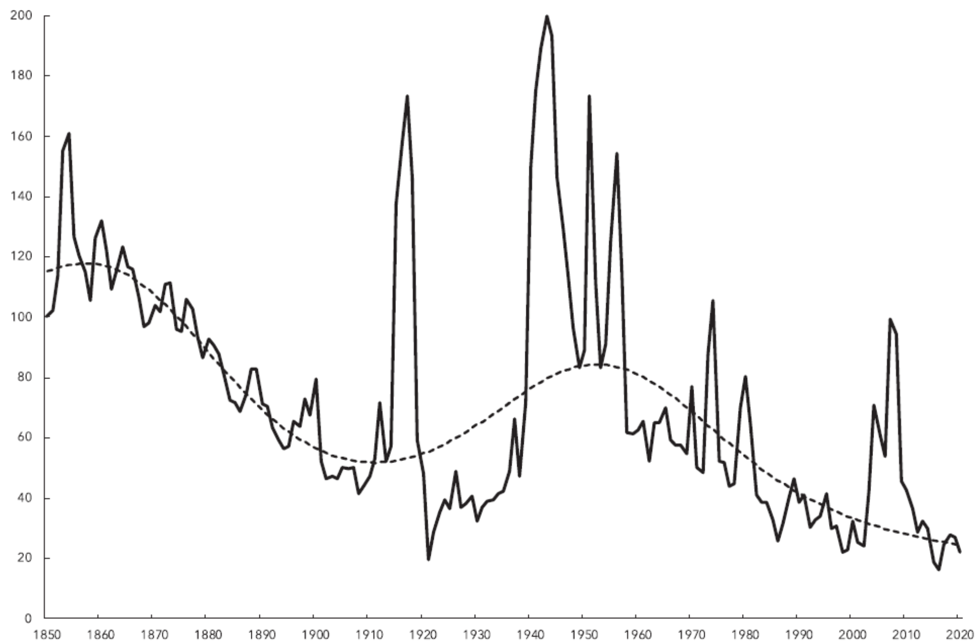
The supply of tonnage is described as highly elastic at extremely low freight rates when part of the fleet, particularly the older vessels, is laid up. Starting from such low levels, small changes in the freight rates trigger a substantial increase in the tonnage supplied until all vessels are back to service. As freight rates continue to rise, the supply curve becomes inelastic since the only way to increase supplied tonnage is to raise the service speed of the ships (Tvedt, 2003). When we reach the maximum operationally feasible speed level, the supply curve becomes perfectly inelastic (Greenwood and Hanson, 2015). In the long term, supply expands further with the delivery of new vessels from shipyards, making the long-term supply curve less inelastic.

The interaction among the four shipping markets gives rise to the well-known shipping cycles, as presented in Figure 3. An increase in demand due to global economic or geopolitical factors drives up freight rates, subsequently boosting second-hand vessel prices and newbuilding orders while discouraging vessel demolitions (Greenwood, 2014; Fan et al., 2021). In subsequent periods, the market experiences an influx of new vessels from the shipyards leading to an excessive vessel supply which

[1] Freight rates are averaged for the four different sizes of the dry-bulk vessels presented in Table 1, based on the number of vessels in each size category. World Seaborne Dry-Bulk Trade is measured in billion ton-miles, weighting the cargo quantities with the distances demanded for their transportation.

drives down freight rates (Luo et al., 2009; Tvedt, 2003). The time lag in adjusting the market supply effectively generates a kind of cobweb model structure where price fluctuations result in supply fluctuations, leading to a loop of rising and falling prices (Luo and Quaddus, 2009; Kaldor, 1934). The longer the time lag between investment commitment and realization, the more pronounced the economic cycle becomes (Kydland and Prescott, 1982).

Figure 3: Shipping cycles in the freight rates of dry-bulk shipping, 1850 - 2020



Source: Jacks and Stuermer (2021)

Our analysis suggests the introduction of a small econometric model describing the interaction between the four shipping markets with measurable forecasting capabilities. We consider our work as providing a valuable tool to participants in the dry-bulk shipping market for deciding whether to time charter their vessels or invest in new tonnage.

The rest of our paper is organized as follows: Section 2 reviews existing academic literature on modelling shipping markets. Section 3 presents the data and outlines our methodology for structuring the model. In section 4, we discuss the results of our model and its forecasting performance. Finally, section 5 summarizes and concludes.

2. Literature review

Academic literature has long endeavoured to understand, describe, model and predict developments in shipping cycles. Freight market analysis has been among the first areas of applied econometrics (Luo et al., 2009). The papers of Beenstock and Vergottis (1989; 1993) are widely acknowledged as the pioneer work in econometric modelling in shipping. Their models treat shipping demand as exogenous since they fail to identify a negative relationship with the freight rates due to the highly inelastic nature of the demand curve, as previously discussed. Their freight market is completed with a supply curve being a function of freight, voyage cost and fleet size. They combine the sales & purchase, newbuilding and demolition markets into what they call the *vessels' market*. The volume of newbuilding orders is a function of prices for such vessels and their cost of production. The volume of demolition activity is determined by price of the second-hand vessels, scrap price per lightweight ton and the age of the fleet.

Luo et al. (2009) employ a three-stage least square method to analyze fluctuations in container freight rates. They introduce the concept that the freight rate is affected by what they call *reuse rate* (ϕ), which measures the turnover in using vessels' capacity within a given time period. This concept is also integrated in our analysis. They estimate an average vessel construction period of 2 - 3 years and they attribute the changes in the fleet to freight rates, cargo quantities and fleet size from two years ago. Kavussanos and Alizadeh (2002) identified seasonality in the development of the freight rates which was more pronounced when the market was recovering compared to when the market was falling.

In an effort to cast further insight into shipping cycles, Scarsi (2007) discusses what he perceives as *periodic mistakes* by the shipowners, primarily consisting of over ordering newbuildings when the freight rates are high. He attributes these decisions to factors such as lack of experience, reliance on intuition, unwarranted optimism or pessimism and unwise imitation of the competition. Similarly, Papapostolou et al. (2013) find that market sentiment serves as a contrarian indicator for future dry-bulk shipping cycles so that a sentiment-based trading simulation on the sale and purchase of the vessels allows the investors to benefit from higher returns compared to a buy-and-hold benchmark. Expanding on this theme, Greenwood and Hanson (2015) develop a behavioral model of industry equilibrium dynamics to investigate dry-bulk industry cycles. They suggest that shipping participants tend to over-extrapolate exogenous demand shocks while partially neglecting the endogenous investment response of their competitors.

Kalouptsidi (2014) discusses investment decisions within the shipping industry, employing a time-lag framework to account for construction delivery lags, while also incorporating demand uncertainty factors during the construction period. Her dynamic model includes variables such as vessel's relative age, construction backlog, and aggregate demand for shipping services. At any period in time, the ship operator first observes the state of the industry and then, by taking into account the vessel’s remaining useful life, decides whether to exit by receiving the vessel’s scrap value or to continue operations. She concludes that investment volatility is significantly higher as time to build declines. The causality direction from freight rate changes to newbuildling prices is evidenced in the work of Xu et al. (2011).

Merika et al. (2019) employ nonparametric regression to estimate the effect of a vector of regressors on expected vessel prices and their variance. Notably, they observe a positive effect for vessel size, LIBOR interest rate, newbuilding price and only a marginal effect for freight rates. Their model may be subject to overspecification with the regressors being possibly correlated among themselves.

Michail and Melas (2020) use a VAR model specification to conclude that the quantity of seaborne trade has a strong impact on the Baltic Dry Index, while, similarly, Lun and Quaddus (2009) find that seaborne trade positively affects freight rates and fleet size. Kagkarakis et al. (2016) employ a VAR model to investigate the significance of international steel prices in determining ship-demolition prices, while Kim and Park (2017), with their own VAR model, identify a strong uni-directional Granger causality from freight rates to newbuilding orders.

A review of the dry-bulk shipping cycles over an impressive period of 170 years is provided by Jacks and Stuermer (2021). They underline the fact that, over such a long-time span, freights have substantially decreased reflecting significant productivity gains as radical changes in naval architecture, vessel propulsion and cargo handling at ports took place. Their VAR model identifies that shipping demand shocks strongly dominate shipping supply shock.

Finally, Lim et al. (2019) analyze the effect of shipping demand and supply factors on freight volatility, measured in the Forward Freight Derivatives (FFA) market. Their conclusion is that demand factors have a more pronounced effect than supply factors. Furthermore, their model exhibits a stronger explanatory power for near-term volatility.

3. Data and Methodology

Our model is a simple simultaneous equation model consisting of six equations, linked together through three identities, as per below:

Equations:

Freight market: $$Freight = f(Turnover) \tag{1}$$

Sales & Purchase Market: $$Price = f(Freight) \tag{2}$$

Newbuilding Market: $$Orders = f(Price) \tag{3}$$

$$Deliveries = f(Orderbook) \tag{4}$$

Demolition Market: $$Age_{t} = Age_{t-1} + 1 + f(Deliveries_{t-1}, Demolition_{t-1})^{2} \tag{5}$$

$$Demolition = f(Price, Age) \tag{6}$$

Identities:

$$Turnover \equiv \frac{Trade}{Vessels} \tag{7}$$

$$Orderbook_t \equiv Orderbook_{t\_1} + Orders_t - Deliveries_t - Cancellations_t \tag{8}$$

$$Vessels_t \equiv Vessels_{t\_1} + Deliveries_t - Demolition_t + Other_t \tag{9}$$

Where:

Freight is the average time charter rate (USD per day) of the four types of dry-bulk vessels,

Price is an index reflecting the price of 5-yr old second-hand dry-bulk vessels,

Orders is the volume of new construction ordered to the shipyards measured in terms of deadweight ton cargo capacity,

Orderbook is the aggregate of vessel construction in progress in a specific year, regardless of when ordered, measured in terms of deadweight ton cargo capacity,

[2] Age is measured at the beginning of the year.

Deliveries is the new vessels delivered from the shipyards measured in terms of deadweight ton cargo capacity,

Demolition is the volume of vessels scrapped, measured in terms of deadweight ton cargo capacity,

Age is the average age of all dry-bulk vessel,

Cancellations are Orders cancelled, measured in terms of deadweight ton cargo capacity,

Vessels is the total fleet of dry-bulk vessels on the water measured in terms of ton cargo capacity,

Trade is the total seaborne dry-bulk cargos transported, measured in ton-miles to account for both the amount of cargoes and the distances transported.

These identities and equations are consistent with the models of Greenwood and Hanson (2015) and Beenstock and Vergottis (1993). The data are yearly derived from Clarsksons Shipping Intelligence Network, the world's largest shipbroker and reliable provider of shipping data. Our dataset spans from 1999 to 2022, the constraint being the first year when data on Trade is available.

The core of the model is based on the concept that Freight is determined by Turnover, defined as the ratio of Trade over Vessels. A high ratio indicates higher demand for cargo transportation (most likely by employing the vessels at a higher speed) which, in turn, is expected to generate higher freight rates. This concept aligns with what Luo et al. (2009) defined as reuse *rate* (ϕ). The mechanics by which higher speed is enabled when freight rates increase are well-documented in Stopford (2009) and involve a disproportionately high increase in fuel cost due to the high speed which can be justified only by the prospect of chartering the vessel at higher freight rates for the days saved by sailing at such high speeds. Beenstock and Vergottis (1989, 1993) determined the freight rates from the interaction of quantities supplied and demanded, in which however, quantity demanded is totally inelastic and treated as exogenous variable in their model. This compares to our Turnover ratio having Trade in the nominator (exogenous demand) and Vessels at the denominator (supply determined by the developments in the shipping market).

Table 2 presents the correlations among our variables. As expected, Freight displays a strong positive correlation with Orders and Price, and a negative correlation with Demolition. Orders are also positively correlated with Price. Contrary to economic theory, Demolition is negatively correlated with Age. As will be discussed below, this is attributed to the fact that during periods of high freight rates shipowners keep operating their overaged vessels instead of scrapping them, thus resulting into raising the average age of the fleet in periods of low demolition activity.

Table 2: Correlations among the variables

	Age	Demolition	Freight	Orders	Price	Turnover
Age	1.000000					
Demolition	-0.687662	1.000000				
Freight	0.480175	-0.544351	1.000000			
Orders	0.163691	-0.229829	0.709609	1.000000		
Price	0.462000	-0.447788	0.794598	0.771026	1.000000	
Turnover	0.926817	-0.566309	0.464866	0.276325	0.525745	1.000000

Source: Authors' own calculations

Based on (5), AgeDif is defined as follows:

$$AgeDif = Age_t - Age_{t-1} + 1 \tag{10}$$

Our unit root test, presented at Table 3, indicates that the data are non-stationary at levels. Note that in order to choose the optimum lag length for our test, we adopt the Schwert formula included in Harris (1995): $l = \text{int}\{12(T/100)^{1/4}\}$. In our case, this suggests 8 lags. We transform our data into percentage change (Δ%) to create a type of standardized first differences. All our variables pass the unit root test after the percentage change transformation.

Table 3: Augmented Dickey-Fuller Unit Root Test (P-value of rejecting Null)

	AgeDif	Demolition	Freight	Orders	Price	Turnover
Level	0.3965	0.2297	0.1546	0.0927	0.4322	0.9604
Percentage change (Δ%)	0.0060	0.0011	0.0005	0.0294	0.0042	0.0272

Source: Authors' own calculations

4. Empirical results and forecasting ability of model

We proceed with estimating our simultaneous equations model through the method of least squares. For each equation we experiment with the inclusion of constant and lagged values of both the dependent and independent variables. The results of our estimations are presented in Table 4, with p-values in parenthesis.

Table 4: Estimations of Regressions

	Freight Δ%	Price Δ%	Orders Δ%	Demolition Δ%	AgeDifΔ%
C	0.30735				
	(0.0089)				
Turnover Δ%	8.65576				
	(0.0015)				
Price Δ%			2.0541	-4.3222	
			(0.0055)	(0.0358)	
Price Δ% (-1)		0.2928			
		(0.0363)			
Freight Δ%		0.445			
		(0.0000)			
Demolition Δ%					-0.075
					(0.0057)
Deliveries Δ%					-0.4113
					(0.0113)
AgeDifΔ%				0.0744	
				(0.0683)	
Adj R^2	0.3877	0.6592	0.2261	0.40607	0.5056
Breusch-Godfrey Serial Correlation LM test (Prob):	0.2673	0.8417	0.4344	0.6657	1.0000
Heteroskedasticity Test Harvey (Prob):	0.2025	0.6805	0.2285	0.025	0.3859

Source: Authors' own calculations

The results of our econometric model are in line to the economic theory already discussed. More specifically, freight rates increase with higher fleet turnover. Vessel prices increase when freight rates are higher as well as with higher vessel prices a one year ago. Higher vessel prices, in turn, increase the volume of newbuilding orders and reduce vessel demolitions, with the latter also affected by the age of the fleet.

Deliveries are estimated to be the historical average of 0.37366 of the orderbook. This is approximately the equivalent of 2.6 years for a vessel construction period which is consistent to Luo et al. (2009); Kim and Park (2017); Scarsi (2007); Kalouptsidi

(2014); Greenwood and Hanson (2015). Orderbook and Vessels are determined through the identities 8 and 9 respectively.

We conducted Breusch-Godfrey and Harvey tests to investigate the possible existence of serial correlation and heteroscedasticity in the residuals of our estimated equations. We only needed to adjust the Demolition equation to obtain White corrected standard errors due to heteroscedasticity.

In our Freight and Price equations we experimented with the inclusion of bunker prices as explanatory variable (similar to Beenstock and Vergottis, 1989), however, we failed to identify any statistically significant effect. In our Price equation, we also included Age and Libor interest rates to account for negative effect from the fleet's age and high funding cost (similar to Beenstock and Vergottis, 1989; Merika et al., 2019) but again no effect was found.

In the Orders equation we considered replacing Price with Freight. We could not include both as their correlation is as high as 0.79 (see Table 2), indicating an apparent problem of multicollinearity. Although the specification with Freight was again statistically significant, it was inferior to the one with Price as it scored an Akaike index of 3.0241 versus 2.9365. Intuitively, we would expect that, as Price also encompasses other aspects that could affect Orders, including cost of construction and relative vessel pricing. This is also in line to the findings of Bai and Lam (2017). When we experimented with including newbuilding prices, index of newbuilding over 5-yr old price (similar to Lun and Quaddus 2009) and Libor interest rates we found no such variable to be statistically significant. This leads again to our earlier comment that care should be taken not to overspecify the model by using variables which are correlated among themselves (Papapostolou et al., 2013). Table 5 describes the strong correlation among potential independent variables that could be used in determining the size of Orders and whose inclusion is quite popular in the academic literature (Merika et al., 2019). Effectively, when freight rates are high, vessel prices and newbuilding prices have also increased, while second-hand vessel prices have increased more than newbuilding prices as shipping participants prefer to invest in vessels readily available for operation in the market.

Table 5: Correlations between Freight, Price, Newbuilding Prices and Newbuilding over 5-yr old Prices

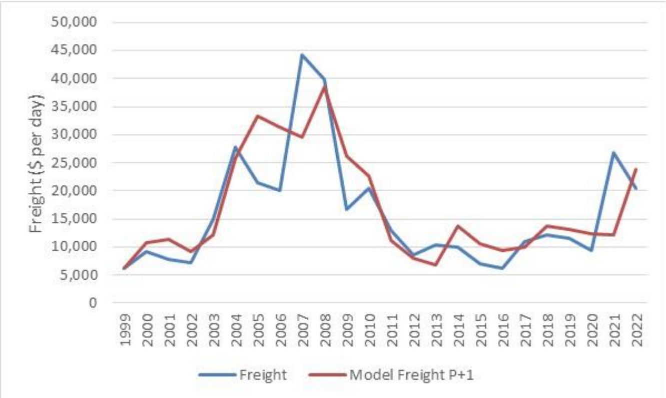
	Freight Δ%	Price Δ%	Newbuild Price Δ%	Index New to 5-yr Δ%
Freight Δ%	1.000000			
Price %%	0.746813	1.000000		
Newbuild Price Δ%	0.867923	0.775447	1.000000	0.
Index New to 5-yr Δ%	0.773372	0.658410	0.822370	1.000000

Source: Authors' own calculations

In the Demolition equation, the Age is statistically significant at the 10.0% level but not at the 5.0%. Attempts to exclude Age resulted into the collapse of the equation with R^2 down to 0.27 and the coefficient of the Price having p-value of 0.099, hardly able to explain the dependent variable. Similarly to the equation of Orders, we experimented by replacing Price with Freight. Again, although the explanatory variable was statistically significant, the overall equation specification was inferior with Akaike score of 4.277 vs 3.811 when employing Price. Finally, we tried including the price of scrap (similar to Lun, 2009) but failed to identify any effect. This underlines that the driving factor in the demolition market is not the potential income from scraping the vessel but the opportunity cost of foregoing the freights from prolonging the vessel's operation.

Our model's in-sample forecasting is performed on a one-year forward basis, therefore providing projections for the period 2000 - 2022. Figures 4 to 7 compare the forecasting to the actual data for the four shipping markets.

Figure 4: Forecasting in the Freight Market

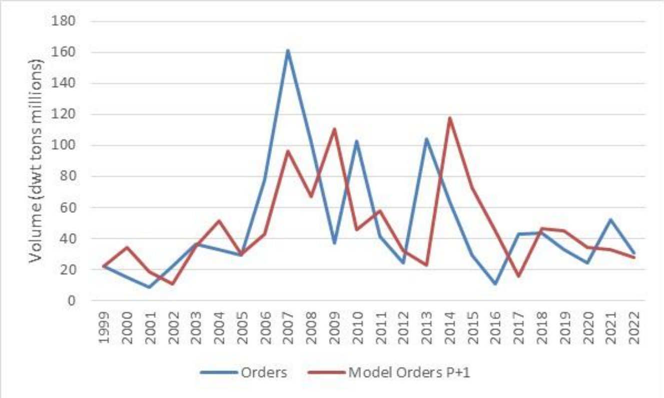


Source: Authors' own calculations

Figure 5: Forecasting it the Sales & Purchase Market

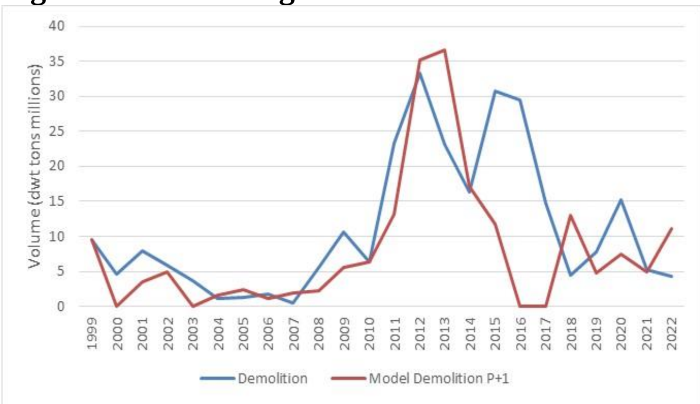
Source: Authors' own calculations

Figure 6: Forecasting in the Newbuilding Market



Source: Authors' own calculations

Figure 7: Forecasting in the Demolition Market



Source: Authors' own calculations

5. Conclusions

We developed a simple econometric model describing the interconnected dynamics among the four shipping markets for dry-bulk vessels. We base the developments in the freight rates on the extent of the vessels' utilization, quantified as the ratio of seaborne trade to total vessels' capacity. In this regard, our model not only reaffirms the core principles of shipping economics but also underscores the fundamental relationship between freight rates and vessel utilization, whereby increased vessel usage results in higher freight rates, subsequently elevating vessel prices. New vessel orders and existing vessel demolitions are intrinsically linked to the developments in the vessel prices.

The main advantage of our model lies in its simplicity and robustness. We explored several additional explanatory variables, frequently employed in academic literature, only to find minimal, if any, impact, and in some cases, potential issues of model overspecification due to the inclusion of correlated variables. Overall, the compelling influence of freight rate fluctuations appears to exert a dominant role in the dry-bulk shipping market compared to other potential explanatory factors.

Further areas of potential enhancement could include the expansion of our model by incorporating sentiment in the determination of shipping prices (Papapostolou et al., 2013). The correlation of the volume of activity in the sales & purchase market with the vessel prices, along with potential implications on the activity of the newbuilding market could also be useful extension (Syriopoulos and Roumpis, 2006). Further enrichment of our explanatory variables should be treated with care as we need to compare the potential statistical improvement against the additional complication we add in the model.

We consider that our model could be of assistance to market participants in order to take decisions in chartering and investing.

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