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Chartering policies and operational efficiency of shipping lines: exploring strategic changes in response to the COVID-19 pandemic

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Abstract

Shipping is a highly cyclical, volatile, and unpredictable industry. In recent history, economic shocks like the COVID-19 pandemic have heavily disrupted supply chains and tested the resilience and adaptability of shipping lines from both operational and financial perspectives. Therefore, the commercial success of shipping lines is increasingly determined by an optimal balance between reliable logistics operations and financial performance. Given this, chartering strategies of shipping lines are pivotal in achieving fleet optimisation and financial sustainability. Using a Mann–Whitney U test and a data envelopment analysis (DEA), this study provides a view on chartering strategies and efficiency levels of shipping lines in response to the COVID-19 pandemic. The findings reveal that chartering strategies have changed considerably since 2020 and that most shipping lines have pursued a peculiar strategy with a different mix in terms of chartered vessels' size, age, and period of charter. Shipping lines which showed the most marked differences in chartering strategies also yielded higher efficiency scores under DEA, whereas those that did not sustain large changes scored lower in terms of efficiency. This study provides significant insights on and managerial guidance for understanding and benchmarking chartering strategies and their impact on efficiency gains.

Highlights

- Chartering strategies help achieve fleet optimization and financial sustainability
- Chartering strategies have changed since 2020 in response to the COVID-19 pandemic
- Most shipping lines pursued peculiar strategies
- Those lines that changed significantly chartering strategies yielded higher efficiency scores under DEA
- Those lines that did not sustain large changes scored lower in terms of efficiency

Keywords: Shipping lines, Chartering strategies, COVID-19, Efficiency, Data envelopment analysis (DEA)

Introduction

The container shipping industry plays a central role in integrated transport systems and value chains. The management of large fleets of container vessels by liners is complex because of high capital investments, operational challenges, and a wide range of risks, all of which can affect the profitability of companies (Cariou and Wolff 2013). Shipping is highly cyclical, volatile, and unpredictable, and political, technological, and social events (Jo and D'agostini 2020; Jo et al. 2020) affect the operational and financial position of shipping companies (Plomaritou et al. 2011). However, the COVID-19 pandemic showed that also sanitary policies and health protocols set by countries have had a strong effect on both demand and supply disrupting national and regional economies (EMSA 2021) as well as international logistics and containerized trade. Consequently, shipping lines and logistics operators had to modify their strategies through adjustments of sailing frequencies and levels of maritime connectivity between different regions (UNCTAD 2020).

Therefore, the capacity of shipping lines to show resilience when challenged by economic and financial disruptions is arguably one of the biggest strategic challenges. The COVID-19 pandemic was an unexpected event that significantly impacted the flow of goods across international supply chains. For instance, in the first six months of 2020, global ship calls decreased by 8.7% compared to 2019 mainly due to lockdowns and economic and social restriction (UNCTAD 2021). However, the pandemic showed that, unlike the 2007–08 financial crisis, the utilisation levels of container vessels increased overall and the challenges as a result of larger ship sizes were handled efficiently by liners (Notteboom et al. 2021). Under these conditions, the commercial success of shipping lines, despite potentially diverging commercial strategies (D'agostini 2022), is determined by finding an optimal balance between reliable operational services and financial sustainability. Thus, asset management or fleet optimisation has become a pivotal area for the competitiveness of shipping lines (Cariou and Wolff 2013; Shin et al. 2019; Chang et al. 2015) in a highly competitive market environment with increasingly changing shippers' requirements (D'agostini et al. 2022). If such balance between operational and financial requirements is not effectively balanced, shipping lines may be subject to increased market pressure leading to financial difficulties in the mid to long run, leading eventually to extreme consequences like bankruptcies. An illustrative example of bankruptcy in the liner shipping industry is represented by Hanjin, whose case showed how external risks and the firm's internal decision-making determined its ultimate failure. In addition to a prolonged depressed container freight market which went in contrast with the management expectations, the South Korean line also failed to take optimal decisions on chartering activities; this mismanagement can be attributed to the miscalculation of the periods and rates of chartered ships, which were significantly higher than those of its competitors (Shin et al. 2019; Song et al. 2019). Moreover, past research on capacity management during the COVID-19 pandemic showed how transport capacity adjustments of shipping lines can be an important resilient strategy to adapt and to mitigate external risks (Notteboom et al. 2021), with a more effective management of alliances and changes in shipping schedule (i.e. blank sailing) (UNCTAD 2021). Whilst research was conducted on the resilience of shipping through such strategies, this study conducted an original investigation of chartering behaviours of liners before and during COVID-19 to extend the research on capacity management adjustments during a crisis.

The two main objectives of this study are as follows. First, it aimed to evaluate whether the short-term chartering strategies of shipping lines showed any fundamental differences because of the COVID-19 pandemic. It is important to confirm whether and how shipping lines reacted to an unforeseen external shock that may repeat in the future. Second, it assessed whether from an operational viewpoint (chartered and owned tonnage) and financial perspective (revenue), some shipping lines were more efficient than others. It tested whether the decision-making on chartering strategies of shipping lines had affected their relative efficiency in 2019 and 2020. Whilst the pandemic did not end in 2020, testing the efficiency of liners prior to the pandemic (2019) and during the first-year pandemic (2020) can provide useful insight on the first strategies deployed by carriers and the resilience shown.

Addressing these research questions is important from both theoretical and practical standpoints. From a theoretical perspective, the results can provide a deeper understanding of the pandemic with respect to chartering strategies of shipping lines and its impact on firms' financial indicators can provide a foundation for the development of specific forecasting models and improvement of the operational models of shipping lines. From a practical perspective, knowledge on the interrelations between chartering strategies and financial indicators can help shipowners, managers, operators, and charterers enhance their decision-making processes. As crises recur in the shipping context, the results can contribute toward enhancing the resilience of shipping lines during unexpected future events and can help learn from past events. It can also help these market players hedge against pandemic risks and take more data-driven decisions to improve their strategies and use the results as a benchmark against competitors' behaviours. The assessment of financial efficiency can help shipping lines determine how to better allocate resources and improve their financial performance.

The rest of this paper is as organised follows. "Literature review" section presents the literature review. "Materials and methods" section introduces the materials and methods. "Results" section presents the results and "Discussion" section concludes the paper.

Literature review

COVID-19 pandemic and the impact on shipping

The complexity involved in successfully managing a shipping company includes several operational options that take the form of organic growth, mergers and acquisitions, alliances and joint ventures, and network development (Lun et al. 2010). These options are available to shipowners for their strategic decision-making and are equally important because, as shown by Bendall and Stent (2007) and D'agostini et al. (2019), the availability of more strategic options can lead to greater value. The effective utilization of some of these options was proven to be of vital importance during the COVID-19 pandemic for shipping lines to adapt resilience mechanisms mitigating operational and financial risks. For instance, when looking from an operational perspective viewpoint, several mechanisms were adopted by shipping lines.

A widely utilized strategy adopted by shipping operators during the pandemic's initial phase has been to cancel service commitments, which have been defined as 'a form of serious transport network disruption' (Dirzka and Acciaro 2022), by laying up capacity and serving longer routes to reduce operational capacity and keep a high loading factor

(Pooler and Hale 2020). Dirzka and Acciaro (2022) further proved that the COVID-19 pandemic put pressure on the service network integrity of shipping operators particularly in Asia at first and then in other major routes. They concluded that service cancellations and agility in operations were the main factors of liners to minimize the effect on transport network of the pandemic (Dirzka and Acciaro 2022). In line with it, Notteboom et al. (2021) found that, during the COVID-19 pandemic, shipping lines showed a higher level of 'crisis preparedness' relying more on service rationalization and space utilization. On the other hand, in the same study, the authors compared the financial crisis of 2008/2009 with the COVID-19 pandemic and showed the existence of fundamental differences amongst them for the global economy and for the shipping industry. For example, during the 2008/2009 financial crisis, the shipping industry relied mainly on slow steaming as operational strategy but were not able to efficiently manage shared capacity which brought poor financial results as a result or low utilization onboard.

Changes in shipping vulnerability before and after the COVID-19 pandemic were tested by the study proposed by Wu et al. (2024). They presented a study to identify the collapse point of the shipping transport network finding that the main factors influencing the vulnerability of shipping networks are port efficiency, increases in container trade and shorter, regional trade routes (Wu et al. 2024).

Fedi et al. (2022) confirmed in their study that shipping alliances were much more agile in adapting to the pandemic compared to the financial crisis and were able to shape more efficient partnerships strategies. Furthermore, the capacity management of liners was strengthened with a greater use of technology (digitalization of some services) to improve faster planning as well as more 'tailored' shipping services to effectively match demand and supply and improve capacity utilization (UNCTAD 2021). One of the most severe consequences due to the adaption of these operational strategies (reduction in the number of direct calls) of shipping lines impacted on container ports' throughput and shipping liner connectivity.

Fedi et al. (2022) investigated the container capacity deployed in 45 ports in the Mediterranean region from 2018 to 2020 to assess the potential transformation of the port hierarchy in the region. They found that due to COVID-19, some ports performed better than others in term of resilience. This is in line with the finding by UNCTAD (2021) which, despite mixed results across regions, showed how shipping connectivity has overall decreased in 2020 with transhipment hubs being affected the most. From a broader macroeconomics perspective, Xu et al. (2021) observed that, during the pandemic, shipping trade exported between China and different regions was affected by government intervention and control measure and overall decreased whilst impots increased in the same period.

Chartering practices as a strategic tool

Chartering is an important strategic tool as it is a form of organic growth allowing shipping companies to adjust transport capacity when needed. Compared to new orders and the purchase of second-hand ships, chartering provides greater operational flexibility, decreases the time of delivery, and reduces the initial capital investment required; however, it can also be more expensive in the long-term (Cariou and Wolff 2013). The largest shipping lines all have a high percentage of chartered ships (e.g. Maersk 44.6%;

MSC 73.2%) in comparison to the total number of ships operated (Alphaliner 2021). Thus, chartering strategies are a fundamental part of the daily operations of a shipping line. Factors like the ship's size, age, period of charter, and rates are all to be weighted in accordance with each line's strategy, vision, market conditions, and expectations. However, the final goal is to achieve fleet optimisation and profitability.

A common strategy is to create an optimal portfolio according to the characteristics of chartered ships. Taylor (1982) was one of the first to investigate several chartering policies and their relative effectiveness in the dry cargo and tanker markets under different market conditions. Ådland et al. (2017) explored whether chartering strategies exist in different geographical regions by testing spatial differences in spot rates in relation to the Capsize market. The problem of strategic decision-making and fleet optimisation in chartering was investigated by Wang et al. (2018), specifically in relation to the number of ships to be chartered and the period of hire. They proposed a stochastic programming model to demonstrate how and why different chartering strategies can affect shipping companies' performance. Yu et al. (2019) developed an advanced portfolio analysis to determine the optimal ship mix considering an expected loss rather than variance as the main risk measure. Their findings suggested that if variance is used, the expected loss in a fleet portfolio may be underestimated.

To improve market efficiency, managerial decision-making of shipping lines for chartering processes can vary significantly (Bang et al. 2012). These strategies are instrumental in hedging a shipping company's commercial and financial risks by adopting a portfolio of different contractual durations of chartered ships and to lock in freight rates at the current market level, thus minimising the risk of dramatic fluctuations in rates in the future (Kavussanos and Visvikis 2006). The period of a charter-party has been central to several studies as shown by Cariou and Wolff (2013), in which the contract duration was considered a factor in testing the relationship between chartering strategies and firms' profitability. Zhang and Zeng (2015) focused on the relationship between time charter and spot freight rates and found that a longer duration coupled with smaller charters showed a stronger price discovery function. Berg-Andreassen (1997) conducted a similar study and showed the rightfulness of the conventional market explanation of the time-charter rates in relation to spot rates. Ådland and Cullinane (2005) illustrated how risk premiums in bulk shipping freight rates vary according to market conditions and the period of charter.

The link between chartering strategies and shipping lines' profitability

As the goal of financial management is to maximise the value of firms (Chandra 2011), an effective link between chartering operational strategies and financial results is a key management area for shipping lines. This can translate into maximising the value of shareholders' equity, especially when the financial decision-making process involves the coordination of several department and activity areas (Fabozzi and Peterson 2003). Therefore, several studies have assessed the profitability of shipping companies based on chartering strategies. Berg-Andreassen (1998) provided a portfolio approach to assess chartering decisions based on profitability in the bulk shipping segment. Alizadeh et al. (2007) tested the effectiveness of six months' time-charter rates in predicting actual future time-charter rates and found that chartering strategies derived from simple

trends following rules were able to generate economic profits. Ådland and Strandenes (2006) used a Kernell regression to identify the best chartering decisions in the tanker market and to test the related profitability on strong and weak market times. Overall, weighting in the operational challenges and the financial efficiency of shipping lines involved in the optimisation of chartering strategies should be interpreted as dynamic capabilities in which the integration of both internal and external competencies is finalised in order to adapt to dynamic and volatile markets such as in the shipping context (Peng et al., 2018). Therefore, it means adapting the strategic needs of a firm in order to develop organisation-specific competencies (Ulrich and Lake 1991). Under this context, operational efficiency in liner shipping linked to financial performance is vital to retain competitiveness. Hsu et al. (2013) investigated the efficiency of shipping lines under four perspectives namely financial, customer, internal business processes and learning and growth and suggested potential improvements to enhance operational performance and investment areas. Guitarrez et al. (2014) utilized a Data Envelopment Analysis (DEA) to measure the efficiency of shipping lines during an economic downturn and included labour, number if ships and fleet capacity as inputs and container throughput and turnover as outputs. The findings suggest that being member of an ocean alliance is not linked to operational efficiency. Chao et al. (2018) employed a dynamic network envelopment analysis separating the fleet capacity into owned tonnage and chartered tonnage to measure the operational efficiency of shipping lines over a period of time of three years.

Effective corporate governance is fundamental for conflict resolution and management monitoring to strengthen the financial profitability of firms (Fosberg and Nelson 1999). For instance, the lack of a well-defined governance structure and poor operational decision-making procedures from the top management were among the major contributing factors that determined the bankruptcy of Hanjin in 2016 (Song et al. 2019). Song et al. (2019) and Shin et al. (2019) highlighted the factors that led to the failure of Hanjin and investigated the errors that were committed in chartering strategies. Song et al. (2019) revealed that Hanjin's failure in restructuring its business units, bad decisions on the timing of charters, and the lack of knowledge and experience on part of the top management were all decisive elements. Shin et al. (2019) illustrated how Hanjin chartering strategy risks were miscalculated and how the chartered tonnage was often fixed for long periods (mostly 10 years at a time) and at higher rates when compared to other shipping lines. Both studies showed how both internal and external risks could be attributed to the ultimate failure of Hanjin.

More recently, researchers have also linked the effects of the pandemic on shipping freight rates and stock values. Gavalas et al. (2022) used a market-model to assess the responsiveness of shipping markets by estimating the abnormal returns before and after the pandemic and their effects on shipping companies' performance. Similarly, Kamal et al. (2022) adopted an event study methodology by using daily data of shipping companies and available in the New York Stock Exchange (NYSE), to find the short-term impacts of the COVID-19 pandemic. The study suggests that shipping companies' stocks reacted negatively to the COVID-19 declaration (Kamal et al. 2022).

Owing to the scarcity of empirical research in chartering activities, this study focused on determining whether there are significant differences in chartering practices of shipping lines in response to an exceptional and disruptive event such as the COVID-19

pandemic. It also evaluated how chartering decisions affected the financial results and efficiency of shipping lines in 2020.

Materials and methods

Data collection

Mann–Whitney U test

This cross-sectional study sought to analyse the strategic decision-making of the top 11 shipping lines before and during COVID-19. The shipping lines considered in the analysis were CMA-CGM, Cosco, Evergreen, Hapag Lloyd, HMM, Maersk, MSC, ONE, Wan Hai, Yang Ming, and Zim. Data were retrieved from two main sources, as this study used different quantitative statistical tools to evaluate the chartering strategies and efficiency levels of shipping lines.

In the first stage, data on chartered tonnage of shipping lines were obtained from Clarkson Shipping Intelligence Network (2021) and utilised to perform a Mann–Whitney U test. The dataset covered the period between January 8, 2018, and October 29, 2021, for a total of 4110 data entry or fixtures. It included specifications on the date of the fixture (date on which the period charter was fixed between the ship-owner and charterer, e.g. the shipping line), ship's name, year of construction, size of ship expressed in TEU, name of the charterer, minimum and maximum period of charter, hire expressed in USD/day, and name of the ship-owner. For analysis, the dates of the fixtures were subgrouped into 2018 and 2019 (before COVID-19) and 2020 and 2021 (during the pandemic). The period of charter was expressed as both minimum and maximum periods. Thus, an average was calculated to obtain a single variable named average period of charter.

Data envelopment analysis (DEA)

In the second stage, a DEA approach was applied. The DEA model is a non-parametric method for measuring the efficiency of Decision-Making Units (DMU) and was first introduced by Charnes et al. (1978). DEA can be applied to measure the overall efficiency of a DMU by comparing it with other homogeneous DMUs by transforming the same group of measurable inputs into the same types of measurable outputs (Cullinane and Wang 2006). The two most widely used DEA models include the DEA-CCR and DEA-BCC. The former assumes constant returns so that observed production combinations can be increased or decreased proportionally while the latter allows for variable returns (Cullinane et al. 2004). The CCR mode utilises linear programming to determine the weight to maximise the outputs/inputs, which are therefore derived from the data. Within the CCR model, both CCR input-oriented (CCR-I) and output-oriented (CCR-O) are available. The former seeks to minimise the input while not increasing the output and the latter aims to maximise the output without decreasing the inputs.

In this study, a 'two input and one output' DEA-CCR-I was used to determine the efficiency level of each DMU for 2019 and 2020. This made it possible to compare how, based on owned and chartered tonnage and revenue, the level of efficiency changed based on the decision-making of DMUs before and during the pandemic. Therefore, the strategic decision-making of liners linked to chartering strategies can influence the productive process and efficiency associated with it. As every shipping line, and more

generally, every productive process, has a limited set of resources available, the concept of efficiency is pivotal in operational optimisation. The rationale for selecting 2019 and 2020 as period of investigation lies in the fact that efficiency is defined as the ratio of output to input in an operational system. The scores derived from the DEA indicate the degree of efficiency in transforming inputs into outputs for decision making units (DMU). In the current study, DMUs are represented by shipping lines. The inputs are 'owned ships' (owned carrying capacity expressed in TEU) and 'chartered ships' (chartered carrying capacity expressed in TEU) and. The output is revenue. We opted for the applications of DEA-CCR, a model which assumes constant return to scale of activities and for an input-based approach as owned ships and chartered ships are variables which can be contracted (reduce chartered tonnage or selling ships) by carriers to achieve the desired level of efficiency. A similar approach was used in the study by Bang et al. (2012) in which both financial and operational efficiency of carriers were investigated. In their study, the inputs for the financial efficiency were 'Total Assets' and 'CAPEX' and the outputs were 'Revenue' and 'Operating Profits'. For the operational efficiency, 'Number of Ships' and 'Capacity' were the selected inputs and 'Cargo Carried' the output.

The set of data on these variables were retrieved from Alphaliner monthly monitor for 2019 and 2020. Data were available monthly, and an arithmetic average for the full year was calculated for 'chartered TEU' and 'owned TEU'. The variable 'revenue' was available on a quarterly basis, and a yearly average was calculated. However, because of the unpublished data on the financial performance of carriers, some liners (MSC, ONE, and PIL), had to be excluded from the efficiency analysis. The financial indicators of the shipping lines were expressed in different currencies. All variables were converted into USD according to the average exchange rate of the relevant currency for the year. For instance, for 2019, the revenue of Hapag Lloyd was converted from Euro to USD (average exchange rate in 2019 for Euro/USD = 1.1199), Evergreen, Yang Ming, and Wan Hai from TWD to USD (average exchange in 2019 for TWD/UD$0.0324), HMM from KRW to USD (average exchange rate in 2019 for KRW/USD = 0.0009), and Cosco from RMB to USD (average exchange rate in 2019 for RMB/USD = 0.1448). For 2020, the same conversion was conducted with the following average exchange rates: Euro/USD = 1.142, TWD/USD = 0.034, KRW/USD = 0.0008 and RMB/USD = 0.145.

Data analysis

The data were analysed using SPSS. A Mann–Whitney U test and a Kruskal Wallis H test were conducted. $P < 0.05$ was considered a significant difference. In the second step, a DEA-Solver software was utilised to measure the relative efficiencies score of the shipping lines examined.

Results

Mann–Whitney U test

The collected dataset included a total of 4110 ships chartered by the 11 largest shipping lines between 2018 and 2021. The main variables considered were the size of the chartered ship (in TEU), the year of construction, and the period of the charter (in years). Table 1 presents the descriptive statistics of the variables. The minimum and maximum sizes of a ship chartered were 366 TEU and 14,952 TEU, respectively. The

Table 1 Descriptive statistics of chartering variables (size, age and period)

Statistics	Size of chartered ship (TEU)	Built year of chartered ship (year)	Period of charter (months)
Minimum	366	1989	0.27
Maximum	14,952	2021	180
Mean	3263.52	2007.39	10.90
SD	2139.38	4.62	13.20

Source: Author's calculation

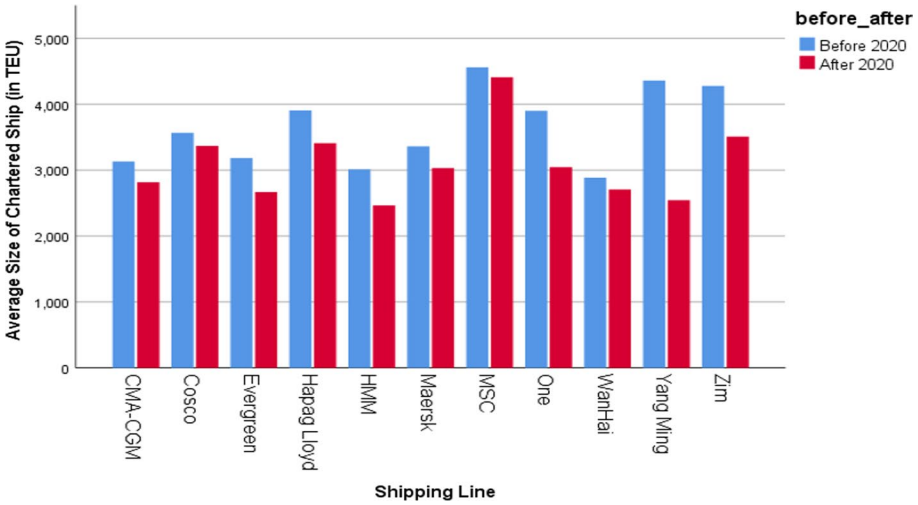

Fig. 1 Average size (TEU) of chartered tonnage of shipping lines before and after 2020. *Source*: Author's calculation

average size was 3263.52 ± 2139.38 TEU. The oldest chartered ship was built in 1989 and the newest was built is 2021. On average, shipping lines chartered ships that were built in 2007. The shortest, longest, and average periods of charter were 0.27, 180, and 10.90 months, respectively.

In terms of the size of chartered tonnage, all shipping lines followed similar strategies. The average size of chartered ships for all lines was smaller after 2020 when compared to before 2020 as shown in Fig. 1. Although, there were no significant differences for some in the mean size before and after 2020, for CMA-CGM, Evergreen, HMM, One, Yang Ming, and ZIM, the mean difference was more significant.

Figure 2 presents the average age of chartered ships per company before and after 2020. The data were computed based on the age of the ships rather than the year of construction. Most shipping lines did not show major differences in terms of the ages of the chartered vessels. HMM and ONE are two of the companies that presented a clear strategy to reduce the age of the vessels after 2020. In contrast, for Yang Ming, the chartered tonnage age increased after 2020.

The average period of chartered ships increased significantly after 2020 for a large majority of shipping lines as shown in Fig. 3. Significant growth in the average period

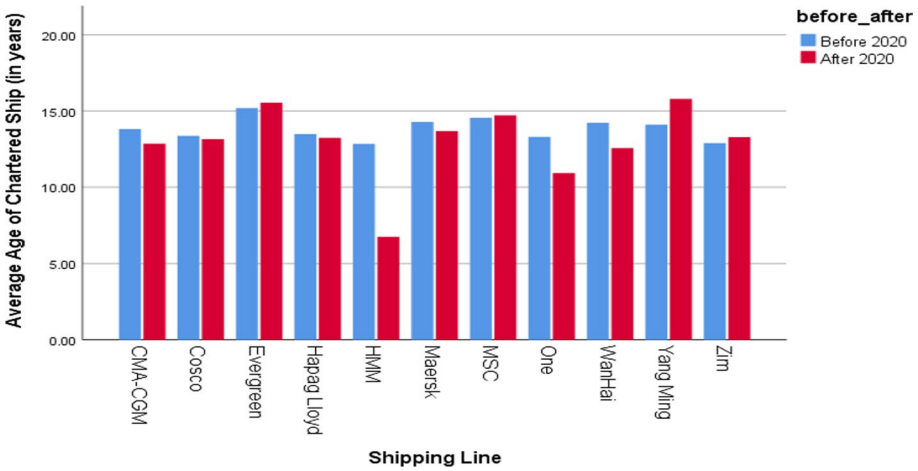

Fig. 2 Average age of chartered ship (years) of shipping lines before and after 2020. *Source*: Author's calculation

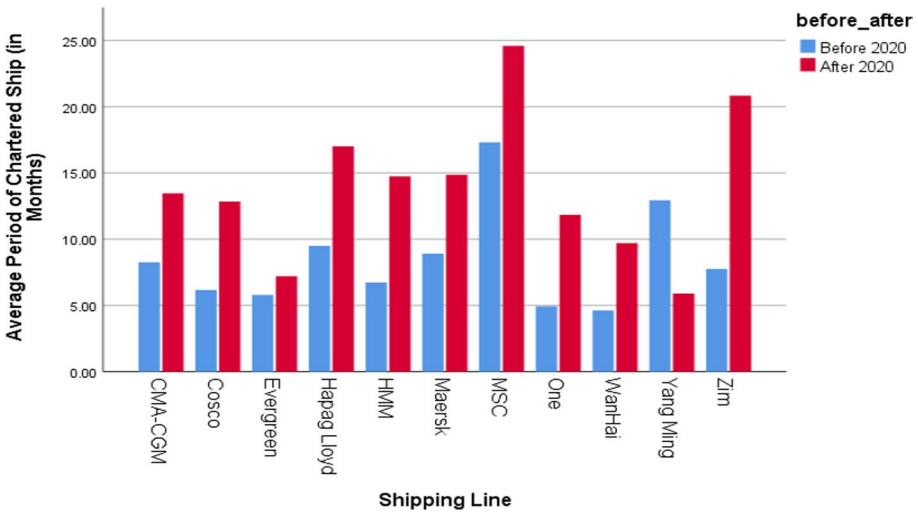

Fig. 3 Average period of shipping lines' chartered ships (months) before and after 2020. *Source*: Author's calculation

of chartered vessels was noted for Cosco, HMM, ONE, Wan Hai, and Zim. Yang Ming was the only shipping line that reduced the average period after 2020.

In the next step, the mean differences of the size, age and charter period of chartered ships observed in the graphs above were statistically tested. First, a two-sample independent t-test was applied to test the mean differences for each variable. However, the sampling distribution of means did not fulfil the assumption of normality. Therefore, a non-parametric technique was used to test the hypothesis. A Mann–Whitney U test and Kruskal Wallis H test were used on the sample data. These tools are useful when the assumption of normality is not met. The main advantage of applying the Mann–Whitney U test, compares to other statistical tests, is that due to its non-parametric nature, it does not require the data to follow a specific distribution, such as in our study.

The results in Table 2 show that the three variables of interest in this study were significantly different after 2020, when compared to the period before that. The null hypothesis was rejected at 5% level of significance. Therefore, size, age, and period of the chartered ships were significantly different after 2020, when compared to the period before that.

Company-wise analysis

In the next step, a company-wise analysis was conducted to test the significance of the statistical differences before and after 2020 for the size, age and charter period of chartered ships in each individual company. First, the Mann–Whitney U test was applied to compare each company before and after 2020 and derive the changes in the chartering practices in greater detail. Second, Kandall's Tau b test was used to measure the direction of the relationship before and after 2020 in the variables.

The results of the Mann–Whitney U test are shown in Table 3. Cosco ($p=0.146$), Hapag Lloyd ($p=0.077$), HMM ($p=0.086$), MSC ($p=0.375$), and Wan Hai ($p=0.137$) chartered ships of approximately the same size after 2020, as they used to in the period before that. The p-value for these lines was greater than 0.05, showing that no significant statistical difference occurred after 2020. In contrast, CMA-CGM ($P=0.001$), Evergreen ($p=0.024$), Maersk ($p=0.002$), One ($p=0.011$), Yang Ming ($p=0.000$), and Zim ($p=0.000$) showed statistical differences in the size of chartered ships. To measure the direction of the relationship before and after 2020, Kandall's Tau b test was used, as shown in Table 4. A negative correlation meant that a specific variable presents a decreasing trend after 2020, that is, a negative correlation for chartered ship size and after 2020 showed that shipping lines chartered smaller ships after 2020. For instance, CMA-CGM, Evergreen, Maersk, ONE, Yang Ming, and Zim all chartered smaller ships after 2020 when compared to the period before that.

The age of ship (year of construction) remained unchanged after 2020 as opposed to before for all companies except CMA-CGM (p-value = 0.002), HMM (p-value = 0.000), One (p-value = 0.001), and WanHai (p-value = 0.005) (Table 3), indicating that they had chartered younger ships after 2020. As depicted by the negative correlation in Table 4, CMA-CGM and HMM chartered younger ships after 2020. However, One and Wan Hai (positive correlation) chartered older ships after 2020. The charter period remained unchanged only for Evergreen (p-value = 0.542) and HMM (p-value = 0.096) (Table 3). Cosco ($p=0.000$), Hapag Lloyd ($p=0.002$), Maersk ($p=0.000$), MSC ($p=0.000$), ONE

Table 2 Hypothesis testing

	Null hypothesis	Test	Sig	Decision
1	The distribution of the size of chartered ships (in TEU) is the same across categories of 'Before_ After'	Mann–Whitney U test	.000	Reject the null hypothesis
2	The distribution of the age of chartered ships (in TEU) is the same across categories of 'Before_ After'	Mann–Whitney U test	.000	Reject the null hypothesis
3	The distribution of the period of chartered ships (in TEU) is the same across categories of 'Before_After'	Mann–Whitney U test	.000	Reject the null hypothesis

Source: Author's calculation

Table 3 Mann–Whitney U test results

	Shipping Line										
	CMA-CGM	Cosco	Evergreen	Hapag Lloyd	HMM	Maersk	MSC	One	Wan Hai	Yang Ming	Zim
	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)	Asymp. Sig. (2-tailed)
Size	0.001	0.146	0.024	0.077	0.086	0.002	0.375	0.011	0.137	0.000	0.008
Age	0.002	0.397	0.719	0.667	0.000	0.066	0.479	0.001	0.005	0.432	0.631
Period	0.001	0.000	0.542	0.002	0.096	0.000	0.000	0.000	0.000	0.026	0.000

*Highlighted cells show that no significant change occurred after 2020

Table 4 Correlation matrix

	Shipping line										
	CMA-CGM	**Cosco**	**Evergreen**	**Hapag Lloyd**	**HMM**	**Maersk**	**MSC**	**One**	**WanHai**	**Yang Ming**	**Zim**
	Correlation coefficient with Before_after 2020										
Size	**−.083****	**−0.064**	**−.134***	**−0.069**	**−0.142**	**−.092****	**−0.036**	**−.181***	**−0.076**	**−.267****	**−.140****
Age	−.080**	0.038	0.022	0.017	−.370**	0.056	−0.030	.249**	.149**	−0.060	−0.026
Period	.088**	.212**	0.036	.122**	0.140	.212**	.184**	.311**	.274**	−.165*	.386**

Source: Author's calculation

(p = 0.000), Wan Hai (p = 0.000), Yang Ming (p = 0.026), and ZIM (p = 0.000) showed statistical significance for the period of charter after 2020. Except for lines that showed no statistical significance, the large majority of shipping lines chartered vessels for longer periods (positive correlation). Only Yang Ming chartered ships for shorter periods after 2020 (negative correlation).

From the analysis, it is possible to draw a generalised summary of the major chartering strategies at the company level. Table 5 presents the differences in chartering strategies for the size, age and charter period of chartered ships after 2020 compared to before 2020. If a company shows 'no change', it indicates that there was no statistical significance before and after 2020. It is evident how each shipping line decided to pursue a specific strategy after 2020 when compared to before that. While some lines showed considerable change, others only showed differences for one of the variables. Zim and Maersk decided to charter smaller ships for longer periods while the age of the ship did not change. Wan Hai focused on older ships for longer period charters. CMA-CGM showed differences in all three variables and chartered smaller, younger ships for longer periods. Similarly, ONE chartered smaller and older ships for longer periods. Hapag Lloyd only chartered ships for longer periods, Evergreen chartered smaller ships alone, and HMM focused on chartering younger tonnage. Yang Ming decided to charter smaller tonnage and was the only one to shorten the charter period.

Data envelopment analysis (DEA)

A DEA model was applied to determine the efficiency level of the shipping lines for 2019 (before pandemic) and 2020 (during pandemic). DEA is a useful non-parametric linear programming method widely utilized in several fields of research to assess the relative efficiency of set of comparable units known as decision making units (DMU). Each DMU utilizes a set of multiple inputs to produce a set of multiple outputs and DEA model allows to obtain a set of efficient units which form the efficient frontier The main advantage of applying a DEA model is identifying potentially non-efficient units and provide managerial guidance on how they can become efficient (Charnes et al. 1978).

Prior to conducting the DEA analysis, the data source used in the evaluation of the lines' efficiency in 2019 and 2020 on the inputs variables (two) and the output variable (one) were examined. Source data for evaluating the efficiency of DMUs for 2019 and 2020 are shown in Tables 6 and 7, respectively.

The computational results of the CCR-I efficient scores for 2019 and 2020 are reported in Table 8. All scores of the DMUs under consideration ranged from between 0 and 1. A DMU with efficiency equal to 1 implies that the unit was efficient in transforming the inputs or outputs. In contrast, a DMU with a score of 0 suggests that the unit was inefficient. The results in Table 8 show that CMA-CGM, ZIM, and Wan Hai were all efficient, as each had a score of 1. Maersk, which scored 0.886, was close to efficiency. To reach efficiency, it should proportionally reduce its chartered and owned tonnage to 1,592,790 and 2,071,813, respectively. On the other hand, Hapag Llyod (0.238), Evergreen (0.381), Yang Ming (0.55), HMM (0.75), and Cosco (0.625) were inefficient units and larger improvements are necessary. Hapag Lloyd should reduce its chartered and owned tonnage to 150,473 TEU and 249,416 TEU, respectively, as the target potential improvement. Similarly, Evergreen should reduce its chartered and owned tonnage to

Table 5 Summary of the shipping lines' chartering strategies before and during 2020

Variables	CMA CGM	Cosco	Evergreen	Hapag Lloyd	HMM	Maersk	MSC	One	Wan Hai	Yang Ming	Zim
Size of chartered Ships (TEU)	Smaller	No Change	Smaller	No Change	No Change	Smaller	No Change	Smaller	No Change	Smaller	Smaller
Age of chartered ships (year of construction)	Younger	No Change	No Change	No Change	Younger	No change	No Change	Older	Older	No Change	No change
Period of charter	Longer	Longer	No change	Longer	No change	Longer	Longer	Longer	Longer	Shorter	Longer

Source: Authors

Table 6 Owned TEU, chartered TEU and revenue of the DMU (2019)

DMU	Owned ships (TEU)	Chartered ships (TEU)	Revenue (Million USD)
Maersk	2,337,858	1,797,323	38,890
CMA-CGM	1,021,568	1,652,126	23,133
Hapag LLOYD	1,048,766	632,725	3743
ZIM	13,657	287,597	3300
Evergreen	578,434	680,348	6175
Yang Ming	189,001	459,101	4833
Wan Hai	164,645	94,590	2363
HMM	129,552	284,700	4291
COSCO	1,480,504	1,390,905	20,967

Source: Alphaliner Monthly Monitor 2019

Owned and chartered ships expressed in TEU (i.e., 20-foot equivalent unit); Revenue Expressed in million USD

Table 7 Owned TEU, chartered TEU and revenue of the DMU (2020)

DMU	Owned ships (TEU)	Chartered ships (TEU)	Revenue (million USD)
Maersk	2,338,032	1,759,406	39,740
CMA-CGM	986,368	1,784,872	24,233
Hapag LLOYD	1,052,189	667,693	14,585
ZIM	6075	298,833	3992
Evergreen	585,744	666,199	7040
Yang Ming	183,422	433,385	5143
Wan Hai	163,565	112,690	2783
HMM	263,226	292,304	4528
COSCO	1,552,417	1,405,436	24,071

Source: Alphaliner Monthly Monitor 2020

Owned and chartered ships expressed in TEU (i.e., 20-foot equivalent unit); Revenue Expressed in million USD

Table 8 CCR-I results for year 2019 and 2020

	DMU	Efficiency score (2019)	Efficiency score (2020)	2019–2020 efficiency comparison
1	Maersk	0.886	0.952	Increased
2	CMA-CGM	1	0.772	Decreased
3	Hapag LLOYD	0.238	0.885	Increased
4	ZIM	1	1	Constant
5	Evergreen	0.381	0.524	Increased
6	Yang Ming	0.55	0.717	Increased
7	Wan Hai	1	1	Constant
8	HMM	0.75	0.762	Increased
9	Cosco	0.625	0.78	Increased

Source: Authors' calculation

259,047 TEU and 220,243 TEU, respectively. Yang Ming should achieve 252,091 TEU and 103,780 TEU in chartered tonnage and owned carrying capacity, respectively. HMM should decrease its chartered and owned ships to 213,607 TEU and 97,201 TEU, respectively. Finally, Cosco should reduce its chartered and owned tonnage to 869,546 TEU and 925,560 TEU, respectively.

The efficiency results for 2020 show an overall improvement in most DMUs. Zim and Wan Hai were efficient, yielding a score of 1 each. CMA-CGM, which was efficient in 2019, was also inefficient (0.772) in 2020. It should reduce its chartered and owned ships to 1,378,794 TEU and 761,958 TEU, respectively, in order to reach the efficient frontier. Maersk (0.952) and Hapag Llyod (0.885) are close to efficiency. Evergreen (0.524) appeared inefficient and should reduce chartered and owned tonnage to 349,156 TEU and 306,989 TEU, respectively. The target potential improvement for Yang Ming is to charter and own 310,747 TEU and 131,517 TEU, respectively. HMM should reduce its chartered and owned ships to 222,708 TEU and 200,553 TEU, respectively. Cosco should decrease its chartered and owned ships to 1,096,724 TEU and 1,211,420 TEU, respectively.

Discussion

The COVID-19 pandemic has had a great impact on supply chains and the maritime logistics industry. Unlike previous crises (i.e. 2008/2009 the financial crisis), shipping lines showed a high level of preparedness and resilience (Notteboom et al. 2021) in relation to operational strategies and, in particular, in relation with service network and capacity deployed as part of alliances on main routes (UNCTAD 2020). However, capacity management can also take the shape of chartering activities as this is commonly considered as an important strategic tool to adjust tonnage requirements (Cariou and Wolff 2013).

The results of this study suggest that the chartering strategies in response to the pandemic have changed both considering all companies in aggregate as well as individual shipping lines. In general, hence, transport capacity management in terms of chartered tonnage can be interpreted as a strategy widely utilized by shipping lines. The tonnage chartered before and during the pandemic, whilst not considering a prolonged time period during the pandemic, showed changes in relation to the size, age and period of the charter. Whilst Notteboom et al. (2021) noted that idling smaller ships and relying on larger vessel to exploit economies of scale and network optimization, our study indicates that, overall, smaller ships were chartered for longer period of times. However, Notteboom et al. (2021) also found that the search for scale was less significant during COVID-19 than during the financial crisis and it should be noted that, in our study, we considered a rather limited period during the pandemic. Moreover, Fedi et al. (2022) stressed that shipping lines adapted, through alliances, to the shock rapidly and effectively. The rapidity shown by shipping lines in capacity adjustments (Fedi et al. 2022), is in the line with the findings of our study as we demonstrated the degree of responsiveness in changes of chartering activities during the first months of the pandemic.

Linking the 2020 efficiency scores with the previous results enables to further investigate on the strategies of liners. It can be stressed, although not generalized, that those shipping lines which yielded higher efficiency score under DEA showed peculiar

chartering strategies. For instance, Zim (CCR-I = 1), Wan Hai (CCR-I = 1) and Maersk (CCR-I = 0.95) showed significant differences in two out of the three variables considered (smaller ships for longer periods in case of Zim and Maersk and older ship for longer period for Wan Hai). On the other hand, shipping lines which showed lower efficiency score had only one variable significantly changing in 2020 (longer period for Hapag-Lloyd (CCR-I = 0.88), smaller ships for Evergreen (CCR-I = 0.52, younger ships for HMM (CCR-I = 0.76). Yang Ming (CCR-I = 0.71) chartered smaller ships and was the only one to charter for shorter period in 2020. As noted by Notteboom et al. (2021), shipping lines during the pandemic reaffirmed their bargaining power showing string financial results. The adaptability of shipping lines.

For these reasons, we argue that, whilst the resilience of shipping has been manly driven by network rescheduling and shared capacity management as shown by past research, capacity management adjustments of liners were also represented by chartering activities and the characteristics of chartered tonnage.

Conclusion

The COVID-19 pandemic represented an unforeseeable event which significantly impacted global supply chains. Shipping lines had to adapt their chartering strategies to pursue fleet optimization, operation efficiency and reliability of transport services. In the present study, we propose a methodology to determine to what degree chartering strategies of liners changed in response to the pandemic. We first apply a Mann Whitney U test to test the chartering strategies under the consideration of the size of chartered tonnage, age of chartered ships and period of charter. We then apply a DEA model to evaluate the efficiency of shipping lines considering tonnage chartered, owned tonnage and revenue. The findings show that chartering strategies differ significantly after the pandemic and the majority of liners follow a peculiar policy on chartered tonnage. Those liners showing deeper changes in terms of chartering strategies, yield higher efficiency score with DEA. On the other hand, shipping lines that are not subject to major changes, show a lower efficiency score.

The implications of this study support both academics and managers. From the research perspective, the analysis showed that shipping lines adopted different chartering strategies and that each one has pursued a peculiar path in response to the pandemic. The findings point out that decision-making of shipping lines was divergent across the sample but all of them showed resilience to a new market scenario represented by the pandemic. The DEA analysis enabled to show the link between these strategies and efficiency levels. It is therefore possible to highlight the importance of elements such as quick reaction time and flexibility of shipping lines to enhance operational efficiency gains in a short-term scenario.

Second, from a management perspective, the findings can support decision-makings in response to unpredictable events and gain the ability to benchmark against competitors' behaviours. The decision-making in terms of chartered tonnage is strictly linked with business risks and financial results. The strategy of chartering ship of a specific size, age and period of charter is important and can directly influence on the financial performance and in turn on the efficiency of shipping lines. Hence, the results can support

decision-making on chartering policies and provide insight on competitors' behaviour and efficient scoring.

A potential limitation of this study is related to the DEA methodology. Only two inputs and one output were used but it would be worthwhile to include one or more output variables related to profitability indicators. The results could be different based upon the nature and the number of inputs and outputs used and would provide more insight on the link between chartering strategies and financial performance. Furthermore, the DEA analysis could be extended for a longer period and assess how chartering strategy are influential to efficiency gains to generalize in greater details the results.

Abbreviations

CAPEX	Capital expenditure
CCR-I	Constant Comparative Ration Input
CCR-O	Constant Comparative Ration Output
COVID-19	Coronavirus disease 2019
DEA	Data envelopment analysis
DEA-BCC	Data envelopment analysis-Bounded Convexity Criterion
DEA-CCR	Data envelopment analysis-Charnes, Cooper, and Rhodes
DEA-CCR-I	Data envelopment analysis-Constant Comparative Ration Input
DMU	Decision making units
TEU	Twenty-foot equivalent unit
SPSS	Statistical Package for the Social Sciences
UNCTAD	United Nations Conference on Trade and Development

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Declarations

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