Green Premium and the Role of Financial Investors in Sustainable Investment in Container Shipping

Jia, Haiying; Jiang, Liping; Azevedo, Paulo

Document Version
Final published version

Published in:
Transportation Research. Part E: Logistics and Transportation Review

DOI:
10.1016/j.tre.2024.103658

Publication date:
2024

Citation for published version (APA):
Jia, H., Jiang, L., & Azevedo, P. (2024). Green Premium and the Role of Financial Investors in Sustainable Investment in Container Shipping. *Transportation Research. Part E: Logistics and Transportation Review*, *189*, Article 103658. https://doi.org/10.1016/j.tre.2024.103658

Transportation Research Part E 189 (2024) 103658

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Green premium and the role of financial investors in sustainable investment in container shipping

Haiying Jia [a], Liping Jiang [b,*], Paulo Azevedo [c]

[a] Department of Business and Management Science, Norwegian School of Economics, Norway
[b] Department of Operations Management, Copenhagen Business School, Denmark
[c] Department of Business and Management Science, Norwegian School of Economics, Centre for Applied Research, Norway

ARTICLE INFO

Keywords:
Sustainable investment
Financial buyer
Operating buyer
Container vessel value
Green price premium

ABSTRACT

Sustainable investment in tangible shipping assets is important for understanding investor behaviour and promoting sustainable development in the industry and the global economy. This research presents a framework for empirically testing the existence of the "green premium" for eco-ships and the role of financial investors in containership investments. Real transaction data from over 2000 sales and purchases of containerships between 2005 and 2023 are utilized in this study. A Generalized Structural Equation Modelling is employed to investigate the relationship among variables, including vessel value, eco-ships, investor categories, age, size, and others. The finding confirms the presence of a green price premium for the second-hand container eco-ships. Furthermore, financial buyers, who typically act as lessors in the financial leasing of ships in the shipping industry, have shown a more pronounced inclination towards investing in container eco-ships compared to operating buyers.

1. Introduction

The heightened commitment to sustainable investing is manifesting in a paradigm shift, whereby investors are systematically incorporating Environmental, Social, and Governance (ESG) criteria into their portfolio selection and investment strategies (GSIA, 2023). The primary goal of this integration is to pursue not merely financial gain but also to generate positive social or environmental outcomes, thereby contributing constructively to the society at large. Sustainable investing strategies have been adopted across a variety of asset classes, where ESG performance is assessed either by employing external ESG ratings for securities (Berg, et al., 2019) or through the analysis of environmental features associated with physical asset investments. As sustainable investing gains broader acceptance, the financial implications of such practices have garnered significant scholarly attention. Consequently, the literature has explored the expected green asset premium within financial markets, particularly in relation to asset allocation and risk management (see for instance, Meuer et al., 2019; Dorfleitner et al., 2018; Douglas et al., 2017).

However, the findings have been varied and show difference across firms and sectors. As Khan et al. (2016) have pointed out, there is a significant distinction between material and non-material ESG issues, which are usually combined into composite ESG ratings. Within the transportation sector, ESG issues related to materials such as fuel type and engine design are more significant than non-material issues like anti-corruption in the public sector. This paper seeks to investigate sustainable investing in relation to tangible vessel assets in the international shipping industry.

* Corresponding author.
E-mail address: lji.om@cbs.dk (L. Jiang).

https://doi.org/10.1016/j.tre.2024.103658
Received 19 March 2024; Received in revised form 2 July 2024; Accepted 2 July 2024
Available online 13 July 2024
1366-5545/

The term "green premium" refers to the added value of an asset that is characterized by their environmentally friendly design and advanced green technologies. Ships with such characteristics are deemed "eco-ships". In this paper, an eco-ship is a vessel that features an Eco Electronic Engine (eco-engine), which can save energy through electronic fuel injection. Container shipping is considered as one of the most significant commercial innovations of the twentieth century. For decades, it has been the workhorse of international trade by transporting containerized general cargo at low costs, which are primarily achieved through standardization and economies of scale (Cosar and Demir, 2018). Approximately 60 % of seaborne trade, measured by dollar value, is transported via container shipping (Placek, 2021). The current containership fleet is valued at USD $320 billion (Clarksons, 2022a), with ship sizes ranging from 100 Twenty-foot Equivalent Unit (TEU) to the mega size of 24,004 TEU. These vessels provide transportation services for consumer goods and industrial products utilizing small feeder containerships for regional deliveries and larger vessels for intercontinental shipments. Container vessels, integral to the global supply chain, are capital-intensive assets that require substantial investment and involve high risks. As an example, in January 2022, the newbuilding price for a 23,500 TEU mega containership was USD 193 million and a 7,000 TEU intermediate containership costed around USD 84 million (Clarksons, 2022b). By January 2024, merely two years onward, the prices surged to USD 264 million for the former and USD 118 million for the later, showcasing the volatile nature of the shipping market (Clarksons, 2024c). In addition to financial risks, container shipping is also vulnerable to various security disruptions along shipping routes, such as the ongoing Red Sea Crisis (Notteboom et al., 2024) and general chokepoint closures (Pratson, 2023).

Oceangoing vessels, including containerships, have been powered by unrefined residual fuels in diesel combustion engines since the late nineteenth century. Ship power systems emit various pollutants, such as particulate matter ($PM_{2.5}$), sulfur oxides (SO_x), and nitrogen oxides (NO_x), which can have hazardous effects on health and the climate. Historically, emissions from international shipping received minimal attention by the mainstream society, primarily due to the operations of these vessels in remote deep-sea areas, far away from major human activities. Furthermore, the international shipping industry's distinctive cross-border trading nature, involving mobile assets, has led to its exemption from the global efforts to address climate change under the 2015 Paris Agreement. The international shipping industry has been slow to embrace sustainable investing, as evidenced by the lack of freight rate premiums for energy-efficient vessels, as noted by Adland et al. (2017). With the growing emphasis on climate change and consumers' awareness of the carbon footprint of the supply chain, the container shipping industry is facing societal and regulatory pressure to reduce its environmental impacts across various aspects.

The objective of this paper is twofold: 1) to develop a framework for investigating the presence of a green price premium associated with container eco-ships and 2) to investigate the role of financial investors in promoting sustainable investment in containerships through the preferential selection of ships equipped with eco-features. We expect there to be a "green premium" for eco-ships for four reasons. Firstly, the green technologies that mitigate environmental impacts from vessels are not typically included in the traditional shipbuilding specifications. To incorporate these green technologies, shipowners must make specific requests during the ordering process and allocate additional capital for their installation. Secondly, non-eco-ships face a higher risk of becoming stranded assets compared to their eco counterparts, which tend to retain a higher residual value. As a result, the present valuation of eco-ships is likely to include a premium, reflecting their environmental advantage and enhanced value retention. Thirdly, the potential for increased freight income from eco-ships, owing to their energy-saving features, could result in higher valuations and suggest the existence of a 'green premium' for the vessel value. Fourthly, eco-ships tend to be more fuel efficient, resulting in lower operational costs.

In the context of the second objective, we also hypothesize that the categories of buyers for vessel assets could have varying impacts on vessel valuation. Ship buyers usually fall into two categories: financial and operating buyers. Financial buyers typically include financial institutions such as specialized ship leasing companies, private equity funds, and commercial banks. On the other hand, operating buyers, typically traditional shipping companies, acquire vessel assets to meet the demand of international trade by managing daily vessel operations. The literature has presented various pieces of evidence regarding the profiles of these investors and their impact on asset value. Gorbenko and Malenko (2014) suggested that strategic buyers, also known as operating buyers, might be willing to pay more for the assets because of potential synergies resulting from the investment. On the other hand, financial buyers may be able to afford a higher value asset due to their relatively low cost of debt (Axelson et al., 2013). Despite the crucial role of investors in fostering sustainable investments in shipping, the differences between financial and operating buyers have not been investigated thoroughly. Understanding these variances is vital for comprehending the dynamics of sustainable investments decision-making within the shipping sector. The two groups of investors in vessel assets – financial buyers and operating buyers – differ fundamentally in their objectives and financial resources, which may significantly influence their investment strategies and decisions. Financial buyers primarily focus on maximizing returns, often using sustainability as a criterion for screening investments rather than integrating it into daily operations. Conversely, operating buyers are more inclined to align their asset investments with their operational sustainability goals. Additionally, financial buyers generally enjoy easier and cheaper access to capital compared to operating buyers. Consequently, these differences in objectives and resources may lead to distinct investment preferences between the two groups. Financial buyers might be more inclined to invest in green aspects of assets, even if they are more costly, especially when sustainability is a mandatory criterion for their investment decisions. On the other hand, operating buyers typically consider the vessel's full specifications to ensure compatibility and efficiency within their entire fleet operations.

In theory, vessel value should reflect both expectations of future earnings and residual value (Beenstock, 1985), and the prevailing supply and demand situation at the time of sales. The latter is influenced by factors such as the freight market, vessel specifications, including age, size, and technical attributes (Stopford, 2009; Adland and Jia, 2015). In this paper, we further evaluate the value of second-hand vessels, considering the impact of buyer type. Specifically, we investigate whether there is a price difference between financial and operating buyers. Therefore, we have the following hypotheses:

H_{01}: Assets of green containership present a price premium over their conventional counterparts.

H_{02}: Financial investors in container shipping demonstrate a preference towards the acquisition of eco-ships over conventional ships.

H_{03}: Financial buyers positively influence the containership value due to their access to lower-cost capital.

H_{04}: Fundamental factors, including vessel age, size, freight rates, and the builder's country, impact the value of containerships.

The paper contributes to the existing literature in the following aspects. Firstly, this study presents pioneering research on sustainable investments in tangible shipping assets, specifically containerships, utilizing real transaction data. Unlike existing literature predominantly focused on financial equity investments with a sustainability lens, our work leverages a unique data set enriched with vessel technical information and buyer profiles. This dataset facilitates a nuanced exploration on whether eco-ships demand a green premium, and how investors prefer such assets. Furthermore, the methodology addresses the dynamic interplay between key variables – asset value, vessel specifications and investor category – within a Structure Equation Model (SEM) framework. The model's multi-directional structure underscores the complex relationships among these variables, offering new insights. Lastly, the paper sheds light on the critical role of financial investors in the maritime industry's green transition. By employing a logistic model simultaneously estimated within the SEM, we examine investors' preferences for asset features, highlighting the contributions of financial investors to sustainable investing in the container shipping industry.

The reminder of the paper is organized as follows. Section 2 presents the relevant literature. Section 3 illustrates the methodology followed by data in Section 4. Section 5 analyses the results, which is followed with conclusions in Section 6.

2. Literature review

Beenstock (1985) elaborated in a theoretical framework that explains how ships are tangible capital assets, the prices of which heavily influenced by expectations of future earnings and residual value. From the perspectives of supply and demand, there has been literature on the factors influencing the price of second-hand vessels. Primary influencers such as age, size, freight rate, technical specifications, and market outlook have been identified (Stopford, 2009; Adland and Jia, 2015). Builder country has been suggested as another factor influencing the secondhand prices of certain vessel types (Adland et al., 2018; Fiasca et al., 2018). There is limited evidence in the literature supporting the hypothesis that energy-efficient vessels result in an increase in vessel value (Adland et al., 2018; Kokosalakis et al., 2021) or freight earnings (Adland et al., 2017). Adland et al. (2017) found that energy-efficient ships attract higher time charter rates during normal freight market conditions. However, these vessels faced disadvantages during booming market periods, as the extra revenue gained by prioritizing speed and capacity-enhancing attributes outweighed the savings on fuel cost associated with energy efficiency. This asymmetric "green premiums" observed in the freight market suggests that the financial benefits of energy efficiency may vary depending on market conditions. In the broader research domain of sustainable shipping, recent literature has made significant contributes to understanding and optimizing the operation of fleets and ports to create more sustainable shipping networks (Wang et al., 2018; Zhen et al., 2020; Ezaki et al., 2022). Additionally, advancements have been made in incorporating diverse data sources and utilizing artificial intelligence and machine learning to improve vessel routing (Du et al., 2022a; Du et al., 2022b; Li et al., 2022).

From the financial perspective, given the average lifespan of 25–30 years for containerships, sustainable investing is of paramount importance to ensure a fleet compliant with decarbonization mandates and mitigate the risks of the ships becoming stranded assets (Bos and Gupta, 2019). In such cases, vessels may require costly retrofitting or premature scrapping due to noncompliance or economic infeasibility (Cairns, 2018; Babiker et al., 2000).

One asset class comparable to ships in sustainable investment is real estate. The relationship between environmental performance and real estate values has been extensively studied, yielding mixed results (see for instance, Reichardt et al., 2012; Del Guidice et al., 2020; Cajias and Piazolo, 2012). Fuerst and McAllister (2011) used hedonic regression procedures to assess the impact of energy performance certificates (EPCs) on appraised capital values and rental values of UK commercial property assets. They found no evidence of a significant correlation. Conversely, successive studies on residential housing prices in Wales and apartment prices in Helsinki support the existence of a price premium for highly energy-efficient real assets (Fuerst et al., 2016).

In the broader investment community, there is evidence of a growing number of investors committed to integrating sustainability issues into their asset choices, as promoted by the United Nations Principles for Responsible Investment (UNPRI). The number of UNPRI investor signatories, indicating their commitment, reached 5,391 by the end of 2023, with an estimated total of assets under management (AUM) of USD 121 trillion in 2021, the most recent data available (PRI, 2024).

The literature presents various theoretical arguments on sustainable prinvestments. For instance, Jensen (2002) argues that sustainable investments increase a company's costs, thereby creating a competitive disadvantage. Scholars such as Sen and Bhattacharya (2001) suggest that sustainability investing can increase the overall demand for products and services in a similar way to advertising. This can lead to competitive differentiation and operating efficiency (Luo and Bhattacharya, 2006; Freeman et al., 2007). Przychodzen and Przychodzen (2015) and Lee and Min (2015) suggest that "green" activities can enhance a company's financial performance. Jenssen and Randøy (2006) also discovered that companies that invest in product and process differentiation, including superior environmental performance, tend to achieve better financial results. Baker and Sinkula (2002) and Darroch and Mcnaughton (2002) argue that innovation is a key driver of long-term success for businesses and helps them navigate the highly volatile external environments.

There is limited research on the green premium of shipping assets, let alone the implications of different ownership structures. However, the growing emphasis on the overall emissions footprint of the entire supply chain makes it essential and inevitable to explore sustainable investing in shipping assets (Kramel et al., 2021). Furthermore, the increasing recognition of the need to measure, manage and report Scope 3 emissions underscores the importance of investigating sustainable investment in shipping. Scope 3 emissions encompass all indirect greenhouse gas emissions occurring in a company's value chain, both upstream and downstream.

These emissions are not directly produced by the company itself (Scope 1 emissions), nor are they the result of the company's energy consumption (Scope 2 emissions), but rather arise from activities such as distribution and transportation across the overall supply chain. Managing Scope 3 emissions is complex due to the lack of knowledge and data from the distribution channel. This research aims to shed light on this crucial aspect of sustainability.

3. Methodology

3.1. Generalized structural Equation modelling (GSEM)

Structural Equation Modelling (SEM) is a comprehensive statistical approach used to analyze complex relationships among measurable or unmeasurable variables. When a variable is not directly observed and the concept is abstract, such as *happiness,* it can be inferred from other measurements, such as the frequency of smiling. This is referred to as a latent variable, which can be constructed and analyzed in the SEM (Bollen, 1989). In this research, however, we do not use any latent variables. Instead, our focus is on examining the relationships between the measurable variables by conducting structural analysis of the causal associations among the variables using path analysis and measurement models.

SEM does not necessarily adhere to the exogeneity assumption, which is a fundamental principle in regression models (Kline, 2015). Under the exogeneity assumption, the independent variables in the regression model are assumed to be uncorrelated with the error term. In other words, the predictors should be independent from factors that are not included in the regression model. However, when endogeneity occurs – meaning there is a two-way relationship between the independent and dependent variables – techniques such as SEM become effective.

SEM generally comprises two main components: a measurement model using Confirmatory Factor Analysis (CFA) to capture the relationships between latent variables and their observed indicators, and a structural model with path analysis to illustrate the relationships among endogenous and exogenous variables. A full SEM model integrates measurement and structural models into a unified framework, optimizing under a single common optimization criterion. (Ramlall, 2017). However, in this research, we utilized only the structure model to investigate the relationships among variables, excluding the CFA model because all variables in the study are observed, eliminating the need for latent variables.

A Generalized SEM (GSEM) relaxes the constrains present in the standard SEM, allowing the inclusion of variable types such as binary, ordered, categorical, or count variables, rather than being limited solely to continuous variables. More importantly, GSEM is powerful in analysing data that exhibits multilevel structures (Hwang and Takane, 2014). In the GSEM analysis, a global optimization criterion is explicitly defined and optimized throughout iterations (Hwang and Takane, 2014). Consider a model with three observed variables: *X, Y*, and *Z*. We hypothesize that *X* influences *Y*, and that both *X* and *Y* influence *Z*. Therefore, the relationship can be specified using the following equations:

$$Y = \beta_{YX}X + \varepsilon_Y \tag{1}$$

$$\mathrm{Z} = \beta_{ZX}X + \beta_{ZY}\mathrm{Y} + \varepsilon_Z \tag{2}$$

Where, β_{YX} is the coefficient representing the effect of X on Y,

β_{ZX} is the coefficient representing the effect of *X* on *Z*, and.

β_{ZY} is the coefficient representing the effect of *Y* on *Z*.

ε_Y *and* ε_Z *are the error terms for the equations predicting Y and Z, respectively.*

This model allows for the estimation of both direct effects, such as the effect of *X* on *Z*, and indirect effects, such as the effect of *X* on *Z* through *Y*.

Moreover, the model can be expanded to include additional variables to investigate complex relationships, such as mediation or moderation effects (Hayes, 2013). Mediation occurs when the relationship between the independent variable *X* and the dependent variable *Z* is explained, at least in part, by one or more exogenous variables, known as mediators. Mediation explores the how or why of a relationship. Moderation occurs when the strength or direction of the relationship between two variables depends on a third variable, known as the moderator. Typically, moderation is represented by an interaction term between the independent variable and the moderators. Moderation addresses when or under what conditions the relationship changes (Baron and Kenny, 1986).

Therefore, the strengths of GSEM over traditional regression models for our application are numerous and compelling. First, the methodology relaxes the stringent exogeneity assumption that is a fundamental requirement in ordinary regression models. This flexibility is crucial for accurately modelling complex relationship where the assumption of strictly exogenous predictors may not hold. Second, GSEM allows for the effective examination of bidirectional relationship between the independent and dependent variables within a multilevel framework. This capability is essential for analysing systems where feedback loops and reciprocal causation are present, providing a more realistic representation of the interactions. Third, the methodology is adept at handling endogenous phenomena by incorporating measurement errors directly into the model, enhancing the robustness and reliability of the results. Fourth, GSEM is well-suited for analysing both mediation and moderation effects. This dual capability allows for a nuanced exploration of complex interactions that traditional regression models might miss. Lastly, GSEM provides greater flexibility in specifying models that can incorporate various types of variables – e.g. continuous, categorical or ordinal variables – and complex error structures. This adaptability makes it particularly suitable for diverse and intricate data scenarios. By leveraging these strengths, GSEM offers a robust and versatile framework for our application, enabling a more comprehensive and accurate analysis of the underlying relationships in our data.

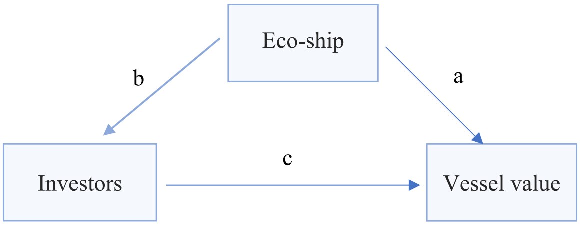

Fig. 1. The conceptual relationship of investors and eco-ships, and the impact on vessel value.

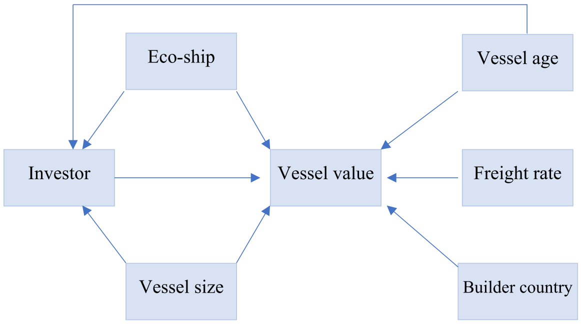

Fig. 2. Interrelationship among the determinants of vessel value and the vessel preferences of investors.

3.2. Model construction and specification

This study aims to examine the factors influencing the value of containerships, particularly focusing on the green price premium and the role of financial investors. The relationship among the three main variables is illustrated in Fig. 1 below. The impact of a vessel's eco-ship status on its value is determined by the direct effect a, and the indirect effect $b*c$ through the influence of the investor preferences in choosing the eco-ship. Therefore, the total effects of eco-ships on vessel value theoretically should be the sum of the direct and indirect effects: $a + b*c$.

To reflect this relationship and incorporate the variables that influence vessel value and investor's vessel preference, we construct the following GSEM:

$$y_{i,t} = \alpha + B^*X_{i,t} + \gamma_1{}^*F_i + \gamma_2{}^*E_i + \Gamma^*D_i + \varepsilon_{i,t} \tag{3}$$

$$F_i = \eta_1 E_i + \eta_2 \log(TEU)_i + \eta_3 \log(age)_{i,t} + \mu_{i,t} \tag{4}$$

Where, $y_{i,t}$ is the logarithm form of transaction prices for vessel i at time t.

$X_{i,t}$ is the logarithm forms of independent variables, including the freight rate, size and age of the vessel.

F_i is a dummy variable, when equal to 1, representing financial investors.

E_i is a dummy variable, when equal to 1, representing eco-ships.

D_i is a categorical variable, indicating ship builder countries.

γ_1 *and* γ_2 are the coefficient estimates of premia for financial investors and *eco-ships,* respectively.

B is the coefficient estimation vector for the numeric independent variables;

Γ is the coefficient estimation vector for the categorical independent variables.

$\varepsilon_{i,t}$ *and* $\mu_{i,t}$ *represent the residuals.*

The GSEM framework comprises two components. Firstly, it represents the primary relationship between vessel value ($y_{i,t}$) and the determinants X (size TEU_i, age age_i and market freight rate TC_t). The potential existence of a green premium is investigated by including the dummy variable E_i. The role of buyer's profile is analysed by including the dummy variable F_i. When $F_i = 1$, it represents financial investors. Investors' investment preferences on vessel are modelled as a logistic structure on vessel size, age, and whether it is an eco-ship in eq. (4). Eqs. (1) and (4) are estimated simultaneously.

The relationship among the variables is illustrated in Fig. 2. The relationship between vessel value, investor preference, and eco-ships is further explored by incorporating key variables namely vessel age, size, market conditions, and the ship builder's country. The selection of these variables is based on a review of the literature and empirical exploration, aiming to strike a balance between model performance and the complexity of the specification.

Moreover, investor's vessel preferences may be affected by vessel size, which indicates leasing prospects based on the corresponding market segment for the vessel's employment. Larger containerships are typically used for long-haul cross-continental trades managed by international shipping companies. Smaller containerships typically operate in national or regional trades that require adherence to local jurisdiction, as indicated by the vessel's flag. Financial buyers may lack the local expertise and legal presence required to lease smaller vessels to regional shipowners. Instead, larger international shipping companies are more likely to lease from financial investors.

The first hypothesis (H_{01}) can be illustrated as the direct effect of the eco-ship variable on vessel value (green premium). The second hypothesis (H_{02}) is the effect of the eco-ship variable on vessel value mediated by financial buyers (investor variable). Hypothesis H_{03} represents the impact of investor profile on the vessel value, while Hypothesis H_{04} illustrates the fundamental factors' effect on vessel value.

3.3. Goodness of fit of the SEM

To test if the model is suitable for the purpose, a wide range of goodness of fit indices are utilized to validate the path and the structure.

3.3.1. Chi-square

The Chi-square χ^2 test is a fundamental statistic measure to assess the goodness-of-fit between a hypothesized model and the observed data. The null hypothesis for the Chi-square test is that there is no significant difference between the observed data and the model-implied data. It measures the discrepancy between the observed covariance matrix and the model-implied covariance matrix. The χ^2 statistic is calculated as:

$$\chi^2 = (N-1) \bullet FML \tag{5}$$

Where, N is the sample size.

FML is the minimized value of the fitting function, which assesses the difference between the observed and model-implied covariance matrices.

The Chi-square statistic is evaluated against a Chi-square distribution with a specific number of degrees of freedom (df), defined as:

$$df = \frac{p(p+1)}{2} - q \tag{6}$$

Where, p is the number of observed variables.

q is the number of parameters estimated in the model.

A non-significant Chi-square value (*p-value* > 0.05) suggests a good fit, meaning that the observed and model-implied covariance matrices are not significantly different (Hu and Bentler, 2009). The Chi-square tests is a fundamental basis for assessing model fit but it is highly sensitive to sample size. With large samples, even trivial discrepancies can result in a significant Chi-square value, suggesting poor fit. Moreover, more complex models with more parameters can lead to smaller degrees of freedom, making it harder to achieve a non-significant Chi-square value (Hooper et al., 2008).

3.3.2. The Comparative fit index CFI

The comparative fit index (CFI) is a measurement for evaluating how well a specified (hypothesized) model fits the observed data relative to an independent, null model that assumes no relationships among the observed variables. CFI values range from zero to one, with values closer to one indicating a better fit (Kline, 2023). The CFI is calculated using the chi-square values and degrees of freedom for both the hypothesized model and the null model. The formula is defined as:

$$CFI = 1 - \frac{\chi^2_{model} - df_{model}}{\chi^2_{null} - df_{null}} \tag{7}$$

Where, χ^2_{model} and df_{model} are the chi-square value and degrees of freedom for the hypothesized model.

χ^2_{null} and df_{null} are the chi-square value and degrees of freedom for the null model.

CFI is less sensitive to sample size than Chi-square text, making it more robust across different sample sizes. However, the measurement is sensitive to model complexity and the accuracy of it depends on the appropriateness of the null model as a baseline (Hooper et al., 2008).

3.3.3. The Tucker-Lewis Index TLI

The Tucker-Lewis Index (TLI), also known as the Non-Normed Fit Index, is a measure to assess the goodness-of-fit in SEM. It is particularly useful, when compared to CFI, because it considers model complexity, penalizing for the number of parameters estimated. TLI values also range from zero to one, although there are rare cases when the values can be slightly above one (Hooper et al., 2008) when the model is overfit, or sample size is too small. TLI values closer to one indicate a better fit (Hu and Bentler, 2009). The TLI is calculated using the chi-square values and degrees of freedom.

$$TLI = \frac{\chi^2_{null}/df_{null} - \chi^2_{model}/df_{model}}{\chi^2_{null}/df_{null^{-1}}} \tag{8}$$

TLI is also less sensitive to sample size compared to Chi-square test. Moreover, by penalizing more complex models, TLI helps prevent

Table 1
Statistical description of key data.

	Mean	St. dev.	Median	Minimum	Maximum	Skewness	Kurtosis
Total sample: observations 2109							
TEU	2721	2536	1732	180	19,224	2.24	6.29
Age (year)	11.74	6.38	11.64	−4	35.76	0.13	0.21
Vessel price (million USD)	16.72	21.22	9.25	0.6	171	2.94	10.41
Eco-ships: observations 228							
TEU	6117	4194	4686	300	19,224	0.75	−0.28
Age (year)	5.79	5.02	5.37	−3.84	19.87	0.36	−0.4
Vessel price (million USD)	40.18	38.84	21.5	0.6	171	1.15	0.49
Non-eco-ships: observations 1881							
TEU	2309	1875	1708	180	13,102	1.85	4.36
Age (year)	12.46	6.14	12.15	−4	35.76	0.13	0.42
Vessel price (million USD)	13.88	15.75	8.45	0.68	113.84	2.84	9.98
Financial investors: observations 124							
TEU	5962	4263	4250	300	19,224	0.87	0.44
Age (year)	7.91	5.16	9.36	−1.29	20.96	−0.05	−0.67
Vessel price (million USD)	36.82	38.22	18.14	0.6	171	1.4	1.28
Buyer investors: observations 1985							
TEU	2518	2238	1728	180	13,102	2.18	5.9
Age (year)	11.98	6.37	11.86	−4	35.76	0.12	0.23
Vessel price (million USD)	15.47	19	9	0.68	156	2.96	10.77

overfitting, which may occur when too many parameters are included in the model (Hooper et al., 2008).

3.3.4. *Root mean square error of approximation RMSEA*

Lastly, we also use Root Mean Square Error of Approximation RMSEA for assessing the goodness of fit of the SEM. The measurement evaluates the discrepancy per degree of freedom between the model-implied and observed covariance matrices. RMSEA is calculated using the formula:

$$RMSEA = \frac{\sqrt{\chi^2/df^{-1}}}{N-1} \tag{9}$$

RMSE adjusts for the complexity of the model, making it a more robust measure, especially in large samples. Typically, RMSEA values of less than 0.05 indicate a good fit (Hu and Bentler, 2009; Hooper et al., 2008).

4. Data

Global containership sales transaction records were collected from January 2005 to March 2023 through Clarksons Shipping Intelligence Network (SIN). There were 2,109 transactions of containerships sales and purchase (S&P) with a total value of USD 35 billion during the sample period. Each transaction record represents a single vessel S&P. The specifications of the vessels are gathered from the Clarksons World Fleet Register (WFR). In addition, we collect freight market data in terms of Time Charter Equivalent (TCE), which measures vessel's daily earnings in USD/day, for various container vessel sizes from Alphaliner and SIN.

The dataset consists of extensive information, which can be categorized as:

a) Transaction information includes the sale date, sale price in both local currency and US dollars, as well as the buyer's company and country.
b) Vessel attributes: including vessel size (TEU), year of build, builder and its country, classification society, engine type and model, fuel and power type, and the set of energy efficiency equipment, particularly the eco-engine specification.

Freight market indicator: Time-charter rate in USD/day. There are 307 unique buyer identities, of which 26 buyer companies belong to the category of financial investors, including corporates, leasing houses, and commercial banks. The financial investors conducted 124 transactions in the sample. These organizations typically purchase vessels and subsequently lease them out to shipping companies on medium to long-term contracts (5–15 years), separating the ownership from vessels' daily operations.

The missing sales price data is imputed using K-Nearest Neighbours (KNN) regression based on TEU size and sale date. The statistical description of the key attributes, including size, age, freight rate, and vessel price, is shown in Table 1. The size of vessels, measured in Twenty-foot Equivalent Units (TEU), ranges from small feeder vessels with a capacity of 180 TEU to megaships with a

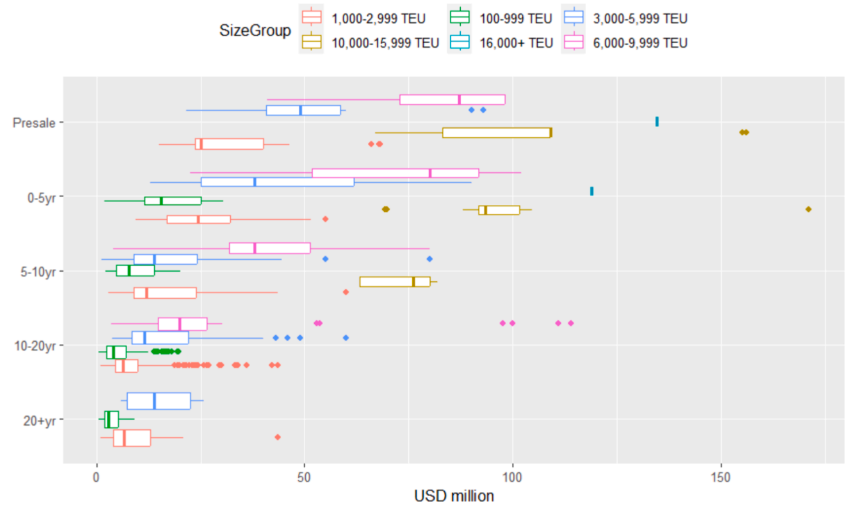

Fig. 3. Containership sales price by vessel size, per age profile, over the sample (Jan 2005-March 2023) (The box plot is based on the distribution of the prices according to age and size at the time of sale. The interquartile range of the prices is shown in the box, with a vertical line representing the mean. The range is depicted by the solid line outside the box, and the outliers are represented as dots.).

Table 2
Number of transactions and total transaction value by size group and age group.

Age / Size	Number of transactions					Total transaction value (USD million)				
	Presale	0–5 yr	5–10 yr	10–20 yr	20 + yr	Presale	0–5 yr	5–10 yr	10–20 yr	20 + yr
100–999 TEU		16	82	244	69		264	685	1,257	230
1,000–2,999 TEU	60	94	216	649	92	1,824	2,438	3,255	5,152	792
3,000–5,999 TEU	28	36	146	167	19	1,403	1,495	2,296	2,793	265
6,000–9,999 TEU	9	21	36	66		739	1,536	1,423	1,829	
10,000–15,999 TEU	13	30	13			1,410	2,853	947		
16,000 + TEU	2	1				269	119			

Table 3
Transaction number and value by the top 10 builder countries.

		Number of transactions	Total transaction value (USD million)	Unit transaction value (USD million)
1	South Korea	571	13,434.9	23.5
2	China P.R.	440	7,202.4	16.4
3	Germany	419	4,982.1	11.9
4	Japan	300	3,841.5	12.8
5	Poland	142	1,751.2	12.3
6	Taiwan	60	1,053.2	17.6
7	Turkey	41	502.0	12.2
8	Denmark	33	843.5	25.6
9	Netherlands	24	204.0	8.5
10	Romania	18	585.4	32.5

capacity of 20,000 TEU. The minimum vessel age being negative (−4 years) suggests that the vessel sale occurred before its completion, a practice commonly termed as pre-sale. For the entire sample, the average S&P price is USD 16.7 million.

Green technologies mainly include Eco Electronic Engine (eco-engine), which can save energy through electronic fuel injection in the main engine. The central component of an electronic engine is the Electronic Control Unit, which essentially functions as the engine's computer. It monitors and controls various engine functions, using sensors and actuators to optimize performance and efficiency. In the sample, there were 228 transactions involving vessels equipped with eco-engines. For the eco-ship sub-sample, the average size increases to over 6,000 TEU, compared to the average size of 2,309 TEU for the full sample. The average age of eco-ships is less than 5.8 years, which is less than half of the average age of non-eco-ships. The average sales price for the eco-ships reached USD 40 million, which is significantly higher than that of the non-eco-ships at USD 13.9 million. There were 124 transactions in which financial institutions acted as buyers. The average size of transactions driven by financial buyers appears to be larger, and the average age appears to be younger compared to transactions in which shipping companies are the buyers. The average sales price also appears to be higher for financial buyers, with an average of USD 36.8 million.

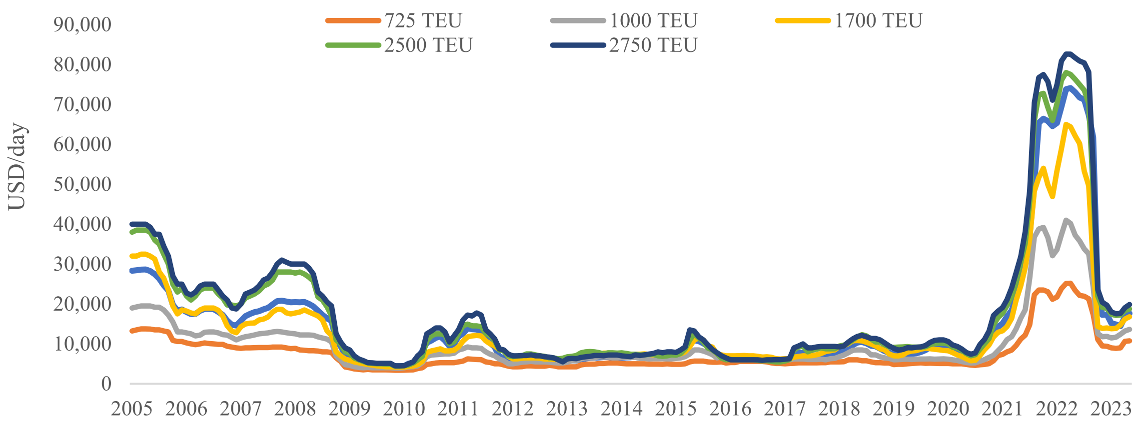

Fig. 4. The freight market indicator, Time Charter Equivalent TCE ($/day).

Table 4
GLM Regression Estimation Results.

Dependent variable:					
	Log_px				
	(1)	(2)	(3)	(4)	(5)
Log_TCE market	0.797***	0.796***	0.626***	0.622***	0.612***
	(0.024)	(0.023)	(0.024)	(0.024)	(0.024)
Log_TEU size	0.286***	0.288***	0.446***	0.442***	0.431***
	(0.017)	(0.017)	(0.019)	(0.019)	(0.019)
Log_age	−0.398***	−0.405***	−0.368***	−0.366***	−0.354***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Builder country		0.126***	0.051*	0.054*	0.065**
		(0.032)	(0.030)	(0.030)	(0.030)
Year trend			−0.047***	−0.048***	−0.051***
			(0.003)	(0.003)	(0.003)
Investor profile				0.098**	0.076
				(0.046)	(0.046)
Eco-ship					0.182***
					(0.038)
Constant	−6.283***	−6.287***	88.777***	90.083***	96.311***
	(0.187)	(0.186)	(5.606)	(5.635)	(5.757)
Observations	2,092	2,092	2,092	2,092	2,092
Log Likelihood	−1,561	−1,553	−1,418	−1,416	−1,405
Akaike Inf. Crit.	3,130	3,117	2,848	2,846	2,825

Note: the levels of statistical significance level are denoted as: * indicates a p-value less than 0.1, **indicates $p < 0.05$, and *** indicates $p < 0.01$

To further illustrate the relationship between vessel price and age or size, Fig. 3 presents a box plot that reveals the distribution of vessel price in relation to size and age. The figure shows a decrease in sale prices as the vessel age increases across all size segments. Table 2 presents the number of transactions and the total transaction value categorized by size and group. As shown, the age profile at the time of S&P occurrence varies across size groups. In the dataset, larger vessels are sold at a younger age, while smaller vessels are sold at a relatively older age. The most active segment in the S&P is 1,000–2,999 TEU containerships aged between 10 and 20 years.

The dataset includes shipyards from 22 shipbuilder countries. Four major builder countries – South Korea, China, Germany, and Japan – dominate the S&P transactions in the sample, accounting for 84 % of transaction value. Table 3 presents the top 10 builder countries for the vessels involved in the sample, showing the number and value of transactions.

The freight market indicators, time charter equivalent (TCE), are shown in Fig. 4 below. The graph displays time charter rates for various vessel sizes with contract lengths ranging from 6 to 12 months over the sample period. One notable observation is the significant volatility towards the end of the observation period, primarily driven by the instability during the COVID-19 pandemic.

To accurately reflect the freight market conditions for the vessels in the S&P transaction records, the vessels are matched by size with the published TCEs for the selected vessel sizes. For example, a $M-$year$-$old containership with a capacity of N TEUs sold on date T is compared with vessels of the same size and age on the same date to determine its market freight rate, which is represented by the 6–12-month TCE for similar ages. If there is no exact match in terms of size or age, the market TCE is adjusted linearly based on the sizes and ages of that specific vessel in the S&P records.

5. Empirical findings and discussions

5.1. The estimation results from Generalized Linear models (GLM)

Our investigation into the existence of a green premium and the role of financial investors begins with an analysis using a stepwise Generalized Linear Models (GLM) modelling procedure, gradually including variables. The main results are reported in Table 4. The overall findings from the multivariate regression models (1) to (5) suggest that the vessel value is positively affected by the freight rate level (TCE) and the vessel size (TEU), but negatively affected by the vessel age. These findings are in line with theory and the existing literature. For instance, Stopford (2009) suggests that a booming second-hand vessel sales market is driven by an increasing freight market. This, consequently, boosts shipping companies' cashflow, enabling them to invest in second-hand vessels to promptly acquire transportation capacity. Newer vessels typically experience higher sales prices due to less operational wear, lower operational cost, and are equipped with advanced technological features. Furthermore, larger vessels achieve higher average sales prices compared to their smaller counterparts within the same age range. Price differentiation is natural because vessels are large steel structures, and the raw material represents a high proportion of the building costs. Moreover, the augmented cargo capacities and operational capabilities inherent to larger vessels amplify their market value.

In relation to the attribute of the builder country, we have investigated various options by considering different combinations of builder countries to determine their significance in influencing vessel value. Eventually, we singled out Japan from the rest of the builder countries. It appears that ships built in Japan command a premium over vessels built elsewhere. Therefore, starting from Model (2) and beyond, we introduce a dummy variable to indicator whether the builder country is Japan. As indicated in the models, there is a clear premium ranging from 5 % to13% for Japan-built container ships across the various model specifications. The data suggests that container vessels built in Japan have consistently commanded an excessive transaction valuation of about 6.7 % in Model (5) in the sample.

This finding is consistent with the study by Adland et al. (2018), which revealed that handysize bulk carriers built in Japan are 6 % more valuable than those built in China, reflecting the perceived variations in build quality. Japanese yards are renowned for their superior quality, reliability, and innovation. This leads to a better condition of the Japanese-built vessel at the time of sale, which contributes to a higher valuation. Consequently, the market's preference for Japanese-built vessels is evidenced by their price premium in the sale and purchase market. We would like to point out that the existence of the builder premium for Japan may vary over time and may not persist going forward. According to orderbook information provided by Clarksons, Japan currently only produces 8–9 % of the world market's container ships. The quality of ships from other Asian shipyards is improving.

Models (3) – (5) include a time trend, and the statistically significant coefficient estimates in all the models suggest a declining vessel value of second-hand containerships from 2005 to 2023. The negative time trend indicates a dynamic shift in the interaction between the sale & purchase (S&P) market and the newbuilding market. The increasingly stringent regulations regarding environmental issues in the shipping industry have contributed to the downward trend in the second-hand containerships market. Instead, the demand is shifting toward newbuildings where newer designs and advanced equipment are available. These technological advancements make new vessels more appealing by reducing the risk of becoming stranded assets in a market that is increasingly prioritizing sustainability and compliance with regulations. In contrast, older ships face the challenges of non-compliance or costly upgrades in the near future, which can reduce their resale value.

The investor's profile is included in Model (4) to compare the transaction value of financial buyers with that of the operating buyers. The statistically significant value of 0.098 in Model (4) suggests that financial buyers, on average, pay a 10 % premium ($e^{0.098}$) compared to operating buyers for the second-hand containerships.

When investigating the potential existence of a premium for eco-ships, we incorporate a dummy variable in Model (5) to factor in the installation of eco engines in the vessels sold. The coefficient is statistically significant, indicating a 20 % ($e^{0.182}$) price premium for vessels equipped with eco engines. This finding supports the hypothesis (H_{01}) that containerships with eco-friendly features command a price premium compared to their conventional counterparts. The implication of such a premium is twofold. Investing in eco-ships can result in higher resale values due to the market's appreciation of associated benefits. It also indicates a market preference that could influence future purchasing decisions towards greener shipping solutions.

Importantly, it is worth noting that the coefficient of the investor's profile, initially significant at a 95 % confidence level in Model (4), becomes insignificant in Model (5) when the eco-engine variable is included. This shift suggests that the eco-ship variable captures a significant portion of the explanatory power that was previously attributed to the investor profile in interpreting vessel value. The potential overlap in the information provided by both variables suggests that the eco-engine characteristics have a more direct and potent influence on vessel value. This is particularly salient when considering the tendency of financial buyers to pay a premium for vessels equipped with eco engines, as identified in Model (4). Thus, the eco-engine variable emerges as a more dominant determinant of vessel value, overshadowing the explanatory power associated with the investor profile once the model accounts for these eco features. This relationship will be further investigated using a SEM structure in the section below.

5.2. The estimation results from GSEM models

The GLM modelling process also demonstrates the specification process for GSEM. We started with a more restricted model specification, the GLM Model (1) and then progressed to identify more general forms by including potentially omitted variables in Model (1) (Bentler and Chou, 1993). The statistically significant variables are selected as the basis for further analysis in the GSEM.

Finally, the study examines the factors influencing vessel value, green premium, as well as the vessel preferences of investors using

Table 5
Estimation results of the Structural Equation Model.

Comparative Fit Index (CFI)		0.998		N	2109
Tucker-Lewis Index (TLI)		0.999		Df	3
RMSEA (90% confidence interval)		0.037 [0.016, 0.060]			
Chi-square		11.45			
p-value		0.010			
		Estimate	Std.Err	z-value	P(>|z|)
Panel 1: dependent variable: log_price					
Log_TCE market	(b1)	0.796***	0.024	33.484	0.000
Log_TEU size	(b2)	0.037	0.038	0.973	0.330
Log_age	(b3)	−0.403***	0.009	−46.102	0.000
Japan built	(b4)	0.129***	0.035	3.641	0.000
Eco−ship	(b5)	−0.133*	0.073	−1.832	0.067
Investor profile	(b6)	0.505***	0.007	70.123	0.000
Intercept		−6.266***	0.182	−34.5	0.000
Panel 2: dependent variable: Investor profile					
Eco−ship	(b7)	0.324***	0.125	2.594	0.009
Logs size	(b8)	0.49***	0.066	7.418	0.000
The impact of eco-ship on vessel value					
Indirect effect_eco-ship		0.163***	0.063	2.586	0.01
Total effect_eco-ship		0.03	0.037	0.81	0.418
R-Square:					
SEM1: Log_price		0.996			
SEM2: Financial buyer		0.166			

Note: the levels of statistical significance level are denoted as: * indicates a p-value less than 0.1, ** indicates $p < 0.05$, and *** indicates $p < 0.01$

the GSEM, with findings detailed in Table 5. The goodness of fit of the model is mainly determined by two evaluation criteria: the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI). Both CFI and TLI compare the goodness of fit of the model specification compared to the null model, in which all observed variables are uncorrelated. CFI and TLI values range from zero to one. Higher values indicate a better fit of the model to the data. Our results show that both CFI and TLI are close to one, indicating a good fit of the model. The advantage of CFI and TLI is that they are less sensitive to sample size, making them more reliable. Also shown in the upper panel of Table 5, chi-square statistic for the GSEM specification achieved a *p*-value of 0.01, suggesting that there is a difference between observed and model-predicted covariances (null hypothesis). Therefore, the chi-square test suggests a poor fit of the model. However, it is recognized that the chi-square test is highly sensitive to sample size and is prone to accepting the null hypothesis (indicating poor fit) for large samples. Often, researchers use the ratio of chi-square to degrees of freedom (χ^2/df). A ratio of 2 to 5 is often considered indicative of an acceptable fit, and our model has $\chi^2/df = 3.8$. Finally, the goodness-of-fit Root Mean Square Error of Approximation (RMSEA) measure achieved was 0.037, which is below the threshold of 0.05 at the 90 % confidence interval.

The estimation results, as reported in Table 5, confirm once again that TCE has a positive effect on vessel value, while age has a negative effect on vessel value. The effect of vessel size on vessel value vanished when introducing the endogenous effect of the vessel being eco-ships and size on financial buyers' choice. When looking at the effect of eco-ships on vessel value in the SEM, the direct effect is negative (−0.133) and the indirect effect through financial buyers is calculated by b6*b7, resulting the total effect of 0.03. This premium estimate is lower than the results obtained in the GLM. We need to point out the differences in interpreting GLM and GSEM model specifications. GSEM coefficients are standardized with a variance of 1, while GLM coefficients are unstandardized. This usually leads to different coefficient estimates from GLM than SEM. Most importantly, SEM allows for the inclusion of multiple interrelated dependent variables and the control of confounding variables in a more comprehensive way. The estimation method of SEM considers the entire covariance structure of the data. This might lead to a more accurate estimate of the effect of a particular variable, as it controls for more potential confounders and pathways of influence than a typical GLM.

The coefficient b6 represents the price difference paid by financial buyers compared to operating buyers. The estimation results suggest that financial buyers pay a substantial premium of 66 % ($e^{0.505}$). While some premium is expected, the magnitude seems exaggerated. However, when we analyse the results in conjunction with the statistically insignificant coefficient of the variable log (size), the coefficient of financial buyer appears to be amplified by absorbing both the impact of size and the buyer-effect on vessel values. This reflects the observation in Table 1, where vessels purchased by financial buyers tend to be larger in size and younger in age compared to those acquired by shipping company buyers. Consequently, the average sale price appears to be higher for financial buyers.

Panel 2 in Table 5 reports the estimation results for the GSEM logistic regression, as shown in Eq. (2). This model predicts the probability of an event occurrence, specifically, the likelihood of a financial buyer acquiring a vessel based on whether it is an eco-ship of a certain size. The coefficient value represents the change in the odds ratio of the predictors. The results suggest that a one-unit increase in eco-ships leads to a 35 % ($e^{0.3}$-1) increase in the odds ratio for the buyer to be a financial investor. In other words, the significantly positive coefficient (b7) suggests that financial buyers have a stronger preference for eco-ships. This finding confirms the H_{02} and evident the proactive role of financial buyers in contributing to sustainable investment within the maritime industry. This inclination towards eco-ships aligns with a broader movement in the financial industry towards ESG criteria. It also reveals a strategic orientation among financial buyers towards capitalizing on the long-term economic benefits of owing eco-ships that may shape the

Table 6
Sale transactions by size segment: Operating buyer VS. Financial buyer.

Size segment	Number of transactions	Total transaction value (usd m)	No. Of transactions by financial buyers	% of financial buyer transactions
100–999 TEU	411	2,435	5	1 %
1,000–2,999 TEU	1111	13,461	32	3 %
3,000–5,999 TEU	396	8,251	37	9 %
6,000–9,999 TEU	132	5,526	34	26 %
10,000–15,999 TEU	56	5,209	13	23 %
16,000 + TEU	3	388	3	100 %
Total	2109	35,270	124	6 %

future landscape of shipping investment.

Therefore, we will further investigate the investment preferences of financial buyers in relation to vessel sizes. We have shown in Table 1 that transactions with financial buyers show higher average size and lower average age compared to transactions made with operating buyers. We further analyse the size group of transactions made by financial buyers, and the evidence can be seen in Table 6. Financial buyers exhibit a clear preference for acquiring larger (above 8,000 TEU) and comparatively newer (aged between 0 to 5 years) containerships. The rationale for this preference may be multifaceted. Predominantly, larger vessels operate in the cross-continental markets, which present a relatively transparent competitive situation. National trades are usually served by smaller vessels, which have restrictive ownership and, as a result, limited S&P trade liquidity. For instance, the Jones Act in the U.S. imposes restrictions on all water transportation of cargo between U.S. ports, mandating that these vessels must be America-built, owned, and operated. For financial buyers who do not have domain knowledge in shipping, to have the opportunity to lease out vessels to international shipping companies is likely more attractive and poses fewer risks compared to leasing in the national markets. Moreover, financial buyers may have lower capital costs due to their advantageous access to the capital market, enabling them to bid for higher-value assets. Precisely, the shipping industry requires the capital flexibility provided by financial investors to free up capital expenditure on high-value assets. Therefore, financial buyers would be able to afford the premium for these modern and larger vessels, which demonstrate a prognosis for elevated future cash flows or capital appreciation.

6. Concluding remarks

The findings confirm that the second-hand containership market commands a green price premium for eco-ships. In addition, financial buyers, who often serve as lessors in the financial leasing of ships within the shipping industry, exhibit a stronger preference for investing in larger and greener container ships compared to operating buyers. Consequently, financial buyers are more willing to pay the green premium for these eco-ships.

Eco-ships, recognized by improved fuel efficiency and reduced emissions, are increasingly favoured in the containership sector due to their economic viability. Financial buyers primarily invest in ship assets to offer financial and operational flexibility to shipping companies. In turn, these investors can also capitalize on the long-term economic benefits of owning vessels that may face fewer regulatory hurdles, lower fuel consumption, higher price premium and potentially lower carbon taxes or emission fees. With their advantage in accessing relatively low-cost capital and focus on efficient capital allocation, financial buyers are well positioned to invest in capital-intensive containerships, particularly the larger ones. The findings suggest that financial investors have significantly contributed to the sustainable investment in containerships by prioritizing eco-ships investment. The pivotal role of financial investors in advancing eco-friendly maritime assets is revealed for the first time, to the best of our knowledge.

Future studies have the potential to extend the scope of analysis by incorporating a wider range of shipping segments. Particularly for tankers, such a study could be valuable, because there already exists a two-tier pricing market for scrubber-fitted and non-scrubber-fitted vessels. This expansion into more segments would enable a more comprehensive understanding of the green premium and how it fluctuates over time. Additionally, there is a significant opportunity for researchers to delve into the realm of financial investment returns, for example by focusing on the role of bargaining on ship transaction prices and financial sale-and-leaseback transactions in the shipping industry (Sahoo et al., 2023; Yoon and Kim (2023)). Another intriguing avenue for research lies in the exploration of diversity within the group of operating buyers. Understanding the variances and unique characteristics within this group could provide valuable insights into their influence on asset valuations in the maritime sector. Such in-depth investigations would not only enrich our current knowledge but also offer practical implications for stakeholders in the shipping industry.

CRediT authorship contribution statement

Haiying Jia: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Liping Jiang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Paulo Azevedo:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adland, R., Jia, H., 2015. Shipping market integration – the case of sticky newbuilding prices. Marit. Eocn. Logist. 17 (4), 389–398.
Adland, R., Alger, H., Banyte, J., Jia, H., 2017. Does fuel efficiency pay? Empirical evidence from the drybulk timecharter market revisited. Transp. Res. A 95, 1–12.
Adland, R., Cariou, P., Wolff, F.C., 2018. Does energy efficiency affect ship values in the second-hand market? Transp. Res. A Policy Pract. 111 (May), 347–359. https://doi.org/10.1016/j.tra.2018.03.031.
Axelson, U., Jenkinson, T., Strömberg, P., Weisbach, M.S., 2013. Borrow cheap, buy high? The determinants of leverage and pricing in buyouts. J. Financ. 68 (6), 2223–2267.
PRI., 2024. Principles for Responsible Investment 2022-2023 Annual Report, n.d.. United Nations Global Compact. https://dwtyzx6upklss.cloudfront.net/Uploads/z/s/n/pri_ar2023_smaller_file_8875.pdf.
Babiker, M.H., J.E. Bauista, H.D. Jacoby, and J.M. Reilly, 2000. Effects of differentiating climate policy by sector: a United States example. *MIT Joint Program on the Science and Policy of Global Change, Report No. 61*.
Baker, W.E., Sinkula, J.M., 2002. Market orientation, learning orientation and product innovation: delving into the organization's black box. J. Mark.-Focus. Manage. 5, 5–23.
Baron, R.M., Kenny, D.A., 1986. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J. Pers. Soc. Psychol. 51 (6), 1173–1182.
Beenstock, M., 1985. A theory of ship prices. Marit. Policy Manage. 12 (3), 215–225. https://doi.org/10.1080/03088838500000028.
Bentler, P.M., Chou, C.P., 1993. Practical issues in structural modeling. In: Long, J.S. (Ed.), Common Problems/proper Solutions: Avoiding Error in Quantitative Research. Sage Publications, Beverly Hills, pp. 161–192.
Berg, F., Kölbel, J., Rigobon, R., 2019. Aggregate confusion: the divergence of ESG ratings. SSRN Electron. J. https://doi.org/10.2139/ssrn.3438533.
Bollen, K.A., 1989. Structural Equations with Latent Variables. John Wiley & Sons Inc.
Bos, K., Gupta, J., 2019. Stranded assets and stranded resources: implications for climate change mitigation and global sustainable development. Energy Res. Soc. Sci. 56.
Cairns, R.D., 2018. Stranded oil of Erewhon. Energy Policy 121, 248–251.
Cajias, M., Piazolo, D., 2012. The Effect of Energy Performance Certificates on the Value of Buildings, No. eres2012_222. European Real Estate Society (ERES).
Clarksons, 2022a. World Fleet Monitor 12(12). December-2021.
Clarksons, 2022b. Shipping Intelligence Network orderbook database.
Clarksons, 2024c. Shipping Intelligence Network orderbook database.
Cosar, A.K., Demir, B., 2018. Shipping inside the box: containerization and trade. J. Int. Econ. 114, 331–345.
Darroch, J., McNaughton, R., 2002. Examining the link between knowledge management practices and types of innovation. J. Intellect. Cap. 3 (3), 210–222.
Del Guidice, V., De Paola, P., Del Giudice, F.P., 2020. Covid-19 infects real estate markets: short and mid-run effects on housing prices in Campania region (Italy). Soc. Sci. 9 (7), 114.
Dorfleitner, G., Utz, S., Wimmer, M., 2018. Patience pays off – corporate social responsibility and long-term stock returns. J. Sustain. Finan. Invest. 8 (2), 132–157 https://doi.org/10/ggk2kd.
Douglas, E., Van Holt, T., Whelan, T., 2017. Responsible investing: guide to ESG data providers and relevant trends. J. Environ. Invest. 8 (1), 92–114.
Du, Y., Chen, Y., Li, X., Schönborn, A., Sun, Z., 2022a. Data fusion and machine learning for ship fuel efficiency modeling: Part II - Voyage report data, AIS data and meteorological data. Commun. Transport. Res. 2, 100073.
Du, Y., Chen, Y., Li, X., Schönborn, A., Sun, Z., 2022b. Data fusion and machine learning for ship fuel efficiency modeling: Part III - Sensor data and meteorological data. Commun. Transport. Res. 2, 100072.
Ezaki, T., Imura, N., Nishinari, K., 2022. Towards understanding network topology and robustness of logistics systems. Commun. Transport. Res 2, 100064.
Fiasca, R.B., Assis, L.F., Pires Jr, F.C.M., 2018. Shipbuilder country and second hand price: Some empirical evidences. Maritime Transp. Harvesting Sea Res. 2, 725–730.
Freeman, R.E., Harrison, J.S., Wicks, A.C., 2007. Managing for stakeholders: survival, reputation, and success. Yale University Press, New Haven, CT.
Fuerst, F., McAllister, P., 2011. Green noise or green value? Measuring the effects of environmental certification on office values. Real Estate Econ. 39 (1), 45–69.
Fuerst, F., Oikarinen, E., Harjunen, O., 2016. Green signalling effects in the market for energy-efficient residential buildings. Appl. Energy 180, 560–571.
Gorbenko, A.S., Malenko, A., 2014. Strategic and financial bidders in takeover auctions. J. Financ. 69 (6), 2513–2555.
GSIA, 2023. Global Sustainable Investment Review 2022. Global Sustainable Investment Alliance. https://www.gsi-alliance.org/wp-content/uploads/2023/12/GSIA-Report-2022.pdf.
Hayes, A.F., 2013. Introduction to Mediation, Moderation, and Conditional Process Analysis: a Regression-based Approach. the Guilford Press, New York.
Hooper, D., Coughlan, J., Mullen, M., 2008. Structural Equation Modelling: Guidelines for Determining Model Fit. Electron. J. Bus. Res. Methods 6 (1), 53–60.
Hu, L., Bentler, P.M., 2009. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equ. Model. Multidiscip. J. 6 (1), 1–55. https://doi.org/10.1080/10705519909540118.
Hwang, H., Takane, Y., 2014. Generalized Structural Component Analysis: A component-based approach to structural equation modelling. Taylor & Francis Group.
Jensen, M.C., 2002. Value maximization, stakeholder theory, and the corporate objective function. Bus. Ethics Q. 12 (2), 235–256.
Jenssen, J.I., Randøy, T., 2006. The performance effect of innovation in shipping companies. Marit. Policy Manage. 33 (4), 327–343.
Khan, M., Serafeim, G., Yoon, A., 2016. Corporate sustainability: first evidence on materiality. Account. Rev. 91 (6), 1697–1724. https://doi.org/10.2308/accr-51383.
Kline, R.B., 2015. Principles and Practice of Structural Equation Modelling. Guilford Press.
Kline, R.B., 2023. Principles and practice of structural equation modeling. Guilford publications.
Kokosalakis, G., Merika, A., Triantafyllou, A., 2021. Energy efficiency and emissions control: the response of the second-hand containerships sector. Energy Econ. 100, 105378 https://doi.org/10.1016/j.eneco.2021.105378.
Kramel, D., Muri, H., Kim, Y., Strømman, A.H., 2021. Global shipping emissions from a well-to-wake perspective_the MariTEAM model. Environ. Sci. Tech. 55 (22), 15040–15050. https://doi.org/10.1021/acs.est.1c03937.
Lee, K.H., Min, B., 2015. Green R&D for eco-innovation and its impact on carbon emissions and firm performance. J. Clean. Prod. 108, 534–542.
Li, X., Du, Y., Chen, Y., Nguyen, S., Zhang, W., Schönborn, A., Sun, Z., 2022. Data fusion and machine learning for ship fuel efficiency modeling: Part I - Voyage report data and meteorological data. Commun. Trans. Res. 2, 100074.
Luo, X., Bhattacharya, C.B., 2006. Corporate social responsibility, customer satisfaction, and market value. J. Mark. 70 (4), 1–18.
Meuer, J., Koelbel, J., Hoffmann, V.H., 2019. On the nature of corporate sustainability. Organ. Environ. 1086026619850180 https://doi.org/10.1177/1086026619850180.
Notteboom, T., Haralambides, H., Cullinane, K., 2024. The red sea crisis: ramifications for vessel operations, shipping networks, and maritime supply chains. Maritime Economics & Logistics 26, 1–20.
Placek, M., 2021. Container shipping – statistics & facts, *Container shipping worldwide*.
Pratson, L.F., 2023. Assessing impacts to maritime shipping from marine chokepoint closures. Commun. Transport. Res. 3, 100083.
Przychodzen, J., Przychodzen, W., 2015. Relationships between eco-innovation and financial performance–evidence from publicly traded companies in Poland and Hungary. J. Clean. Prod. 90, 253–263.
Ramlall, I., 2017. Applied Structural Equation Modelling for Researchers and Practitioners. Emerald Group Publishing Limited, UK.
Reichardt, A., Fuerst, F., Rottke, N., Zietz, J., 2012. Sustainable building certification and the rent premium: a panel data approach. J. Real Estate Res. 34 (1), 99–126.

Sahoo, S., Jiang, L., Song, D.W., 2023. Review of bargaining and transaction prices: future avenues for shipping studies. Maritime Business Review 8 (4), 351–371.
Sen, S., Bhattacharya, C.B., 2001. Does doing good always lead to doing better? Consumer reactiosn to corporate social responsibility. J. Mark. Res. 38 (2), 225–243.
Stopford, M., 2009. Maritime Economics, 3rd edition. London and New York, Routledge.
Wang, S., Zhen, L., Zhuge, D., 2018. Dynamic programming algorithms for selection of waste disposal ports in cruise shipping. Transp. Res. B Methodol. 108, 235–248.
Yoon, S., Kim, C.Y., 2023. The announcement effect of shipping sale-and-leaseback transactions. Maritime Bus. Rev. 8 (4), 389–401.
Zhen, L., Wu, Y., Wang, S., Laporte, G., 2020. Green technology adoption for fleet deployment in a shipping network. Transp. Res. B Methodol. 139, 388–410.