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Capital Structure in the Shipping Industry

An Analysis of Leverage and Asset Volatility in Publicly Traded Shipping Companies

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This thesis will contribute to a greater understanding of how a shipping company chooses its capital structure and how the market affects these decisions. The thesis presupposes a certain knowledge of methods within mathematical finance, but we hope the main points will be understandable to a broader audience.

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Abstract

This research paper provides a comprehensive analysis of the optimal leverage in the shipping industry, focusing on the influence of asset volatility on static and dynamic capital structure decisions. Under static model conditions with fixed bankruptcy costs, the optimal leverage ratio is determined to be 47%. However, when including additional costs such as call premiums and debt issuance costs in the dynamic model, this ratio adjusts to 43%.

Our research is based on a sample of 167 shipping companies over a period between 2010 and 2022. The companies are primarily based on the global SIC code 44, which includes companies within waterborne transport. Additionally, we include firms operating large vessels that may not solely focus on shipping and exclude companies focusing on harbor- and port management and passenger- and cruise ship operations.

The study provides insights into leveraging practices and highlights the impact of market perceptions of risk on capital structure decisions in the shipping sector. The results have practical implications for shipping companies looking to optimize their capital structure and enhance their financial performance. The findings indicate that increased asset volatility raises a shipping company's value at default. Using comparative static and dynamic models, the study finds that higher asset volatility lowers leverage ratios among shipping companies. A 1% increase in asset volatility suggests that the market leverage ratio for a shipping company decreases by 2.8%. Furthermore, when the freight rates increase, the earnings follow, leading to a decrease in leverage due to higher valuations in the market. This suggests that the shipping industry relies more on using excess cash to fund its investments during booms rather than issuing debt.

Keywords – Corporate Finance, Shipping, Static Capital Structure, Dynamic Capital Structure, Asset Volatility

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1 Introduction

Extensive research in both modern and historical financial literature has focused on the existence of an optimal capital structure. Such an inquiry explores ways of maximizing a company's value by selecting the best combination of debt and equity. This topic is of significant theoretical and practical interest, especially for capital-intensive manufacturing companies that require financial loans to fund fixed assets, machinery, and other equipment essential for maintaining or increasing production.

Similarly, the relevance of this concept extends to the shipping industry. However, unlike manufacturers of tangible goods, shipping companies are primarily involved in transporting products and delivering services, representing an estimated 90% of international trade volume. Additionally, they provide activities beyond transportation, such as logistics and supply chain management. The availability, low cost, and efficiency of maritime transport have facilitated the international division of labor and the relocation of industrial production to emerging countries (UNCTAD, 2021).

Therefore, access to financing is essential for shipping companies to remain liquid and meet market demand. Due to the high initial investment costs of purchasing and maintaining ships and the expenses of running a fleet, the shipping industry has high barriers of entry, making it among the most capital-intensive businesses. Thus, the optimal capital structure debate is central to the shipping industry.

This paper will examine the theoretical framework for estimating the optimal capital structure for shipping companies. We will discuss two models developed by Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014). By comparing and analyzing these models, we aim to determine their relevance to the shipping industry and their recommendations regarding optimal leverage in this sector.

1.1 Thesis

This study aims to determine the optimal debt ratio for the shipping industry using models developed by Leland (1994), Goldstein et al. (2001) and Christensen et al. (2014). We have formulated our research question as follows:

What is the optimal capital structure for a shipping company?

1.2 Restrictions

Given the study's objectives, it is reasonable to delimit the boundaries of this thesis. However, conducting additional analyses would have allowed for a more in-depth examination of the shipping industry. The aim is to address the research question and thus understand the composition of the industry's capital structure and the factors that determine it. It would have been more appropriate and insightful to identify which determinants significantly influence the companies' choices of capital structure by examining each subcategory of shipping companies individually. However, given the time horizon of the study, this has not been done.

Moreover, we consider a further analysis of the actual bankruptcy costs within the industry to be valuable. The absence of reliable data prevents a definitive assertion that the models used in this study apply to the shipping industry.

1.3 Outline

The study is organized as follows: Chapter 2 reviews how shipping companies manage financing. We provide our data and restrictions in Chapter 3. Chapter 4 will examine well-known studies on our topic and literature on capital structure. Further, in Chapter 5, we will clarify the variables used in our analysis. Chapter 6 will present a comprehensive breakdown of asset volatility. We analyze the static and dynamic capital structure models in chapters 7 and 8, respectively. Based on empirical studies, Chapter 9 will explore the regressions and our results. Finally, Chapter 10 will present our conclusion.

2 Ship Financing

The global shipping industry operates within a complex and financially demanding environment. The sector is capital-intensive and marked by substantial investments and high debt levels, particularly compared to other industrial sectors in the G7 countries (Drobetz et al., 2013).

Historically, about 80% of the external financing necessities of the shipping industry have been covered by bank loans. Over the years, the industry has fluctuated heavily due to global economic changes (Drobetz et al., 2013). This was seen during the financial crisis of 08/09, which saw a dramatic decrease in the availability and affordability of bank loans in the industry. The reason was caused by a combination of falling freight rates, reduction in ship values, and tighter banking regulations such as the Basel III[1] capital requirements (Albertijn et al., 2011). Financial institutions specializing in shipping faced both capital and credit challenges. The industry shifted towards using capital markets for financing. Issuance of bonds and equity has increased, signifying a shift of risk from the banks to the capital markets.

Shipping companies traditionally use their retained earnings for production and investments. However, the industry's capital-intensive nature often means that internal funds are insufficient to meet the total capital demand. This requires exploration of external financing methods, primarily debt and equity financing. Debt financing options include bank loans, bonds, mezzanine loans, and financial leases. The bank loans differ between credit and syndicated loans. Bond issuance and mezzanine loans offer companies the opportunity to raise funds from the public.

Equity financing enables companies to source funding from the capital markets, commonly via issuing stocks. A shipping company's financial performance and stability are largely influenced by its investment decisions, chartering strategy, and financing options. However, the selection of financing alternatives is a significant factor to consider. Market conditions and these strategic choices collectively determine the range of financing alternatives available to a company at any time, as outlined in table 2.1.

[1]The Basel III accord raised the minimum capital requirements for banks from 2% in Basel II to 4.5% of common equity, as a percentage of the bank's risk-weighted assets (Bank for International Settlements, 2023).

Table 2.1: Financing Alternatives

Bank Financing	**Capital Markets**	**Other**
Mortgage-backed loans	High yield bonds	Seller's credit
Newbuilding financing	Convertible notes	Finance lease
Unsecured/corporate loans	IPOs	Operating lease
Mezzanine	Follow-on offerings	Private equity
	At-the-market offerings	Securitization
	MLPs	Export agency finance
	SPACs	

Note: All financing alternatives in the shipping industry. However, note that some of these methods are rarely used. Source: (Kavussanos & Visvikis, 2016).

3 Data

The study uses Compustat and Refinitiv Eikon data to uncover factors influencing capital structure decisions within shipping firms. Annual revised financial data for 167 global shipping companies from 2010 to 2022 has been compiled and employed to construct selected company-specific variables. These variables have been combined with macroeconomic variables to conduct analyses based on models developed by Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014). The macroeconomic data obtained from Refinitiv Eikon was processed to suit the study's needs. This included computing year-on-year changes for certain variables and determining the volatility of Brent crude oil prices and freight rates.

3.1 Selection Criteria

To ensure that the sample is representative and suitable for analysis, specific selection criteria were established. The company must be defined as a shipping firm. The selection criteria are initially based on global SIC codes. The shipping sector operates under SIC code 44, which encompasses companies engaged in waterborne transport, including passenger- and cruise ship operations and port- and harbor management. We also include firms operating large vessels that may not solely focus on shipping, a category we term as maritime services, which also falls under code 44.

We excluded passenger and cruise ship operators and harbor- and port management, as these companies deal with ships in another matter, driven by other macroeconomic factors. Additionally, the companies must have been publicly listed between 2010 and 2022. Given the cyclical nature of the shipping industry and the need to generalize the findings, a period over a complete cycle, including significant macroeconomic events such as the oil crisis of 2014/2015 and the COVID-19 pandemic, was chosen.

3.2 Data Processing

The data processing involved in this study was extensive and time-consuming, as it was essential for the accuracy of our analysis. We collected data on all active and inactive companies that were listed on global exchanges during our sample period. After that, we excluded companies that did not provide essential financial figures.

3.3 Potential weaknesses in the dataset

Although the corporate data collected are based on audited annual reports, several potential issues may arise. IFRS allows for flexibility in accounting principles, allowing room for subjective judgement. Discretionary assessments, such as the valuation of assets and depreciation schedules and smoothing of earnings, can influence the dataset. There is a risk that earnings adjustments occur in the shipping industry due to its cyclical nature and high levels of indebtedness, especially during economic downturns. However, Compustat revise and standardize all data, which minimizes these potential issues.

Survivorship bias, which results when successful companies are favored over unsuccessful ones in the analysis, can lead to skewed outcomes. However, we have attempted to mitigate the risk of this bias by including companies delisted and relisted during the period, thus capturing firms that have been acquired, merged, gone bankrupt, or voluntarily delisted.

In summary, while there may be potential problems in the selected dataset, we consider the risk of misleading results low, thanks to the precautionary measures we have taken, as discussed in section 3.1.

4 Literature Review

4.1 Previous Empirical Research

Frank and Goyal (2009) studied capital structure determinants in U.S.-listed companies from 1950 to 2003. They identified six consistent factors across regression models for market-based debt. First, firms in industries where the median firm has high leverage tend to have high leverage. Second, firms that have more fixed assets tend to have higher leverage. Third, firms that have more profits tend to have lower leverage. Fourth, large firms (in terms of assets) tend to have higher leverage. Fifth, firms with a high market-to-book ratio tend to have lower leverage. Lastly, when inflation is expected to be high, firms tend to have high leverage (Frank & Goyal, 2009).

Bressler et al. (2012) compared companies without debt to a diverse sample from the G7 countries. They suggest that debt-free companies often share small size, low risk, and low profitability characteristics. These firms were also among the most active in issuing equity and tended to maintain substantial cash reserves. The study pointed out that these companies' reliance on equity financing was due to their limited capacity to incur debt. The research may provide valuable insights on capital structure and liquidity management in the shipping industry for companies with similar size and risk profiles (Bressler et al., 2012).

Drobetz et al. (2013) studied capital structure in 115 listed shipping companies from 1992 to 2010. They found a positive relationship between the fixed asset level and the debt-to-book ratio. Conversely, the study revealed a negative relationship between profitability and company risk. This article is relevant to our study, examining a capital-intensive sector and considering both firm-specific and macroeconomic factors (Drobetz et al., 2013).

4.2 Defining Capital Structure

Capital structure is the proportion of debt to a company's total capital (Van-Horne, 2001). Other researchers describe it as the relative proportions of debt, equity, and other securities that a firm has outstanding, and the firm's sources of long-term financing (Brealey et al., 2011).

Modigliani and Miller (1958), hereafter M&M, are key contributors to capital structure theory. Under the assumptions of perfect capital markets, M&M demonstrated the irrelevance of capital structure to a firm's total value and cost of capital. According to M&M, the impact of factors on capital structure is relatively minor compared to newer research. However, in 1963, M&M adjusted their original propositions, made under perfect capital markets, by considering market imperfections such as taxes. Taxes influence a firm's cost of capital. Under the assumption of risk-free debt, firms are incentivized to pursue debt financing due to tax-deductible interest expenses. This model assumes a consistent interest rate and a stable debt level, ensuring the perpetual constancy of the interest tax shield value (Berk & DeMarzo, 2019).

In both M&M's propositions, as a firm increases its leverage, its value also increases. Additionally, the cost of equity decreases directly due to offsetting taxation by interest expenses. However, the theorem of M&M is limited as it does not fully capture the complexities of real-world markets, such as issuance and transaction costs.

4.3 Static Capital Structure

This chapter will introduce several theories related to static capital structure. We will discuss dynamic capital structure theory in section 4.4.

4.3.1 Tradeoff Theory

The tradeoff theory indicates that an optimal capital structure balances the tax benefits of debt against the rising costs of financial distress. This approach challenges the concept of debt financing as it can increase the risk of default and bankruptcy due to higher leverage. The theory acknowledges that while debt offers tax advantages, the associated distress costs[2] – both direct, like bankruptcy proceedings, and indirect, like asset liquidation losses – must be carefully managed to maintain corporate value (Kraus & Litzenberger, 1973).

The tradeoff theory suggests that a company's enterprise value[3] equals its unlevered value, including the interest tax shield subtracted by bankruptcy costs. This indicates that companies can benefit from setting a target debt level, indicating optimal leverage

[2]Financial distress cost and bankruptcy costs serve the same purpose.
[3]Enterprise value and levered value of a company serve the same purpose.

decisions for capital structure choices (Frank & Goyal, 2009). However, optimal leverage is determined by considering firm-specific and institutional factors, such as bankruptcy costs and applicable tax rates. Consequently, the target debt ratio varies based on each company's unique characteristics and the respective countries' institutional frameworks. The levered firm value can be expressed as

$$V_L = V_U + PV(\text{TS}) - PV(\text{BC}), \tag{4.1}$$

where,

- V_L = Levered firm value,
- V_U = Unlevered firm value,
- $PV(\text{TS})$ denotes the present value of the interest tax shield,
- $PV(\text{BC})$ denotes the present value of the bankruptcy costs.

4.3.2 Leland 1994

Leland (1994) explores the optimal capital structure of a firm using a quantitative approach. According to Leland (1994), capital structure is determined by corporate risk, taxes, default barrier, and the risk-free rate. The model assumes that the company's valuation is arbitrary and does not affect its generality. Furthermore, the company's total value is assumed to follow a geometric Brownian motion with constant volatility.[4]

Assessing the value of debt requires knowledge of the firm's capital structure and the costs associated with potential defaults and bankruptcy. In Leland's model, the bankruptcy threshold is endogenously determined, and the valuation of debt and equity is linked to the total value of the company. This model differs from other models and theories by assuming an infinite lifetime for the debt, unlike, for example, Brennan and Schwartz's paper on optimal capital structure, which uses a finite time horizon for the debt (Brennan & Schwartz, 1978). Leland highlights a clear tradeoff between bankruptcy costs and tax benefits related to coupon payments. This differs from the assumptions of Modigliani and

[4] Geometric Brownian motion (GBM) models the company's value as a continuously evolving variable with predictable and random elements. The 'constant volatility' refers to the consistent level of variation or risk in the company's value over time.

Miller (1958) and, therefore, breaks with the pillars of traditional capital structure theory.

The coupon payments on debt are a measure of a company's leverage. In the static and dynamic models, these coupon payments represent the fixed interest obligations a company must pay its debt holders. The size of the coupon payments is directly related to the amount of debt a company has; higher coupon payments indicate higher debt levels.

Bankruptcy costs increase with higher leverage, reinforcing the likelihood of bankruptcy, as supported by the tradeoff theory. Interest expenses, i.e., coupon payments, result in tax deductions that make debt more attractive than equity. Conversely, bankruptcy costs in isolation make equity more advantageous than debt. The value of these two effects is independent of time and directly relates to the company's value (Leland, 1994). If the corporate tax rate of a firm is zero, it will be optimal to avoid debt since there are no deductions for coupon payments while the bankruptcy costs persist. A tax rate above zero motivates debt financing, taking advantage of the potential tax shields, where a higher tax rate will lead to a larger optimal leverage.

4.3.3 Pecking Order Theory

M&M's theorem and the tradeoff theory introduce capital structure concepts, but do not address corporate responses to asymmetric information. The pecking order theory builds on this foundation and explores asymmetric information in financial markets. This theory explains how companies prioritize their sources of financing, beginning with internal funds before turning to less costly external options. This prioritization is due to the varying costs associated with different forms of financing. It arises from company insiders, like owners and management, possessing superior information compared to external investors, such as banks or new shareholders. Consequently, information costs are higher for these external parties and the general compensation for risk.

Internal owners typically have lower return expectations than external investors, making external equity financing more expensive than funding through retained earnings. The asymmetry may lead to the exclusion of certain projects from the capital market due to "rationing" or capital market restrictions, as external investors may not be able to evaluate them sufficiently (Myers & Majluf, 1984).

Additionally, the pecking order theory suggests that firms prefer internal financing to avoid the potential decline in value resulting from external financing. When external funds become necessary, debt is often favored over equity. This is because debt is less exposed to the company's mispricing and presents a lower risk profile to lenders, provided the firm can meet its debt obligations.

4.4 Dynamic Capital Structure

Goldstein et al. (2001) present the dynamic model where firms adjust their leverage in response to changes in economic conditions, balancing the benefits of debt tax shields against the cost of bankruptcy. The dynamic model allows for continuous capital structure optimization over time, depending on the firm's valuation and the tradeoff between tax shields and bankruptcy costs.

This approach contrasts with static theories that assume a one-time optimization. The model of Goldstein et al. (2001) endogenously determines optimal capital structure boundaries. The firm's management will choose to issue or repurchase debt based on the firm's current leverage and economic conditions. It extends the framework of tradeoff theory by incorporating the effects of business cycles, asset volatility, and other factors that cause the firm's value to fluctuate, impacting the optimal leverage.

Their dynamic model integrates features of both the tradeoff theory and the pecking order theory. It predicts that firms with volatile earnings or valuable growth options will optimally choose lower leverage ratios to minimize the costs of financial distress.

Moreover, Christensen et al. (2014), hereafter CFLM, extends the dynamic capital structure model of Goldstein et al. (2001) to include debt renegotiations, addressing the case where equity holders can call debt to take advantage of tax benefits or restructure it to prevent bankruptcy costs.

In this dynamic setting, the equity holders can call the existing debt when the firm is performing well, which can increase the tax shield benefits of debt financing. Conversely, when the firm faces financial distress, equity holders are incentivized to propose restructuring the debt to avoid bankruptcy costs. Such proposals are designed to benefit the debt holders by avoiding the reduced value of their holding in bankruptcy and the equity holders by preserving some value in the firm.

CFLM's model suggests that the firm's capital structure is continuously optimized as earnings fluctuate, adhering to endogenously determined upper and lower boundaries that trigger either debt call or restructuring. The existing capital structure is deemed suboptimal at these boundaries due to the firm's changed EBIT. This dynamic optimization contrasts with static model where the capital structure is adjusted at discrete intervals or remains fixed despite firm earnings or risk profile changes.

The dynamic capital structure also indicates that the firm's enterprise value, debt value, and equity value are not fixed but change as the firm's earnings vary over time. CFLM suggests that optimal leverage is inversely related to both the growth options and earnings risk, indicating that firms with higher growth and earnings will choose lower leverage.

This dynamic approach to capital structure allows firms to maintain an optimal balance between debt and equity that is more closely aligned with their current financial state. It suggests that capital structure is not merely a decision made at a point in time but a strategic management tool that can be adjusted as circumstances change. The model underscores the importance of flexibility in capital structure management, particularly for firms operating in volatile markets or those that experience significant changes in their operating environment (Christensen et al., 2014).

The extension of the Goldstein et al. (2001) model by CFLM contributes to our understanding of how companies can manage their capital structure dynamically.

We will further investigate the static and dynamic models within optimal capital structure based on the frameworks of Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014) in Chapters 7 and 8.

5 Variables

In the following chapter, we will discuss variables that can support our capital structure analysis. The first section will introduce the two dependent variables, while the second section will discuss the independent variables, which include company-specific and macroeconomic factors. The independent variables influence the capital structure of shipping companies (Drobetz et al., 2013). Rajan and Zingales (1995) and Frank and Goyal (2009) suggests that independent variables can be classified into standard and additional factors, as discussed in Section 5.2. Furthermore, we will analyze the impact of macroeconomic factors on capital structure in the shipping industry. Our investigation aims to identify these determinants, offering a view of the links between macroeconomic forces and financial decisions in this sector. Each variable will be defined and discussed individually. In Appendix A, you can find an overview of the different variable constructions and their respective sources.

5.1 Dependent Variables

5.1.1 Debt-to-asset ratios

Defining the relationship between debt and equity in empirical research on capital structure requires a clear choice between book value or market-based debt ratios, but previous studies have conflicting definitions. The differences between these definitions are minor and primarily depend on the value of equity used. The book value debt ratio uses the book value of equity, whereas the market-based debt ratio uses the market value of equity. Yet, not all companies have their debt traded in the market (Frank & Goyal, 2009). Therefore, empirical studies tend to rely on book values of debt. We use the book value of debt for all companies in our sample.

Graham and Harvey (2001) found that financial directors focus on the debt-to-book ratio for financing decisions. Myers (1977) supported using the book value debt ratio, reasoning that the debt level links more closely to the company's assets than its growth opportunities. Book values are less sensitive to irregular fluctuations and market noise than market values. For instance, during a boom period, the market-based debt ratio would decrease as the market value of equity increases, potentially providing a misleading picture of companies' financing behaviors (Hennessy et al., 2007). However, the market-based debt ratio has gained increasing support in recent times. Welch (2004) states that the book value of equity is only used to balance a balance sheet's left and right sides. However, when this variable is negative, it may misrepresent a company's capital structure.

The book value debt ratio and the market-based debt ratio have different perspectives. The former is based on historical data, while the latter reflects the market's perception of the company's future. As a result, it is unlikely that these two variables will produce similar results (Barclay et al., 2006). Bowman (1980) found no significant difference in the impact of explanatory variables[5] on the book and market-based debt ratios, thus arguing that the choice between them was insignificant. Conversely, Fama and French (2002), Frank and Goyal (2009), and Drobetz et al. (2013) found contrasting results using book and market-based debt ratios. As a result, most modern studies use both variables to provide a comprehensive picture of factors influencing capital structure.

Given previous empirical studies as discussed, we include the book and market debt ratios to investigate whether conflicting effects exist for listed shipping companies.

To address endogeneity, that is, when variables influence each other in ways not accounted for, we include the lagged debt ratios. A lagged debt ratio is simply the debt ratio from the previous year. For example, the 2015 lagged ratio uses data from 2014. This approach helps in understanding how past financial decisions impact the current situation. We use this variable to focus on the actions of individual firms, separate from broader market trends that affect all firms equally. This way, we can better identify the unique financial behaviors of the companies in our sample (Myers, 1977).

5.2 Independent Variables

5.2.1 Standard Factors

The standard factors are variables applicable to all industries (Rajan & Zingales, 1995). In this section, we will provide a detailed discussion about each variable.

[5]Explanatory variables and dependent variables serve the same purpose.

Fixed Assets

Fixed assets serve as a measure of the company's collateral value when incurring debt. The tradeoff theory suggests companies with a higher fixed assets ratio expect to face lower costs related to financial distress. Furthermore, fixed assets are less challenging to value for outsiders, which reduces information asymmetry and increases the debt capacity (Drobetz et al., 2013). Hence, the tradeoff theory suggests a positive correlation between fixed assets and leverage.

Conversely, the pecking order theory suggests that fixed assets decrease information asymmetry, making equity financing less costly. This leads to a lower leverage ratio for companies with a higher fixed assets ratio (Harris & Raviv, 1991). Fixed assets are calculated as the property, plant, and equipment ratio to the total book value of assets.

Profitability

Profitable companies are expected to have higher leverage, as they are more capable of servicing debt obligations. This is consistent with the tradeoff theory of increasing leverage for higher shareholder returns. The pecking order theory suggests that profitable companies are more likely to retain earnings and use internal funds for investments, reducing their reliance on external debt. As a result, they may have lower leverage ratios than less profitable companies (Rajan & Zingales, 1995).

Several indicators can measure a company's profitability, such as return on equity (ROE), return on assets (ROA), cash coverage ratio, and operating profit margin. Profitability on capital structure bears no consensus with scholars.

The capital-intensive nature of the shipping industry requires significant investments in ships and equipment. Depreciation and amortizations are substantial expenses due to these assets' high cost and long lifespan. By excluding these non-cash expenses, operating income before depreciation return on assets focuses on the cash-generating ability of the assets. Moreover, depreciation policies vary across the industry. Additionally, the shipping sector is cyclical and is affected by volatile market conditions. Due to the significant leverage ratios within the industry, operating income before depreciation helps in understating the company's operational earnings capacity without influencing financing decisions. Ultimately, stakeholders and potential investors can assess the underlying business strength.

Firm Size

The tradeoff theory suggests that larger companies tend to be diversified and have a lower risk of default (Frank & Goyal, 2009). This leads to lower costs associated with financial distress, suggesting a positive relationship between a firm's size and leverage ratio (Drobetz et al., 2013).

Conversely, the pecking order theory suggests that firm size can be viewed as an indicator of asymmetric information between the capital markets and the company itself. Larger companies tend to have more information available to investors due to being listed (Rajan & Zingales, 1995). This reduces the likelihood of mispricing, making issuing equity a more attractive financing method for these companies. Thus, a negative relationship is expected, where larger companies will have a lower leverage ratio.

Overall, the relationship between firm size and the leverage ratio is multi-dimensional. Larger firms may benefit from diversification and a better market position, leading to a higher leverage ratio. However, the size also affects information asymmetries, which can lead to a lower leverage ratio.

5.2.2 Additional Factors

Operational Debt

The operating debt is directly proportional to its fixed production costs. The tradeoff theory suggests that companies with high levels of operational debt tend to have lower leverage, and vice versa (Drobetz et al., 2013).

Conversely, the pecking order theory suggests a different view. The operational debt ratio has a less direct impact. Firms with higher operating debt ratios might lean more towards internal financing due to perceived riskiness. In comparison, those with lower ratios may be less risky and could have better access to external debt, although they would still prefer internal financing first (Brealey et al., 2011).

Dividends

A company with a stable dividend policy pays out a steady dividend every given period, regardless of the volatility in the market (Brav et al., 2005). An increase in dividend payouts may signal that companies expect higher future earnings, thus sending a positive message to potential shareholders (Berk & DeMarzo, 2019).

The pecking order theory offers conflicting predictions about dividends. Dividend payouts reduce retained earnings, which could pressure companies to seek external financing (Drobetz et al., 2013). The tradeoff theory suggests that companies prefer debt over equity issuance; typically, those that pay dividends maintain a higher debt ratio. Conversely, dividend payments can provide informative signals in the market that reduce asymmetric information. Lower asymmetric information makes equity issuance less costly, potentially leading to a negative relationship between dividend payments and debt ratio (Li & Zhao, 2008).

From another perspective, issuing dividends can impose a disciplinary effect on a company's management, limiting the tendency to over-invest (Jensen, 1986). This perspective aligns with the tradeoff theory, suggesting a negative relation between dividends and debt ratio.

Previous empirical studies, including those by Frank and Goyal (2009), Mjøs (2007), and Drobetz et al. (2013), have observed a lower debt ratio in companies that pay dividends. Consistent with these empirical findings, we anticipate a negative relation between dividend payments and debt ratio in listed shipping companies.

5.2.3 Macroeconomic Variables

Brent Crude Oil Price

Higher oil prices can indicate economic growth, especially in countries that heavily depend on oil. However, these prices can also be influenced by factors besides global economic health, such as political stability, affecting oil supply and demand. On the other hand, lower oil prices can suggest economic slowdowns, which is consistent with counter-cyclical leverage ratios. While high oil prices can signal economic growth, they can also negatively impact leverage ratios (Maitra et al., 2020).

The oil price directly impacts shipping companies' operational costs and market dynamics.

The global demand for oil affects freight rates and fuel costs, while supply changes influence operational expenses and revenue. It is important to note that the relationship between oil prices and exports is stronger than that of imports. For instance, the shipping industry typically shows a three-month delayed reaction to shifts in the oil price (Luo et al., 2019).

We use the Brent crude spot price as our oil price index. The price is aggregated from daily oil prices by Clarksons.

MSCI Global World Index

The MSCI World Index reflects the global stock market's performance. We are looking at how the world index moves compared to the Clarksea Index and the oil price. Generally, year-on-year increases in the world index signal bullish conditions, making it easier to acquire financing. The pecking order theory suggests that the leverage ratio will decline as the valuations rise. That is, bullish conditions might strengthen the ability to gain equity financing by issuing new shares to a high valuation. Conversely, a bearish market or negative returns opens for debt financing, leading to higher leverage ratios (Frank & Goyal, 2009).

Inflation in the G7 Countries

When assessing the global economic climate, the inflation rates of the G7 nations can serve as a benchmark for the broader impact of inflation on industries worldwide. Inflation can cause a reduction in the actual value of debt, which can lead to lower borrowing costs and increased leverage. This may lead to an uptick in leverage. Moreover, inflation can impact a company's profitability, contributing to a favorable leverage ratio (Drobetz et al., 2013).

The Yield Curve

To adjust for fluctuations in the market, we include the term spread between the 10-year and 1-year U.S. Treasury Government bonds, whereas a negative spread can signal an incoming recession (Dahlquist & Harvey, 2001). A negative relation between the leverage ratio and the term spread will support that the leverage is counter-cyclical. On the contrary, if there is a positive relation, the leverage will be cyclical and then explained by the tradeoff theory.

U.S. Dollar Index

The U.S. Dollar index measures the value of the U.S. dollar relative to some U.S. trade partners' currencies. An increase in the index indicates that more foreign currency is required to purchase each dollar. This factor is important as the U.S. dollar is the primary currency used in the maritime industry (Drobetz et al., 2013). Shipping companies typically ask for loan agreements in their preferred currency, the U.S. dollar (Secretariat-General, 2004). The value of the U.S. dollar can adversely affect most firms' competitiveness in the shipping industry. Stopford (2009) noted that an appreciation of the dollar could reduce the operating cash flow for non-American firms in their currency, an increase in external capital demands, and a higher leverage ratio.

ClarkSea Index

The ClarkSea Index is a measure that calculates the average revenue earned by three different types of ships, namely tankers, bulkers, and containers. This metric is significant for companies as it directly affects their revenue streams. An increase in the index generally indicates a rise in freight rates, ultimately leading to higher cash flows for companies. As a result, companies may be able to expand their debt capacity, which in turn can increase their targeted leverage ratio (Drobetz et al., 2013).

5.3 Descriptive Statistics

5.3.1 Company-Specific Variables

Table 5.1 presents descriptive statistics for company-specific variables, offering an overview of each variable's distribution. Despite strict data collection criteria as discussed in section 3.1, there may still be instances of unreasonable and misleading observations. To ensure that the analysis is robust, we have selected a representative sample and handled extreme observations (Drobetz et al., 2013). Therefore, the variables are winsorized at both upper and lower percentiles with 1% threshold to mitigate the effects of extreme observations (Frank & Goyal, 2009).

Table 5.1: Descriptive statistics - Firm-specific variables

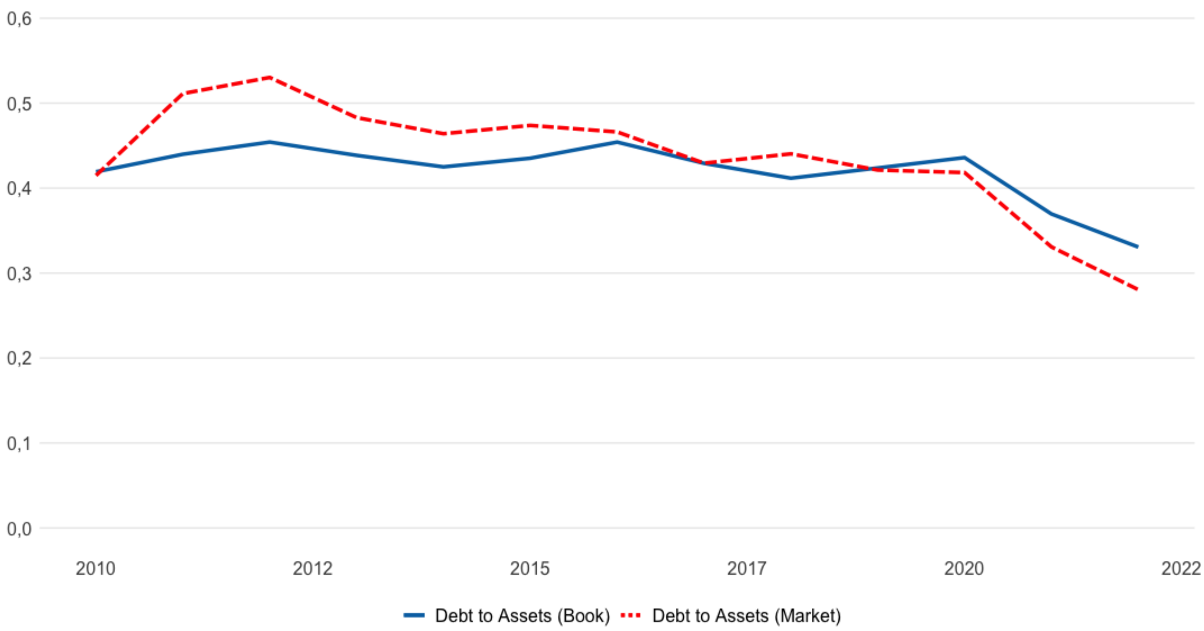
	Number of Obs	Mean	Std Dev	Median	Percentiles		Min	Max
					25%	75%		
Debt to Assets (Book)	1532	0.421	0.211	0.416	0.281	0.556	0.005	1.063
Debt to Assets (Market)	1513	0.436	0.296	0.435	0.158	0.694	0.000	0.977
Lagged Book	1397	0.426	0.206	0.421	0.294	0.557	0.005	1.025
Lagged Market	1379	0.448	0.294	0.463	0.174	0.703	0.000	0.975
Fixed Assets	1549	0.636	0.229	0.680	0.515	0.806	0.004	0.951
Operational Debt	1581	0.405	0.520	0.240	0.116	0.512	0.007	3.878
Profitability	1577	0.075	0.084	0.069	0.037	0.102	-0.215	0.450
Firm Size	1585	8.553	2.912	8.064	6.547	10.383	-0.472	17.073
Asset Volatility	1550	0.458	0.383	0.361	0.244	0.532	0.080	2.593
Dividends	1589	0.587	0.492	1.000	0.000	1.000	0.000	1.000

Note: Descriptive statistics of the firm-specific variables after winsorization. Source: Compustat.

Further, we will compare the findings of Drobetz et al. (2013), Frank and Goyal (2009), and Bressler et al. (2012) with our findings.

On average, from 2010 to 2022, there is a minor difference between the book and market debt ratios. The market debt ratio tend to be more volatile in the short term than the book debt ratio, as seen in Figure 5.1. However, over a longer timeframe, these differences level out.

Figure 5.1: Average Debt Ratios



Note: Debt-to-market value of assets and debt-to-book value of assets aggregated means over the sample period. Source: Compustat.

We find near similar debt ratios in the shipping industry sample from Drobetz et al. (2013). However, the debt level is notably higher than of the Bressler et al. (2012) sample, which examined publicly traded companies in the G7 countries. Drobetz et al. (2013) also confirm the capital-intensive nature of the shipping industry, as the average proportion of fixed assets is 64%, much higher than the 29% Bressler et al. (2012) reported.

Bressler et al. (2012) suggests that the profitability for shipping companies show parallels to other industrial firms. The median for the shipping companies shows an operating profit before the depreciation to total assets ratio of 6.9%, lower than the 9.71% median for the G7 countries.

The mean size of companies, including those in the shipping sample by Drobetz et al. (2013), is significantly larger than those in the analysis samples of Frank and Goyal (2009) and Bressler et al. (2012).

Overall, the descriptive statistics for our sample do not deviate significantly from the studies of Drobetz et al. (2013). However, the statistics show that shipping companies operate and have different capital structures than the average listed company.

5.3.2 Macroeconomic Variables

The macroeconomic environment influences the shipping industry, as section 5.2.3 outlines. The selected period saw notable changes in the industry and economy. We will not undertake a detailed examination of each variable, as our primary focus is the major macroeconomic trends throughout the sample period. However, the macroeconomic variables are used in the analysis in the following chapters. See Appendix B for the developments of the macroeconomic variables over the sample period.

6 Asset Volatility

The cash flow volatility cannot be directly measured through market observations. This was observed by Merton (1974), who suggests that a firm's cash flow's volatility corresponds with its assets' volatility. Intuitively, this should vary across different industries but may be more accurate in capital-intensive industries where most of the firm's cash flows come directly from its assets.

Our approach for determining the asset volatility of shipping companies employs the Black and Scholes (1973) model, hereafter the BSM model. This model relies on historical stock price data to forecast the future volatility of asset returns. The BSM model operates based on several assumptions of foundational market behavior and asset characteristics. It assumes a stable risk-free interest rate over one year and projects that stock prices will exhibit a mix of continuous and random trajectories, maintaining a steady trend over time.

In our assessment of asset volatility, we interpret the company's equity as if it were a call option on its total assets. The debt's face value represents the strike price, and the debt's maturity is the option's expiration. This analogy is supported by Vassalou and Xing (2004) and Bharath and Shumway (2008).

The market value of assets, A_t, and the book value of debt, D_t, are indicated respectively. The equity value at time, t, denoted, E_t, is described by the Black-Scholes-Merton equation,

$$E_t = A_t N(d_1) - D_t e^{-r(T-t)} N(d_2), \tag{6.1}$$

where,

$$d_1 = \frac{\ln\left(\frac{A_t}{D_t}\right) + \left(r + \frac{1}{2}\sigma^2\right)(T-t)}{\sigma\sqrt{T-t}}, \tag{6.2}$$

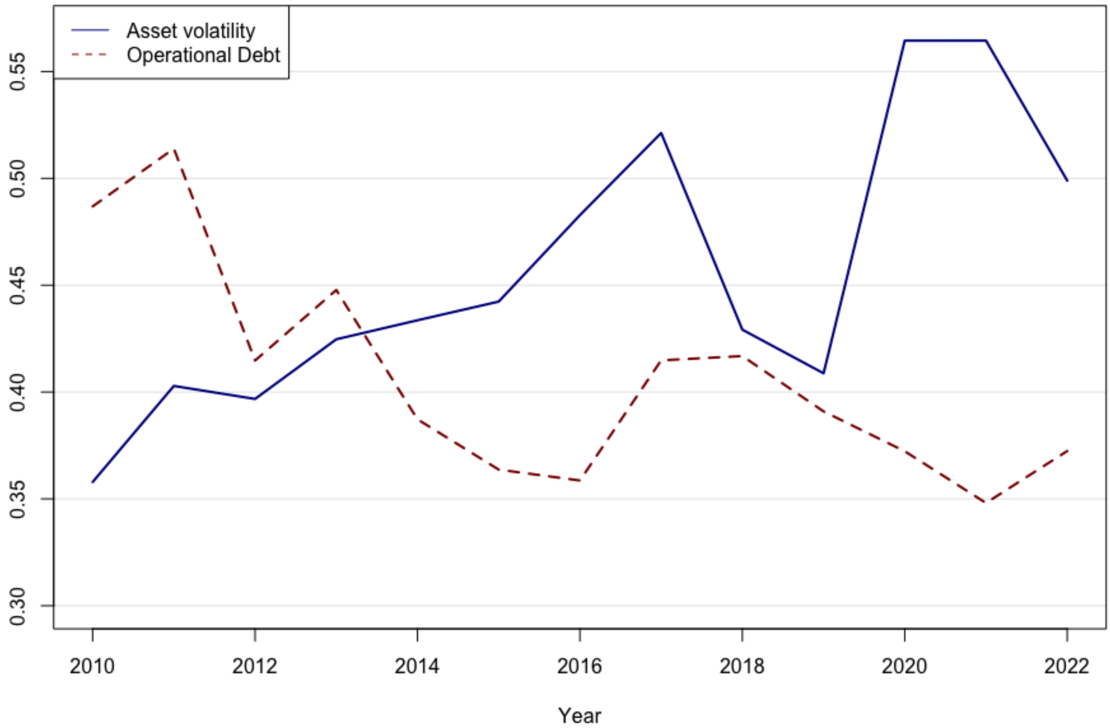
$$d_2 = d_1 - \sigma\sqrt{T-t}. \tag{6.3}$$

First, we gather daily stock price data for each company in the sample. Second, we calculate the log returns of each company and find the equity volatility by multiplying the square of number trading days with the standard deviations of the companies. This leaves us with equity volatility values for each firm for every year they are included. In the optimization, we use equity volatility as an initial guess for asset volatility. While equity volatility is derived from a company's stock price movements, the asset volatility refers to the company's total value, including debt and equity. The optimization process aims to find the asset volatility that best explains the observed market values, given the firm's equity volatility, debt, current risk-free rate, and the time, T, to maturity. The optimization uses a Nelder-Mead Simplex method, a heuristic search strategy for optimizing functions that are irregular and not necessarily differentiable (Singer & Nelder, 2009). This method fits well when using the BSM model for empirical data, as such data usually contain market imperfections and irregularities. The optimization method adjusts the total value of the company and the asset volatility such that the theoretical value of equity, E_{BSM}, equals the observed market capitalization[6]. The process usually involves several iterations and stops when the difference between market capitalization and E_{BSM} is as close to zero as possible.

According to the tradeoff theory, companies with high asset volatility might aim to sustain a lower operational debt ratio to mitigate risk exposure. The operational debt is here captured by the operating expense ratio. It is important to recognize that asset volatility is not observable in the market. The dynamic between asset volatility and operational debt is complex and not merely a case of one variable influencing the other directly. High asset volatility may stem from broader market conditions, which could reduce operating expenses.

[6]Note that the market capitalization is the same as the market value of equity.

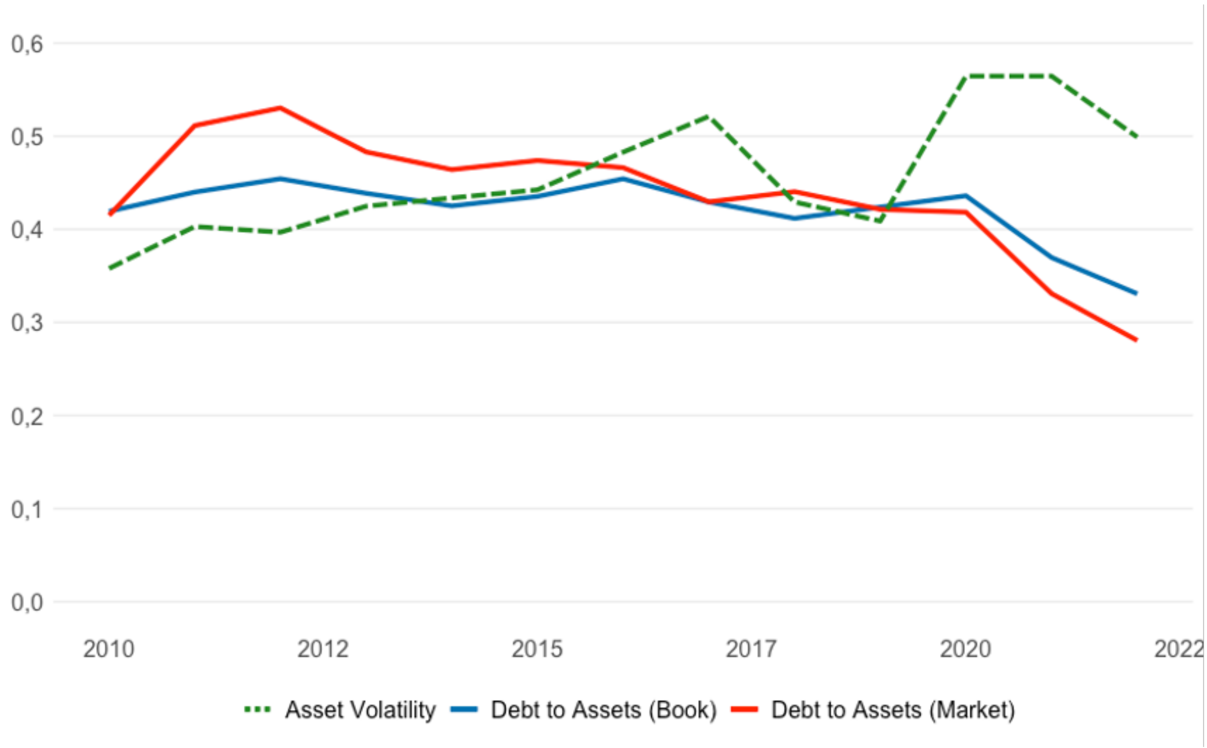
Figure 6.1: Comparing Asset Volatility and Operational Debt



Note: The operational debt and asset volatility over the sample period. Both measures are aggregated means for each year. Source: Compustat.

Figure 6.1 illustrates the relationship between asset volatility and operational debt. As the operational debt ratio decrease, the asset volatility usually increase. The operational debt is the operating expenses to total asset ratio. Intuitively, the operational debt decrease may be caused by a valuation increase, explaining both the pattern of the operational debt and the increase in asset volatility.

Figure 6.2: Book and Market debt ratios compared with Asset Volatility

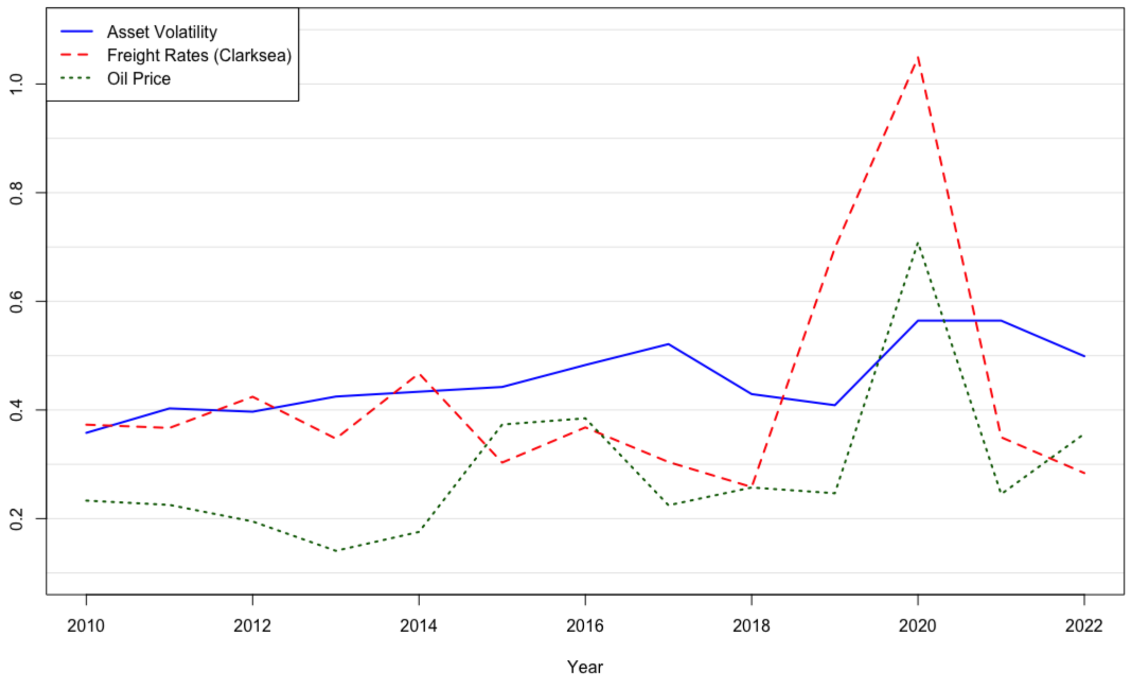


Note: These are the same debt ratios as shown in figure 5.1. The asset volatility is the aggregated means of every company in the sample, for each year. Source: Compustat.

The asset volatility within the shipping industry, illustrated in Figure 6.2, moves almost inversely to the industry's aggregated debt ratios. We can spot the impacts of the 2015 oil crisis and how the coronavirus pandemic affected the market. Notably, there was a significant volatility increase just before the virus outbreak. Observing how the industry's debt ratio weakened during the pandemic, as seen in Figure 6.1 is particularly intriguing. This occurring could be attributed to interests approaching zero, decreasing the tax shield's effectiveness. Despite near constant tax levels, the tax shield will not significantly impact the optimal enterprise value when interest expenses fall.

Figure 6.3 indicates that oil prices behave as a somewhat lagged variable in relation to freight rates. Simultaneously, oil prices and asset volatility exhibit similar patterns of peaks and downers, though the oil price shows greater volatility.

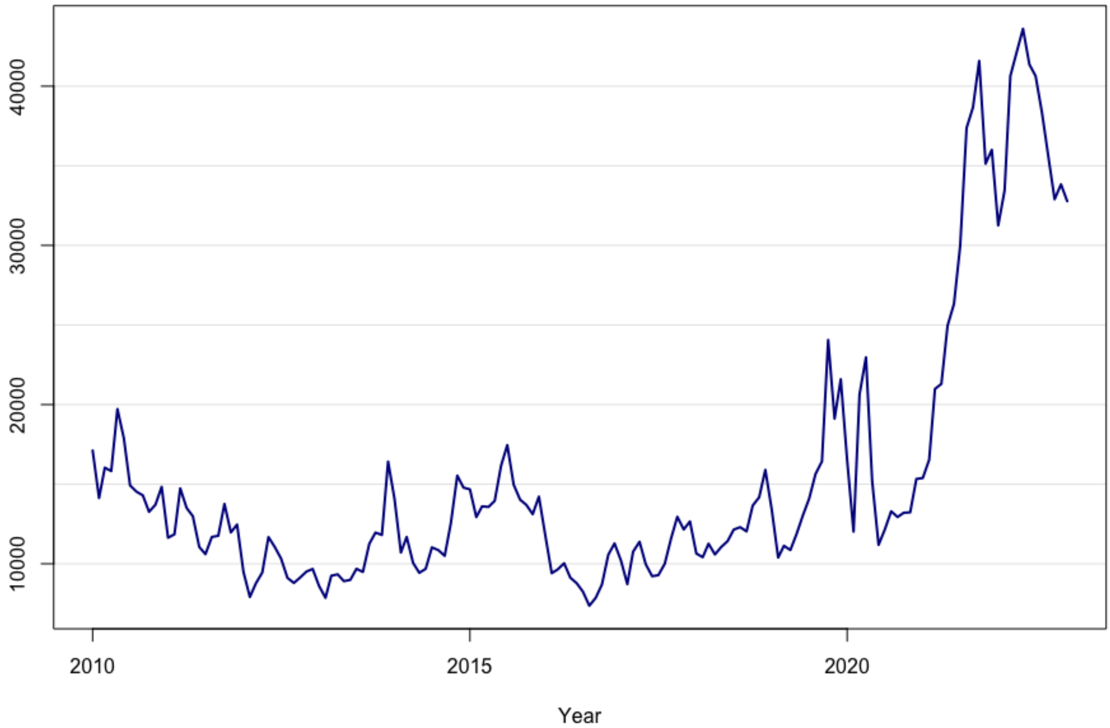
Figure 6.3: Asset Volatility, Freight Rates and Oil Price



Note: The freight rates and oil price graphs are the respective volatilities. The volatilities are the yearly volatilities of each determinant. Source: Compustat and Clarksons.

The noticeable surge in freight rates around the outbreak of the Covid pandemic can be attributed to an extreme increase in demand. In addition, there were other governmental challenges, such as closed borders and curfews. On average, the lead time for maritime freight shipments saw a 75% increase since the pandemic began (Condon, 2020). Moreover, in September 2020, the freight rates increased by approximately 300%. Furthermore, the leap in the ClarkSea index volatility stems from the drastic rise in freight rates.

Figure 6.4: Freight Rates 2010-2022



Note: The graph shows the development of the ClarkSea Index over the sample period. That is, the shipping freight rates for the industry. Source: Clarksons.

7 Static Capital Structure

Our research into the optimal capital structure within the shipping industry is firstly grounded in the Leland (1994) model. We further use the insights of Goldstein et al. (2001) and move from the asset value-based approach of Leland (1994) to an EBIT-based model.

We initiate our analysis by deconstructing the static model and transitioning to the dynamic one. The premise is to integrate insight gained from the static model into the dynamic framework. Our preliminary assumptions suggest that the optimal leverage ratio identified by the dynamic model is anticipated to be lower than that the static model.

In the context of Leland (1994), the static model represents a simplified approach to capital structure that excludes the dynamic aspects of debt management, such as the costs of issuing new debt or retiring existing debt. The static framework is based on the premise that the firm's capital structure is fixed and does not change over time. The firm's value is maximized by determining an optimal debt level that balances the tax shield benefits of debt against the cost of bankruptcy without considering the timing or frequency of refinancing.

Preliminaries

An EBIT process models the fundamentals in this class of models. We estimate the drift and the volatility of the underlying cash flow process using historical equity, debt, and asset values. To estimate the drift, we use the insight of Goldstein et al. (2001) that the cash flow growth, under the equivalent martingale measure Q[7], equals the risk-free rate, r, if the company retains all its earnings. However, a company with a payout rate δ proportional to earnings has a drift under Q equal to $r - \delta$. Payouts to investors and governments typically consist of dividends to shareholders, interest payments to debt holders, and tax payments to the government. To estimate δ, we used data on operating income before depreciation (oibd), interest expenses, income taxes, and total dividends. δ is given as

$$\delta = \frac{\text{Interest expenses} + \text{Income taxes} + \text{Dividends}}{\text{oibd}}. \tag{7.1}$$

[7]The equivalent martingale measure Q is a risk-neutral framework where the expected return of an asset is the risk-free rate, used for theoretical asset valuation.

To approximate the risk-free interest rate, we use the 10-year U.S. government treasury bond quote. Using the risk-free rate for the respective year, the observed firm-specific numbers, and the corresponding δ, give us the drift process, μ,

$$\mu = r - \delta. \tag{7.2}$$

It is assumed a simple tax structure, including both personal taxes for investors and corporate taxes. Furthermore, the model focuses on the effective corporate tax rate, θ_{eff}, and the investors' tax rate, θ_i. That is, taxation of dividends and corporate profits, and taxation of interest payments, respectively. Further, there is only one type of debt within the model: a consol bond[8]. Specifically, a consol bond, where a coupon, c, is paid until default. When the firm defaults, the creditors will receive the remaining asset value. Equity holders strategically determine the default time, ceasing coupon payments when the EBIT value is sufficiently low. The equity holders, therefore, maximize the firm value at time 0 value of EBIT.

To find the default barrier, we calculate the default barrier, δ_b, as a function of the coupon, c. We use the help of Arrow-Debreu prices[9] to calculate the default barrier. Arrow-Debreu prices represent today's cost of receiving a unit of currency in a specific future state of the world, reflecting a comprehensive market for every conceivable outcome. These theoretical prices underpin understanding risk, uncertainty, and efficient resource allocation in complete markets, setting the stage for complex financial calculations like the default barrier assessment (Arrow & Debreu, 1954). We use the Arrow-Debreu price to compute γ, which serves as a constant. The default barrier, δ_b, is given as

$$\delta_b = \frac{\gamma_1 c(1-\theta_{\text{eff}})}{1+\gamma_1 r(1-\theta_i)\xi}, \tag{7.3}$$

where,

$$\gamma_1 = \frac{\left(\psi + \sqrt{\psi^2 + 2r(1-\theta_i)\sigma^2}\right)}{\sigma^2} > 0, \tag{7.4}$$

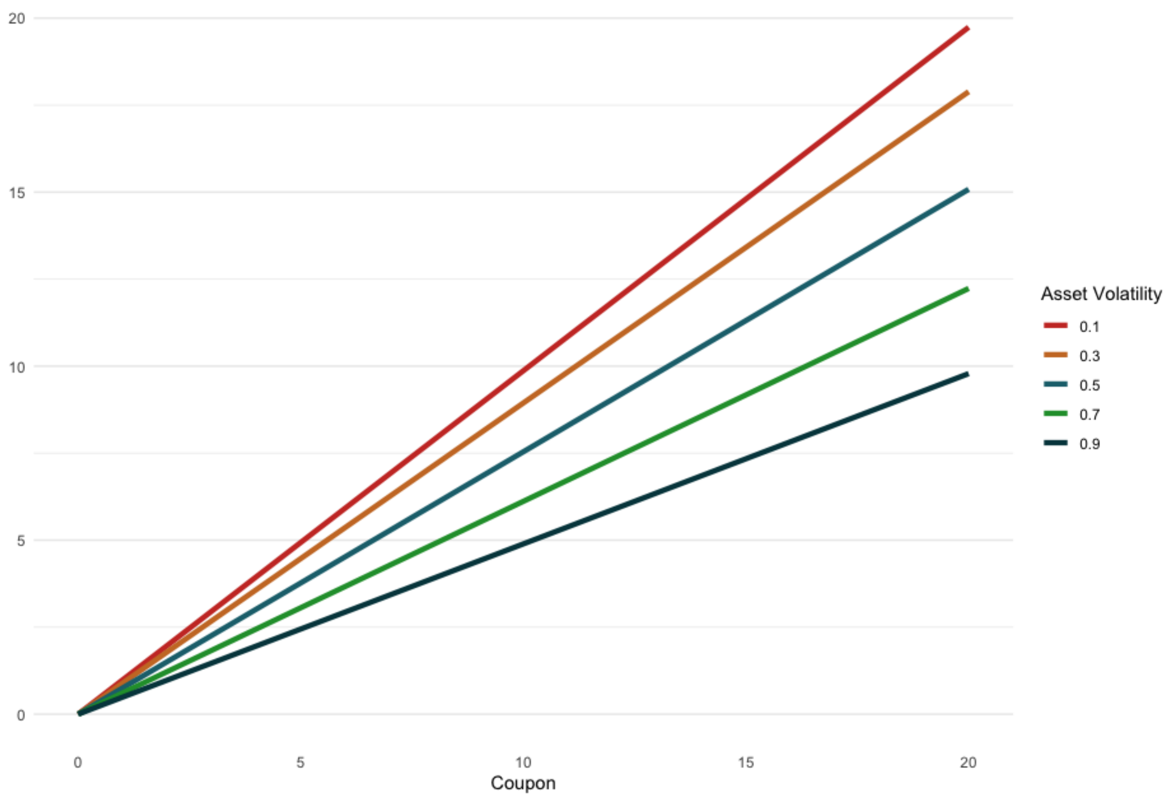
and,

$$\psi = \mu - \frac{1}{2}\sigma^2. \tag{7.5}$$

[8]A consol bond is a perpetual bond with no maturity date, paying fixed interest payments indefinitely.
[9]Arrow-Debreu prices is the price of an asset paying 1 at bankruptcy.

The gamma constant, γ, yields a parameter that captures both the leverage effect and the asset volatility impact on the firm's risk of default. This part opens for looking at the default barrier's sensitivity to market conditions, such as asset volatility.

Figure 7.1: Default Barrier Sensitivity to Asset Volatility



Note: The default barrier sensitivity to changes in asset volatility. As the asset volatility increase, the default barrier decrease. Source: Compustat.

As seen above, the default barrier moves downwards as the asset volatility increases. As the asset volatility increases, the value of the firm's equity behaves more like a call option on the firm's assets. A higher volatility increases the potential upside for equity holders, while the downside is limited to the equity value hitting zero. As a result, equity holders might prefer taking on more risk, which can lead to a lower default barrier, as the firm is more likely to take on debt and approach default.

When the asset volatility increases, equity holders may find renegotiating their agreements more attractive. Higher volatility leads to a greater risk of asset value falling below the default barrier. Therefore, renegotiating debt to avoid default becomes a more valuable option. Furthermore, debt holders may be more inclined to accept renegotiation proposals in a high volatility environment because default becomes more likely as volatility increases. Moreover, it effectively lowers the default barrier because the point at which equity holders choose to renegotiate (to prevent the asset value from falling below the debt obligations) is reached sooner (Christensen et al., 2014). More on this in Chapter 8.

Leland (1994) requires calculating the tax shield value and bankruptcy cost, which together form the tradeoff. Following Goldstein et al. (2001), we employ ξ, as a multiple to calculate the unlevered value of the firm. ξ is multiplied with EBIT to determine the unlevered value of a company, where ξ represents the price-earnings ratio. To derive the levered value, we add the tradeoff. That is, $Enterprise\ value = EBIT \times \xi + tradeoff$.

ξ is given as

$$\xi = \frac{1-\theta_{\text{eff}}}{r(1-\theta_i)-\mu}. \tag{7.6}$$

Next, we address the optimal leverage ratio within the shipping industry. Note that the metrics used in the model are aggregated means for each year in the sample period. Initially, we have set the bankruptcy costs, α, as a constant fixed at 30%. Further details on bankruptcy costs will follow later in this chapter. Since we have winsorized the data, outliers have been mitigated.

Standard in all the models, the bankruptcy costs do not influence the equity value. Given the price-earnings ratio, ξ, we can find the equity value. Note that if $\delta \leq \delta_b$, the equity value is 0. The equity value when $\delta \geq \delta_b$ is

$$\hat{w}(\delta) = \delta\xi - \delta_B\hat{\xi}(\delta) - \frac{c(1-\theta_{\text{eff}})}{r(1-\theta_i)}(1-\hat{\pi}(\delta)). \tag{7.7}$$

We compute the debt value by first using the Arrow-Debreu price, π_1. Recall γ_1, the Arrow-Debreu price is given as

$$\hat{\pi}_1(\delta) = \left(\frac{\delta}{\delta_B}\right)^{-\gamma}. \tag{7.8}$$

The debt value does contain the bankruptcy costs because if a company defaults, the costs connected to this are the debt holders to pay. Hence, the computation of equity does not contain any bankruptcy costs. Moreover, the debt value for the creditor is given as two equations, hence the possibility for default. Then

$$\hat{U}(\delta) = \begin{cases} \frac{c}{r} + (\delta_B \xi(1-\alpha) - \frac{c}{r})\hat{\pi}_1, & \delta \geq \delta_B, \\ (1-\alpha)\delta\xi, & \delta \leq \delta_B. \end{cases} \tag{7.9}$$

The enterprise value is

$$V(\delta) = \hat{w}(\delta) + \hat{U}(\delta) = \delta\xi + \frac{c(\theta_{\text{eff}} - \theta_i)}{r(1-\theta_i)}(1 - \hat{\pi}_1(\delta)) - \delta_B \hat{\xi} \hat{\pi}_1(\delta). \tag{7.10}$$

The optimal leverage ratio is obtainable by this model. It is tied to the optimal coupon[10], which is calculated based on balancing the tradeoff. That is, the process of finding the optimal coupon is going through an iterative process to converge on the coupon that maximizes the tradeoff. This goes through an optimization function that adjusts the coupon until the optimum is reached. The choice of coupon determines the capital structure. We seek the coupon that maximizes the enterprise value. The interest tax shield is given as

$$H(\delta) = \frac{c(\theta_{\text{eff}} - \theta_i)}{r(1-\theta_i)}(1 - \hat{\pi}_1(\delta)), \tag{7.11}$$

and,

$$h(\delta) = \alpha \delta_B \hat{\xi}_1(\delta), \tag{7.12}$$

is the bankruptcy costs.

Given that the unlevered enterprise value can be given as $\xi \times \delta$, the levered enterprise value is

$$E_1 = \xi\delta + H(\delta) - h(\delta). \tag{7.13}$$

Bankruptcy costs

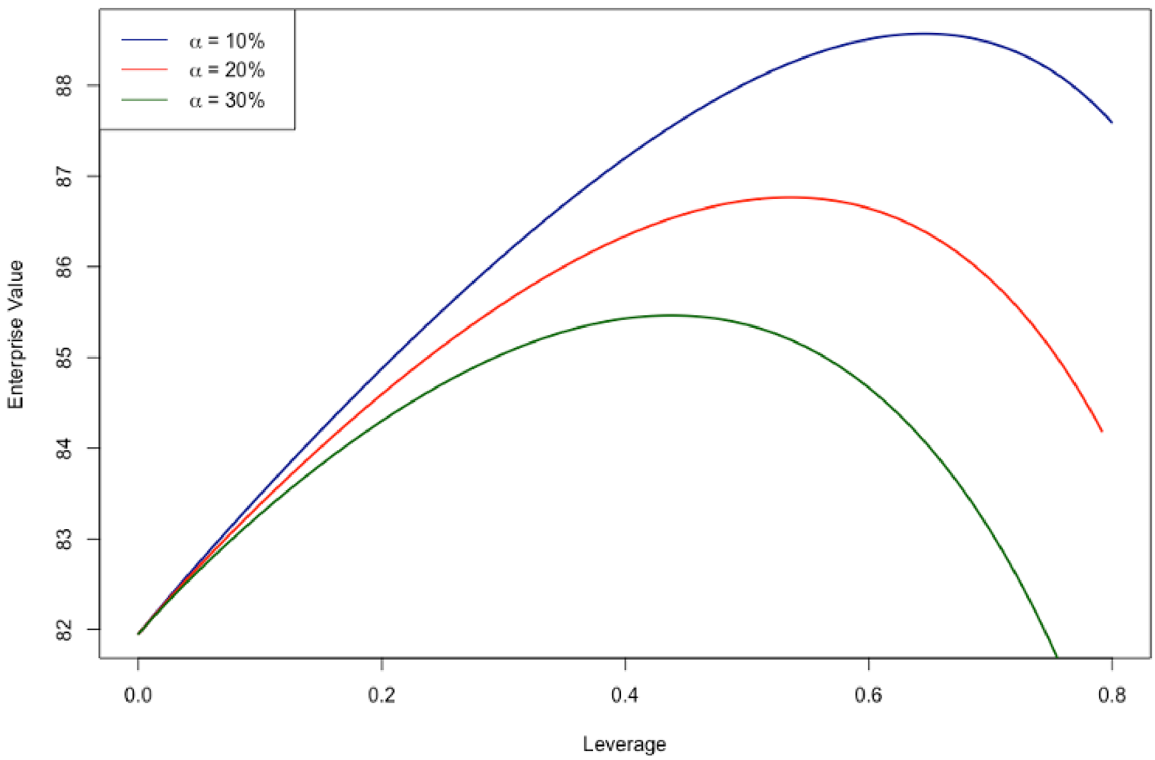
The discussion of bankruptcy costs in industrial firms, as presented by Althman (1984), indicates that direct and indirect expenses can amount to approximately 15% of a firm's value prior to distress. Branch (2001) echoes the significance of these costs. When considering the shipping industry specifically, a thorough examination is necessary to find the accurate bankruptcy costs.

[10] The coupon in this context is the fixed interest payment the company pays to the debtholders.

The impact of varying bankruptcy cost levels — 10%, 20%, and 30% — suggests significant sensitivity in the optimal enterprise value and leverage, as seen in the figure 7.2. The sensitivity is primarily due to the relation between total tax shields and the bankruptcy costs. An in-depth analysis is necessary to establish an appropriate benchmark for these costs; however, such an analysis is beyond the scope of this discussion. Consequently, we rely on the precedents set by Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014), employing three distinct levels of bankruptcy costs for our considerations.

Despite the lack of extensive analysis, it can still be reasonably presumed that the bankruptcy costs for the shipping industry are likely below the 30% threshold. This assumption is based on the fact that costs are associated with the loss of contracts and actual revenues rather than asset devaluation. Shipping companies typically have a significant portion of their total assets tied up in fixed assets. It is reasonable to suggest that bankruptcy costs would not be as damaging, considering that fixed assets value would not drop solely due to lost revenue.

Figure 7.2: Optimal Enterprise Value as function of Leverage



Note: The optimal leverage shifts to left as a response to the increase in bankruptcy costs. Addionally, the enterprise value falls due to the smaller tradeoff. Source: Compustat.

Below follows a numerical presentation of the static model. The given parameters, *params*, are derived from descriptive statistics of the observations in table A.2. The parameters are aggregated means after winzorisation, as previously mentioned.

Table 7.1: Numerical presentation of the Static model outputs

Leland 94	EBIT	μ	σ	r	$\theta_e ff$	θ_i	α
Params	55	-0.379	0.458	0.023	0.409	0.233	0.3
Static	E*	y*	c*	T(c)*			
	82.6	0.47	11.4	4.4			

Note: Numerical results from the static model. Optimal leverage ratio show 47%. Source: Compustat.

8 Dynamic Capital Structure

Following the static model, we will further implement the practicalities of the dynamic model. The key difference is the cost of calling the debt and renegotiate debt. That is, the costs associated to call the debt before maturity, and the costs associated to renegotiate the debt terms. The model is based on the same fundamentals as the static model. The tax system remains the same.

We denote the time 0 value of debt and equity as functions of the time 0 EBIT value by $D(\delta_0)$ and $E(\delta_0)$, respectively. Now,

$$D(\delta_0) = D\delta_0, \tag{8.1}$$

$$E(\delta_0) = E\delta_0. \tag{8.2}$$

Note that the debt and equity move proportional to δ. The principal value of debt with coupon rate c equals its time 0 market value. The debt can be called at a premium, $(1 + \lambda)D\delta_0$, where the parameter $\lambda > 0$ determines the call premium as a percentage of the principal. Additionally, there is an issuance cost of debt, k, proportional to the par value, given as

$$V = E + (1 - k)D. \tag{8.3}$$

The representative value for the call premium and issuance costs are derived later in this chapter. The call and liquidation boundaries are interesting in the dynamic model. We denote u and d, which determine the call and liquidation boundaries. The call boundary is then $u\delta_0$. At the call boundary, the increase in debt value is

$$(1 - k)D(\delta_u) - (1 + \lambda)D(\delta_0) = ((1 - k)u - (1 + \lambda))D\delta_0. \tag{8.4}$$

The enterprise value at $u\delta_0$ is $E(\delta_0 u) + (1 - k)D(\delta_0 u) = V_u\delta_0$. We can write the value of equity after refinancing at the call boundary as the difference between the enterprise value and the value of debt. For example,

$$E(\delta_u) = (Vu - (1 + \lambda)D)\delta_0. \tag{8.5}$$

We define $\bar{e} = Vu(1+\gamma)D$ and write $E(\delta_0 u) = \bar{e}\delta_0$. The value of the debt at the call boundary is

$$D(\delta_0 u) = (1+\lambda)D\delta_0. \tag{8.6}$$

At the liquidation barrier we have that

$$D(\delta_0 d) = \min((1-\alpha)V_d, D)\delta_0, \tag{8.7}$$

and,

$$E(\delta_0 d) = \max((1-\alpha)V_d - D, 0)\delta_0. \tag{8.8}$$

We define $\underline{e} = \max((1-\alpha)Vd - D, 0)$ and write $E(\delta_0 d) = \underline{e}\delta_0$. We can now solve for E and D, and clearly, V, by solving the following two equations. First,

$$D = \frac{c}{r} = (1 - \overline{P} - \underline{P}) + \min((1-\alpha)V_d, D)\underline{P} + (Vu - (1+\lambda)D)\overline{P}, \tag{8.9}$$

where $\underline{P}$ is the time 0 value of 1 payable only if δ_t reaches the lower boundary before the upper boundary. Likewise, $\overline{P}$ is the time 0 of 1 payable only when δ_t hits the upper boundary before the lower boundary. Second,

$$E = \xi(1-\underline{P}d-\overline{P}u) - B(1-\overline{P}-\underline{P}) + \max((1-\alpha)Vd-D, 0)\underline{P} + (Vu-(1+\lambda)D)\overline{P}, \tag{8.10}$$

where,

$$B = \frac{c(1-\theta_{\text{eff}})}{r(1-\theta_i)}. \tag{8.11}$$

ξ is given in expression 7.6. Furthermore, we need to determine the upper, u, and the lower, d, boundaries. As previously noted, at the call boundary, when $\delta_t = \delta_0 u$,

$$E(\delta_t) = V(\delta_t) - (1+\lambda)D(\delta_0) = V_t - (1+\lambda)D\delta_0. \tag{8.12}$$

So,

$$E'(\delta_t) = V \quad \text{or} \quad E'(\delta_u) = V. \tag{8.13}$$

At the liquidation boundary, when $\delta_t = \delta_0 d$,

$$E(\delta_t) = \max\{(1-\alpha)V(\delta_t) - D(\delta_0), 0\} = \max\{(1-\alpha)V\delta_t - D\delta_0, 0\}. \tag{8.14}$$

So, when assuming differentiability,

$$E'(\delta_0 d) = (1-\alpha)V \cdot \mathbf{1}\{(1-\alpha)Vd - D > 0\}. \tag{8.15}$$

We have that

$$E(\delta_t) = \xi\delta_t - B + (\underline{e}\delta_0 - \xi d\delta_0 + B)\underline{P}(\delta_t) + (\overline{e}\delta_0 - \xi u\delta_0 + B)\overline{P}(\delta_t). \tag{8.16}$$

Therefore,

$$E'(\delta_t) = \xi + (\underline{e}\delta_0 - \xi d\delta_0 + B)\underline{P'}(\delta_t) + (\overline{e}\delta_0 - \xi u\delta_0 + B)\overline{P'}(\delta_t). \tag{8.17}$$

This expression is homogeneous of degree zero, we therefore pick $\delta_0 = 1$,

$$E'(\delta_t) = \xi + (\underline{e} - \xi d + B)\underline{P'}(\delta_t) + (\overline{e} - \xi u + B)\overline{P'}(\delta_t). \tag{8.18}$$

Finally, we use this expression to write the smooth-pasting conditions as

$$E'(u) = \xi + (\underline{e} - \xi d + B)\underline{P'}(d) + (\overline{e} - \xi u + B)\overline{P'}(u) = V, \tag{8.19}$$

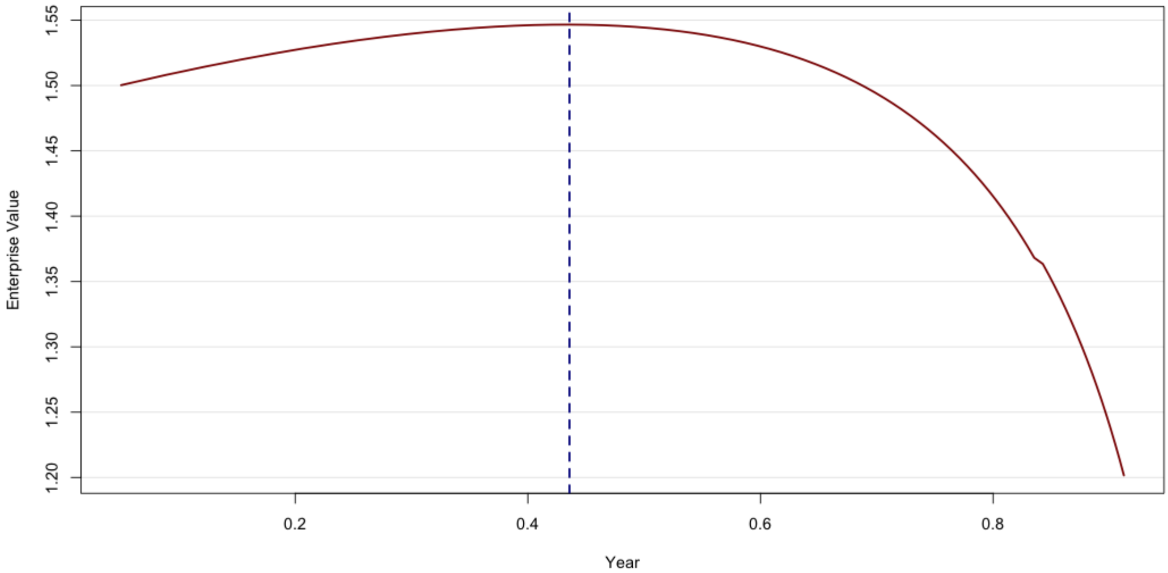
and,

$$E'(d) = \xi + (\underline{e} - \xi d + B)\underline{P'}(d) + (\overline{e} - \xi u + B)\overline{P'}(u) = (1-\alpha)V \cdot \mathbf{1}\{(1-\alpha)Vd - D > 0\}. \tag{8.20}$$

From these two expressions u and d are determined. See Christensen et al. (2014) for details.

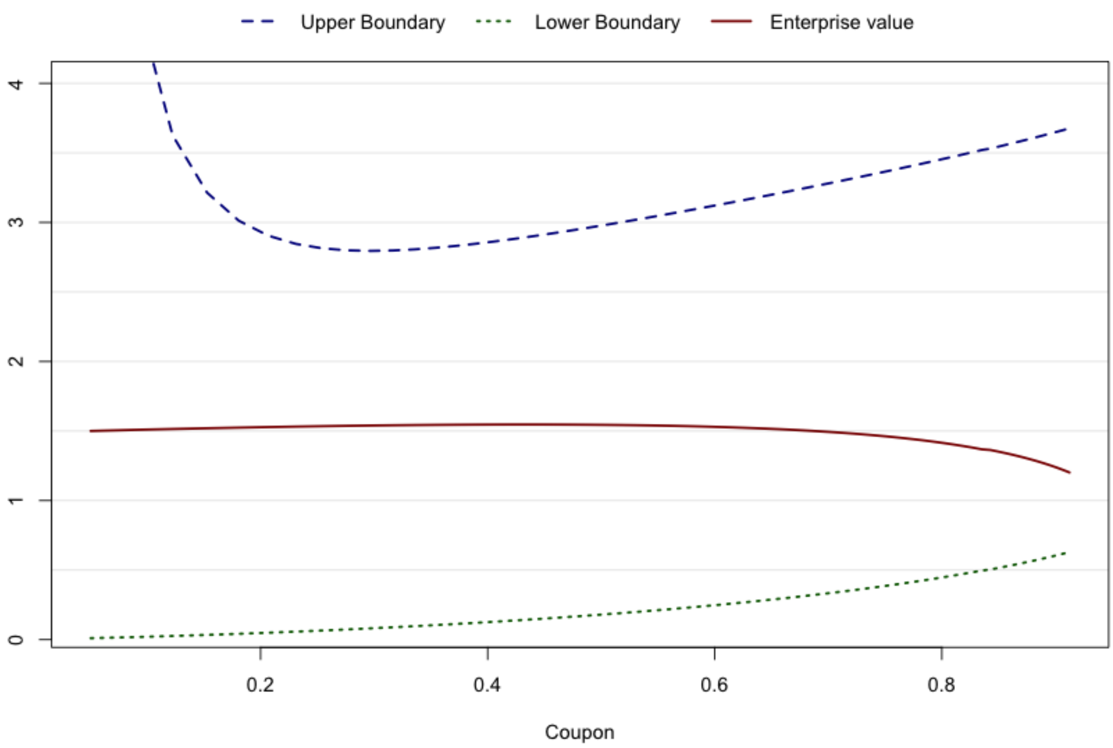
We have experienced that the dynamic model provides a higher optimal leverage ratio when bankruptcy costs are low, below 18.5%. This partly supports our preliminary assumption that the static optimal leverage ratio is higher than the dynamic. Plotting the same parameters as in the static model gives us the optimal leverage of $y^* = 0.43$, as seen in Figure 8.1.

Figure 8.1: Optimal Enterprise value as function of Leverage



Note: The dynamic presentation of the enterprise value as function of leverage. Source: Compustat.

Figure 8.2: Moving Enterprise Value with Upper and Lower Boundaries, as function of the coupon

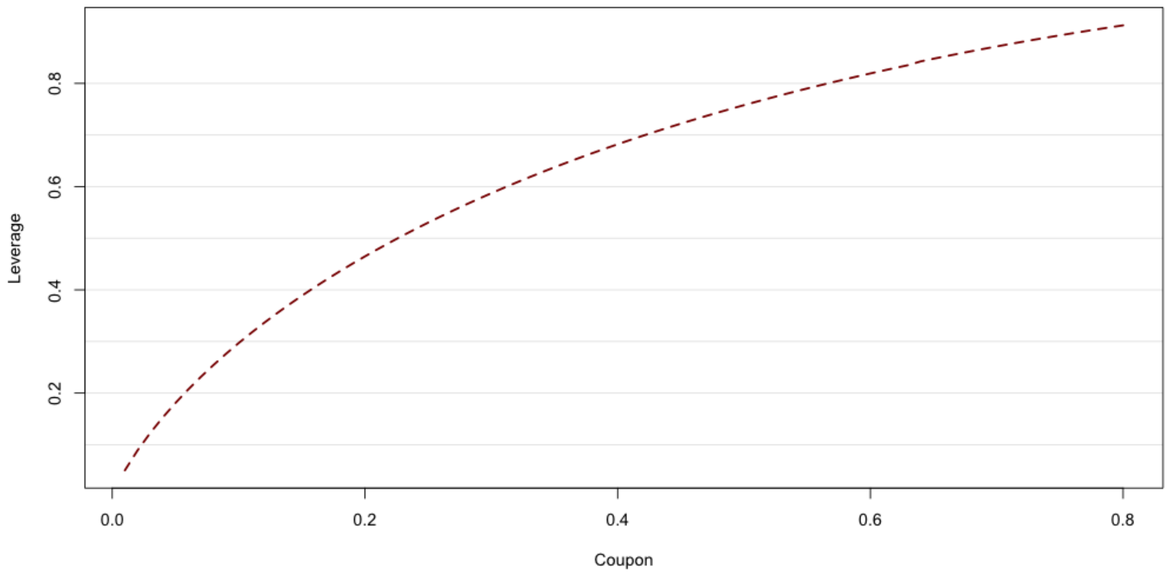


Note: The dynamic presentation of the upper and lower boundaries. The graph shows the development of these boundaries as function of the coupon rate. Source: Compustat.

Figure 8.2 above demonstrates that the lower boundary moves slightly upwards as the coupon value increases. As the coupon rises, the firm must generate greater earnings to meet its coupon payments. Hence, the enterprise value moves closer to the bankruptcy threshold, that is, the lower boundary. This can reduce the likelihood of calling the debt before maturity. As the coupon rises, the earnings should exceed these payments to call the debt. Hence, there is an upward trend in the upper boundary towards a higher coupon.

The behavior of the upper boundary is distinct. A high coupon rate usually leads to lower enterprise value due to higher costs. This will, in turn, make it difficult to obtain excess cash to call the debt before maturity.

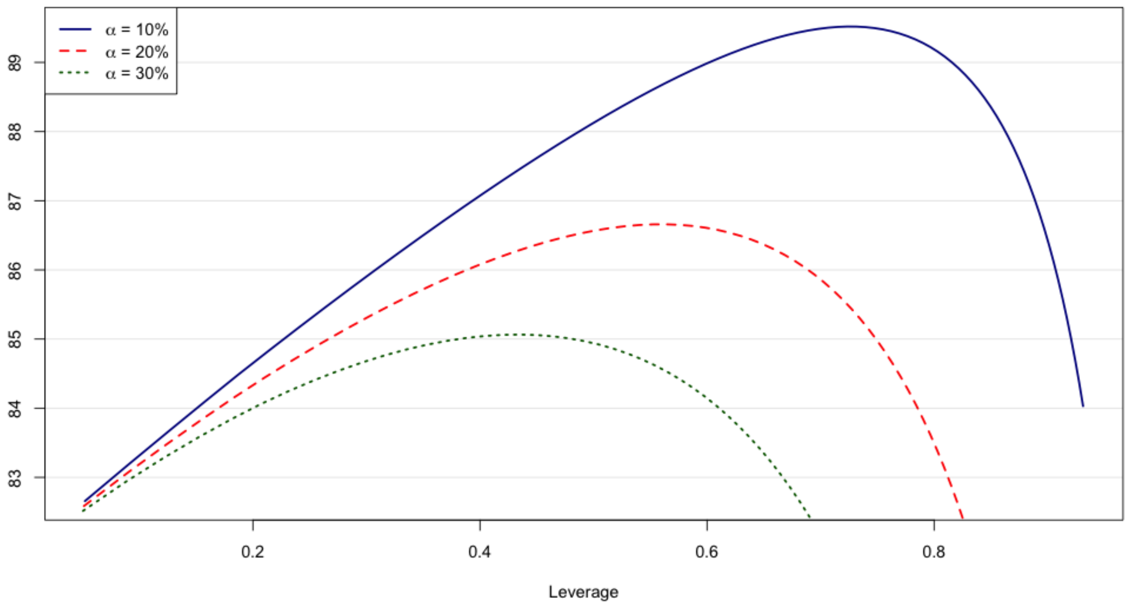
Figure 8.3: Leverage as function of the Coupon rate



Note: The development of leverage as function of the coupon rate. A higher coupon constitutes higher leverage. Source: Compustat.

Note that higher coupon rates explain a higher leverage ratios, as seen in Figure 8.3. Hence, in the relationship between coupon rate and leverage, the upper boundary moves upwards as a reaction to higher leverage. The call premium and the debt might form a significant amount to pay down eventually. Additionally, the increasing leverage raises the firm's risk. Thus, the lower boundary moves closer to the optimal enterprise value.

Figure 8.4: Bankruptcy Cost sensitivity in the Dynamic Model



Note: The enterprise value as function of leverage and how it responds to changes in bankruptcy costs. With increasing bankruptcy costs, the leverage ratio decrease, lowering the tradeoff. Source: Compustat.

As we previously discussed in chapter 7, we saw the enterprise values decline when bankruptcy costs increase. The dynamic and static model responds similarly to changes in bankruptcy costs.

Finding the issuance cost

The cost of securing debt in the shipping industry has changed over time, reflecting shifts in the international financial climate. For instance, when a shipping firm arranges a mortgage-backed bank loan, the loan arranger is compensated for organizing and managing the loan, typically around 1% of the loan value. In contrast, issuing bonds generally entails higher costs and fees than those associated with standard shipping loans. Issuing bonds is a more labor-intensive process, usually taking a month or longer, and the fees and expenses can be double those of a loan. However, for shipping bonds with large principal amounts, running into hundreds of millions of dollars, the costs are competitive and warranted, ranging from 2-3% of the bond value (Kavussanos & Visvikis, 2016). European bank portfolios accounted for nearly a 60% share of global ship finance in 2021, providing bank loans (Glass, 2021). Due to this, when setting an issuance cost in the model, we will account for the industry's 60% weight of bank loans. Hence, we set the issuance cost, k, to 1,6% of the debt principal.

Finding the call premium

The call premium is an additional amount the issuer pays to the debt holder when the debt is called before its maturity. It compensates the investor for the loss of future interest payments that they would have received if the debt had not been called. This premium is often calculated as a percentage of the face value of the bond or loan and might decrease as the debt approaches its maturity date.

While researching a proper call premium level, it became apparent that empirical data explicitly supporting the choice of a call premium on debt is scarce. Despite a thorough literature review and extensive data searches, no direct sources were identified that provide a clear basis for determining an appropriate call premium. Given the lack of specific empirical guidance, this thesis adopts the call premium as used in the study by Christensen et al. (2014). This decision is predicated on the recognition that Christensen et al. (2014) provides a well-considered approach to the call premium. The call premium selected will, therefore, be at 5%. That is, the price a company must pay to reduce its debt before maturity is 5% of the debt principal.

8.1 Comparing the models

Earlier in chapter 7, we assumed the optimal leverage ratio should be smaller through the dynamic model. As we have discovered, the static model is more sensitive to bankruptcy costs, giving the static model an optimal leverage lower than the dynamic model. On the contrary, with levels for bankruptcy costs over 18.5%, the models support our hypothesis. In this section, we will break down the key differences and similarities of the models.

Table 8.1 follows a numerical comparison using the same parameters as the numerical presentation of the static values.

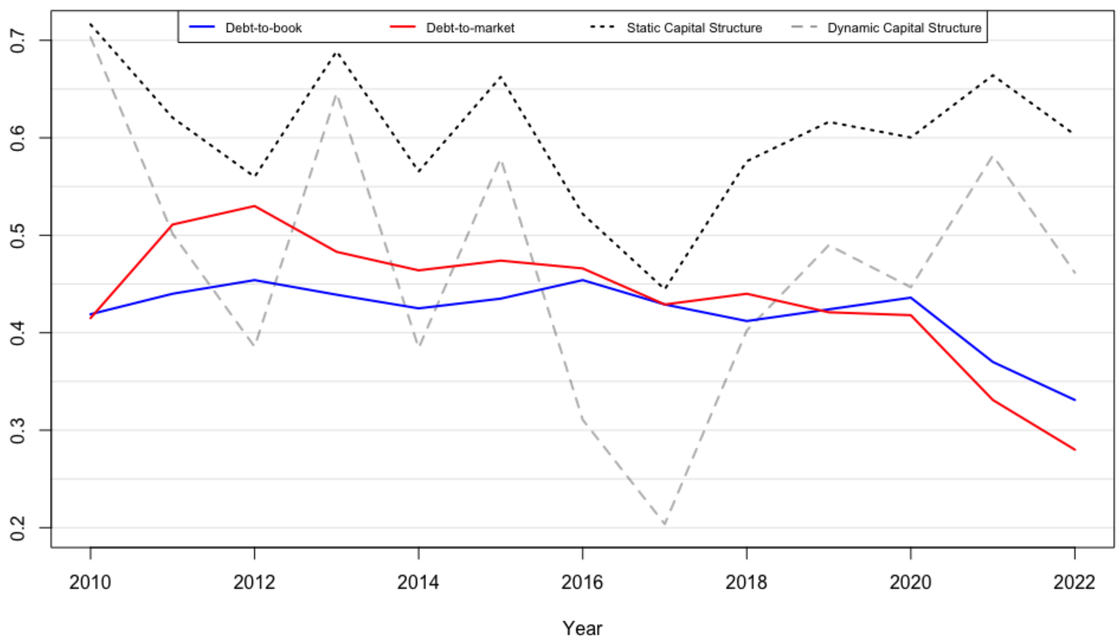
Table 8.1: Numerical comparison of model outputs

CFLM	k	λ		
	0.016	0.05		
Static	E^*	y^*	c^*	$T(c)^*$
	82.6	0.47	11.4	4.4
Dynamic	E^*	y^*	c^*	
	85.1	0.43	9.9	

Note: The results of the dynamic model are based on the same descriptive statistics as the static presentation in Table 7.1. See that in the dynamic model, additional costs are included, lowering the optimal leverage ratio. Source: Compustat.

Given the bankruptcy costs, α, of 30%, the optimal leverage for the dynamic model shows approximately 4% less than the static. Note that the enterprise values differ for each model; thus, they are both based on the same EBIT. The optimal coupon for the static model is also greater than for the dynamic model.

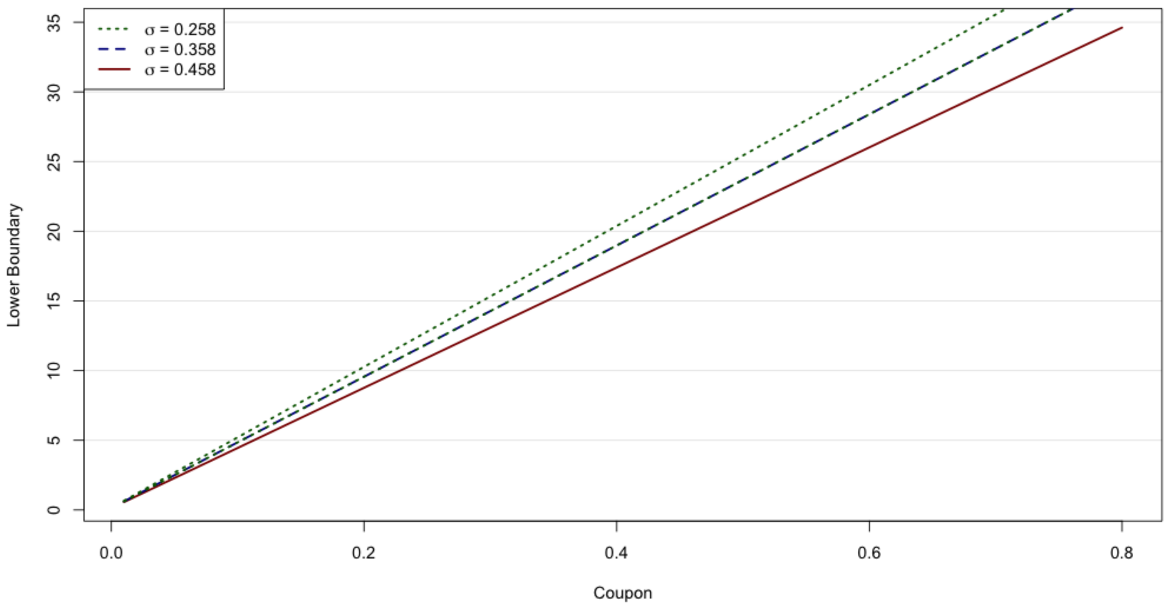
Figure 8.5: Optimal Capital Structure on observed Leverage ratios



Note: Model specific optimal leverage levels on observed leverage in the industry for each year. $\alpha = 30\%$. Source: Compustat.

Figure 8.5 show how the optimal leverage ratios for each year deviates from the observed data. The graphs suggests that the dynamic model indicates lower optimal leverage than the static model, supporting our initial assumption. However, the optimal leverages differ more than the observed leverage, making it hard to spot any patterns. We can see that the observed leverage declines significantly after the Covid-19 outbreak. Recall Figure 6.4, we can see the freight rates pattern over the sample period might explain the behavior of the optimal leverages.

Figure 8.6: Default barrier sensitivity to Asset Volatility



Note: Default barrier sensitivity to asset volatility in the dynamic model. With a decrease in asset volatility, the default barrier increase, contrasting to the static default barrier in Figure 7.1. Source: Compustat.

Recall that the default barrier in the static model is sensitive to changes in asset volatility. In Figure 7.1, it was shown that higher asset volatility lowers the default barrier. However, the default barrier in the dynamic model shows a different sensitivity to changes in asset volatility. As the asset volatility decreases, the lower boundary moves upwards. As previously discussed, the leverage ratio increases towards a higher coupon, and so does the chance for default. This works in contrast to the static model.

Renegotiation options can change the timing and likelihood of default. Asset volatility decreases and increases the default barrier, making renegotiation more appealing. The dynamic model introduces an additional strategic element where equity and debt holders prefer renegotiation as an alternative to outright default. This results in a more complex relationship between asset volatility, leverage, and the default barrier.

Overall, the dynamic model offers an insightful approach to determining optimal leverage, reflecting the bankruptcy costs, the impact of asset volatility, and additional financing considerations, such as issuance cost and the call premium. The findings suggest that the dynamic model aligns closely with the industry leverage, although deviations happen due to extraordinary macroeconomic events. If we were to do extensive research on the actual bankruptcy costs, we could better determine if the models align well with the industry.

9 Further Analysis

In the following chapter, we examine factors that influence capital structure decisions in the shipping industry through regression analysis. We want to find additional aspects affecting capital structure decisions that supplement our previous analysis with the static and dynamic models. We explore several independent variables to see if these are determinants affecting shipping companies' debt ratios, as discussed in Section 5.2. Additionally, we examine how the independent variables affect each other.

We use Fixed Effects and pooled OLS regression to analyze the factors that impact leverage decisions in the shipping industry. Statistical test results are presented in Appendix D.2, while we discuss the results in the following section.

9.1 Results

In the subsequent section, we will present the results of the analysis. This presentation will include an interpretation of the variables related to capital structure theory and prior empirical research. We will concisely discuss these variables' coefficients and their statistical significance levels. Additionally, we will emphasize the explanatory power of the various models to evaluate the results more effectively.

The beta coefficients will be interpreted using the framework in Table 9.1. All variables in this analysis appear in their level-form[11], except firm size. This variable is the natural logarithm of the book value of assets, requiring its interpretation through a level-log[12] perspective.

Table 9.1: Interpretation of beta coefficients

Model	**Dependent variable**	**Independent variable**	**Interpretation of** β
Level-Level	Y	X	$\Delta Y = \beta_k \cdot \Delta X$
Level-Log	Y	$\text{Log}(X)$	$\Delta Y = \frac{\beta_k}{100} \cdot \%\Delta X$

Note: The table outlines how to interpret beta coefficients in regression models.
Source: (Woolridge, 2021).

[11]Level-form means that the variable appears in its original form.
[12]Log-form means that the variable appears in logarithmic form.

9.1.1 Results with company-specific variables

To highlight the impact of firm and time-specific effects, we have presented results from different regression models in Table 9.2 and Table 9.3 for the debt-to-book and debt-to-market ratios, respectively. Column 1 represents a standard pooled OLS where no specific effects are considered. It is appropriate to examine the influence of year-specific effects on the results, given the 13-year period. This is examined in column 2. Our previous F-tests, as seen in Table D.4, detected firm-specific information in the sample, and we control for this in column 3. In column 4, we include firm and time-specific effects to examine their total effect.

Table 9.2: Regression results with fixed effects (Debt to Assets (Book))

	(1)	(2)	(3)	(4)
Debt to Assets (Book)				
Lagged Book	0.849***	0.852***	0.607***	0.614***
	(0.015)	(0.015)	(0.022)	(0.022)
Fixed Assets	0.125***	0.113***	0.238***	0.218***
	(0.014)	(0.013)	(0.023)	(0.023)
Profitability	-0.300***	-0.233***	-0.341***	-0.284***
	(0.031)	(0.034)	(0.036)	(0.039)
Firm Size	0.001	0.001	0.0004	0.001
	(0.001)	(0.001)	(0.004)	(0.004)
Asset Volatility	-0.008	-0.005	-0.006	-0.004
	(0.007)	(0.007)	(0.007)	(0.007)
Operational Debt	0.001	-0.001	-0.002	-0.002
	(0.006)	(0.006)	(0.009)	(0.009)
Dividends	0.002	-0.0002	0.001	-0.002
	(0.005)	(0.005)	(0.007)	(0.007)
Constant	-0.005	0.023		
	(0.013)	(0.015)		
Company Spesific Effects	No	No	Yes	Yes
Time Spesific Effects	No	Yes	No	Yes
Observations	1,346	1,346	1,346	1,346
R^2	0.811	0.818	0.523	0.504

Note: The table illustrates regression results that include Fixed Effects. Column 1 represents the results from the standard pooled OLS regression, column 2 contains the results from the pooled OLS regression with time-specific effects, column 3 presents the results from the FE regression, and column 4 shows the results from the FE regression with time-specific effects. The firm-specific and time-specific effects represent the fixed effects included in the model. The R^2 value indicates the model's explanatory power. Parentheses provide robust standard errors for each coefficient. Source: Compustat.
* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

Table 9.3: Regression results with fixed effects (Debt to Assets (Market))

	(1)	(2)	(3)	(4)
Debt to Assets (Market)				
Lagged Market	0.888***	0.895***	0.558***	0.583***
	(0.013)	(0.012)	(0.023)	(0.023)
Fixed Assets	0.095***	0.076***	0.173***	0.138***
	(0.016)	(0.015)	(0.027)	(0.026)
Profitability	-0.324***	-0.243***	-0.451***	-0.349***
	(0.039)	(0.041)	(0.045)	(0.047)
Firm Size	0.005***	0.005***	0.044***	0.043***
	(0.001)	(0.001)	(0.005)	(0.005)
Asset Volatility	-0.034***	-0.029***	-0.028***	-0.023***
	(0.008)	(0.008)	(0.009)	(0.008)
Operational Debt	0.006	-0.0001	0.020*	0.016
	(0.008)	(0.008)	(0.012)	(0.011)
Dividends	0.001	-0.004	0.005	-0.0002
	(0.007)	(0.007)	(0.009)	(0.009)
Constant	-0.022	0.069***		
	(0.016)	(0.018)		
Company Spesific Effects	No	No	Yes	Yes
Time Spesific Effects	No	Yes	No	Yes
Observations	1,328	1,328	1,328	1,328
R^2	0.858	0.871	0.514	0.507

Note: The table illustrates regression results that include Fixed Effects. Column 1 represents the results from the standard pooled OLS regression, column 2 contains the results from the pooled OLS regression with time-specific effects, column 3 presents the results from the FE regression, and column 4 shows the results from the FE regression with time-specific effects. The firm-specific and time-specific effects represent the fixed effects included in the model. The R^2 value indicates the model's explanatory power. Parentheses provide robust standard errors for each coefficient. Source: Compustat.
* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

The results from all models suggest that the lagged variables, fixed assets, and profitability, are statistically significant for both the debt-to-book and debt-to-market ratios. However, firm size and asset volatility are statistically significant only for the debt-to-market ratio. Operational debt and dividends remain insignificant for both dependent variables, except in column 3 for the debt-to-market ratio, where operational debt is significant at the 10% level.

Column 1 demonstrates high explanatory power, as indicated by R^2 values of 0.811 and 0.858, respectively. The regression model, therefore, explains 81.1% and 85.8% of the observed variation in the debt ratios over the past 13 years — year-specific effects in column 2 yield similar results. Despite the addition of year-specific effects, the variables remain significant, and the model's explanatory power increases slightly for both the debt-to-book and debt-to-market ratios.

Omitting firm-specific effects in the regression may lead to inconsistent and meaningless estimates if the included variables do not capture these effects (Hsiao, 2014). Firm-specific effects, revealed by the F-test, must be considered to achieve meaningful estimates. Including firm-specific effects in column 3 reduces the model's explanatory power because fixed effects control firm-specific variations. Standard pooled OLS does not account for such variations and can overestimate the explanatory power (Kunst, 2009). A significant change in R^2 suggests considerable individual heterogeneity in the sample, necessitating control. However, it is essential to note that this analysis aims to demonstrate causality through statistically significant coefficients. High explanatory power does not imply causality and therefore receives less emphasis in this analysis (Gujarati, 2003).

In column 3, the effect of operational debt on the debt-to-book ratio remains insignificant. However, its significance increases for the debt-to-market ratio when we account for firm-specific effects. Additionally, the coefficient for operational debt exhibits a change in sign for the debt ratios. This observed change indicates that the findings in columns 1 and 2 could be misleading, especially since the F-test has identified firm-specific effects.

Column 4 presents results with controls for both time and firm-specific effects. Given the firm-specific effects in the dataset, we compare these results with those in column 3. The economic interpretations of the variables in columns 3 and 4 remain consistent, with no change in signs except for dividends, which remain insignificant. Moreover, operational debt becomes insignificant for the debt-to-market ratio. The explanatory power for debt-to-book and debt-to-market ratios is similar, with column 3 showing slightly higher values.

Further analysis will focus on the Fixed Effects regression model (column 3), involving an in-depth examination of each variable. To compare the results, we will follow the approach of Drobetz et al. (2013) and Erel et al. (2012), which excludes fixed-year effects. The object of such analysis aims to determine whether varying time effects, as represented by macroeconomic conditions, affect the capital structure decisions of shipping companies. We will first analyze the firm-specific variables before including the macroeconomic variables in section 9.2.

Fixed Assets

Fixed assets demonstrate statistical significance at the 1% level, suggesting they influence shipping companies' debt-to-book and debt-to-market ratios. Both positive coefficients (0.238 and 0.173) indicate that shipping companies with a more significant proportion of fixed assets tend to have a higher debt ratio when all other factors are constant. This finding aligns with the tradeoff theory's principles, as this theory emphasizes that the collateral security of fixed assets can lead to increased debt financing. However, the positive relationship trend diverges from the pecking order theory's expectation of lower leverage for companies with more fixed assets due to decreased information asymmetry.

Profitability

The analysis reveals a significant and robust inverse relationship at the 1% level between profitability and debt ratios for shipping companies. As profitability increases, debt ratios decrease. The findings align more closely with the pecking order theory, which suggests firms prioritize internal financing over debt as they become more profitable. Simultaneously, the findings do not entirely diverge from the tradeoff theory, recognizing that more profitable firms might seek to optimize their debt levels, thereby minimizing costs associated with financial distress.

Firm Size

There is a positive and significant relationship at 1% between firm size and debt-to-market ratio. This supports the tradeoff theory, which posits that larger shipping companies, with their lower relative costs of financial distress and greater earnings predictability, are more inclined to use market-based debt. The result contradicts the pecking order theory, which would expect larger firms with more internal resources to have lower leverage ratios.

There is no significance between the variable and the debt-to-book ratio. The difference between the two models can be explained by the signaling effect of firm size on companies' creditworthiness or risk. Companies cannot immediately adjust the debt-to-book ratio based on historical cost values to reflect such signals, unlike the debt-to-market ratio, which responds more sensitively to market perceptions and can change quickly with new information.

Asset Volatility

The asset volatility's significant negative relationship with the debt-to-market ratio suggests a market-driven response to the firms within the shipping industry. According to the tradeoff theory, the negative coefficient indicates that the industry may be a riskier investment as the uncertainty of returns increases due to higher asset volatility. In line with this theory, the market recalibrates the firm's debt capacity. These results are consistent with the tradeoff theory and align with the findings of Frank and Goyal (2009) and Drobetz et al. (2013).

The results contradict the pecking order theory's suggestion that firms with volatile assets prefer debt over equity to avoid the signaling concerns of equity issuance. The shipping industry may face challenges securing debt due to lenders' risk aversion or may choose to limit their debt levels to avoid increased distress costs due to unpredictable cash flows. We can explain the significant impact of asset volatility on debt-to-market ratio from the insights of Leland (1994) and Goldstein et al. (2001). Moreover, the Leland model, which accounts for the tradeoff between tax shields and bankruptcy costs, suggests that increasing asset volatility raises the firm's value at default.

The specificity of the asset volatility's significance to the debt-to-market ratio underscores the market's capacity to incorporate risk evaluations into valuations rapidly. Market valuations are forward-looking and reflect contemporary investor sentiments and expectations, which might explain their sensitivity to the fluctuating risk profile of the shipping firms' assets. On the other hand, the book values are based on historical data and are less affected by current market fluctuations.

Operational Debt

The coefficients for operational debt are relatively small and primarily insignificant, indicating a weak relationship with both debt ratios. However, operational debt is significant at the 10% level on the debt-to-market ratio, suggesting some evidence to support a relationship between the operational debt and debt-market ratio. The potential relationship can be explained by the fact that firms with higher operational risk might exhibit slightly higher market-based leverage to balance their overall risk profile, consistent with the tradeoff theory and Drobetz et al. (2013). Conversely, the pecking order theory suggests that firms prefer internal funding over new equity due to the perceived riskiness. The evidence for the pecking order theory would be more robust if operational debt consistently predicted higher market leverage.

Dividends

The regression results do not show a significant relationship between dividend payments and debt ratios for shipping companies. The dividend coefficients are close to zero and do not support a clear positive or negative relationship. This finding does not align with the negative relationship between dividend payments and debt ratios suggested by empirical studies such as Frank and Goyal (2009) and Drobetz et al. (2013). Instead, the results indicate considerable uncertainty around the impact of dividend payments on the leverage of shipping companies, as reflected by the insignificance of the coefficients.

9.2 Results including macroeconomic variables

Considering the demand for the industry's services, the hypothesis that macroeconomic conditions affect companies' ability to raise capital is fundamental for shipping. According to Stopford (2009), macroeconomic conditions primarily influence this demand.

By Drobetz et al. (2013) and Erel et al. (2012), we analyze macroeconomic factors' impact on the debt ratio without including time-specific effects. However, we will still control for firm-specific effects using FE regression. Table 9.4 illustrates the impact of having macroeconomic variables, and we will discuss the results further.

Table 9.4: Regression results including macroeconomic variables

	Debt to Assets (Book)	**Debt to Assets (Book) w/Macro**	**Debt to Assets (Market)**	**Debt to Assets (Market) w/Macro**
Lagged Book	0.607***	0.609***		
	(0.022)	(0.022)		
Lagged Market			0.558***	0.571***
			(0.023)	(0.023)
Fixed Assets	0.238***	0.220***	0.173***	0.144***
	(0.023)	(0.023)	(0.027)	(0.027)
Profitability	-0.341***	-0.287***	-0.451***	-0.366***
	(0.036)	(0.039)	(0.045)	(0.047)
Firm Size	0.0004	0.001	0.044***	0.044***
	(0.004)	(0.004)	(0.005)	(0.005)
Asset Volatility	-0.006	-0.005	-0.028***	-0.027***
	(0.007)	(0.007)	(0.009)	(0.008)
Operational Debt	-0.002	-0.002	0.020*	0.018
	(0.009)	(0.009)	(0.012)	(0.011)
Dividends	0.001	0.0001	0.005	0.003
	(0.007)	(0.007)	(0.009)	(0.009)
Freight Rates		-0.020		-0.033**
		(0.013)		(0.016)
Oil Price		-0.024*		0.0001
		(0.015)		(0.017)
World Stock Index		0.006		-0.105***
		(0.024)		(0.029)
US Dollar Index		-0.010		-0.047
		(0.077)		(0.092)
Yield Curve		0.053		-0.124
		(0.418)		(0.499)
G7 Inflation		-0.100		-0.763**
		(0.266)		(0.319)
Company Spesific Effects	No	No	Yes	Yes
Time Spesific Effects	No	Yes	No	Yes
Observations	1,346	1,346	1,328	1,328
R^2	0.523	0.534	0.514	0.538

Note: The table displays the regression results that include macroeconomic variables. Columns 1 and 3 show the FE with firm-specific variables for the Book Debt Ratio and debt-to-market ratio, respectively. These columns correspond to the data in column 3 of Tables 9.2 and 9.3. Columns 2 and 4 show the FE when incorporating macroeconomic variables for the debt-to-book ratio and debt-to-market ratio, respectively. The R^2 values denote the models' explanatory power. Parentheses provide robust standard errors for each coefficient. Source: Compustat.
* Statistically significant at the 10% level
** Statistically significant at the 5% level
*** Statistically significant at the 1% level

Freight Rates

The freight rates show significance and a negative coefficient. This suggests that higher freight rates typically indicate stronger demand and better earnings in the industry. Hence, the firms may rely less on debt. According to the tradeoff theory, firms may use the excess cash to reduce debt as earnings increase with higher freight rates. The pecking order theory suggests that a negative coefficient means that the shipping industry leans towards using excess cash and internal funds to finance operations and investments, reducing the necessity of issuing new debt.

Brent Crude Oil Price

Fluctuations in the oil prices could affect the shipping industry. However, we show no significance for the debt-to-market ratios to oil prices. On the contrary, the oil price shows significance when looking at the debt-to-book value of assets. According to the tradeoff theory, if higher oil prices increase operational costs and thus reduce profitability, the firms might lower their debt to lower the risk of default. Hence, the negativity of the oil price in the book setting, to some degree, increases the debt-to-book value ratio as the oil prices fall.

MSCI World Global Index

The MSCI global index appears non-significant for the book values. However, it shows significance with the market values. This suggests that an increase in the global index, that is, higher valuations in the market, is associated with a decrease in the debt-to-market value of assets. In line with the tradeoff theory, a negative and significant relationship with the debt-to-market ratio indicates that as stock markets perform well, firms may prefer equity financing over debt. However, the correlation matrix, as seen in Table D.2, shows that the inflation in the G7 countries is negatively correlated with the global index. That suggests that during periods of economic optimism, as reflected by a rising global index, the shipping companies are likely to leverage favorable market conditions to issue equity, thus keeping their debt-to-market ratios lower. High inflation, which typically signals higher interest rates and economic uncertainty, may also lead the shipping industry to reduce its reliance on debt due to the higher costs of borrowing and the unpredictability of future cash flows.

G7 Inflation

High inflation can erode the value of internal cash flows and push towards external financing. The negative relation with the debt-to-market ratio may indicate a preference for debt over equity during high inflation periods. However, the significant negative relationship suggests that inflation may drive costs too high, making debt less attractive than equity, or that inflation uncertainty makes debt financing riskier.

Yield Curve

The yield curve is not significant with the debt ratios within this study. This suggests that the term structure of interest rates, as depicted by the yield curve, might not be a factor in the shipping industry's capital structure decisions. Theoretically, a steeper yield curve indicating higher long-term rates could affect the cost of capital. However, no evidence supports this relationship in this specific analysis of the shipping industry and chosen variables.

The U.S. Dollar Index

The lack of significance with the dollar index suggests that exchange rate risks or the broader implications of currency value fluctuations are not primary considerations in the shipping firms' leverage decisions. Intuitively, the firms might be employing strategies to hedge against currency risk, reducing the direct impact of dollar value fluctuations on their capital structure.

10 Conclusion

This thesis investigates the optimal capital structure for a shipping company using the frameworks proposed by Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014). The focus is on the determinants influencing capital structure, particularly in static and dynamic models. In the static model, the default barrier and coupon rate are essential, while the dynamic model also considers an upper boundary for debt recall. The study further explores how asset volatility influences these models and traces the capital structure trends in the shipping industry over the sample period.

The research find a link between a company's asset volatility and debt-to-market ratio. Greater asset volatility reduces leverage for shipping companies, indicating the market's response to risk. This highlights the significance of asset volatility in shaping capital structure decisions within the shipping industry, as shown in both static and dynamic model analyses. Our study suggests an optimal leverage of 47% when the static model is applied under the assumption of a fixed 30% bankruptcy cost. However, when additional costs, such as call premiums and debt issuance costs, are incorporated into the dynamic model, the optimal leverage ratio decreases to 43%. Moreover, the analysis indicates that the dynamic models show lower optimal leverage than the static model over the sample period between 2010 and 2022. However, these findings differ from the observed data on leverage, which was drawn from a sample of 167 shipping companies.

Our supplementary analysis suggests several determinants influencing the debt-to-market ratio of shipping companies. The debt-to-market ratio shows sensitivity to current market conditions and its ability to quickly reflect changes in the industry's capital structure. The determinants include fixed assets, profitability, firm size, asset volatility, freight rates, the global stock index, and inflation in the G7 countries. The asset volatility determinant suggests increased investment risk due to the uncertainty of returns. This finding emphasizes the market's response in adjusting valuations to reflect risk assessments, contrasting with book values that rely on historical data and are less responsive to market changes.

10.1 Future Research

The study lays the ground work for further exploration in this domain. Future research could look into a deeper understanding of the external shocks' affection to asset volatility and debt renegotiations. Furthermore, to know more for sure that the models of Leland (1994), Goldstein et al. (2001), and Christensen et al. (2014), work in the shipping industry, the exact determination of bankruptcy costs should be found.

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Appendices

A Company-specific variables

Table A.1: Company-specific variables with describing datacodes and formulas

Company variables	Definition	Data source	Datacode
Debt-to-book value of assets	Ratio of long-term debt, short-term debt, and long-term debt (hereafter "Total debt") with maturity within one year to total book assets	Compustat	(dltt+dlc)/at
Debt-to-market value of assets	Ratio of total debt to total market value of assets	Compustat	(dltt+dlc)/ (mcap+dltt+dlc)
Fixed Assets	Ratio of property, plant & equipment to total book assets	Compustat	ppent/at
Profitability	Ratio of gross profit before D&A to total book assets	Compustat	oibdp/at
Firm Size	The natural logarithm of total assets	Compustat	log(at)
Equity Volatility	Annualized stock price returns	Compustat	(std.dev(log(r)) *(252)^0.5
Dividend	Dummy variable indicator if a firm paid a dividend in given year	Compustat	= 1 if dv >0 year t = 0 if dv = 0 year t

The datacodes are shortcuts for items in the balance sheet. Source: Compustat.

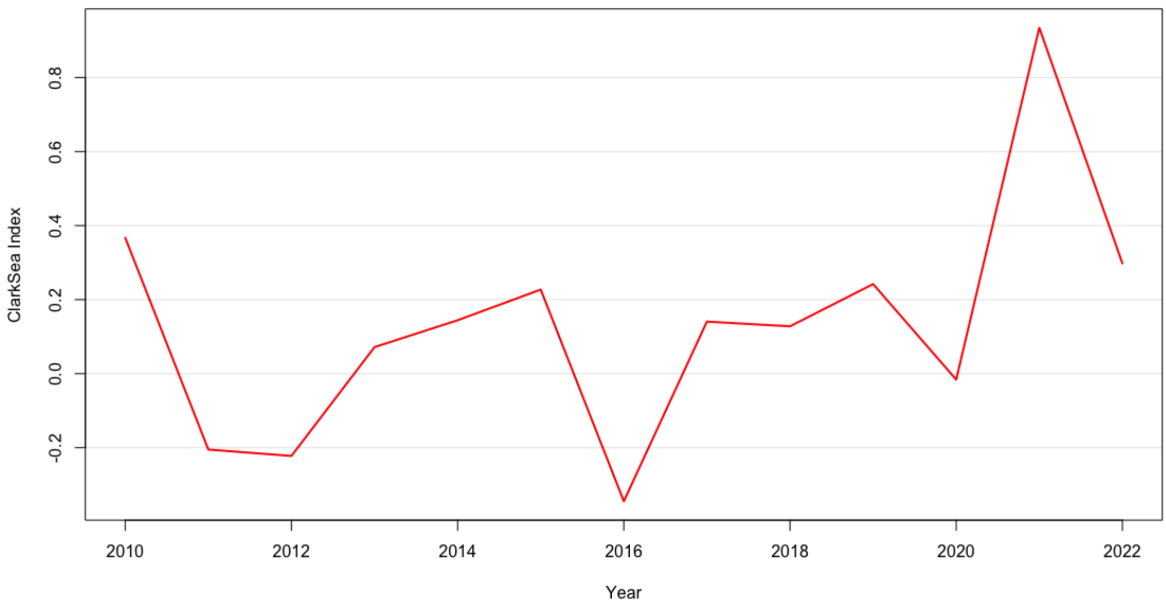
Table A.2: Descriptive Statistics of the model parameters

	Number of Obs	Mean	Std Dev	Median	25%	75%	Min	Max
EBIT	1589	55.233	42.682	43.324	10.234	61.465	1.321	1115.517
Asset Volatility	1589	0.458	0.281	0.361	0.239	0.536	0.073	1.515
$\theta_e ff$	1589	0.409	0.201	0.399	0.350	0.536	0.04	0.892
μ	1589	-0.379	0.126	-0.287	-0.500	-0.127	-6.512	0.782

Note: Aggregated means of all observations from the sample companies. These are the variables within the models that require raw data. Source: Compustat.

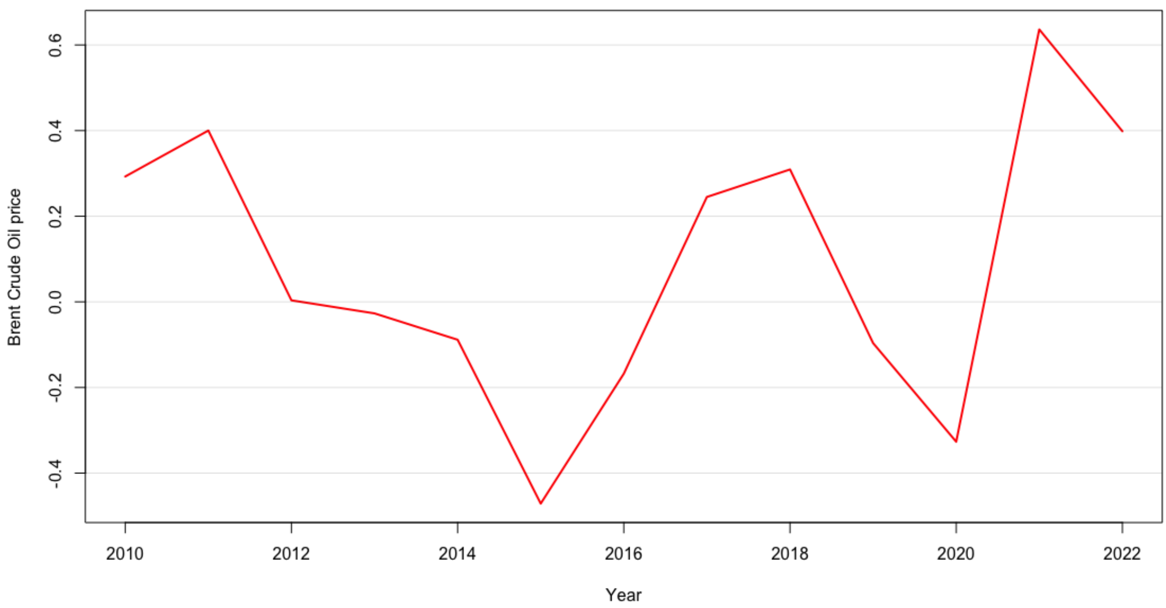
B Macroeconomic Variables

Figure B.1: ClarkSea Index



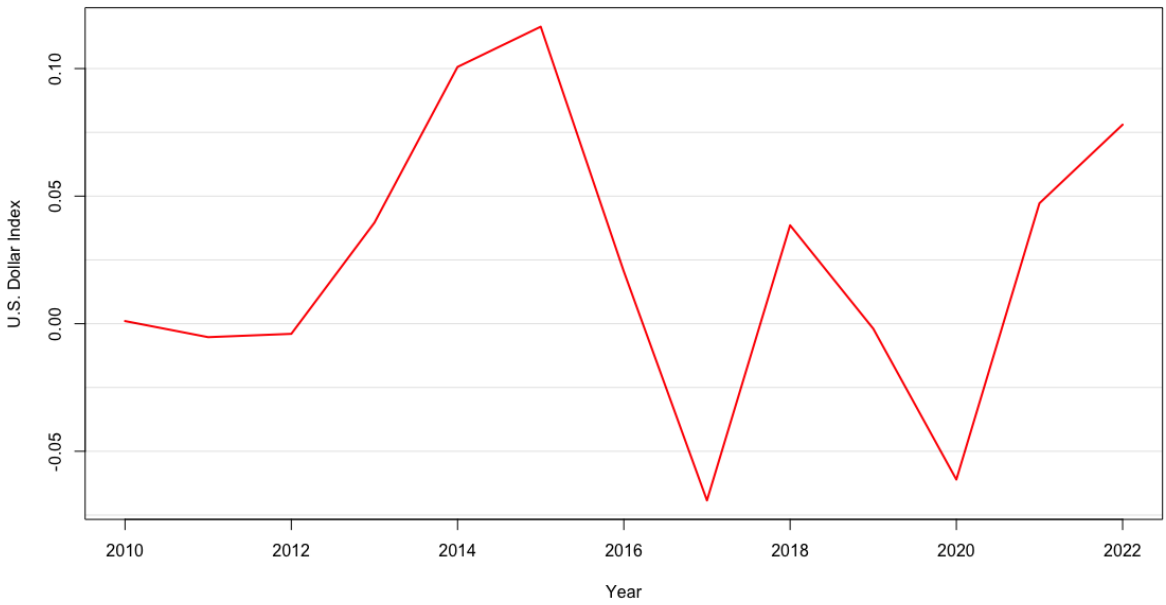
Note: Year on year change in shipping freight rates. Source: Clarksons.

Figure B.2: Brent Crude Oil Price



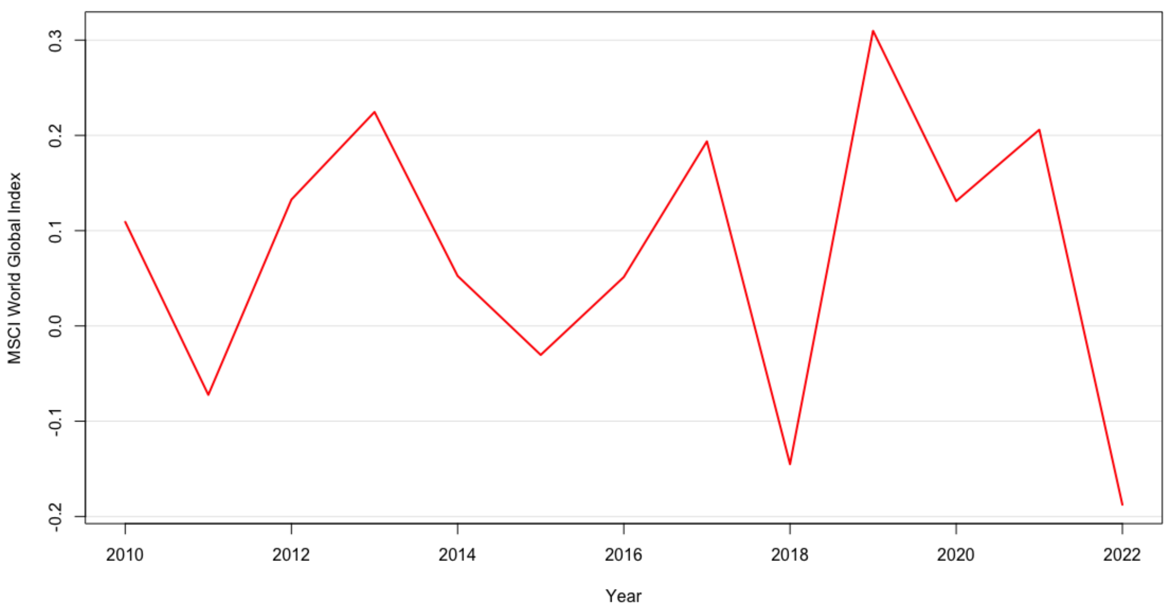
Note: Year on year change in the Brent crude oil price. Soruce: Clarksons.

Figure B.3: U.S. Dollar Index



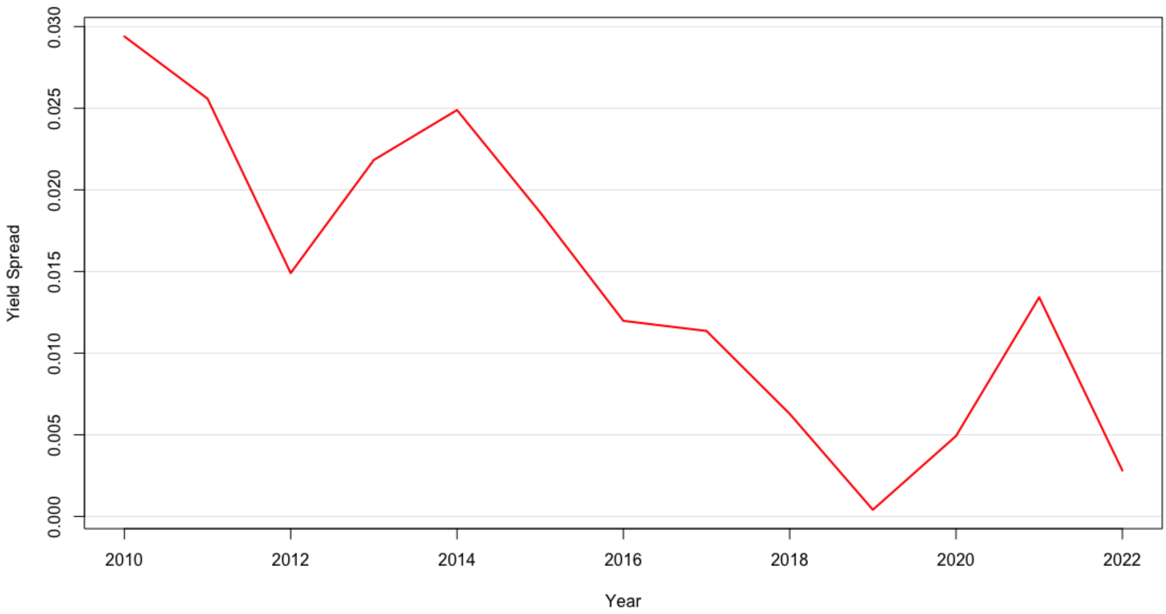
Note: Year on year change in the U.S. Dollar Index. Source: Refinitiv Eikon.

Figure B.4: MSCI World Global Index



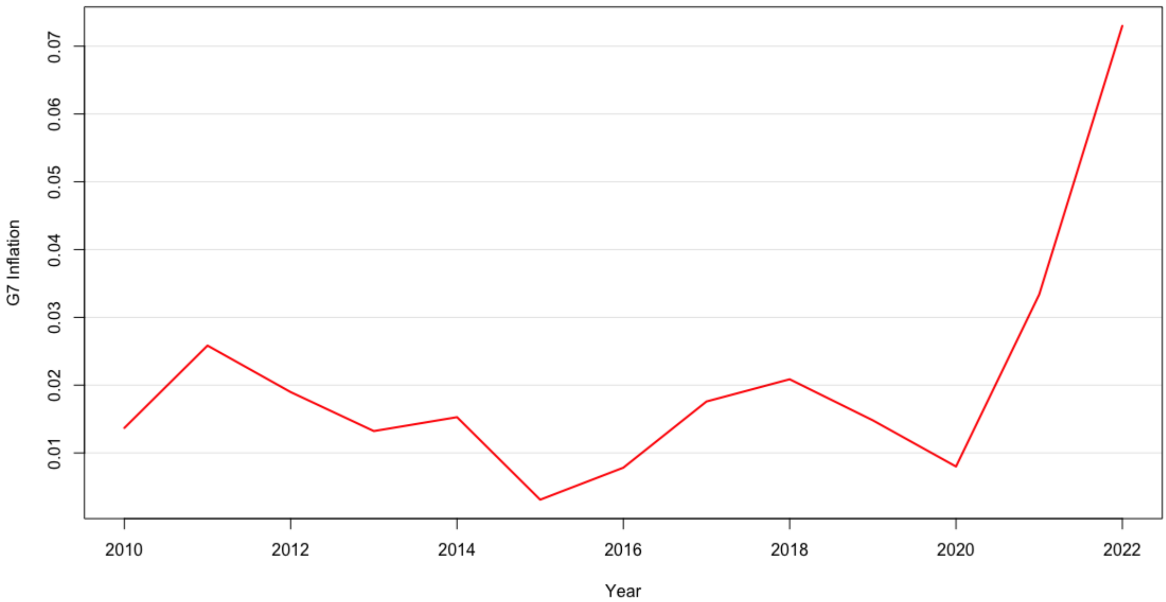
Note: Year on year change in the MSCI World Global Index. Source: Refinitiv Eikon.

Figure B.5: Yield Curve



Note: Term spread yield curve of 10 and 1 year U.S. government treasury bond. Source: Refinitiv Eikon.

Figure B.6: G7 Inflation



Note: Year on year change in the inflation of the G7 countries. Source: Refinitiv Eikon.

C Methodology

The purpose of this section is to describe the quantitative method used for the analysis. The data used in the study are both time series and cross-sectional data. The dataset contains values for companies over several years. Ultimately, panel data can be seen as combining the two data types. By doing a panel study, we can control for specific unobserved characteristics of companies and understand their development over time.

C.1 Correlation Analysis

Correlation analysis is a statistical method used to evaluate the strength and direction of the linear relationship between two quantitative variables. The analysis provides a correlation coefficient that lies between -1 and 1. If the relationship between x and y gives a correlation coefficient equal to 0, there is no correlation between the two variables. If the coefficient equals 1, there is a perfect correlation between the two; if it is negative 1, the two are perfect negative correlated. If the coefficient is negative, a significant value of x will give a small value in y, and vice versa. Equation C.1 shows how the correlation coefficient between two variables can be derived,

$$\rho(X,Y) = \mathrm{Corr}(X,Y) = \frac{\mathrm{Cov}(X,Y)}{\mathrm{sd}(X)\cdot \mathrm{sd}(Y)} = \frac{\sigma_{xy}}{\sigma_x \cdot \sigma_y}. \tag{C.1}$$

The correlation analysis is not the most suitable method in this context due to its inability to indicate causality. It is not enough to prove positive covariation to establish a causal relationship, as the covariation might come from other underlying variables. However, the correlation analysis provides a brief insight into what to expect from a more comprehensive regression analysis and can determine if multicollinearity exists in the dataset.

C.2 Regression Analysis

Regression analysis is an appropriate method to uncover causality. Regression analyses will be conducted to explore how different factors influence the capital structure of shipping companies. One can perform simple or multiple regressions depending on the number of variables considered. The simplest form of OLS is a simple model with only one explanatory variable, demostrated as

$$y = \beta_0 + \beta_1 x + \varepsilon. \tag{C.2}$$

Here, y is the dependent variable, and x is the independent variable. β_0 represents the intercept, β_1 is the coefficient of the independent variable x, and ε is the residual. Unlike the simple model, a multiple regression can explain a dependent variable based on multiple independent variables. This allows for a more comprehensive understanding of the variance in the predicted value with a multiple regression model, given as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon. \tag{C.3}$$

The factors have similar meanings as in the simple model. However, the coefficients β_1, …, β_n refer to each explanatory variable's isolated effects on the dependent variable y. An isolated effect means the coefficient indicates the effect of the explanatory variable on y while keeping other independent variables constant. The coefficient is estimated by minimizing the error between the predicted value $\hat{y}$ and the actual y as the following equation indicates

$$\sum (y_i - \beta_0 - \beta_1 x_1 - \beta_2 x_2 - \cdots - \beta_n x_n)^2. \tag{C.4}$$

This formula sums the squared errors, measuring the deviation between observed data and the estimated model (Woolridge, 2021).

In multiple regressions, it is also possible to differentiate among various factors by adding a dummy variable. Such a variable shows 1 if true and 0 if false. As in the dataset, whether a company pays out a dividend one year, that year has the dummy variable 1. The coefficient of the dummy variable checks and might indicate if a dividend payment significantly affects the debt ratios. The model, including a dummy variable, is

$$y = \beta_0 + \beta_1 \times \text{dummy} + \ldots + \beta_n x_n + \varepsilon. \tag{C.5}$$

D Estimation Methods

Given the complex composition of panel data, using equivalently complex estimation methods is essential. Specifically, this study's panel data analysis will use three prevalent regression estimation methods: Pooled Ordinary Least Squares (pooled OLS), Fixed Effects (FE), and Random Effects (RE).

D.1 Assumptions for OLS

Issues that commonly arise in OLS include multicollinearity, normality, linearity, homoscedasticity, and autocorrelation. Additionally, outliers and the number of independent variables can pose challenges. Further exploration of these prerequisites is provided below.

D.1.1 Linearity

A key assumption is that the dependent variable, y, should be a linear function of the independent variables. If the linearity criterion is not met, the model will still try to estimate a linear relationship. This can lead to unreliable outcomes as the coefficients for the explanatory variables may be skewed. To address this, one can transform the variables. This transformation can be applied to independent and dependent variables, such as converting them into a logarithmic form, done with the firm size variable.

D.1.2 Normality

Normality indicates that the residuals must follow a normal distribution with a mean $\mu = 0$ and variance (sigma squared). However, this does not apply to other explanatory variables. If the residuals are not normally distributed, determining significance levels becomes problematic. Even so, perfect normality is not crucial for unbiased estimates, and minor deviations from normality can still produce reliable results. To test for normality, it is possible to examine the measurements of skewness and kurtosis. Skewness measures if the distribution is symmetric around the mean, while kurtosis assesses the distribution's tails. A normal probability plot can also be used to see if residuals align with a straight line. Alternatively, one can employ the Kernel density estimate for comparison with a normal curve or use the Shapiro-Wilk test for normality.

D.1.3 Homoskedasticity

Another critical assumption for valid multiple regression is the consistency of residual variance, irrespective of the values of the independent variables. This is mathematically given as

$$\mathrm{Var}(\varepsilon|x_1, \ldots, x_n) = \sigma^2. \tag{D.1}$$

The presence of heteroscedasticity means some data points are more likely to be influenced by noise. Such data points then become less reliable. If residuals exhibit varying variance, OLS is not the best estimator, and concluding this model becomes problematic. The Breusch-Pagan test can identify heteroscedasticity. If heteroscedasticity is not linear, White's test can be employed.

D.1.4 Multicollinearity

Multicollinearity arises when two or more independent variables are closely correlated. This refers to an almost perfect correlation, approaching -1 or 1. A mild correlation among independent variables is acceptable. However, when these variables correlate highly, it complicates understating the causal relationships. High correlation introduces noise, leading to unreliable results. The multicollinearity can be checked by examining the correlation matrix or conducting a Variance Inflation Factor (VIF) test.

D.1.5 Autocorrelation

Autocorrelation occurs when the residual, ε, correlates over time, a common issue with time series data. This can result in wrong standard errors, increasing the likelihood of Type 1 errors. The requirement is $\mathrm{Corr}(\varepsilon_i, \varepsilon_j|x) = 0$ for all $i \neq j$. This means the correlation between residuals at different time points should be zero. The Wooldridge-test for autocorrelation can detect autocorrelation in panel data. In the presence of autocorrelation, employing robust standard deviations or introducing omitted variables and modifying variable specifications can mitigate its effects.

D.1.6 Outliers

Outliers are data points or extremals that significantly deviate from other values in the dataset. A limitation of OLS is its sensitivity to these points, as they can distort regression coefficient estimates. This can result in unreliable outcomes, potentially misrepresenting the actual situation. In OLS, the sum of squared residuals is minimized, giving outliers an extreme impact on estimated coefficients. Winzorisation may be used to manage these outliers.

D.1.7 Number of independent variables

More information usually leads to better predictions. However, when data overloads, some algorithms yield weaker results under specific conditions. OLS is particularly susceptible to this issue, especially when too many independent variables are included. Hence, focusing on variables that can predict the dependent variable effectively is crucial. This ensures the regression solution remains unique.

D.2 Tests for selection of regression method

This section will perform explicit tests to validate the OLS assumptions. Additional tests are presented in Appendix E.

D.2.1 Multicollinearity

We employ a correlation matrix and a VIF-test to detect multicollinearity in the dataset. A high correlation between explanatory variables may result in incorrect estimates, leading to misinterpretation of coefficients. The figures in Table D.2 suggest low correlation levels between the variables. Except for lagged book and market correlations, all others are moderately or lower correlated, as detailed in Table D.1. The debt-to-book and debt-to-market ratios will not be included in any regression model, allowing us to disregard their correlation.

Table D.1: Interpreting the Size of a Correlation Coefficient

Size of Coefficient	**Interpretation of Correlation**
0.90 to 1.00 (-.90 to -1.00)	Very high positive (negative)
0.70 to 0.90 (-0.70 to -0.90)	High positive (negative)
0.50 to 0.70 (-0.50 to -0.70)	Moderate positive (negative)
0.30 to 0.50 (-0.30 to -0.50)	Low positive (negative)
.00 to 0.30 (.00 to -0.30)	Negligible

Note: Correlation coefficient strengths from very high to negligible. Source: (Schober et al., 2018).

Table D.2: Correlation Matrix

Variables	Debt to Assets (Book)	Debt to Assets (Market)	Lagged Book	Lagged Market	Fixed Assets	Profitability	Firm Size	Asset Volatility	Operational Debt	Dividends	Freight Rates	Crude Oil Price	World Stock Index	US Dollar Index	Yield Curve	G7 Inflation
Debt to Assets (Book)	1.000															
Debt to Assets (Market)	0.591***	1.000														
Lagged Book	0.888***	0.541***	1.000													
Lagged Market	0.532***	0.918***	0.591***	1.000												
Fixed Assets	0.520***	0.328***	0.470***	0.305***	1.000											
Profitability	-0.117***	-0.162***	-0.022	-0.102***	0.043	1.000										
Firm Size	0.148***	0.389***	0.152***	0.369***	0.048	0.116***	1.000									
Asset Volatility	0.156***	0.105***	0.217***	0.172***	0.002	-0.003	-0.032	1.000								
Operational Debt	-0.122***	-0.097***	-0.139***	-0.132***	-0.056*	0.182***	0.278***	-0.193***	1.000							
Dividends	-0.110***	-0.158***	-0.010	-0.065*	-0.078**	0.213***	-0.018	0.057*	-0.019	1.000						
Freight Rates	-0.095***	-0.104***	-0.017	-0.069*	-0.051*	0.163***	0.007	0.016	0.004	0.479***	1.000					
Crude Oil Price	0.048	0.022	0.053*	0.090***	0.006	-0.085***	0.009	0.016	-0.030	0.208***	-0.162***	1.000				
World Stock Index	-0.053*	-0.029	-0.027	-0.019	-0.024	0.080**	-0.013	-0.032	0.032	0.294***	-0.065**	-0.424***	1.000			
US Dollar Index	0.052*	0.106***	0.029	0.091***	0.031	-0.122***	0.052*	-0.076**	0.076**	-0.079**	0.058*	-0.038	0.249***	1.000		
Yield Curve	-0.136***	-0.156***	-0.070**	-0.132***	-0.067**	0.279***	-0.024	0.035	0.011	0.339***	0.662***	-0.439***	0.218***	-0.285***	1.000	
G7 Inflation	-0.208***	0.060*	-0.176***	-0.036	-0.401***	0.006	0.035	0.003	0.026	-0.029	0.027	-0.009	-0.027	0.052*	-0.006	1.000

Note: *** - Statistical significance at 1% level, ** - Statistical significance at 5% level, * - Statistical significance at 10% level.
The table presents the pairwise correlation coefficients for the debt-to-book and debt-to-market ratios with company-specific and macroeconomic variables. The observations are adjusted using the winsorization method, described in Section 5.3 and Table 5.1. Source: Compustat.

D.2.2 VIF-test

A limitation of correlation coefficients is their reliance on bivariate analysis, which fails to capture multivariate relationships. A variable might be a linear function of several variables included in the model, which should be examined (Harrel, 2013). Therefore, a VIF-test, capable of detecting multivariate relationships, enhances the analysis. VIF values below 10 suggest the absence of multicollinearity (Williams, 2015). None of the VIF values in Table D.3 exceed this threshold, with the average VIF value being only 2.17, confirming the assumption of no multicollinearity.

Table D.3: VIF-test including macroeconomic factors

Variable	**VIF**	$\frac{1}{\textbf{VIF}}$
Lagged Book	1.89	0.53
Lagged Market	1.90	0.53
Fixed Assets	1.44	0.69
Profitability	1.23	0.81
Firm Size	1.36	0.73
Asset Volatility	1.13	0.89
Operational Debt	1.18	0.85
Dividends	1.24	0.81
Freight Rates	3.28	0.31
Crude Oil Price	4.04	0.25
World Stock Index	2.45	0.41
US Dollar Index	3.48	0.29
Yield Curve	2.14	0.47
G7 Inflation	3.63	0.28
Mean VIF	**2.17**	

Note: The VIF-test results suggesting a moderate correlation.
Source: Compustat.

D.2.3 F-test

Table D.4 illustrates the F-test results using ANOVA[13] with four different models analyzing the relationship between debt-to-book value and debt-to-market value of assets, two of which include macroeconomic variables. The results suggest that models incorporating macroeconomic variables capture more data variability as these exhibit a lower RSS[14], suggesting a better fit to the data.

[13]Analysis of variance (ANOVA) is a statistical method used to compare the fits of different models.
[14]Residual Sum of Squares (RSS) is deviations predicted from actual empirical data values.

The p-values with the F-test results, all below the 1% threshold, suggest rejecting the null hypothesis and indicating significant heterogeneity within the dataset. These results support the preference for the fixed effect model over the pooled OLS, as the fixed effect model accounts for individual heterogeneity and provides more accurate estimations for the given dataset.

Table D.4: F-test by using ANOVA

Model	RSS	Difference in Df	F-Value	P-Value
Debt to Assets (Book)	10.95	-	-	-
Debt to Assets (Book) w/Macro	10.63	6	6.64	0.000
Debt to Assets (Market)	16.26	-	-	-
Debt to Assets (Market) w/Macro	15.31	6	13.51	0.000

Note: F-test results suggest heterogeneity due to low p-values. Including macroeconomic variables captures more variability with lower RSS. Source: Compustat.

D.2.4 Breuch-Pagan Lagrange Multiplier (LM)

A high $chi2$-value indicates the presence of heteroskedasticity in the dataset. The data reject the null hypothesis of homoskedasticity at all statistical levels, as evidenced by p-values less than 1%. Consequently, Pooled OLS can no longer be considered the BLUE[15]; thus, we should employ Fixed Effects or Random Effects to manage the effects of heteroskedasticity.

Table D.5: Breusch-Pagan LM-test

Model	Chi2	P-Value
Debt to Assets (Book)	108.42	0.000
Debt to Assets (Book) w/Macro	109.28	0.000
Debt to Assets (Market)	60.42	0.000
Debt to Assets (Market) w/Macro	61.64	0.000

Note: The Breusch-Pagan findings indicate heteroskedasticity in the data due to low p-values. Source: Compustat.

D.2.5 Fixed Effects

The Fixed Effects regression model, hereafter FE, is designed to account for unobservable effects that remain fixed over time. This method differentiates unobserved effects into time-variant and time-invariant variables. By addressing the time-invariant variables, the

[15]Best Linear Unbiased Estimator (BLUE) of $t'\beta$.

FE method offers a more flexible approach than pooled OLS (Woolridge, 2021). The strategy used by the FE model to handle time-invariant effects is elucidated starting with the foundational regression, presented as

$$y_{it} = \beta_0 + \beta_1 x_{1,it} + \ldots + \beta_j x_{j,it} + \alpha_i + u_{it}, \quad t = 1, 2, \ldots, T. \tag{D.2}$$

Where,

$$\begin{aligned} y_{it} &= \text{The dependent variable for a firm } i \text{ at time } t, \\ \beta_0 &= \text{The intercept}, \\ \beta_j &= \text{The parameter associated with } x_{j,it}, \\ x_{j,it} &= \text{The independent variable } j, \\ \alpha_i &= \text{Unobserved time-invariant effects}, \\ u_{it} &= \text{Unobserved time-varying error (Idiosyncratic error)}. \end{aligned}$$

The primary objective of the FE regression model is to eliminate unobserved time-invariant effects. Consequently, this method permits correlation between independent variables and time-invariant errors (Woolridge, 2021). By adopting this approach, the FE regression model addresses potential issues of homoskedasticity in the time-invariant effects. This is achieved by averaging out the terms in equation D.2 to derive equation D.3, and then subtracting equation D.3 from equation D.2, leading to equations D.4 and D.5. The omission of unobserved time-invariant effects (α_i) is evident in these resultant equations.

$$\bar{y}_{it} = \beta_0 + \beta_1 \bar{x}_{ijt} + \alpha_j + \bar{u}_{it}, \quad t = 1, 2, ..., T; \quad i = 1, 2, ...n, \tag{D.3}$$

$$\begin{aligned} (y_{it} - \bar{y}_{it}) = \beta_0 - \bar{\beta}_0 + \beta_1(x_{1,it} - \bar{x}_{1,it}) + \cdots + \beta_i(x_{j,it} - \bar{x}_{j,it}) \\ + (\alpha_i - \bar{\alpha}_i) + (u_{it} - \bar{u}_{it}), \quad t = 1, 2, \ldots, T; \quad i = 1, 2, \ldots, n, \end{aligned} \tag{D.4}$$

or

$$\widehat{y_{it}} = \beta_1 \widehat{x_{1,it}} + \cdots + \beta_j \widehat{x_{j,it}} + \widehat{u_{it}}, \quad t = 1, 2, \ldots, T; \quad i = 1, 2, \ldots, n. \tag{D.5}$$

However, the FE regression model has its limitations. Notably, the results from this model can be misleading or unreliable if any underlying assumptions are not met, especially in panel data that spans numerous periods but contains few observations (Woolridge, 2021). Additionally, since the FE model eliminates all time-invariant variables, it cannot incorporate time-invariant independent variables, as they would be completely excluded from the analysis.

D.3 Random Effects

The Random Effects estimation method, hereafter RE, is commonly used with the FE method for panel datasets. The RE method proves particularly beneficial when one assumes that the unobserved individual effects (a_i) are uncorrelated with all explanatory variables. This assumption allows for more efficient estimators by preventing the unnecessary elimination of time-invariant effects.

However, adherence to stricter assumptions is necessary for the RE estimation method to produce reliable results compared to the FE method (Woolridge, 2021). Specifically, the RE method necessitates that the unobserved individual effects (a_i) are uncorrelated with all explanatory variables, given as

$$\text{Cov}(\alpha_i, x_{j,it}) = 0, \quad t = 1, 2, \ldots, T; \quad j = 1, 2, \ldots, k. \tag{D.6}$$

Moreover, the method demands constancy in the expected value and variance of the unobserved individual effects (a_i), given all the independent variables, explicitly detailed in equation

$$E(\alpha_i | x_{j,it}) = \beta_0, \tag{D.7}$$

and,

$$\text{Var}(\alpha_j | x_{j,it}) = \sigma_\alpha^2. \tag{D.8}$$

When these assumptions and those proposed for applying the FE method are met, the RE method is balanced to yield results that stand as both consistent and reliable (Woolridge, 2021).

There are several advantages associated with using the RE estimation method. This method delivers more efficient estimators and smaller residuals than the FE estimation method and accommodates time-invariant independent variables (Woolridge, 2021). However, the FE method can yield biased and unreliable results when certain assumptions are unsatisfied. Moreover, the FE method is prone to producing inconsistent outcomes in scenarios where datasets have limited observations and extensive time intervals. In contrast, the performance characteristics of the RE method in such scenarios remain somewhat ambiguous despite its previous usage in similar circumstances (Woolridge, 2021).

D.3.1 Hausman-test

Based on the expectations regarding the data sample presented in Section D.2, we reject the aggregated OLS in favor of FE and RE. However, the preference between these two depends on the Hausman-test. Based on the presented $prob > chi$-value, we can reject the null hypothesis and RE. It turns out that RE may not be suitable for our data across all the Hausman-tests shown in the following tables. In a statistical context, the error term correlates with the explanatory variables, and we should use FE since RE provides inconsistent estimates.

Table D.6: Hausman-test Debt to Assets (Book) including macroeconomic variables

	Coeffcients			
	(b)	**(B)**	**(b-B)**	**sqrt(diag(V_b-V_B))**
	FE	**RE**	**Difference**	**Standard Error**
Lagged Book	0,609	0,850	-0,241	0,059
Fixed Assets	0,220	0,115	0,105	0,055
Profitability	-0,287	-0,238	-0,048	0,087
Firm Size	0,001	0,001	0,000	0,008
Asset Volatility	-0,005	-0,006	0,001	0,015
Operational Debt	-0,002	-0,001	-0,001	0,014
Dividends	0,000	0,000	0,000	0,010
Freight Rates	-0,020	-0,029	0,009	0,016
Crude Oil Price	-0,024	-0,027	0,002	0,020
World Stock Index	0,006	-0,003	0,009	0,032
US Dollar Index	-0,010	-0,023	0,013	0,118
Yield Curve	0,053	0,292	-0,239	0,689
G7 Inflation	-0,100	-0,048	-0,052	0,330

b = Consistent under the null hypothesis (H0) and alternative hypothesis (H1)
B = Inconsistent under the alternative hypothesis (H1), efficient under the null hypothesis (H0)
H0 = The difference between the coefficients is not systematic

chi2(13) = 1184.79
Prob > chi2 = 0

Note: The Hausman-test results favor the use of FE over RE, indicating that FE provides more consistent estimates for this data. Source: Compustat.

Table D.7: Hausman-test Debt to Assets (Book)

	Coeffcients			
	(b) **FE**	**(B)** **RE**	**(b-B)** **Difference**	**sqrt(diag(V_b-V_B))** **Standard Error**
Lagged Book	0,607	0,849	-0,242	0,061
Fixed Assets	0,238	0,125	0,113	0,055
Profitability	-0,341	-0,300	-0,041	0,077
Firm Size	0,000	0,001	-0,001	0,008
Asset Volatility	-0,006	-0,008	0,001	0,015
Operational Debt	0,001	0,002	-0,001	0,010
Dividends	-0,002	0,001	-0,003	0,014

b = Consistent under the null hypothesis (H0) and alternative hypothesis (H1)
B = Inconsistent under the alternative hypothesis (H1), efficient under the null hypothesis (H0)
H0 = The difference between the coefficients is not systematic

chi2(13) = 325.7
Prob > chi2 = 0

Note: The Hausman-test results favor the use of FE over RE, indicating that FE provides more consistent estimates for this data. Source: Compustat.

Table D.8: Hausman-test Debt to Assets (Market)

	Coeffcients			
	(b) **FE**	**(B)** **RE**	**(b-B)** **Difference**	**sqrt(diag(V_b-V_B))** **Standard Error**
Lagged Market	0,558	0,888	-0,329	0,046
Fixed Assets	0,173	0,095	0,079	0,040
Profitability	-0,451	-0,324	-0,127	0,088
Firm Size	0,044	0,005	0,038	0,011
Asset Volatility	-0,028	-0,034	0,006	0,017
Operational Debt	0,005	0,001	0,004	0,012
Dividends	0,020	0,006	0,014	0,018

b = Consistent under the null hypothesis (H0) and alternative hypothesis (H1)
B = Inconsistent under the alternative hypothesis (H1), efficient under the null hypothesis (H0)
H0 = The difference between the coefficients is not systematic

chi2(13) = 595.63
Prob > chi2 = 0

Note: The Hausman-test results favor the use of FE over RE, indicating that FE provides more consistent estimates for this data. Source: Compustat.

Table D.9: Hausman-test Debt to Assets (Market) including macroeconomic variables

	Coeffcients			
	(b) FE	(B) RE	(b-B) Difference	sqrt(diag(V_b-V_B)) Standard Error
Lagged Market	0,571	0,891	-0,320	0,045
Fixed Assets	0,144	0,081	0,063	0,038
Profitability	-0,366	-0,26	-0,106	0,092
Firm Size	0,044	0,005	0,039	0,011
Asset Volatility	-0,027	-0,033	0,006	0,017
Operational Debt	0,018	0,002	0,017	0,018
Dividends	0,003	-0,002	0,005	0,012
Freight Rates	-0,033	-0,036	0,003	0,021
Crude Oil Price	0,000	-0,002	0,002	0,022
World Stock Index	-0,105	-0,150	0,045	0,040
US Dollar Index	-0,047	-0,111	0,064	0,130
Yield Curve	-0,124	0,667	-0,791	0,711
G7 Inflation	-0,763	-0,357	-0,406	0,398

b = Consistent under the null hypothesis (H0) and alternative hypothesis (H1)
B = Inconsistent under the alternative hypothesis (H1), efficient under the null hypothesis (H0)
H0 = The difference between the coefficients is not systematic

chi2(13) = 324.3
Prob > chi2 = 0

Note: The Hausman-test results favor the use of FE over RE, indicating that FE provides more consistent estimates for this data. Source: Compustat.

D.3.2 Wooldridge-test

The FE model is the preferred choice based on the test results reviewed below. FE yields consistent estimates. However, the presence of autocorrelation in the error terms over time could still lead to incorrect conclusions. If Wooldridge's test null hypothesis is valid, it would indicate an absence of autocorrelation. However, the p-values in Table D.10 suggest rejecting the null hypothesis. It is essential to account for autocorrelation to prevent misleading significant levels and inaccurate conclusions.

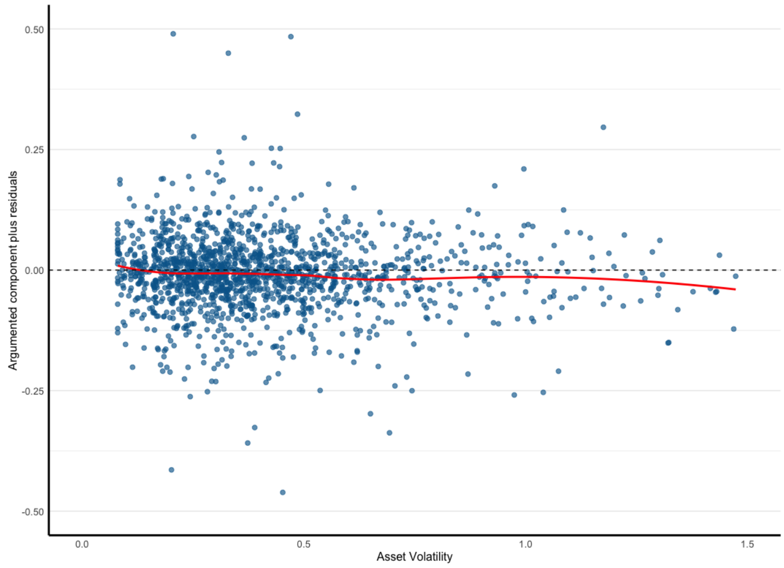
Table D.10: Wooldridge-test for serial correlation in FE panels

Model	**F(1, 1170)**	**P-Value**
Debt to Assets (Book)	6.59	0.010
Debt to Assets (Book) w/Macro	6.46	0.011
Debt to Assets (Market)	24.23	0.000
Debt to Assets (Market) w/Macro	23.42	0.000

Note: The Wooldridge-test for serial correlation in FE models indicates significant serial correlation in all variations of the debt-to-asset ratios. Source: Compustat.

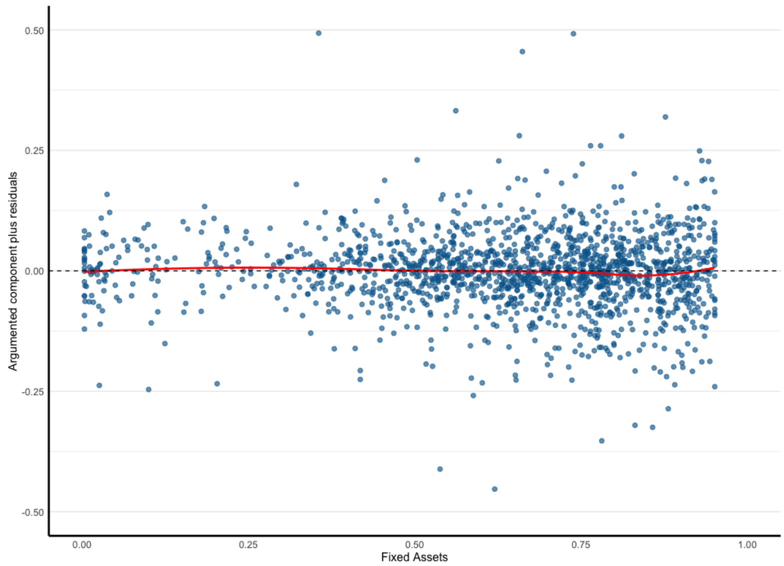
E Additional Tests for OLS Assumptions

Figure E.1: Linearity - Asset volatility



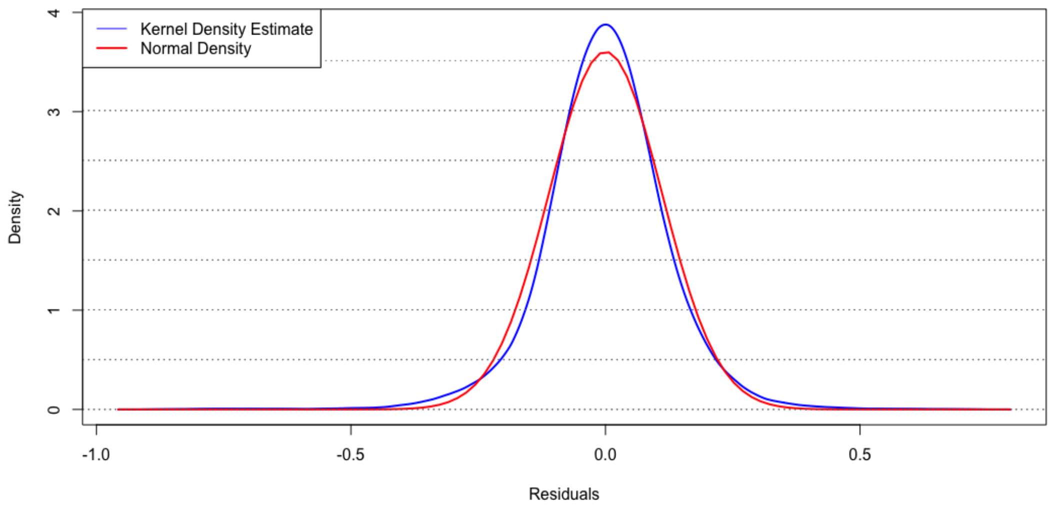
Note: The ACPR plot shows the relationship between the debt-to-book ratio and asset volatility. The red line represents this relationship, while each dot represents the residual of an individual observation. The dashed line shows the linear relationship between the two variables. In this model, the red line closely aligns with the dashed black line, indicating only minor variations. This consistency leads us to conclude that the linear relationship assumption holds. Source: Compustat.

Figure E.2: Linearity - Fixed Assets



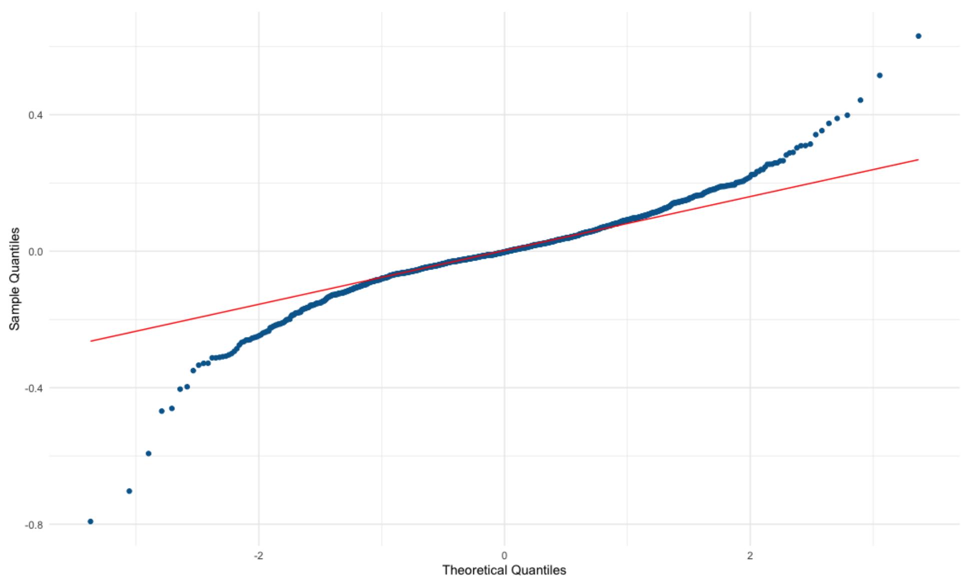
Note: The ACPR plot shows the relationship between the debt-to-book ratio and fixed assets. The red line represents this relationship, while each dot represents the residual of an individual observation. The dashed line shows the linear relationship between the two variables. In this model, the red line closely aligns with the dashed black line, indicating only minor variations. This consistency leads us to conclude that the linear relationship assumption holds. We have tested for the other variables, all suggesting linearity. Source: Compustat.

Figure E.3: Kernel-Density Estimate



Note: In the presented Kernel Density Estimate, the blue line represents the actual distribution of the residuals, as estimated from our dataset. In contrast, the red line illustrates the expected normal distribution for comparison. The proximity of the two lines suggests that the residuals of our regression model closely approximate a normal distribution, verifying the normality assumption essential for valid OLS regression analysis. This observation is consistent across models with different dependent variables, suggesting robustness in the normality of residuals within our dataset. Source: Compustat.

Figure E.4: QQ-plot



Note: The Q-Q plot indicates some deviations from normality, particularly in the tails, suggesting possible outliers or heavy tails. Source: Compustat.

Table E.1: Shapiro-Wilk test

Model	Statistic	P-vlaue
Debt to Assets (Book)	0.8541	0.000
Debt to Assets (Market)	0.9369	0.000

Note: With large samples and even small deviations from normality, the results can show a significant p-value. P-values less or equal to 0.05 suggests that we reject the hypothesis of normality. Failing this test allows us to state with 95% confidence the data does not fit the normal distribution. Our presence of outliers may have affected the Shapiro-Wilk test results. Source: Compustat.