Navigating Basel IV and Environmental Regulations: Strategic Approaches to Shipping Finance

By

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Declaration

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Abstract

This dissertation consists of three essays on shipping finance, focusing on the regulatory impacts of environmental changes in banking and maritime sectors. Under Basel IV, the Loss Given Default (LGD) input floor requires higher capital reserves for loans with substantial collateral. The analysis, using ANOVA, OLS regression, and *T*-tests, suggests that the LGD floor is not overly restrictive but may impose excessive capital demands on low-leverage portfolios. To optimize capital allocation, banks should explore alternatives like export credit agency financing, collateral insurance, and loan portfolio securitization.

In additoin to banking regulations, the environmental regulations in shipping have stricter, which have impacted on shipping finance. Therefore, the research also examines the potential "green premium" for environmentally-friendly vessels, particularly those with LNG or methanol dual-fuel engines. However, findings indicate insufficient evidence for a green premium or notable asset volatility differences between green and conventional vessels. Despite this, environmental regulations like the EU Emissions Trading System (ETS) could enhance the value of green vessels in the future. Furthermore, the study assesses the financial effects of greenhouse gas (GHG) regulations by bodies such as the International Maritime Organization (IMO) and the EU, which are reshaping ship financing. The research promotes financial strategies, including retrofitting investments and CO_2 pricing evaluation under the EU ETS, to advance sustainable shipping initiatives.

This research underscores the necessity for adaptable financial strategies that balance regulatory adherence, capital efficiency, and environmental sustainability in the maritime sector.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

The historical trajectory of maritime financing is profoundly intertwined with global economic phenomena and the evolution of financial markets. Prior to the onset of the Global Financial Crisis (GFC) in 2008, conventional banking institutions predominantly functioned as the principal sources of maritime financing, primarily through loan agreements secured by maritime mortgages. Nevertheless, the GFC represented a pivotal juncture for this sector. The economic recession precipitated a substantial contraction in conventional bank financing, compelling the maritime industry to explore alternative sources of capital. This era witnessed the emergence of private equity funds, which financed over 22 transactions valued at $6.4 billion during the period from 2011 to 2012. Furthermore, the crisis culminated in a precipitous decline in charter rates and vessel valuations, leading to extensive financial losses and insolvencies among maritime enterprises (Kotlubai, 2022). These occurrences prompted traditional financial institutions to impose more stringent financing conditions (Girvin, 2019), highlighting the industry's susceptibility to economic volatility and underscoring the imperative for diversified financial strategies.

In the post-GFC landscape, maritime financing experienced considerable alterations. Financial institutions, now exhibiting heightened risk aversion, instituted more rigorous lending standards to mitigate exposure to prospective economic downturns. This paradigm shift engendered opportunities for alternative financial entities, such as private equity funds, to occupy the void left by conventional lenders. While banks continue to serve as the principal sources of debt financing for maritime activities, the advent of more stringent regulatory frameworks and the dynamic nature of economic conditions have introduced new challenges for both lenders and borrowers alike.

One of the paramount regulatory transformations influencing contemporary maritime financing is the transition from Basel III to Basel III post-crisis reform, known as Basel IV (Nguyen, 2022). Under the Basel IV framework, loans designated for maritime financing are categorized as "object finance" within the realm of specialized lending. The implementation of a Loss Given Default (LGD) input floor under the internal rating-based approach mandates that financial institutions maintain a higher capital reserve to mitigate potential risk exposures. This regulatory modification is anticipated to escalate the cost of borrowing, either through elevated interest margins or diminished engagement by banks in maritime financing endeavors. These developments pose formidable challenges for shipowners, who are significantly reliant on external capital to invest and maintain their fleets. In this framework, Chapter 2 analyzes the requisite transformations in ship financing necessitated by the evolving regulatory landscape.

In conjunction with regulatory transformations, the maritime sector is experiencing escalating demands to mitigate environmental issues. As an industry accountable for 3% of worldwide CO_2 emissions, shipping has attracted considerable examination from both public and private entities. The implementation of more stringent environmental regulations has prompted certain shipowners to allocate resources toward "green vessels," which are furnished with dual-fuel propulsion systems capable of utilizing alternative fuels such as LNG and methanol in conjunction with traditional bunker fuel. Nonetheless, the elevated construction expenses associated with green vessels pose significant financial obstacles for shipowners, many of whom necessitate assistance from financial institutions to facilitate these expenditures.

The financing of green vessels engenders intricate challenges for lenders. Should the sales and purchase market fail to sufficiently reflect the escalated construction expenses of green vessels, their collateral valuation may be diminished. This scenario would compel banks to allocate additional capital to finance such vessels, thereby exacerbating the cost of lending. Conversely, if the market assigns a premium to green vessels, banks may experience a reduction in capital requirements, rendering green financing more appealing. Consequently, comprehending how market participants perceive green vessels is imperative for the development of future financing strategies, a subject that is examined comprehensively in Chapter 3 of this research.

Environmental regulations aimed at mitigating greenhouse gas (GHG) emissions constitute a significant challenge for both shipowners and financiers. In 2018, the International Maritime Organization (IMO) instituted a comprehensive framework to achieve a minimum reduction of GHG emissions by 50% by the year 2050 in comparison to the levels recorded in 2008. This framework experienced an enhancement in 2023, introducing a more ambitious objective of attaining net-zero emissions by 2050, in congruence with the Paris Agreement's objective of limiting global temperature rise to below 1.5°C. Additionally, the European Union has enacted supplementary measures, including the EU Emissions Trading System (ETS) and the FuelEU Maritime regulations. The EU ETS, recognized as one of the preeminent carbon trading frameworks globally, is slated to commence the inclusion of maritime emissions in 2024. Within the parameters of this system, ship operators are mandated to possess emissions allowances corresponding to their CO_2 emissions, encompassing both intra-EU voyages and 50% of emissions arising from journeys between EU and non-EU ports. This regulatory framework is anticipated to escalate operational expenditures for vessels reliant on fossil fuels, thereby fostering incentives to transition towards cleaner technologies or to adopt low-emission fuel alternatives. FuelEU Maritime, which is scheduled to be implemented in 2025, represents another regulatory initiative aimed at diminishing the GHG intensity of fuels utilized in maritime operations. This regulation stipulates increasingly stringent targets every five years, culminating in an overarching aim of achieving a 75% reduction in GHG intensity by the year 2050. This initiative is meticulously crafted to stimulate the demand for alternative marine fuels and to galvanize investments in the requisite infrastructure for sustainable fuel production, distribution, and bunkering within EU ports.

Collectively, these regulations impose both market-driven and direct pressures on ship operators to curtail emissions. Enterprises that successfully attain lower emissions are poised to reap financial advantages, whether through diminished compliance expenses or by capitalizing on the sale of surplus emissions allowances. Nonetheless, the financial burden associated with compliance and investment in cleaner technologies is significantly contingent upon the market price of CO_2, which directly affects the payback duration for such investments. Chapter 4 of this research undertakes a scenario analysis to elucidate optimal investment strategies for ship operators under diverse regulatory and market conditions, inclusive of the computation of breakeven CO_2 prices.

The maritime financing sector currently stands at a pivotal juncture, influenced by the dual dynamics of regulatory transformations and ecological mandates. The introduction of Basel IV's more stringent capital stipulations, coupled with the increasing focus on sustainable financing, poses substantial challenges for both conventional financiers and shipowners. Concurrently, the drive towards decarbonization through frameworks such as the International

Maritime Organization’s net-zero objective, the European Union Emissions Trading System, and FuelEU Maritime accentuates the necessity for inventive financial mechanisms to facilitate sustainable shipping methodologies. Through a comprehensive analysis of these matters, this study seeks to furnish pragmatic insights into the ways in which ship financing may evolve in response to these shifting paradigms.

In summary, Chapter 2 outlines the macro-financial environment by explaining how Basel IV's capital requirements, such as LGD input floors, limit ship financing options. This chapter is crucial as it sets the stage for understanding the financial constraints and risk-averse atmosphere that maritime lenders and borrowers must navigate. Chapter 3 logically builds on this groundwork by concentrating on financing for green vessels, demonstrating how these regulatory pressures impact a sector that is dealing with environmental mandates. It emphasizes the unique financial and operational risks associated with green shipping, connecting regulatory capital challenges to the obstacles faced in ESG investments. This shift introduces the concept of sustainable finance, bridging market limitations with emerging opportunities and risks. Chapter 4 integrates the previous analysis by applying these constraints and risks to actual decision-making through scenario analysis and investment breakeven modeling. Collectively, these chapters form a cohesive, progressive argument — transitioning from the regulatory framework to sectoral implications to strategic financial planning in a high-stakes, regulated industry.

Chapter 2
The transformation of shipping finance following regulatory changes: Focus on the Basel III reforms (Basel IV)

2.1. Introduction

Shipping financing has a long history, dating back to the 16th century, when wealthy individuals financed ships under a limited liability structure. Since the current form of ship financing began in the 1950s and 1960s, there have been many changes in the ship financing industry in terms of financing structure, sources of financing and available financial products, especially after the global financial crisis. However, the predominant source of financing was bank loans from a number of ship financing banks, particularly European banks. However, ship financing trends have slowly shifted towards alternative sources of financing such as private equity funds, high-yield bonds, Chinese leasing products and the equity capital market, largely due to the withdrawal or significant decline in the shipping business of some traditional ship financing banks, including Royal Bank of Scotland, Commerzbank, NordLB and HSH, triggered by these banks' significant losses in the shipping industry in recent years as well as tightening regulation and control. Although many ship finance banks continue to selectively provide liquidity to shipowners, these banks have become more conservative in order to cope with the increasingly stringent regulatory environment.

Meanwhile, the amendment of the Third Basel Capital Accord, referred to as Basel III post-crisis regulatory reforms, namely Basel IV, was endorsed by the Group of Central Bank Governors and Heads of Supervision (GHOS), the Basel Committee's oversight body, on 7 December 2017. The revised standards, amongst others, require more stringent and standardized controls for measuring risk-weighted assets (RWA) by limiting banks' flexibility in calculating RWA. This new framework is expected to have a significantly negative impact on asset classes whose credit risk has been assessed by the advanced internal ratings-based (A-IRB) approach under the Basel framework. In particular, Loss-Given-Default (LGD), one of the main parameters to calculate RWA together with Probabilities of Default (PD) and Exposure at Default (EAD), will be the most affected parameter, given that the revised Basel framework has introduced minimum input floor values for bank-estimated IRB parameters. Banks that adopt the A-IRB approach have the flexibility to estimate some parameters required for calculating RWA compared to the standardized approach and the foundation internal ratings (F-IRB) based approach. Among the risk parameters, LGD is considered the most critical parameter in calculating RWA for shipping loans because internally estimated LGD is highly correlated to loan-to-value (LTV), which is a ratio calculated based on the loan amount against the fair market value of the mortgaged vessel. The A-IRB methodology under the prevailing Basel framework encourages banks to develop an internal model for estimating LGD, which could result in a loan requiring less capital than the same loan under the standardized or foundation methodology.

The fact that shipping is a highly cyclical industry means that the default risk of shipping loan portfolios can vary significantly depending on the industry cycle. Many existing ship finance banks that have weathered a downturn in the economic cycle may not have sufficient default data to support their internal model. This implies that the surviving banks' estimated LGD of their loan portfolios is most likely lower than the LGD input floor newly introduced by Basel IV. These banks had no incentive to calculate LGD at a high level, effectively losing the benefits of the IRB approach. Assuming that Basel IV is implemented as initially announced, banks using the IRB approach would require more capital, particularly for low-leverage loan portfolios that previously required less capital due to the low LGD estimate. The additional capital requirement must be compensated for in one form or another to satisfy the banks' shareholders and stakeholders. This may be additional revenue to maintain similar levels of profitability, solutions to mitigate increased capital requirements, or a combination of both methods. The pressure for additional profits could lead to an increase in the margin on shipping loans, which could eventually be passed on to ship owners. Therefore, it is obvious that the new regulatory environment should play a crucial role in shaping the future of the ship financing industry. The simple, unchangeable rule in the Basel framework from the outset is that higher RWA requires higher capital reserves. To minimize the RWA impact, banks will seek to optimize their balance sheet by allocating available capital into less restricted asset classes and requiring more collateral and/or higher margins to meet their internal profitability hurdle such as return on equity. This study analyzes and anticipates the impact of Basel IV on the ship financing industry, focusing on the LGD restriction and predicting how the ship financing industry and ship owners will adapt to the new environmental changes.

The contribution of this paper consists of two parts: (1) verifying the validity of the new LGD input floor and (2) proposing possible solutions to minimize the RWA impact. First, it tests whether the new LGD floor for the internal ratings-based approach is appropriate by analyzing the historical default case and creating the theoretical ship finance loan model that replicates the commercial financing conditions in an actual ship finance loan. The theoretical credit model further examines what other factors besides LTV have a significant impact on LGD. Secondly, some practical financing ideas are suggested for banks to reduce the RWA impact when the new LGD input floor is implemented in its current form. The proposed ideas can be extended to other asset-backed financing, such as intermodal financing, aviation financing, rail financing, etc.

2.2. Introduction of Basel Accord

2.2.1. Summary of the current Basel Accord

The Basel framework has developed since it was first introduced in 1988 by the Basel Committee, initially named the Committee on Banking Regulations and Supervisory Practices. The Basel Committee, established by the central bank governors of the group of ten countries in 1974, has the key objective of enhancing financial stability by improving the quality of banking supervision worldwide and serving as a forum for regular cooperation between its member countries on banking supervision matters. The Committee has established a series of international standards for bank regulation, most notably its landmark publications on capital adequacy accords, commonly known as Basel I, Basel II, and, most recently, Basel III. (History of the Basel Committee)

The terms Basel Framework, Basel Accord, and Basel Regulations carry unique implications in the realm of international banking standards. The Basel Framework represents the extensive set of regulatory standards crafted by the Basel Committee on Banking Supervision (BCBS) to bolster bank regulation and risk management practices. It comprises three pillars: Basel I, Basel II, and Basel III. The Basel Accord pertains to specific agreements made by the BCBS: Basel I (1988) set forth credit risk requirements, Basel II (2004) introduced risk management principles, and Basel III (2010-2017) improved standards for capital, liquidity, and leverage. Basel Regulations outline the manner in which individual nations adopt these guidelines within their own banking frameworks.

The initial Basel Accord, Basel I: the Basel Capital Accord, was endorsed by G10 governors and released to banks in July 1988, which came into force in 1993. The main goal of Basel I is to promote a single methodology for calculating capital adequacy and introduce the concept of risk-weighted assets. This agreement is aimed at the international level to maintain a minimum level of commercial banks' solvency, a level that must always be complied with (Sbârcea, 2014). The salient features of Basel I encompass three principal elements. Firstly, it initiated the concept of risk-weighted assets (RWA), whereby banking assets are allocated ratings ranging from 0% to 100% predicated on distinct risk classifications: zero (0%), low (20%), moderate (50%), and high risk (100%). Secondly, it formulated an updated definition of capital, which includes both core capital and supplementary capital. Thirdly, it established the capital adequacy ratio, mandating a minimum total capital ratio (comprising both core and supplementary capital) to RWA of 8%, with core capital required to constitute at least 4% of the total RWA.

However, the first Basel accord was criticized by both the regulators and the supervised banks mainly due to some deficiencies, such as the lack of capital requirements for risks other than credit, the mismatch between credit risk weights and the actual level of risk, and the limited recognition of the results of risk reduction techniques, which led to the new regulatory framework for the capital deficiency of banks, Basel II (Vousinas, 2015).

In June 1999, subsequent to the introduction of a novel proposal aimed at instituting a capital adequacy framework to supplant Basel I, a reformed capital framework was unveiled, referred to as "Basel II," which was composed of three intricately interconnected pillars. The first pillar concentrated on establishing minimum capital requirements, stipulating that the capital adequacy ratio must not fall below 8%, while concurrently weighting assets in accordance with credit risk, market risk, and operational risk. In response to critiques regarding the risk mitigation methodologies employed in Basel I, an Internal Ratings-Based approach was sanctioned for the computation of credit risk. The second pillar concerned itself with supervisory review and internal assessment mechanisms, thereby addressing the regulatory framework established by the first pillar through the delegation of responsibility for banks' risk evaluations to supervisory authorities. The third pillar sought to promote market discipline and adherence to sound banking practices by instituting comprehensive reporting mandates. Financial institutions were obligated to routinely disclose pertinent information regarding their financial exposures, risk assessment methodologies, ownership configurations, and capital adequacy in relation to their risk profiles. Such disclosures were mandated to occur at least biannually, with qualitative disclosures permitted on an annual basis.

Although Basel II was attributed to improving risk management by expanding its coverage area and increasing the stability of the financial system and the existence of a closer link between the required risk and capital, it also revealed its limitations following the Lehman Brothers collapse in September 2008 which are (1) underestimating the importance of the systemic risk, (2) overestimating the credit institutions' capacity to accurately measure the key risks, (3) overestimating the true nature of the assessments provided by rating agencies in the absence of some minimum professional standards and supervision, and (4) inadequate reflection of prudential requirements of the liquidity risk both on the financing component and on the recovery of assets (Guvernanta economica la nivel european, 2011).

Responding to these risk factors, the Basel Committee announced a new framework in September 2010 regarding the overall design of the capital and liquidity reform package for commercial banks, referred to as "Basel III". The enhanced Basel framework revised and strengthened the three pillars set by Basel II, and extended it in several areas. The summary points of Basel III are (Rizvi, Kashiramka and Singh, 2018) :

- Reinforcing the central role of common equity as presented below Table 2.1 (Vousinas, 2021)

Table 2.1: Minimum capital requirement

	Common Equity	
Capital	**Basel II**	**Basel III**
Minimum	2%	4.5%
Stabilizing	0%	2.5%
Total required	2%	7%
Tier 1 Capital		
Minimum	4%	6%
Total required		8.5%
Total Capital		
Minimum	8%	8%
Total required		10.5%

Source: Vousinas, 2021

- In a period of stress (capital adequacy ratio < 7 %), financial institutions are permitted to use the excess capital generated by reducing the distribution of dividends or bonuses.
- Countercyclical capital surplus (0-2.5 %) applied only to periods of excessive credit growth (based on the discretion of the national regulatory authorities)
- Introduction of Liquidity Coverage Ratio (LCR, (*Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools*, 2013)) and Net Stable Funding Ratio (NSFR, (*Basel III: the net stable funding ratio*, 2014)).

2.2.2. Calculation of risk-weighted asset for credit risk

Risk-weighted assets are designed to address unexpected losses from exposure, which are calculated based on estimates of Probability of Default (PD), Loss given Default (LGD), Exposure at Default (EAD), and, in some cases, effective maturity (M), for a given exposure. There are broadly two ways to calculate RWA for credit risk for banking book exposure which are (1) the standardized approach (SA) and (2) the internal ratings-based (IRB) approach. The

IRB approach is divided into two sub-categories, the foundation IRB (F-IRB) approach and the advanced IRB (A-IRB) approach.

The primary difference between SA and IRB approaches is that SA requires banks to use a prescribed risk weighting for calculating RWA, which depends on asset class and is generally linked to external ratings, whereas the IRB approach allows banks to use their internal rating systems for credit risk, subject to the explicit approval of their respective estimates of risk parameters such as PD, LGD, and EAD (Akkizidis and Kalyvas, 2018). The difference between F-IRB and A-IRB is that F-IRB uses only their internal estimates of PD, while PD, LGD, and EAD can be estimated by the internal rating model developed by banks under A-IRB.

In accordance with the IRB approach under Basel III, RWA for corporate, sovereign, and bank exposures not in default is derived based on the Equation 2.1 formula (CRE31 - IRB approach: risk weight functions)):

Equation 2.1: RWA calculation formula under the IRB approach

$$Correlation = R = 0.12 \cdot \frac{\left(1-e^{-50 \cdot PD}\right)}{\left(1-e^{-50}\right)} + 0.24 \cdot \left(1 - \frac{\left(1-e^{-50 \cdot PD}\right)}{\left(1-e^{-50}\right)}\right)$$

$$Maturity\ adjustment = b = \left[0.11852 - 0.05478 \cdot \ln\left(PD\right)\right]^2$$

$$Capital\ requirement = K = \left[LGD \cdot N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \cdot G(0.999)\right] - PD \cdot LGD\right] \cdot \frac{\left(1+(M-2.5)\cdot b\right)}{\left(1-1.5 \cdot b\right)}$$

$$RWA = K \cdot 12.5 \cdot EAD$$

Where,

ln denotes the natural logarithm

N(X) denotes the cumulative distribution function for a standard normal random variable.

G(z) denotes the inverse cumulative distribution function for a standard normal random variable.

Shipping finance can be classified as object finance which is one of the sub-asset classes of specialized lending (SL) asset class in the IRB approach under Basel IV. Banks that meet the requirements for the estimation of PD, LGD, and EAD (where relevant) will be able to use the advanced approach for the corporate asset class to derive risk weights for SL sub-classes.

Probability of default

The probability of default (PD) is an estimate of the likelihood that the default event will occur. The default event is assumed to have occurred under the Basel framework if (1) it is unlikely that the obligor will be able to repay its debt to the bank without giving up any pledged collateral or (2) the obligor is more than 90 days past due on a material credit obligation (Committee on Banking Supervision, 2006). Banks are allowed to use one or more of three specific techniques, internal default experience, mapping to external data, and statistical default models, as long as the applied techniques are satisfied by the supervisors. Banks using the F-IRB or A-IRB methodologies must provide supervisors with an internal estimate of the PD associated with borrowers in each borrower grade. Regardless of the applied techniques for the PD estimation, the length of the underlying historical observation period used must be at least five years for at least one source (Committee on Banking Supervision, 2006). In order to address the excess cyclicality of the minimum capital requirement, it is required to use the long-term date horizon to estimate the PD. For corporate and bank exposure, the PD is the greater of the 1-year PD associated with the internal borrower grade or 0.03%, which is the so-called "PD floor" (Committee on Banking Supervision, 2011). Each estimate of PD must represent a conservative view of a long-run average PD for the grade in question and thus must be grounded in historical experience and empirical evidence.

Loss given default

Loss given default (LGD) is expressed as a percentage of exposure at default, equivalent to 1 minus recovery rate. The F-IRB and A-IRB approaches are the two approaches allowed under the Basel framework to estimate the LGD for corporate, sovereign, and bank exposure. The difference in terms of assessing LGD between F-IRB and A-IRB is that the F-IRB approach under Basel II assigns a fixed LGD for senior unsecured claims (45%) and subordinated claims (75%), whereas the A-IRB approach provides the flexibility to banks to estimate the LGD (Schuermann, 2004). Regarding a senior secured claim, the LGD floor using the F-IRB method under Basel III can be reduced to 0-40%, subject to the eligible collateral type. For instance, LGD for a senior term loan fully secured by a vessel or an aircraft (>140% over-collateralization) can be 40% instead of 45% in the F-IRB approach under Basel II (see Table 2.2).

Table 2.2: Minimum LGD in the F-IRB approach under Basel III

	Minimum LGD	**Required minimum collateralisation**	**Required level of overcollateralization for full LGD**
Eligible financial collateral	0%	0%	n.a.
Receivables	35%	0%	125%
Commercial or residential real estate	35%	30%	140%
Other collateral	40%	30%	140%

Note. The above table is derived from (CRE32 - IRB approach: risk components for each asset class)

With the A-IRB approach under Basel III, banks can use their own estimates of LGD for corporates, sovereign, and bank exposure subject to additional minimum requirements. The supplementary requirements for all asset classes encompass several crucial elements. Firstly, the Loss Given Default (LGD) needs to be sufficiently conservative to account for economic downturn scenarios and cyclical fluctuations in loss severities. The projected LGD must not dip below the long-term default-weighted average loss rate upon default, which is derived from the typical economic loss observed across all defaults recorded in the data source pertinent to that specific type of facility. Moreover, banks are obligated to take into account any currency discrepancies between the underlying obligation and the collateral, in addition to any correlation between the borrower's risk and the collateral or collateral provider when evaluating their LGD. Ultimately, although the market value of collateral holds significance, it should not solely dictate the estimation of the LGD. These evaluations must be based on historical recovery rates, and banks are mandated to uphold effective collateral management practices, akin to those used in the Standardised Approach (SA).

For corporate, sovereign, and bank exposures, the minimum data observation period should be more than seven years for at least one source in any case, covering at least one complete economic cycle.

Exposure at default

EAD, measured as currency (e.g., euros), is defined as the expected gross exposure of the facility upon default of the obligor. For on-balance sheet items, EAD is rarely ambiguous, which is no less than the current drawn amount, subject to recognition of the netting effect. In most practical cases, a ship financing loan is a secured term loan where there is no off-balance sheet item. Thus, EAD is usually the outstanding of the loan facility.

2.3. Literature review

The general impact of Basel IV on bank

Several studies have examined the general impact of the new Basel framework on the banking sector. The common views of the previous studies are that it is imperative to put more efficient and articulated regulations in place for banks to stabilize the financial industry across the countries. In addition, the minimum capital requirements for banks will considerably increase to meet the Basel IV recommendations. However, there are different views on implementing Basel IV in its current form, whether it will ultimately improve financial stability or threaten stability by incentivizing banks to invest in higher-risk assets to increase their profitability and offset the increased equity costs.

One study carried out by Feridum and Özün (2020) emphasizes the positive aspect of the Basel IV to enhance credibility in the calculation of RWAs and improve the comparability of banks' capital ratios. In this context, the authors urged the consistent global implementation of the reforms by all jurisdictions to avoid pricing distortions and an unlevel playing field across jurisdictions and transposition into national banking laws concurrently with the European Union to prevent regulatory arbitrage opportunities. On the other hand, the authors acknowledged that implementation of the capital floor might lead banks to lose attraction in the lower-risk portfolio, resulting in negative consequences for the supply and pricing of bank finance. Currently, there are ongoing discussions in the EU as to whether the output floor should be applied at all levels of the banking group, sub-consolidated and consolidated, or at the highest level of consolidation.

Ozdemir et al. (2015) concluded that the simplified approach suggested by Basel IV could mislead the intention of the Basel Committee to make RWA more risk-sensitive and to close the gap between the standardized approach and the A-IRB approach, increasing the gap between economic risk and capital, providing perverse incentives, marginalizing good management practices, and eventually increasing systemic risk. The authors agreed with the intention to reduce the variability in the IRB approach but insisted that oversimplifying the A-IRB approach is dangerous as it could mask differences in risk practices among banks and regions, which ultimately requires banks to deploy similar levels of capital regardless of different economic risks. Therefore, the authors suggested adding a full set of risk drivers, most notably LGD drivers, to the new standardized approach in order to capture the economic risk better and build constraints within the A-IRB framework when data availability limits the robustness of the internal models.

In terms of the impact on the loan market following the banking regulation changes, Gavalas and Syriopoulos (2014) investigated the impact of the new capital requirements under the Basel III framework and concluded that the volume of loans would decrease by 4.97%-18.67%, and the loan rate increase by 0.13-0.22% on average due to the higher capital requirements which would require 1.3 percentage point increase in the equity-to-asset ratio to comply with the Basel III recommendations. However, there are limited studies about the potential implications of the new Basel framework, particularly for the shipping industry.

RWA / LGD discussions in ship financing

Sambracos and Maniati (2013) expected the increasing pressure on banks to create a sufficient reserve, with a focus on core tier 1 capital under Basel III, which in turn would adversely influence the shipping sector because banks could limit their exposure to the shipping sector or require much-restricted financing terms and impose higher interest rates for financing to compensate the increased cost of capital in shipping financing. However, they expected that it did not alter the concept of shipping financing entirely, but merely the part relating to banking. Hence, Basel III could provide opportunities to non-traditional investors in shipping by filling the gap of liquidity supplied by traditional shipping banks. The author also anticipated that there would be a change in the long-term strategy of shipping financing in terms of the commercial terms and conditions of such financing. The contribution of this study is that it analyzed the negative impact on shipping finance from a liquidity perspective, assuming that long-term loan facilities such as shipping finance loan requires banks to increase their retail deposit or issue debt securities to comply with the Net Stable Funding Ratio (NSFR) under Basel III.

A recent study by Markus et al. (2020) concluded that Basel IV could result in severe retrenchment in lending activities in the affected countries. The study refers to estimates by the European Banking Authority (EBA), which forecasts an average 26% increase in capital requirements across the EU, mainly driven by the newly introduced output floor benchmark, which is the calculation of RWAs using the standardized approach. The effects will be substantial to all banks that use internal models for the calculation of RWAs, but notably on mortgage lenders, as the output floor limits banks' ability to make use of internal models. Given that the output floor enables banks to set aside the same amount of capital between low-risk and relatively high-risk loans, the authors highlighted that banks might prefer to lend to riskier borrowers to achieve higher profits to compensate for the increased equity costs while reducing credit supply to low-risk borrowers. The study also warned that the output floor might incentivize banks to move real estate loans to less regulated shadow banking sectors such as asset-backed securities and debt funds to avoid the restrictions. Although this study examined the possible impact of Basel IV from the point of view of real estate financing, the analysis can be applied to shipping finance, given that shipping finance is also asset-backed financing which used to enjoy a low RWA under internal models thanks to the collateral value under Basel III.

Some previous studies also concluded that a change in regulatory capital ratios has only a small impact on the costs of bank funding ((Brealey, 2006) and (Admati *et al.*, 2013)) due to various distortions such as tax advantages of debt or disciplinary effects of debt. The research carried out by Allen et al. (2012) even argued that higher capital requirements could actually lower the cost of borrowing for some borrowers if the efficiency-promoting impact of higher capital and liquidity requirements is strong enough. On the other hand, Allan (2014) anticipated that the stringent liquidity requirement would create challenges for banks to support long-term loans, which would put hard pressure on the shipping banks, in particular, to exit the sector or reduce the tenor of their shipping loans and increase their pricing spread to cover their increased cost of capital.

However, most of the previous research has focused on the regulatory effects from the liquidity perspective whilst the most notable change from the Basel IV in relation to the shipping banks is the constraint on LGD calculation, including the introduction of the LGD floor.

Regulatory capital relief method in ship financing

Several empirical studies indicate that banks can reduce RWA for their loan portfolio by obtaining credit default swaps (CDS), total return swaps, and eligible guarantees, among which many academics examine CDS as the leading credit mitigation technique. Given CDS basically transforms the credit risk of the loan portfolio to the counterparty risk of the CDS seller, inherited risk in the loan portfolio remains unchanged. However, the required capital for banks can be reduced due to the different risk weighting between the loan portfolio and the CDS seller.

First-loss credit protections on a pool of loans can be a better option for the bank that wants to reduce its RWA more than the notional size of the CDS would suggest (Cetina, Mcdonough and Rajan1, 2014). Noting CDS protection is only up to a contracted cut-off point agreed upon between CDS buyer and seller, the notional amount of first-loss CDS protection can provide a wider coverage than its notional loan size. Although the authors acknowledged the positive effects of credit derivatives as a tool to relieve capital requirements, they also highlighted the opacity of reporting requirements for CDS, reminding American International Corp (AIG) case where European banks lost some of the US$290 billion in CDS protection they had bought for regulatory capital relief.

Shan et al. (2016) echoed the function of CDS as a credit mitigation product to lower RWA while maintaining the regulatory capital ratios. However, they also emphasized that CDS also allows banks to get away with regulatory scrutiny, weakening the effectiveness of bank regulations.

Another empirical study (Thornton and Tommaso, 2018) based on data from European banks showed that CDS is an effective tool for reducing RWA, resulting in higher returns on capital. However, the outcome also implies that the actual risk of banks that use CDS remains unchanged when considering counterparty risk, which is not captured under Basel III. By the same token, a lower ratio of risk weighed to total assets does not necessarily indicate that a bank's asset portfolio is less risky.

Karaoglu (2011) presented evidence that loan transfers can play a role in managing regulatory capital. The loan transfers in this study refer to the securitization process where the loans are transferred to third parties through the issuance of debt whose cash flows are collateralized by the original loan pool. This is different from the loan sale, which is a complete transfer of the loans without any future involvement by the transferor. By comparing securitization and secured borrowing with a simple example, the author demonstrated that securitization positively affects the capital ratio due to the additional earnings and reduced loan size. The previous analysis using the fixed-rate mortgage loan samples in the U.S. market concurred with the motivation of securitization for regulatory capital incentives but also highlighted that banks would have an incentive to sell lower-risk loans for their portfolio while selling lower-risk loans into the secondary to get benefits of regulatory capital relief (Ambrose, Lacour-Little and Sanders, 2005).

Despite the several studies for regulatory capital relief methods, it is surprisingly difficult to find previous research focusing on ship financing. Based on the earlier studies, some suggestions are proposed in the discussion chapter.

2.4. Expected issues with Basel IV in ship financing

2.4.1. Comparison with Basel III for credit risk

The Basel Committee endorsed its Basel III post-crisis reforms in 2017, introducing new standards for calculating capital requirements for credit risk, credit valuation adjustment risk, and operational risk. The final reforms' key objective, commonly referred to as "Basel IV, " was to reduce the excessive variability of RWA by incorporating an output floor based on the revised standardized approaches, which limits the extent to which banks can use internal models to reduce risk-based capital requirements.

Whilst substantial changes were proposed across all asset classes in Basel IV, the focus area in this paper regarding the changes lies with the corporate exposure because ship financing is categorized as specialized lending (Object Finance) under the IRB approach, which will follow the general corporates exposure in terms of RWA calculation.

Standardised approach for credit risk

A more granular approach was introduced to split the risk weights for credit ratings BBB+ to BB- at 100% to 75% for BBB+ to BBB- and 100% to BB+ to BB. Standardised Credit Risk Assessment Approach (SCRA) can be applied to corporate risk weights in jurisdictions where the rating approach is not permitted (see Table 2.3).

Table 2.3: Risk weights to general corporates under SA in Basel IV

Risk weights in jurisdictions where the rating approach is permitted						
External rating	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to BB-	Below BB-	Unrated
Risk weight	20%	50%	75%	100%	150%	100% or 85%*
Risk weights where the rating approach is not permitted						

SCRA grade	Investment grade	All other
General Corporate	65%	100%
SME general corporate	85%	
Exposures to project finance, object finance and commodities finance		
Exposure	Project Finance	Object and Commodity Finance
Ratings available and permitted	Same as for general corporate (see above)	
Rating not available or not permitted	130% pre-operational phase 100% operational phase 80% operational phase (high quality)	100%

* It applies if the borrower is a corporate SME (Committee on Banking Supervision, 2017).

Table 2.4 provided below illustrates the risk weighting of rated corporates claims under Basel III for comparison.

Table 2.4: Risk weights to general corporates under SA in Basel III

External rating	AAA to AA-	A+ to A-	BBB+ to BB-	Below BB-	Unrated
Risk weight	20%	50%	100%	150%	100%

Note. The above table is derived from (*CRE20 - Standardised approach: individual exposures*, 2019)

IRB approach for credit risk

Under the IRB approach, banks must categorize banking-book exposures into broad classes of assets with different underlying risk characteristics, subject to the definitions below. The classes of assets are (a) corporate, (b) sovereign, (c) bank, (d) retail, and (e) equity. Within the corporate asset class, five sub-classes of specialized lending are separately identified, which are project finance (PF), object finance (OF), commodities finance (CF), income-producing real estate (IPRE) lending, and high-volatility commercial real estate (HVCRE) lending. Each of these sub-classes is defined as follows (*CRE30 - IRB approach: overview and asset class definitions*, 2022):

- **PF:** PF is a method of funding in which the lender looks primarily at the revenues generated by a single project, both as the source of repayment and as security for the exposure. The lender is usually paid solely or almost exclusively out of the money generated by the contracts for the facility's output, such as the electricity sold by a power plant. The borrower is usually an SPE that is not permitted to perform any function other than developing, owning, and operating the installation. The consequence is that repayment depends primarily on the project's cash flow and on the collateral value of the project's assets.
- **OF:** OF refers to a method of funding the acquisition of physical assets (e.g. ships, aircraft, satellites, railcars, or fleets) where the repayment of the exposure is dependent on the cash flows generated by the specific assets that have been financed and pledged or assigned to the lender. A primary source of these cash flows might be rental or lease contracts with one or several third parties.
- **CF:** CF refers to structured short-term lending to finance reserves, inventories, or receivables of exchange-traded commodities (e.g. crude oil, metals, or crops), where the exposure will be repaid from the proceeds of the sale of the commodity and the borrower has no independent capacity to repay the exposure. Such lending can be distinguished from exposures financing the reserves, inventories, or receivables of other more diversified corporate borrowers.
- **IPRE:** IPRE lending refers to a method of providing funding to real estate (such as office buildings to let, retail space, multifamily residential buildings, industrial or

warehouse space, or hotels) where the prospects for repayment and recovery on the exposure depend primarily on the cash flows generated by the asset. The primary source of these cash flows would generally be a lease or rental payments or the sale of the asset. The distinguishing characteristic of IPRE versus other corporate exposures that are collateralized by real estate is the strong positive correlation between the prospects for repayment of the exposure and the prospects for recovery in the event of default, with both depending primarily on the cash flows generated by a property.

- **HVCRE:** HVCRE lending is the financing of commercial real estate that exhibits higher loss rate volatility (i.e., higher asset correlation) compared to other types of SL. Where supervisors categorize certain types of commercial real estate exposures as HVCRE in their jurisdictions, they are required to make such determination public.

As per the above classification, a typical ship financing exposure is classified as OF. However, if the debt repayment capability is not dependent on the specific pledged assets, the exposure should be treated as a secured corporate exposure.

In terms of the exposure, which risk can be accessed with the A-IRB approach has become more restricted (see Table 2.5). Under Basel IV, only specialized lending exposure is still allowed to adopt the A-IRB approach.

Table 2.5: Revised scope of IRB approaches for asset classes

Exposure	Basel III	Basel IV
Large and mid-sized corporates	A-IRB, F-IRB, SA	F-IRB, SA
Banks and other financial institutions	A-IRB, F-IRB, SA	F-IRB, SA
Equities	Various IRB approaches	SA
Specialised Lending	A-IRB, F-IRB, SA, Slotting	A-IRB, F-IRB, SA, Slotting

Source: High-level summary of Basel III reforms, 2017

2.4.2. Introduction of input floors

Although banks continue to be permitted to use the A-IRB approach for specialized lending exposure, Basel IV introduced the minimum floor values for bank-estimated IRB parameters that are used as input for the RWA calculation. These include PD floors for both the F-IRB and A-IRB approaches and LGD and EAD floors for the A-IRB approach.

2.4.2.1. LGD estimation under F-IRB approach

Under Basel IV, the unsecured LGD for senior claims on banks, securities firms, and other financial institutions, including insurance companies, is 45%, whereas the unsecured LGD for senior claims on other corporates is 40%. The LGD for subordinated claims on corporates, sovereigns, and banks remains at 75%.

Similar to the eligible financial collateral recognized in the SA, some other forms of collateral, known as eligible IRB collateral, continue to be recognized under the F-IRB as credit mitigation means (see Table 2.2). In addition, the basic concept is that the total LGD should be calculated based on the weighted average of the LGD applicable to the unsecured part of exposure and the LGD applicable to the collateralized part of exposure when it comes to partially secured loans. However, a new concept of haircut on the collateral is introduced, while the level of supervisory LGD assigned to each collateral type is slightly relaxed (see Table 2.6).

Table 2.6: LGD comparison in F-IRB approach under Basel III and Basel IV

Minimum LGD	Basel III	Basel IV	Haircut (Basel IV)
Eligible financial collateral	0%	0%	0-30%*
Receivables	35%	20%	40%

Commercial or residential real estate	35%	20%	40%
Other collateral	40%	25%	40%

Note. The above table is derived from (CRE32 - IRB approach: risk components for each asset class) and ('Basel Committee on Banking Supervision CRE Calculation of RWA for credit risk CRE32 IRB approach: risk components', 2022). * It is subject to the issuer of collateral and an external credit rating of the issuer.

In this context, "fully secured" means that the value of collateral after applying haircuts exceeds the value of the exposure. From a ship financing perspective, it is hard to judge whether RWA for a secured ship financing loan is increased using the F-IRB approach under Basel IV compared to Basel III. For a case where the collateral value after applying 40% can fully cover the exposure, the LGD assigned under Basel IV (25%) is lower than Basel III (40%). However, if the post-haircut collateral value partially covers the total exposure, the weighted LGD is subject to a portion of the unsecured part in the full exposure.

2.4.2.2. LGD estimation under A-IRB approach

Banks are permitted to continue to use their own internal estimates of LGD for corporate and sovereign exposures. However, there is a floor for both secured and unsecured LGD estimation on corporate exposure, whereas the LGD floor does not apply to sovereign exposures (see Table 2.7).

Table 2.7: LGD floor for corporate exposures

Unsecured	Secured
25%	Eligible financial: 0% Receivables: 10% Commercial or residential real estate: 10% Other physical: 15%

Note. The above table is derived from ("CRE32 IRB approach: risk components," 2022).

The application of haircuts to the collateral value also applies to the LGD estimation under the A-IRB approach, consistent with the LGD estimation under the F-IRB approach. Similar to the F-IRB approach, the LGD floor for a partially secured exposure is calculated as a weighted average of the unsecured LGD floor for the unsecured portion and the secured LGD floor for the secured portion.

2.4.2.3. PD and EAD floor under both F-IRB and A-IRB approach

For corporate exposures, the PD floor increased from 0.03% to 0.05%, and the new EAD floor was introduced in Basel IV (see Table 2.8).

Table 2.8: PD and EAD Floor for corporate exposures

	Basel III	**Basel IV**
PD	0.03%	0.05%
EAD	N.A.	Sum of (1) the on-balance sheet exposures and (2) 50% of off-balance sheet exposure*

* The off-balance sheet exposure is calculated using the applicable credit conversion factor in the standardized approach.

2.4.3. Effective maturity

The effective maturity is calculated as the maximum remaining time (in years) that the obligor is permitted to take to fully discharge its contractual obligation, including principal, interest, and fees, under the terms of a loan agreement. Therefore, for an instrument subject to a determined cash flow schedule, effective maturity M is defined as

Equation 2.2: Effective maturity calculation

$$\text{Effective Maturity (M)} = \sum_{t=0}^{n} t * CF_t \,/\, \sum_{t=0}^{n} CF_t$$

Where CF_tdenotes the cash flows (principal, interest payments and fees) contractually payable by the borrower in period t.

Under Basel IV, the effective maturity for banks adopting the F-IRB approach for corporate exposure is 2.5 years, whereas the effective maturity using the A-IRB approach is subject to a floor of 1 year and a cap of 5 years.

2.4.4. Introduction of the output floor

To allow better comparison between the standardized and IRB approaches and increase the credibility of risk-weighted calculations, banks using the IRB approaches will face a limit on capital calculation relative to the standardized approach under the revised capital floor. The new approach will allow banks to calculate their risk-weighted assets as the higher of

a) total risk-weighted assets calculated under the approach approved by their regulator
b) 72.5% of the total risk-weighted assets calculated using the standardized approach

This means that the total risk-weighted assets calculated by the IRB approaches cannot be less than 72.5% RWA determined by the SA approach.

In effect, the output floor provides a risk-based backstop that limits the extent to which banks can lower their capital requirements relative to the standardized approaches. This helps to maintain a level playing field between banks using internal models and those on the standardized approaches. The output floor will be implemented gradually over time, starting at 50% on January 1, 2020, increasing to 55% in 2023, 60% in 2024, 65% in 2025, and 70% in 2026, before reaching its final level of 72.5% on January 1, 2027.

2.4.5. Impact study on the newly introduced restrictions

It is believed that the input floors are an important aspect of increasing the robustness and risk sensitivity of the IRB approach used in RWA calculations. The Basel IV framework, therefore, proposed to increase the starting point for the risk components of PD and LGD. The European Banking Authority (EBA) (BASEL III REFORMS, 2019) has concluded, from a macroeconomic point of view, that i) the long-term benefits of the reform are substantial and outweigh the transitory costs, which fade in significance over time, and ii) the reform would mitigate the severity of future economic downturns through a reduction in both the probability and intensity of future banking crises. Thus, Basel IV will bring net benefits for EU economies in terms of higher long-term growth and better resilience in the financial sector.

In respect of the transitory costs, referring to the recent report published by EBA in December 2020, Basel IV would require European banks' minimum capital requirement to increase by 15.4% at the full implementation date (2028), which would result in EUR 9.4 billion of additional Tier 1 capital based on the assumption that Basel IV requirements are implemented in full. The impact is expected to be more significant to Global Systemically Important Institutions (G-SII), with a 23.0% increase in the minimum capital requirement, of which the leading factors are the output floor (6.8%) and credit risk (6.2%).

Apart from the expected benefits to the financial sector as a whole, there are arguments regarding the side effects of Basel IV, particularly in relation to the newly introduced restrictions, the input floors for PD and LGD under the A-IRB approach, and a cap and floor for the effective maturity.

2.4.5.1. PD floor

Regarding raising the PD input floor, there is a view that it is too simplistic, considering that banks will need to combine their lowest PD grades into a single bucket, thereby reducing the granularity at the lower end of the PD master scale. This revision is against one of the critical elements of PD models that should be monitored in terms of homogeneity/heterogeneity.

Nevertheless, the negative impact on shipping finance exposure from the increased PD input floor is expected to be limited. In other words, the RWA of shipping finance exposure calculated using the A-IRB or F-IRB approach under Basel IV would not meaningfully increase due to the revised PD input floor. Referring to the statistics data from Fitch Ratings regarding global corporate finance average cumulative default rates from 1990 to 2021 (2021 Transition and Default Studies), the 1-year default rates for the B to BBB+ credit rating range from 0.08% to 2.08% (see Table 2.9).

Table 2.9: Global Corporate Finance Average Cumulative Default Rates: 1990-2021

(%)	Year One	Year Two	Year Three	Year Four	Year Five
AAA	0.11	0.23	0.36	0.49	0.62
AA+	-	-	-	-	-
AA	-	-	-	-	-
AA–	0.08	0.08	0.08	0.09	0.09
A+	-	0.06	0.10	0.15	0.20
A	0.07	0.20	0.36	0.51	0.69
A–	0.06	0.15	0.23	0.28	0.34
BBB+	0.08	0.14	0.26	0.47	0.64
BBB	0.06	0.29	0.54	0.82	1.22
BBB–	0.23	0.60	1.04	1.42	1.89
BB+	0.26	1.27	2.37	3.20	3.92
BB	0.48	1.46	2.31	3.76	4.98
BB–	1.11	2.37	3.64	4.49	5.20
B+	1.48	3.75	6.06	7.91	8.77
B	2.08	5.35	8.48	10.35	11.69

B–	3.03	6.95	8.78	9.84	10.95
CCC to C	23.34	30.62	33.69	35.76	36.99
Investment Grade	0.08	0.22	0.38	0.54	0.73
Speculative Grade	2.64	4.88	6.63	8.03	9.08
All Global Corporate Finance	0.76	1.43	1.97	2.40	2.76

Source: Fitch 2021 Transition and Default Studies

A.P. Moller - Maersk Line A/S is known as the largest and the best-performing shipping conglomerate globally across the sub-shipping sectors. The current credit rating of Maersk Line is BBB+ by S&P, which was upgraded by one notch in September 2021 due to its exceptionally outstanding performance, benefiting from the supply disruption during the COVID-19 situation. Despite the consistent operating cash flow generation and solid profitability, Seaspan Corporation, the largest containership tonnage provider worldwide, obtained its first BB credit rating from Fitch in June 2021.

Taking into account that (1) shipping companies are relatively highly leveraged due to their capital-intensive nature and (2) the balance sheet size is also relatively small compared to a general corporate, it is not easy to get an investment grade rating (BBB- by S&P/Fitch, Baa3 by Moody's) from the external credit rating agencies. Therefore, it is reasonable to assume that the expected credit rating for most unrated shipping companies would range from B to BBB. If the default rate of shipping companies tends to follow the default rate of a general corporation, the expected PD (0.08% to 2.08%) is already higher than the proposed PD floor (0.05%).

In addition, the empirical data provided by Global Credit Data (GCD) (*Global Credit Data by banks for banks Internal ratings, transitions and observed default rates collected from GCD contributing member banks*, 2019) demonstrates a conservative approach within banks in relation to the PD estimation for the large corporates with a consolidated turnover larger than EUR50 million, which means that the estimated PD by banks' internal model is higher than the observed defaulted rate. This is because banks' PD estimates typically include a "margin of conservatism" for estimation errors and data constraints. In accordance with below Table 2.10, the average PD estimates by banks for B to BBB rated company is 0.27% to 4.38%, whereas the actual average default rate is 0.15% to 1.80%, both of which are much higher than the PD floor under Basel IV.

Table 2.10: Comparison between PD and Realized Default Rates Per Rating Class

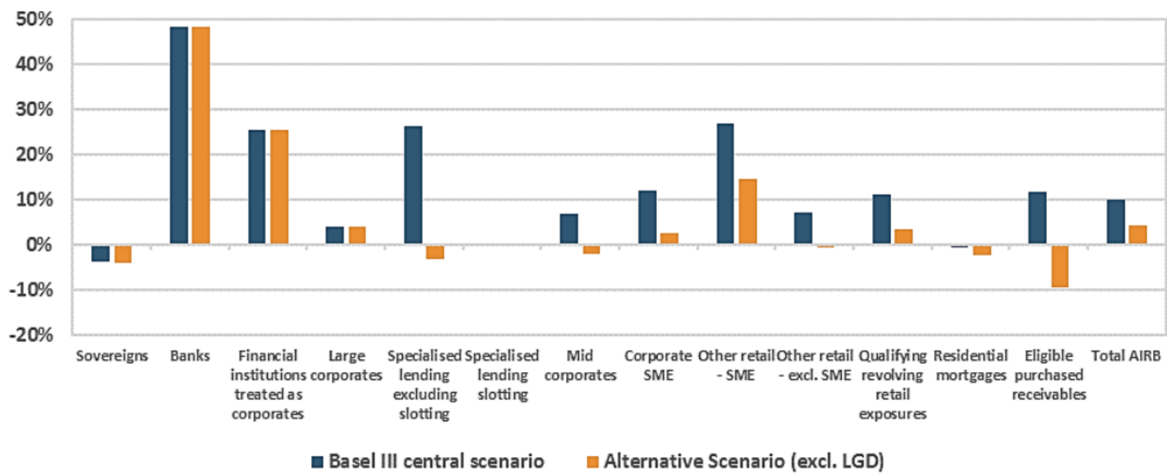
	# of Banks	1st quartile PD	Average PD	Median PD	3rd quartile PD	Average Default Rate
AAA	21	0.01%	0.02%	0.01%	0.03%	0.04%
AA	25	0.03%	0.03%	0.03%	0.04%	0.03%
A	26	0.06%	0.08%	0.08%	0.09%	0.08%
BBB	26	0.24%	0.27%	0.26%	0.31%	0.15%
BB	26	0.92%	1.04%	1.04%	1.22%	0.50%
B	26	3.58%	4.38%	4.16%	5.28%	1.80%
CCC/C	26	15.73%	20.42%	19.69%	23.40%	12.12%

Source: (*Global Credit Data by banks for banks Internal ratings, transitions and observed default rates collected from GCD contributing member banks*, 2019)

2.4.5.2. LGD Floor

As expected, given the structure of the IRB risk weight formula, the newly established LGD input floors play a very material role in explaining the impact of the reform on exposures treated under the A-IRB approach (Figure 2.1). For all exposure classes that remain under the A-IRB in Basel IV, LGD input floors are the main drivers of impact. In particular, the effect of the proposed LGD input floors on RWA will be particularly noticeable for exposures to specialized lending classes. When excluding the new LGD floors from the calculation of the RWA, the impact of the IRB reform is materially dampened for certain exposure classes. It becomes negative for others, removing the existing IRB 1.06 scaling factor prevailing as a revision that determines RWA relief across the IRB framework. Overall, according to the analysis performed by the European Banking Authority in 2019, the LGD input floors appear to account for around 80% of the increase in IRB RWA in the sample of 48 European banks.

Figure 2.1: Percentage change in A-IRB RWA per exposure class



Source: EBA 2018-Q2 QIS data and EBA calculations

Considering a vessel used as collateral for a ship financing loan is treated as other physical assets recognized as eligible collateral in the A-IRB approach, the LGD estimate is limited to 15%. As analyzed by EBA in Figure 2.1, it would result in a substantial increase in RWA calculation for ship financing loan portfolio, particularly for a portfolio with a low Loan-to-Value (LTV), factoring into account that a low LTV used to be an influential material factor for a low LGD estimation (below 15%) in the A-IRB approach under Basel III.

A detailed analysis of the impact of the LGD input floor is performed in the next chapter.

2.4.5.3. Effective Maturity

Subject to the choice of IRB approaches between F-IRB and A-IRB, the effective maturity will be determined. The notion of effective maturity is equivalent to the concept of calculating the weighted average loan life. Taking into account the usual tenor and amortization profile of ship financing loans, the effective maturity cap and floor are deemed to be positive in reducing RWA calculation in general. Suppose a typical secured term loan for ship financing entails a 7-year loan tenor based on 15 years of amortization repayment profile. Based on the formula proposed by Basel IV, the loan has around 5.6 years of effective maturity (or weighted average loan life). However, for the bank that would adopt the F-IRB approach, the effective maturity would be 2.5 years in any event, which is shorter than 5.6 years, resulting in a reduced RWA compared to the RWA estimated without the cap of effective maturity. Although the A-IRB approach allows more flexibility in terms of effective maturity, ranging from one year to five years, it would still provide benefits in RWA calculation for a loan whose weighted average loan life is longer than five years. However, this may wrongly incentivize banks to offer a longer tenor loan, given that the required capital for the longer tenor loan is the same as a loan with a shorter tenor.

2.5. Research Model and Results

2.5.1. Introduction

Chapter 2.4 examines the general problems with the implementation of Basel IV that could have a negative impact on ship financing. The LGD input floor is one of the critical issues for ship finance banks as it could result in more capital reserves being set aside due to increased risk-weighted assets (RWA). This chapter examines whether the 15% LGD input floor in the A-IRB approach adequately reflects market conditions by comparing two reference points, the empirical LGD data and the LGD results derived from a hypothetical loan model based on historical data. Although the F-IRB approach also includes the LGD input floor, the analysis focuses on the scenarios of the A-IRB approach because (1) a large number of traditional banks used the A-IRB approach when calculating RWA according to Basel III and (2) the change of the LGD input floor for the F-IRB approach under Basel IV is generally perceived as positive.

2.5.2. Model development

A ship financing loan model is built to calculate the theoretical LGD and compare it with the actual LGD to determine whether the hypothetical LGD results are consistent with the actual LGD. In order to create the model, some assumptions are required, such as the LTV, the tenor of the loan, the repayment profile of the loan, the fair market value of the vessel at the time of financing, and the fair market value of the vessel at default and costs associated with enforcement of mortgage vessel. The tenor and repayment profile of the loan is assumed to be 5 years, based on a repayment profile of 15 years. It should be noted that a term of 5 to 7 year years is the most commonly used financing term, and a repayment profile of 15 years reflects the economic life of the vessel (with the exception of LNG vessels) accepted by banks which is usually between 15 and 18 years old.

To simplify the loan model, the mortgaged vessel is assumed to be sold immediately to recover the loan outstanding at the time of default, although it would typically take a few weeks to sell a vessel in the market. In a similar context, the financing loan model ignores cases where the loan is repaid by a corporate guarantee or other collateral such as cash and reserve accounts, and the loan is restructured/refinanced.

For the sale value of the mortgaged vessel, a 23% haircut on the fair market value is applied. According to the GCD data (Brumma and Rainone, 2021), the average historical discount rate of vessel sales in the default scenario is 23%. The observed haircut is defined as the post-default collateral value minus the pre-default collateral value divided by the post-default collateral value.

In terms of the vessel type, dry bulk, tanker, and container vessels are selected, which represent the main sub-sectors of the shipping industry, as evidenced by the fact that dry bulk, tanker, and container vessels account for 79% of the vessels trading globally, whereas LPG, LNG carrier, car carrier, and offshore support vessels, etc. accounts for the remaining 21% ("World Fleet Monitor," 2021). A representative ship is selected for each ship type. For dry bulk, Capesize dry bulk carriers and Panamax dry bulk carriers are selected, and Very Large Crude Carrier (VLCC), Suezmax, and Aframax tankers are chosen for tanker and 1,100TEU containership for the container segment. Among the various sizes of containerships, the 1,100 TEU containership is chosen as the representative for this category, as its sample data is more extensive compared to other sizes of containerships. Historical data on the representative vessels, such as contract price and fair market value in a particular year, is obtained from Clarksons Research.

In order to estimate the LGD for a vessel representing each sub-sector, the model assumes that the vessel is purchased in year T and subsequently sold in year T+5 to cover the loan balance amount, when the loan becomes due. If the loan amount at maturity (which should be around 66.7% of the initial amount) is less than the adjusted market value of the vessel (which is the fair market value after applying a 23% haircut), no loss will arise, therefore LGD is 0%. On the other hand, the LGD can be calculated using the shortfall, which is the difference between the loan balance amount and the adjusted market value of the vessel divided by the initial loan amount. This exercise is repeated when the LTV is 60%, 70%, 80%, and 90% while maintaining other commercial conditions remain unchanged, which would also provide the relationship between LTV and LGD, analyzed through regression analysis. The outcome is compared with the actual LGD of the GCD data, and it would lead to a conclusion as to whether or not the 15% LGD input floor to be imposed by Basel IV would constitute a significant constraint on ship finance banks. Further analysis can be performed to determine whether other critical, independent variables besides LTV also influence LGD.

In addition, one-way analysis of variance (ANOVA) is used to determine whether there is a meaningful difference in LGD between different ship types.

2.5.2.1. Empirical data

According to Global Credit Data (Brumma and Winckle, 2017), the average LGD is 11.5%, with 1.6 years to resolution, which is calculated as the period between a borrower's default and resolution. This information was based on 1,250 facilities and 1,600 collateral vessels from 25 different lenders worldwide over 15 years. The current LGD study for ship financing loans assumes 15% and is based on 1,547 defaulted facilities with 1.2 years to recovery (Brumma and Rainone, 2021).

Of the 1,547 defaulted facilities, 955 facilities are classified as Specialized Lending under Basel III, whereas the rest of the facilities fall under Large Corporates, SME, and Other categories. Considering that a typical ship financing loan, where a borrower is an SPC that owns a collateral vessel, is mostly classified as Specialized Lending under Basel IV, the historical average LGD for shipping loans appears to be 14% (see Table 2.11).

Table 2.11: Lending Portfolio

	Number of facilities	Observed LGD	Time to recovery
Ship Finance (Specialized Lending)	995	14%	1.2
Large Corporates	346	87%	1.0
SME	200	78%	1.2
Other	46	82%	1.3

Source: Global Credit data 2021
Note. SME means Small and medium-sized enterprises where the consolidated group's reported sales are less than EUR50 million.

The most common deal structure is commercial secured term loans, representing 70.7% of the total defaulted facilities, with 14% LGD. Twelve defaulted facilities are backed by Export Credit Agencies (ECAs), such as KSURE (Korea Trade Insurance Corporation), NEXI (Nippon Export and Investment Insurance), and SINOSURE (China Export & Credit Insurance Corporation). As anticipated, the LGD for ECA-backed facilities is 1%, given that the ECAs provide 90-95% comprehensive cover per OECD (Organisation for Economic Co-operation and Development) disciplines, meaning only the 5-10% tail-end risk should be covered by corporate guarantee and/or collateral vessel.

In respect of LTV, the average LTV at the time of financing of the defaulted facilities is around 66%. The logical conclusion is that higher LTV prior to default resulted in higher

LGD, and the value of the collateral vessel is the most important driver of low LGD. However, the report showed that the sale of the collateral vessels was not the first resolution for banks, as evidenced by more defaulted loans being resolved through loan restructuring, such as extending the maturity and payment holidays of principal or interest payments. A 23% haircut in value was observed when monetizing the collateral vessel. This observation can be explained by a decline in value due to changes in market circumstances or low price indications from buyers who view the disposal of collateral by banks as a fire sale, knowing that banks do not prefer to hold collateral vessels for a long period of time. In some jurisdictions, banking regulations do not legally allow banks to own and operate collateral vessels for an extended period of time.

2.5.2.2. Hypothetical loan model

When a loan is due, several variables play a role that determines whether the loan has been fully repaid or defaulted. In the case of a fully amortized repayment profile, for instance, a loan with a 7-year tenor based on a 7-year repayment profile, there is no balloon risk, meaning that a loan is repaid as long as a borrower can service the scheduled principal and interest. In other words, it is crucial to know how the loan outstanding at maturity, excluding scheduled principal amount payment, will be covered with the balloon structure loan. The balloon can be covered by refinancing the loan, corporate guarantee, sale of collateral, cash holdings, and so forth. In this study, I assume that collateral vessels are the only means that should cover the balloon and rule out the possibilities for other aforementioned manners. This implies that the hypothetical loan model is structured on a non-recourse basis, and the calculated LGD is conservative and less likely to be underestimated.

In the hypothetical loan model, it is treated as a defaulted loan if the value of the collateral vessel is less than the loan balance of the loan. In the event of a default, the LGD is calculated by dividing the shortfall between the collateral value and the outstanding loan by the loan outstanding. The percentage of the loan balance is fixed at 66.67% of the initial loan amount in this model, given the model assumes a 5-year tenor based on a 15-year repayment profile.

In respect of the initial loan amount, the model assumes multiple cases where LTV ranges from 60% to 90%, with a 10% interval. If the vessel's fair market value (FMV) is X, the initial loan amounts are $0.6X$ for a 60% LTV case. Therefore, the model can predict how the level of LTV affects LGD.

It is also essential to consider enforcement costs when selling the collateral vessel as it is not a neglectable amount of money. However, it is hard to standardize the enforcement costs as they vary subject to the type of vessel, length of time, the extent of involvement of legal counsel, the court fee, shipbroker fees, and so on. In this model, it is assumed that the enforcement cost is 8% of the gross proceeds of the sale, which is the median cost based on data from a UK port measured by the previous study (Franks, Sussman and Vig, 2016). The gross proceeds of the sale are defined as the fair market value of the collateral vessel at the time of sale, with a 23% haircut.

In summary, six variables are identified in the hypothetical loan model that would impact LGD, which are (1) Loan-to-Value (LTV), (2) fair market value at financing, (3) fair market value at default, (4) enforcement costs, (5) loan amount at financing and (6) loan outstanding at default. The positive correlation between LGD and LTV was examined earlier by Brumma and Winckle (Brumma & Winckle, 2017), who also explored the significance of collateral valuation in the assessment of LGD (Brumma & Winckle, 2018), prompting me to choose fair market value at financing and fair market value at default as variables.This can be equated with the following Equation 2.3:

Equation 2.3

$$LGD = \beta_0 + \beta_1 X_{LTV} + \beta_2 X_{FMV\_Financing} + \beta_3 X_{FMV\_Default} + \beta_4 X_{Cost} + \beta_5 X_{EAD\_Financing} + \beta_6 X_{EAD\_Default} + \varepsilon$$

Where,

β_0 is the LGD when the other six variables are zero, but β_0 cannot possibly take on the value of 0 in this study because zero LGD means no default.

X_{LTV} is LTV ranges from 60% to 90%, with a 10% interval.

$X_{FMV\_Financing}$ is the fair market value at financing.

$X_{FMV\_Default}$ is the fair market value at default after applying a 23% discount.

X_{Cost} is enforcement costs which are 8% of $X_{FMV\_Default}$.

$X_{EAD\_Financing}$ is financing loan amount at inception, which can be replaced with X_{LTV} multiply by $X_{FMV\_Financing}$.

$X_{EAD\_Default}$ is a loan outstanding at default, which can be written as $X_{EAD\_Financing}$ multiply by 10 years and divide by 15 years (repayment profile). In other words, $X_{LTV} \times X_{FMV\_Financing} \times \frac{10}{15}$.

Therefore, Equation 2.3 can be substituted by the following Equation 2.4:

Equation 2.4

$$LGD = \beta_0 + \beta_1 X_{LTV} + \beta_2 X_{FMV\_Financing} + \beta_3 X_{FMV\_Default}$$
$$+ 0.08 \times \beta_4 X_{FMV\_Default} + \beta_5 X_{LTV} X_{FMV\_Financing}$$
$$+ \frac{10}{15} \beta_6 X_{LTV} X_{FMV\_Financing} + \varepsilon$$

Equation 2.4 shows that the six independent variables can be shortened to three variables which are X_{LTV}, $X_{FMV\_Financing}$ and $X_{FMV\_Default}$.

2.5.3. Analysis

With Equation 2.4 as the base loan model, I collect historical data on the fair market value for each vessel type from 2000 to 2020 and calculate other variables based on the assumptions. Once the data is collected, 21 samples are grouped by each LTV level, meaning that there are a total of 84 samples in each vessel type, given that the LTV ranges from 60% to 90%, with a 10% interval. Since six different vessel types are selected to represent the shipping industry, the total initial sample size is 504. However, after eliminating non-default cases the number of samples decreases from 504 to 151 (see Table 2.12). This study focuses on 151 samples because non-defaulted cases (453 samples) are irrelevant for LGD estimation.

Table 2.12: Sample Size Comparison

	Sample size		LGD	
Vessel type	Raw data	Adjusted data	*M*	*SD*
Cape	84	40	0.25	0.15
Panamax	84	41	0.24	0.16
VLCC	84	13	0.21	0.13
Suezmax	84	7	0.20	0.09
Aframax	84	14	0.18	0.13
Containership	84	36	0.25	0.15
Total	504	151	0.23	0.15

Note. M = Mean; SD = Standard deviation. Mean and standard deviation are only applicable to the adjusted data.

Given the comparatively fewer default instances for VLCC, Suezmax, and Aframax, I consolidated these categories into a single classification referred to as tankers and re-examined the analysis accordingly.

Table 2.13: Revised Sample Size Comparison

	Sample size		LGD	
Vessel type	Raw data	Adjusted data	*M*	*SD*
Cape	84	40	0.25	0.15
Panamax	84	41	0.24	0.16
Tanker	84	16	0.14	0.13
Containership	84	36	0.25	0.15
Total	504	151	0.23	0.15

Note. M = Mean; SD = Standard deviation. Mean and standard deviation are only applicable to the adjusted data.

Of the filtered 151 default cases, 53.6% are dry bulk carriers, 22.5% are tankers and 23.9% are container ships. This result first raises the question of whether there is a significant difference in the probability of default between different types of assets. In particular, this could lead to the misleading conclusion that the dry bulk industry is more vulnerable than other sub-sectors. However, in this study I exclude the cases in which the repayment of a loan comes from sources other than the collateral vessel (company guarantee, insurance from ECAs and cash holdings, etc.). Therefore, the conclusion that the dry bulk industry has a higher probability of failure is premature. Further research is needed to determine whether the probability of default is higher in the dry bulk industry than in the other subsectors, which is beyond the scope of this research. However, at least based on this preliminary analysis, it can be assumed that the dry bulk market is more volatile than the other sub-sectors.

The second question arising from Table 2.12 is whether there is a significant difference in LGD between different asset types. To compare the LGD result by asset type, a one-way ANOVA test is performed, which provides no evidence that the difference in LGD is a statistically significant difference by the asset type ($F(5,145) = .74$, $p = .5966$). A Scheffé post-hoc test also revealed no significant pairwise differences between asset types (see Table 2.14).

Table 2.14: LGD Difference by Asset Type - Scheffé Test

	Cape	Panamax	VLCC	Suezmax	Aframax
Panamax	-.01 (1.000)				
VLCC	-.04 (.989)	-.03 (.995)			
Suezmax	-.05 (.978)	-.05 (.987)	-.02 (1.000)		
Aframax	-.07 (.774)	-.07 (.832)	-.04 (.995)	-.02 (1.000)	
Containership	-.00 (1.000)	.00 (1.000)	.03 (.992)	.05 (.983)	.07 (.808)

Note. *P*-value is presented in parentheses.

The one-way ANOVA test, after merging VLCC, Suezmax, and Aframax into a unified category referred to as tankers, further validates that there is no statistically significant difference regarding LGD based on the asset type ($F(3,147) = 1.1$, $p = .3493$) (see Table 2.15).

Table 2.15: Revised LGD Difference by Asset Type - Scheffé Test

	Cape	Containership	Panamax
Containership	-.00 (1.000)		
Panamax	-.00 (.999)	-.00 (1.000)	
Tanker	-.05 (.475)	-.05 (.528)	-.05 (.560)

Note. *P*-value is presented in parentheses.

As demonstrated in Table 2.14, there is no significant difference in LGD between the asset types. Therefore, a single sample *t*-test is conducted to determine whether there is a statistically significant difference between the overall LGD regardless of the type of asset and

15%, which is the same level of the LGD input floor newly introduced by Basel IV. The result indicates a significant difference between the mean LGD for the samples (*M*=0.23, *SD*=0.15) and 15%, $t(150) = 7.0138$, $p = .000$. In addition, a one-tailed single sample t-test is also conducted to examine whether the mean LGD for the entire default cases is higher than 15%. The result confirms that the mean LGD is well above 15%, $t(150) = 7.0138$, $p = .000$. This result is summarized in Table 2.16.

Table 2.16: Average LGD of The Asset Classes (Single Sample t-test)

						95% CI	
	T	*df*	*Sig. (2-tailed)*	*Sig. (1-tailed)*	*Mean*	*LL*	*UL*
LGD	7.0138	150	$.0000^{***}$	$.0000^{***}$	.2344	.2106	.2582

Note. CI = confidence interval; LL = lower limit; UL = upper limit. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. df = degree of freedom.

Before concluding that 15% LGD input floor introduction by Basel IV would have little impact on banks' capital requirements compared to Basel III, further investigation should be conducted as to whether LGD is significantly different by LTV level, given it is not common for banks to provide >80% LTV financing, while LGD for >80% LTV financing cases in the financing loan model would push the mean LGD value to a high side. Therefore, a one-way ANOVA test is conducted to see if there is a material difference in LGD depending on LTV level. The results show that the LGD differs significantly depending on the LTV level ($F(3,147)= 5.53$, $p = .0013$). A Scheffe post-hoc test also reveals that the LGD for both 60% and 70% financing cases is statistically significantly different from 90% LTV financing cases. Thus, I rerun a single sample *t*-test after removing 90% LTV cases from the total 151 samples, which reaffirms that the calculated LGD (*M*=0.21, *SD*=0.14) is significantly different from 15% and is higher than 15%, $t(98) = 3.9453$, $p = .0001$ for both two-tailed and one-tailed. Subsequently, one-way ANOVA is performed again to confirm whether the LGD still defers significantly depending on the LTV level. The outcome indicates that the LGD is marginally different subject to the LTV level ($F(2,96)= 2.52$, $p = .0858$) (see Table 2.17).

Table 2.17: LGD analysis by LTV - One-Way ANOVA Test

LTV	*M*	*SD*	1	2	3
1. 60%	0.15	0.14			
2. 70%	0.20	0.13	0.05		
3. 80%	0.23	0.14	0.08	0.03	
4. 90%	0.29	0.15	0.14**	0.09*	0.06
F (for 1 - 4)	5.53	*p*	.0013		
F (for 1 - 3)	2.52	*p*	.0858		

Note. M = Mean; SD = Standard deviation. Mean differences are shown. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

As demonstrated in Table 2.18, the single sample *t*-test for each LTV case shows that the LGD is significantly higher than 15% except for the 60% LTV case, where the average LGD is statistically different from 15% (see Table 2.18).

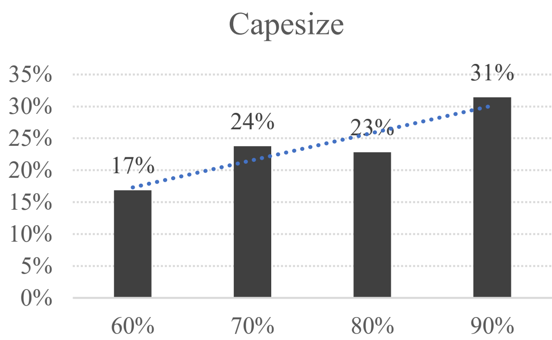
Table 2.18: LGD analysis by LTV - Single Sample T-Test for Each LTV Case

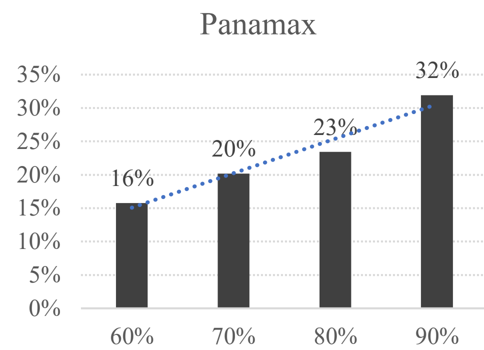
						95% CI	
LTV	*T*	*df*	*Sig. (2-tailed)*	*Sig. (1-tailed)*	*Mean*	*LL*	*UL*
60%	.042	19	.9665	.4833	.151	.087	.215
70%	2.17	32	$.0368^{**}$	$.0184^{**}$	.199	.153	.246
80%	3.93	45	$.0003^{***}$	$.0001^{***}$	.233	.190	.276
90%	6.80	51	$.0000^{***}$	$.0000^{***}$	.289	.247	.330

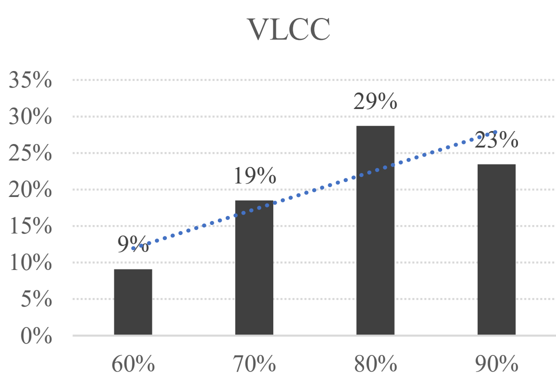
Note. CI = confidence interval; LL = lower limit; UL = upper limit. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. df = degree of freedom.

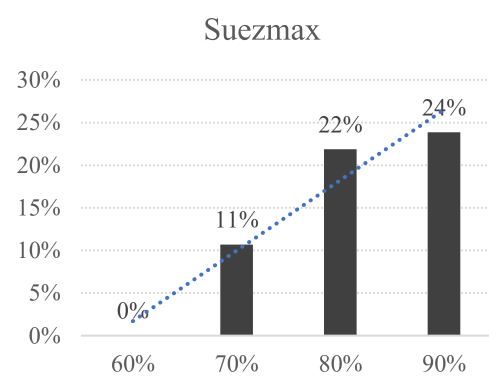
The relationship between LGD and LTV depending on the asset class is clearly shown in Figure 2.2 .

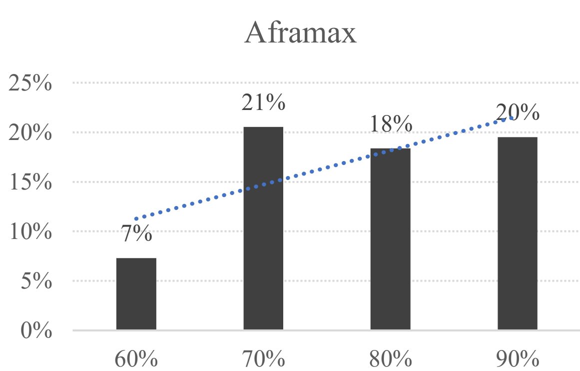
Figure 2.2: Relationship between LGD and LTV depending on the Asset Class


Capesize
35%
30%
25%
20%
15%
10%
5%
0%
17%
24%
23%
31%
60%
70%
80%
90%


Panamax
35%
30%
25%
20%
15%
10%
5%
0%
16%
20%
23%
32%
60%
70%
80%
90%


VLCC
35%
30%
25%
20%
15%
10%
5%
0%
9%
19%
29%
23%
60%
70%
80%
90%


Suezmax
30%
25%
20%
15%
10%
5%
0%
0%
11%
22%
24%
60%
70%
80%
90%


Aframax
25%
20%
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5%
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7%
21%
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20%
60%
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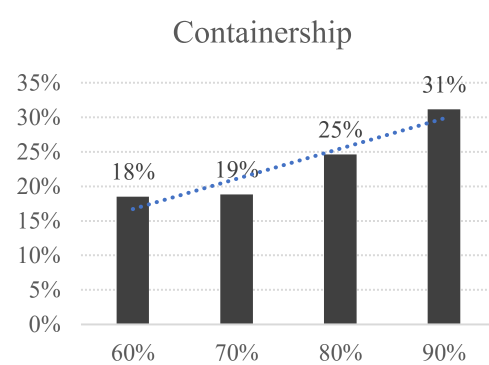
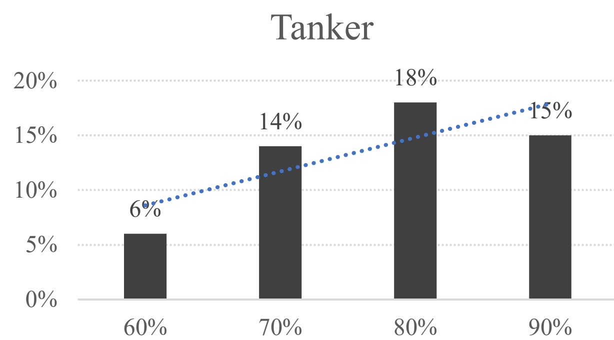
80%
90%


Containership
35%
30%
25%
20%
15%
10%
5%
0%
18%
19%
25%
31%
60%
70%
80%
90%



Note. The X-axis indicates LTV while the Y-axis indicates LGD. The categories of tanker encompass VLCC, Suezmax, and Aframax.

Based on the above result, it appears that LTV is correlated with LGD to some considerable extent. However, it is insufficient to conclude that LTV is the most influential factor in determining LGD. To further examine the effects of the other two variables on LGD, $X_{FMV\_Financing}$ and $X_{FMV\_Default}$, regression analysis is carried out based on Equation 2.4.

The results of multiple linear regression indicated that the model explained 77.2% of the variance and that the model is a significant predictor of LGD (F(3, 147) = 166.07, p < .0001, R^2 = .77, $Adj\ R^2$ = .76). In addition, the results also show that all three independent variables contribute significantly to the model, with no significant sign of multicollinearity between the independent variables (see Table 2.19). Since LTV is expressed as a percentage while FMV_Financing and FMV_Default are quantified in USD millions, it becomes challenging to compare the effects of the variables without neutralizing the impact of the measurement units. However, based on standardized coefficients which remove the units of measurement, it is found that the fair market value at financing and fair market value at default is relatively more important than LTV.

Table 2.19: Regression Analysis predicting LGD (N=151)

Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta (β)	*T*
Constant	-.4333	.0479	.	-9.04***
LTV	.8608	.0593	.6049	14.49***
FMV_Financing	.0108	.0005	2.5052	20.41***
FMV_Default	-.0258	.0012	-2.5318	-20.64***

Note. F (3,147)=166.07, *** $p < .001$, $Adj\ R^2 = 0.767$, VIF = 6.85

To determine whether the result does not differ depending on the asset, the same regression analysis is performed for each asset type. Since the sample size of VLCC (13), Suezmax (7) and Aframax (14) is not enough to generate reliable results, the regression analysis is carried out by combining these three ship types as tankers. The results are compared with the result of the regression analysis carried out on a consolidated basis (see Table 2.20). The standardized coefficients obtained from the individual regression analysis for various asset classes further validate that the fair market value at financing and the fair market value at default hold greater significance than LTV in predicting LGD.

Table 2.20: Regression Analysis for Each Asset Type

Capesize

Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta (β)	*T*
Constant	-.3839	.0626	.	-6.13***
LTV	.8418	.0656	.5917	12.83***
FMV_Financing	.0099	.0004	1.2037	20.75***
FMV_Default	-.0257	.0018	-.7916	-14.06***

Note. F (3,36)=160.22, *** $p < .001$, $Adj\ R^2 = 0.9245$, VIF=1.49

Panamax

Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta (β)	*T*
Constant	-.4298	.0571	.	-7.52***

LTV	.8984	.0631	.5984	14.24***
FMV_Financing	.01687	.0008	.9945	20.93***
FMV_Default	-.0432	.0025	-.8140	-17.10***

Note. F (3,37)=190.42, *** $p < .001$, *Adj* $R^2 = 0.9342$, VIF=1.28

Tanker (VLCC/Suezmax/Aframax)

Variable	Unstandardized Coefficients		Standardized Coefficients	T
	B	SE	Beta (β)	
Constant	-.5470	.0658	.	-8.30***
LTV	.9575	.0775	.8359	12.35***
FMV_Financing	.0081	.0005	2.3024	14.92***
FMV_Default	-.0186	.0014	-1.9382	-12.97***

Note. F (3,30)=86.10, *** $p < .001$, *Adj* $R^2 = 0.8855$, VIF=4.87

Containership

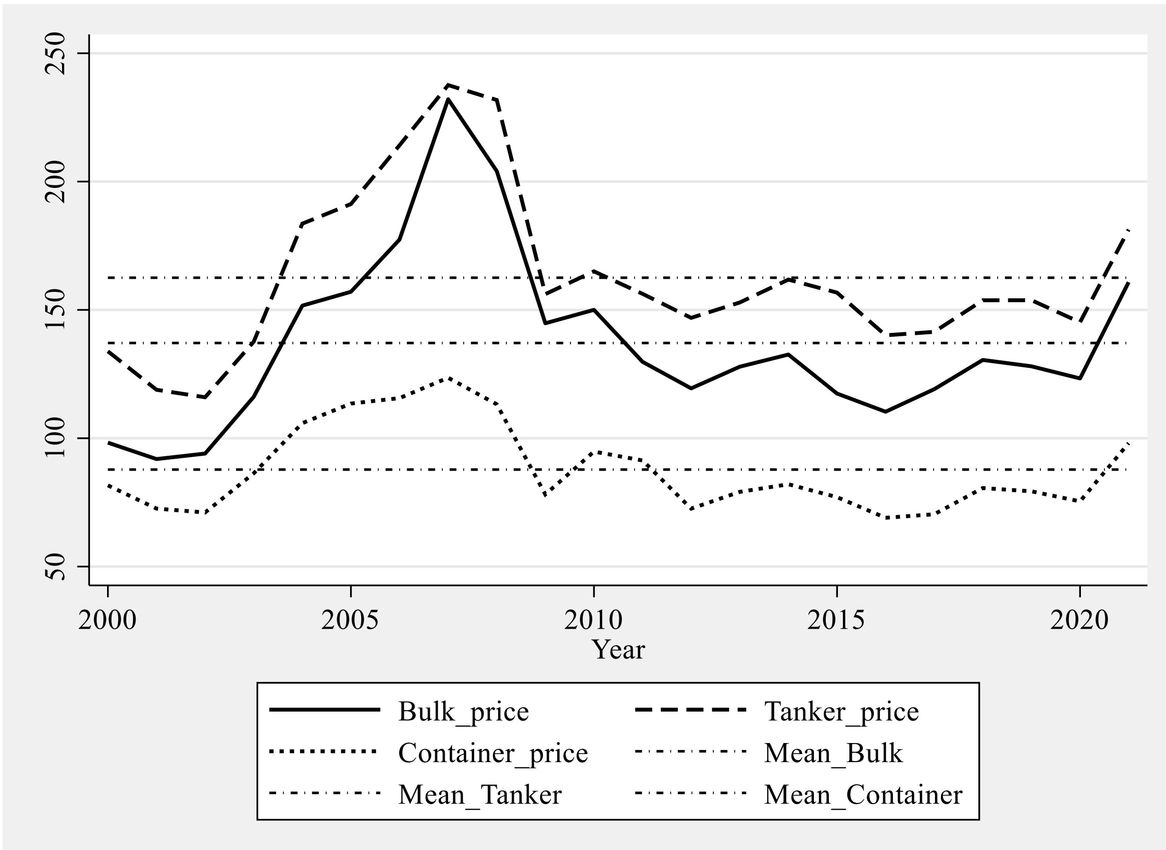
Variable	Unstandardized Coefficients		Standardized Coefficients	T
	B	SE	Beta (β)	
Constant	-.5503	.0421	.	-13.04***
LTV	.9499	.0401	.6253	23.68***
FMV_Financing	.0349	.0015	.6438	21.94***
FMV_Default	-.0765	.0020	-1.1317	-37.06***

Note. F (3,32)=517.53, *** $p < .001$, *Adj* $R^2 = 0.9779$, VIF=1.32

From a bank's perspective, the fair market value at default is not a controllable variable. It is subject to the market situation at the time of default. In contrast, the fair market value at financing is a controllable factor for a financier as the financier can determine the timing of funding and adjust other financing terms such as LTV, tenor, and repayment profile if the fair market at financing is perceived to be on a favorable side.

The question is how to set the benchmark level to determine whether the market value at financing is relatively high or not. Figure 2.3 shows the indexed historical value for dry bulk, tanker, and Containership from 2000 to 2020. It clearly reflects the cyclical nature of the shipping industry, with the values fluctuating throughout the period. However, it is also important to note that the values tend to revert to the mean over time (see Figure 2.3).

Figure 2.3: Historical Value for Dry Bulk, Tanker, and Containership

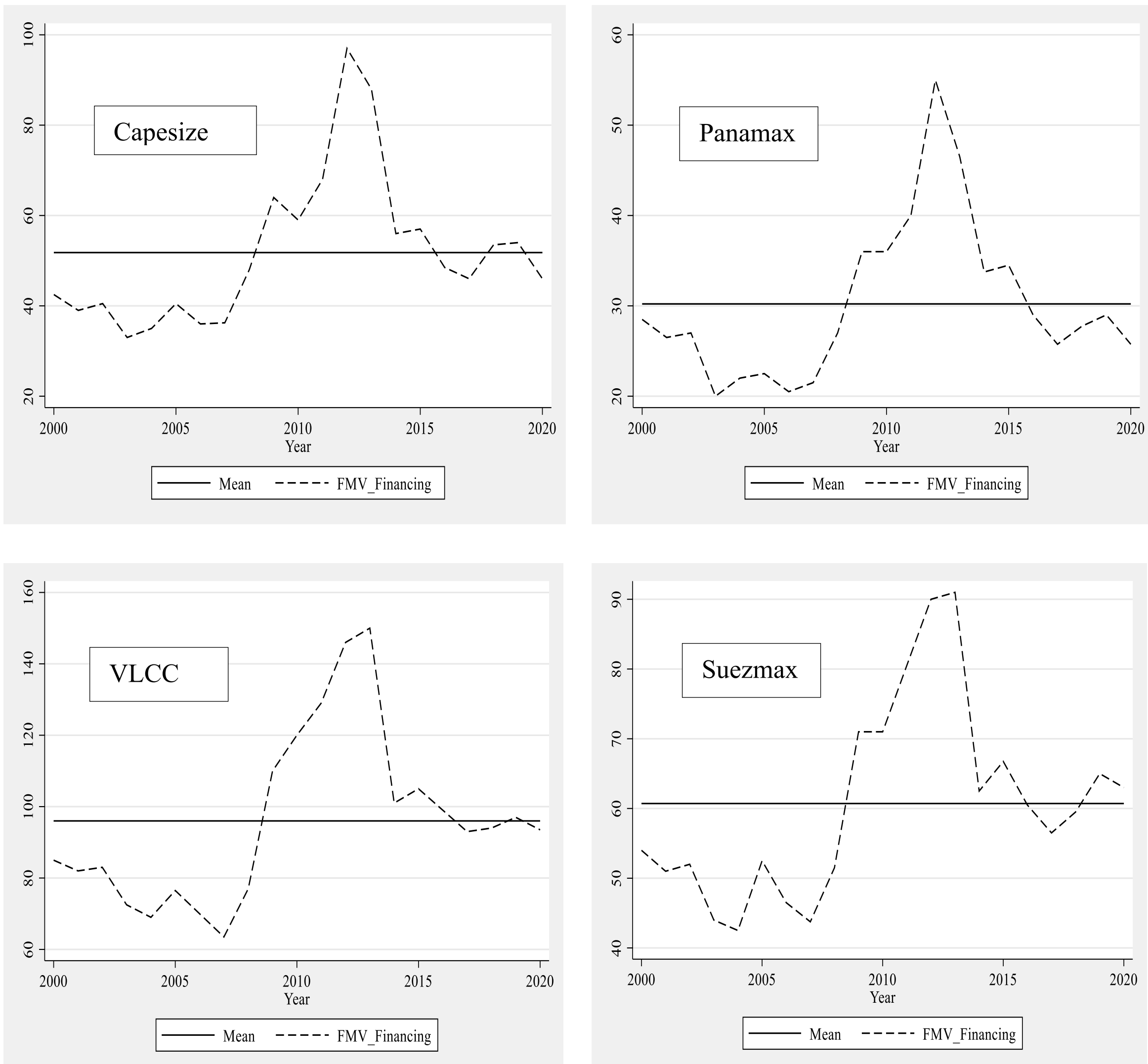


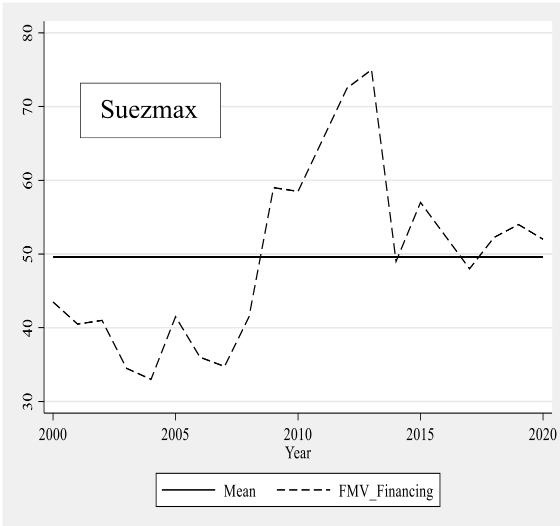
Note. The data is collected from Clarksons Research (https://www.clarksons.net/n/#/portal). The dry bulk values and the tanker value are indexed by setting the value in January 1988 at 100, respectively, while the value in January 1997 is set at 100 for the containership value.

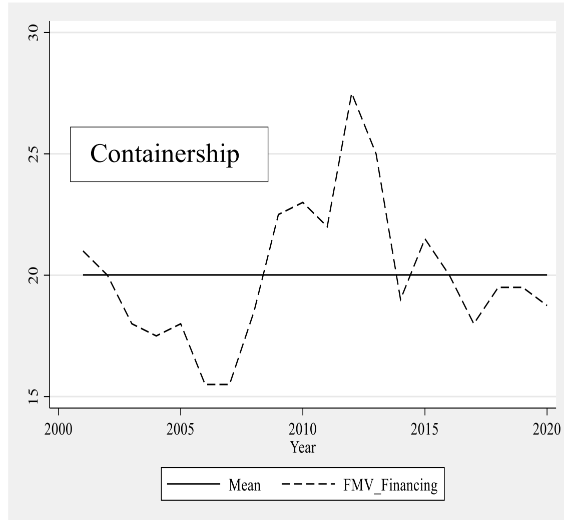
Therefore, I choose the historical average value of each vessel type during the selected period (2000 – 2020) as a benchmark to determine the fair market value when financing, whether it is relatively high or not. If the fair market value at financing is above the average value, it is classified as 'Above Average' and 'Below Average' in the opposite case (see Figure 2.4).

Afterward, one-way ANOVA is performed to determine whether there is a significant difference in LGD between ‘Above Average' and 'Below Average’ cases.

Figure 2.4: Historical value and Mean for Each Vessel Type







Note. The above graph is prepared based on the adjusted data in Table 2.12.

As presented in Table 2.21, the results demonstrate that the LGD difference between the 'Above Average' case and the 'Below Average' case is statistically significant for Cape and Panamax dry bulk carriers, whereas there are no defaulted cases for Suezmax and Aframax when financing occurs at 'Below Average'. The results do not support the statistical evidence for VLCC and Containership that the LGD is different between the 'Above Average' and the 'Below Average' cases. For the VLCC case, the results are not statistically reliable due to the small sample size. It is clearly noted that 12 out of 13 defaulted cases occur when financing occurs at 'Above Average'. Therefore, it can be concluded that the LGD for dry bulk and tankers would be significantly higher if financing is based on the fair market value, which is higher than the historical average.

Table 2.21: LGD Comparison Between Above-Average Financing and Below-Average Financing

LGD	Above Average			Below Average			*F*
	M	*SD*	*N*	*M*	*SD*	*N*	
Cape	0.29	0.16	25	0.18	0.11	15	5.74^{**}

Panamax	0.32	0.17	17	0.18	0.12	24	9.43***
VLCC	0.23	0.12	12	0.00	0.00	1	3.43
Suezmax	0.20	0.09	7	-	-	0	N/A
Aframax	0.18	0.13	14	-	-	0	N/A
Containership	0.26	0.17	26	0.22	0.10	10	0.56

Note. M = Mean; SD = Standard deviation. * $p < .05$. ** $p < .01$. *** $p < .001$.

Another ANOVA test is performed to assess whether there exists a significant difference in LGD between 'above-average' and 'below-average' cases without distinguishing asset types. The results indicate that there is no statistically significant difference in the mean LGD ($F(1, 149) = 1.81$, $p > .005$), which warrants further scrutiny. This outcome should primarily be ascribed to the fact that the amalgamation of various asset types resulted in overlooking the differing values of the vessels, which led to an underestimation of the 'Above Average' cases from 101 to 63 and an overestimation of the 'Below Average' cases from 50 to 88. Ultimately, the average LGD between the two case categories appeared to be quite similar. Since the value of vessels significantly varies across different asset classes, it is illogical to establish a reference value while overlooking the valuation discrepancies among these asset classes. Therefore, the ANOVA outcome that does not distinguish between asset types is unlikely to yield meaningful insights

2.5.4. Results

Based on the analysis in this chapter, the following conclusions can be drawn:

(1) There is no significant difference in LGD between different asset types.

(2) The overall LGD is higher than 15% depending on the LTV level. For 60% LTV cases, there is no statistical evidence that the LGD is higher than 15%. Furthermore, there is a significant difference in LGD between cases with LTV of 60-70% and LTV of 90%.

(3) The regression analysis suggests that the fair market value at financing and the fair market value at default are as important independent variables as LTV in determining LGD.

(4) By dividing the defaulted cases between 'Above Average' and 'Below Average' cases and comparing the LGD, the results show that the LGD for dry bulk and tanker would be significantly higher in the 'Above Average' case than in the ‘Below Average’ case.

(5) The empirical data shows that the actual LGD for shipping loans is around 14%.

Meanwhile, there are some limitations in the hypothetical loan model that could lead to a higher LGD. Firstly, the model assumes a 5-year tenor. If the tenor is longer than 5 years, the balloon is smaller, so the LGD could be lower than the 5-year tenor case. However, it should also consider that the value of the ship generally depreciates, meaning that the longer tenor does not always guarantee less likelihood of default, which is subject to the fair market value at maturity. Secondly, the loan model rules out the chances that the balloon can be covered by other means (corporate guarantee, cash collateral, ECA insurance, and reserve accounts, etc.) other than the collateral vessel. Any additional security should reduce the LGD in practice. Thirdly, the loan model does not assume the interim default case before the loan maturity due to insufficient vessel earnings to cover the debt service and OPEX of the vessel. This could well be an actual default case in real life. Finally, the model does not assume that the probability of default is the independent variable of LGD. When calculating risk-weight assets according to the Basel guidance, the probability of default and LGD are supposed to be mutually exclusive variables. This means the probability of default should not be correlated with LGD. However, a positive correlation is observed between the probability of default and LGD in the model, evidenced by the number of defaulted cases and LGD increase as the LTV level increases. This is mainly due to the assumption of non-recourse financing, which is one of the assumptions in the model. This correlation could lead to an overestimation of risk-weighted assets but does not pose a critical issue for LGD estimation since the default represents a given situation for LGD calculation.

Despite the above restrictions in the model, in the context of verifying if the new LGD input floor of 15% introduced by Basel IV would constitute excessive regulation for ship financing banks, one can reasonably conclude that the 15% LGD input floor is a fair reflection of the market data. However, the 15% LGD floor could still represent a critical constraint for banks that have their own pricing model under the A-IRB approach if the bespoke model produces below 15% LGD for 60-70% LTV financing under the current Basel III. Given that the bank's model was developed and should be approved by the ECB for European banks based on the bank's historical default data, the estimated LGD from the model developed by a bank with fewer default cases is likely to be lower than the average LGD in the market. In such a case, the new LGD input floor guideline will force banks to accumulate more capital if the guideline becomes compulsory in the jurisdictions where the banks operate, which in turn may have a negative impact on shipowners.

2.6. Discussions

2.6.1. The possible consideration to reduce risk-weighted assets under Basel IV

With regard to strengthening stability through standardizing rules in the international banking system, Basel IV is not a controversial issue. Although the Basel accords have no enforcement powers and rely on the regulatory authorities of each participating country for implementation, most countries follow the Basel framework. Some regulators in certain countries, such as the EBA in Europe, impose stricter standards than the Basel framework. There are arguments and lobbies in many countries regarding whether the current form of Basel IV should be implemented or not. From a conservative perspective, banks should be prepared to respond to the upcoming implementation of Basel IV, regardless of whether it is delayed or modified. As analyzed in the previous chapters, the impact of Basel IV is expected to be significant to the banks that adopt the A-IRB approach, and specialized lending asset classes will be materially affected by Basel IV implementation.

Basel IV presents banks that provide liquidity in the shipping market with the question of whether they should withdraw or scale back their ship financing business due to the substantially increased capital requirements. Alternatively, they may decide to continue to be the primary source of funding for ship financing by way of finding solutions to mitigate the increased risk-weighted assets. Given that a number of traditional ship financing banks have already existed in the ship financing business, this could be a disaster for ship owners, as the capacity of the alternative players such as private equity funds and leasing companies is not enough to fill the gap of the traditional ship financing banks if they were to withdraw. From a bank's point of view, they will lose one of the most profitable businesses in the world of corporate financing. Therefore, banks are expected to find a way to minimize the impact of

Basel IV in order to continue shipping finance business. In this context, in the following subchapters, I suggest some possible considerations for reducing the RWA impact of Basel IV.

2.6.1.1. Utilization of Export Credit Agencies

An Export Credit Agency (ECA) is an institution that serves as an intermediary between governments and exporters, providing credit insurance, financial guarantees, or both as part of the financing. Governments provide officially supported export credits through ECAs to support national exporters competing for overseas sales. ECAs can be government institutions or private companies operating on behalf of governments. The OECD is a forum for maintaining, developing, and monitoring the financial disciplines for export credits contained within the Arrangement on Officially Supported Export Credits (Arrangement). These disciplines stipulate the most generous financial terms and conditions that OECD members (excluding Chile, Costa Rica, and Iceland) may offer when providing officially supported export credits.

The OECD has also developed guiding terms and principles in the form of a Sector Understanding on Export Credits for Ships, which is the annex of the Arrangement (Arrangement and Sector Understandings - OECD). According to the Sector Understanding in shipping, ECAs can support the financing of up to 80% of the contract price of the underlying export, such as the shipbuilding contract, with loan tenors of up to 12 years after delivery of the ship. The cover percentage of the insured loan may vary, usually from 80% to 95%, and a premium charge applies subject to the level of risk assumed by the ECA (i.e., the buyer's credit risk).

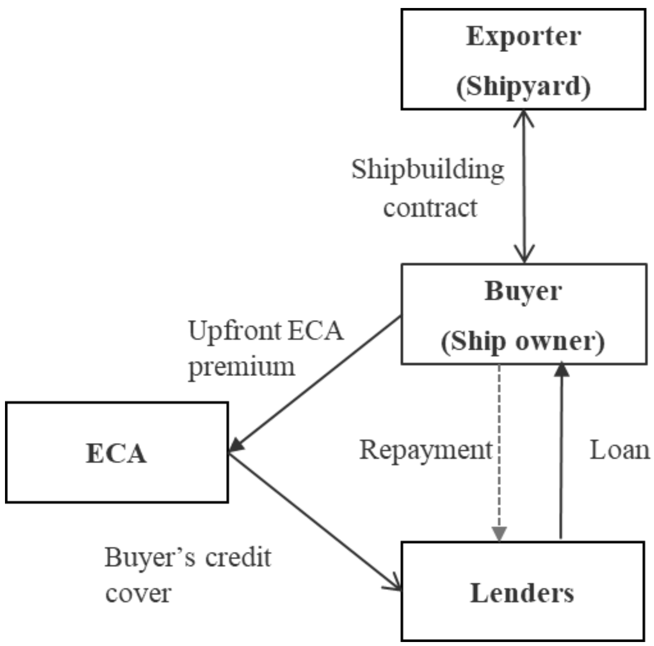
Raquel ((Raquel Mazal Krauss, 2011) summarized that ECAs address two fundamental export transaction risks: political and commercial risks. Political risk refers to events due to the government's political actions that impact buyer payment. These may include transfer risk (inability to exchange the local deposit for that of the ECA country), expropriation, war risks, cancellation of an existing import and export license, and political violence. The risks of countries are usually evaluated by the OECD and classified into seven categories depending on their risk profile. Countries rated 1 have the lowest risk, and those rated 7 have the highest risk. Commercial risk refers to non-payment resulting from bankruptcy, insolvency, protracted default, fluctuation in demand, unanticipated competition, shifts in tariffs, and failure to take up goods shipped according to the supply contract. Commercial risk also includes other factors not covered under political risks.

The ECAs provide five basic financing needs of an exporter: (1) Pre-export working capital, (2) Short-term export terms extended to importers, (3) Medium- to long-term financing support to overseas importers, (4) Project financing, and (5) Special export structures (e.g., leases, aircraft/shipping financing, on-lending credit facilities, etc.).

ECAs extend a diverse array of assistance to both importers and exporters. They furnish buyer credit by rendering financial support to importers for the acquisition of exported goods or services, which can be executed through direct financing mechanisms or guarantees provided to commercial financial institutions. Furthermore, they facilitate supplier credit by offering support to exporters via deferred payment arrangements that may involve bills of exchange or promissory notes. In addition to these services, ECAs also provide political risk insurance and interest rate subsidies aimed at promoting and facilitating international trade.

The most relevant product in the context of this research is the buyer credit (i.e., a cover issued by the ECA to the benefit of financiers), which covers lenders' losses against the ship owner's non-payment on the loan facility triggered by political or commercial credit risk. The typical financing structure is demonstrated in Figure 2.5 below:

Figure 2.5: Typical ECA-backed ship financing structure (buyer's credit)



In most cases, the buyer in Figure 2.5 is a special purpose company (SPC) established by the ship owner, who provides a guarantee to the SPC in a recourse financing structure. No guarantee provided by the ship owner to the SPC is usually considered non-recourse financing. Regarding ECA-backed ship financing, ECAs typically require a guarantee from the parent company with a strong balance sheet.

The major ECAs in shipping finance sit in Japan, South Korea, China, and Norway, where major shipyards are located (see Table 2.22).

Table 2.22: Major ECAs in Shipping Finance

Country	ECA	Full Name
Japan	JBIC	Japan Bank for International Cooperation
	NEXI	Nippon Export and Investment Insurance
Korea	KEXIM	The Export-Import Bank of Korea
	KSURE	Korea Trade Insurance Corp
China	CEXIM	The Export-Import Bank of China
	SINOSURE	China Export & Credit Insurance Corporation
Norway	Eksportfinans ASA	
	GIEK	The Norwegian Export Credit Guarantee Agency

Note. JBIC, KEXIM, CEXIM, and Eksportfinans can provide both direct and indirect support by giving guarantees or insurance. In contrast, NEXI, KSURE, SINOSURE, and GEIK can only provide indirect support.

ECA financing provides benefits for both exporters (shipyards) and importers (ship owners). Ship owners can access large amounts of capital without consuming the lending capacity of existing lending banks, given the ECA-covered portion in a loan (80-95%) can be carved out from the commercial exposure of the borrower. From a shipyards' point of view, ECA financing facilitates ship owners, including the ship owners who could not have ordered a vessel without ECA financing, to order new ships at their domestic shipyards.

Providing ECA financing also provides advantages to lenders that they can allocate less capital compared to the same amount of commercial funding due to ECAs' risk being recognized as sovereign risk. Under Basel IV, a guarantee from ECAs is identified as eligible collateral, which can be used as a credit risk mitigating factor in SA, F-IRB, and A-IRB approaches. In SA, risk weighting is subject to the country risk scores assigned by ECAs. Banks may choose to use the risk scores published by individual ECAs that are recognized by their supervisor or the consensus risk scores of ECAs participating in OECD arrangements. The risk weighting corresponding to the ECA risk scores under Basel IV is as below.

ECA risk scores	0-1	2	3	4-6	7
Risk weight	0%	20%	50%	100%	150%

Source: (CRE20 - Standardised approach: individual exposures)

According to OECD's country risk classifications (as of July 2022), the risk scores for Japan, Korea, and Norway are 0, while China is 2. It means, for example, the risk weight for the ECA-covered portion in a shipping loan is nil under SA if the secured vessel for the loan is ordered at a Korean shipyard. This is already a known capital benefit since Basel III.

The question is whether ECA financing can reduce RWA under Basel IV given the revised LGD input floor in the IRB approach. Suppose a tanker owner is seeking a loan to purchase a new US$ 100 million Very Large Crude Carrier (VLCC) quoted by a Korean shipyard. The tanker owner has no external credit rating, and the probability of default estimated by banks using the IRB approach is 0.8%. The expected commercial financing terms from banks are as follows:

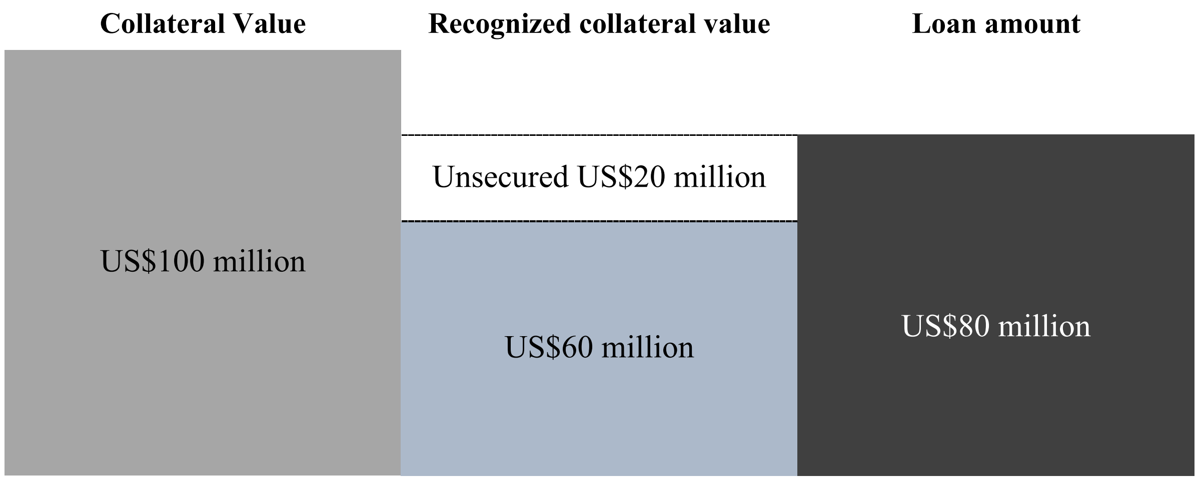
- Loan-to-Value (LTV): 80% of the contract price
- Loan Tenor: 7 years
- Repayment profile: 15 years

Regarding the RWA estimated by SA, object, and commodities finance exposure will be risk-weighted at 100% if the specialized lending exposure does not have an issue-specific external rating. Therefore, the RWA should be US$80 million (= US$100 million × 80% LTV).

As vessel collateral is not eligible collateral to reduce RWA in SA, there is no credit mitigating effect due to the vessel collateral.

However, the vessel collateral is recognized as eligible collateral under the IRB approach, with a 40% haircut on value (refer to Table 2.6 and Table 2.7). Applying the above example, the US$ 80 million loan amount is effectively secured by US$60 million collateral (i.e., 75% of the loan is secured), and the remaining US$20 million is an unsecured portion (see Figure 2.6).

Figure 2.6: Example of collateral recognition in the IRB approach



Based on this information, LGD can be calculated for F-IRB and A-IRB as below:

	Secured LGD (1)	Unsecured LGD (2)	Total LGD ((1) +(2))
F-IRB	0.75×0.25	0.25×0.4	28.8%
A-IRB	0.75×0.15	0.25×0.25	17.5%

Based on the above assumptions, the RWA for the financing is estimated as shown in Table 2.23.

Table 2.23: RWA calculation per each approach

	SA	F-IRB	A-IRB
PD	N/A	0.8%	0.8%

LGD	N/A	28.8%	17.5%
EAD	N/A	80	80
Maturity	N/A	2.5	5
R		0.200	0.200
b		0.147	0.147
K		0.043	0.036
Risk Weighting	100%	-	-
RWA	**80.0**	**43.4**	**36.1**

Note. R,b, and *K* are calculated based on Equation 2.1.

The result shows that banks adopting the A-IRB approach can take advantage of RWA calculation.

If the tanker owner wants to explore ECA-backed financing using KSURE's buyer's credit program, the RWA calculation would be different from the results in Table 2.23. Noting ECA financing cannot accommodate balloon structure, the above commercial financing terms need to be amended as below:

- Loan-to-Value (LTV): 80% of the contract price
- Loan Tenor: 12 years
- Repayment profile: 12 years
- KSURE insurance coverage: 95%

Given the KSURE insurance covers 95% of the total exposure, 5% of the exposure should be a commercial portion. Under the SA, the risk weighting for the ECA covered portion is 0%, given the ECA score of South Korea is 0, allowing 0% risk weighting. On the commercial portion, 100% risk weighting should be assigned, resulting in US$ 4 million RWA (=US$80 million × 5% × 100%).

In order to calculate the RWA for the KSURE-covered exposure, PD and LGD should be estimated by banks. For the PD estimation, I refer to Table 2.10 and assign 0.03% PD considering an AA rating from S&P for South Korea. With respect to the LGD estimation, 0.8% is used based on the LGD study for European sovereign bonds (Jobst, Kellner and Rösch, 2020), where the academics found that average LGD estimates are between 0.46% and 0.64%, while downturn estimates vary between 0.50% and 0.86%. As the PD and LGD floor do not apply to the sovereign exposure under Basel IV, low PD and LGD estimates are still allowed. With the new assumptions above, Table 2.24 and Table 2.25 illustrate the RWA calculation results for both KSURE-covered and commercial exposure.

Table 2.24: RWA estimation for KSURE covered exposure (95%)

	SA	**F-IRB**	**A-IRB**
PD	N/A	0.03%	0.03%
LGD	N/A	0.8%	0.8%
EAD	N/A	76	76
Maturity	N/A	2.5	5
R		0.238	0.238
b		0.317	0.317
K		0.000	0.000
Risk Weighting	0%	-	-
RWA	**0**	**0.20**	**0.35**

Note. R,b, and *K* are calculated based on Equation 2.1.

Table 2.25: RWA estimation for commercial exposure (5%)

	SA	**F-IRB**	**A-IRB**
PD	N/A	0.8%	0.8%
LGD	N/A	28.8%	17.5%
EAD	N/A	4	4
Maturity	N/A	2.5	5
R		0.200	0.200
b		0.147	0.147
K		0.043	0.036
Risk Weighting	100%	-	-
RWA	**4.0**	**2.17**	**1.81**

Note. R,b, and *K* are calculated based on Equation 2.1.

In short, the total RWA requirement for KSURE-covered financing is as below.

(Unit: US$ million)

	SA	**F-IRB**	**A-IRB**

RWA	4.0	2.37	2.16

Note. The total RWA is the sum of RWA in Table 2.24 and Table 2.25 per each approach.

The example in this study clearly demonstrates a significant RWA reduction effect, ranging from 94% to 95%, for ECA-backed ship financing regardless of the LGD input floor (see Table 2.26).

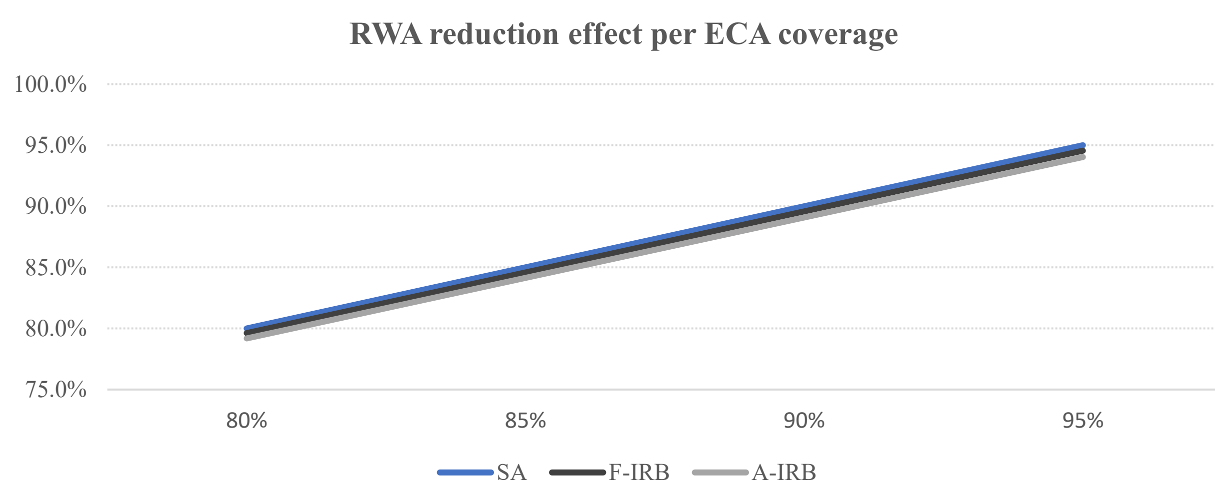
Table 2.26: Summary of RWA effect for KSURE-backed financing

(Unit: US$ million)

RWA	SA	F-IRB	A-IRB
ECA-backed	4.0	2.37	2.16
Commercial	80.0	43.4	36.1
RWA reduction (%)	*95%*	*94.6%*	*94.0%*

Repeating the above calculation based on different ECA coverage ratios from 80% to 95%, the RWA reduction effect varies from 79.2% to 95%, subject to the ECA coverage ratio (see Figure 2.7).

Figure 2.7: RWA reduction effect per ECA coverage



Note. The Y-axis refers to the RWA reduction effect. The X-axis shows the ECA coverage ratio.

Despite the obvious RWA benefits, there are limitations to the use of ECA financing for ship financing in general. First of all, there are restrictions in terms of the loan tenor and amortization profile. It is not suitable financing for owners who wish to have a more extended repayment profile (> 12 years) and have a balloon structure (i.e., the tenor and repayment profile are not aligned). Secondly, the ECA financing is only applicable to a newbuilding project, given that ECAs support domestic companies' exports. Therefore, the refinancing of existing shipping loans or the financing of secondhand vessels cannot benefit from ECA support. Thirdly, the overall process, including due diligence on the borrower, is relatively longer than commercial financing, which typically takes more than six months. Finally, all-in margins to be absorbed by the borrower could be higher subject to the premium quoted by the ECAs.

2.6.1.2. Collateral Risk Insurance

This idea is based on the fact that the standardized approach recognizes a lower need for RWA requirements when collateral is in the form of a guarantee from a well-rated counterparty. Suppose a loan portfolio consists of a single borrower (unrated) who owns 1x Very Large Crude Carrier worth US$100 million. The prevailing financing conditions are as follows:

- Loan amount: US$80 million
- Loan Tenor: 7 years
- Repayment profile: 15 years

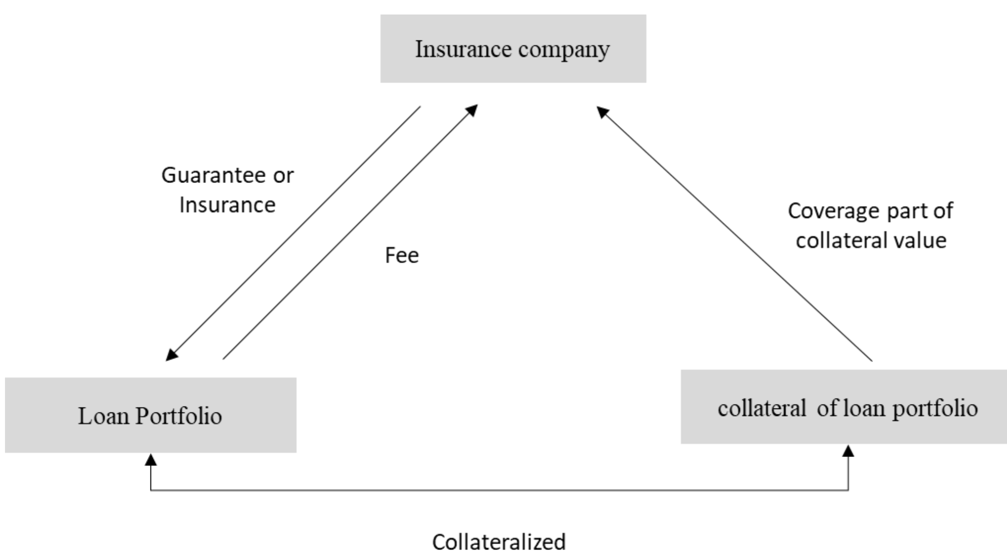
Given this situation described in Chapter 2.6.1.1 Utilization of Credit Agencies, the RWA calculation should be the same as Table 2.23.

	SA	F-IRB	A-IRB
PD	N/A	0.8%	0.8%
LGD	N/A	28.8%	17.5%
EAD	N/A	80	80
Maturity	N/A	2.5	5
R		0.200	0.200
b		0.147	0.147
K		0.043	0.036
Risk Weighting	100%	-	-
RWA	**80.0**	**43.4**	**36.1**

Note. R,b, and *K* are calculated based on Equation 2.1.

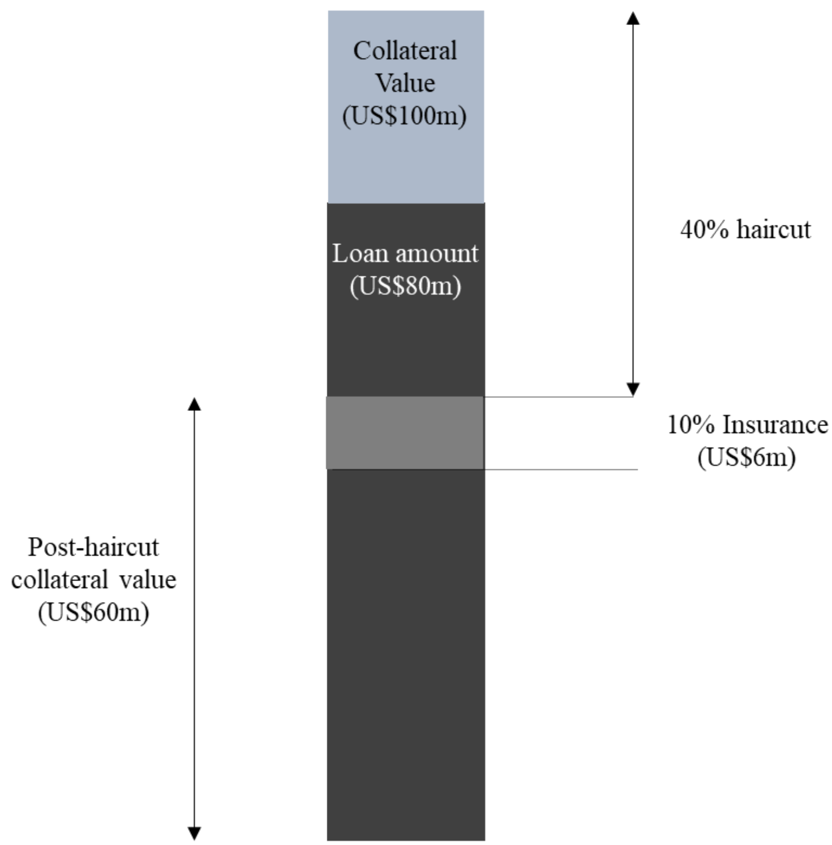
If the financing bank wants to secure part of the collateral value with an insurance company, the risk of the covered claim is transferred to the insurance company. In return, the insurance company receives a regular fee from the bank so long as they provide protection to the loan portfolio (see Figure 2.8). The cover is only triggered if the realized collateral value upon default is less than the expected collateral value.

Figure 2.8: Collateral Risk Insurance Structure



Assume the bank in the above example takes out insurance cover for 10% of the post-haircut collateral value (see Figure 2.9). The actual claim only arises if the collateral vessel is repossessed and sold for less than the post-haircut collateral value.

Figure 2.9: Example of Collateral Risk Insurance



Assuming that the insurance company's external credit rating from S&P is A+ and the internal PD estimate is 0.05%, the RWA estimate for the risk covered by insurance is as described below in Table 2.27. As mentioned in Table 2.5, the A-IRB approach is not permitted under Basel IV to capture the credit risk of financial institutions.

Table 2.27: RWA estimation for insurance-covered exposure (10%)

	SA	**F-IRB**	**A-IRB**
PD	N/A	0.05%	N/A
LGD	N/A	45%	N/A
EAD	N/A	6	N/A
Maturity	N/A	2.5	N/A
R		0.237	N/A
b		0.286	N/A
K		0.016	N/A
Risk Weighting	30%	-	N/A

RWA	1.8	1.18	N/A

Note. R,b, and *K* are calculated based on Equation 2.1.

Table 2.28 shows the RWA estimation for the commercial exposure.

Table 2.28: RWA estimation for the commercial exposure

	SA	F-IRB	A-IRB
PD	N/A	0.80%	0.80%
LGD	N/A	28.75%	17.50%
EAD	N/A	74	74
Maturity	N/A	2.5	5
R		0.200	0.200
b		0.147	0.147
K		0.043	0.036
Risk Weighting	100%	-	-
RWA	**74.0**	**40.15**	**33.40**

Note. R,b, and *K* are calculated based on Equation 2.1.

The total RWA requirement for collateral risk insurance on a single asset portfolio is as below.

(Unit: US$ million)

	SA	F-IRB	A-IRB
RWA	75.8	41.33	34.58

Note. The total RWA is the sum of RWA in Table 2.27 and Table 2.28 for each approach.

In conclusion, the result demonstrates a certain degree of RWA relief effect by taking collateral insurance. The positive impact is more profound to the bank that uses the standardized approach.

(Unit: US$ million)

RWA	SA	F-IRB	A-IRB
Collateral Risk Insurance	75.8	41.33	34.58
Commercial	80.0	43.4	36.1
RWA reduction (%)	*5.3%*	*4.8%*	*4.2%*

The critical consideration for banks when deciding whether to take out collateral risk insurance is the expected RWA relief versus expected lower profitability. If the fee to the protection provider, the insurance company in the example, is very high, some profitability metrics, such as return on equity, on the bank may decrease despite the reduced RWA.

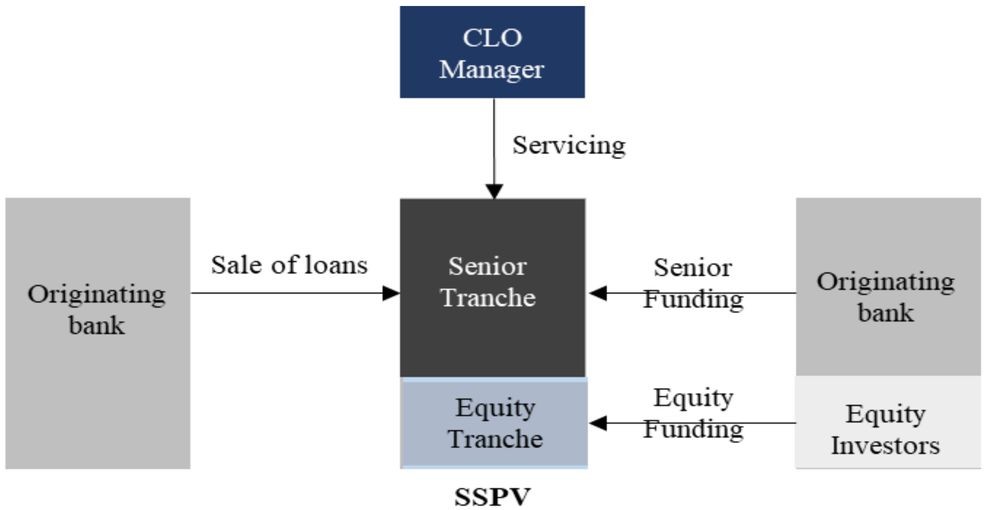
However, there are some advantages for the insurance company: (1) they can diversify the portfolio of borrowers across countries and rating profiles, (2) they expect stable fee income from the loan portfolio, and (3) the LTV for them is very low because the insurance is provided up to the post-haircut collateral value, which means the likelihood of an insurance claim event is very low to them. Considering the mutual benefits for both banks and insurance companies, I expect that there will be a market for these types of products if Basel IV is implemented as planned.

2.6.1.3. Securitization (CLO)

Traditional securitization involves the originating institution, traditionally a bank, which sells a set of homogeneous assets to a securitization special purpose vehicle (SSPV), which is considered a true sale. The true sale transactions are a funding source for the originating institution. The SSPV bundles and tranches these transactions into super senior tranches, mezzanine tranches, and junior tranches (equity tranches) according to their priorities and issues securities to different investors with different risk appetites. Securitization of loans through collateralized loan obligation (CLO) is one of the traditional securitizations and a well-known funding source for corporate lending.

Suppose a bank holding a US$1 billion notional ship financing loan portfolio considers securitization of loans through CLO, which has two tranches, a senior tranche and an equity tranche. The bank finances the senior tranche, while the equity tranche is sold to third parties (see Figure 2.10).

Figure 2.10: CLO structure diagram



The senior tranche is covered by the first priority mortgage over the whole collateral vessels and ranks higher than the equity tranche in terms of cash flow (i.e., any cash flow should be applied to the senior tranche before it goes to the equity tranche). Therefore, the PD of the senior tranche should be lower than the original loan portfolio.

The above structure is different from a typical CLO structure. The main purpose of this CLO is to reduce the RWA of the original loan portfolio by transferring the equity tranche to third-party investors and rejoining the original bank as the lender in the senior tranche. In contrast, the fundamental purpose of a CLO is to provide an efficient source of financing to below-investment-grade corporate borrowers.

In order to investigate the RWA relief effect by the proposed CLO structure, The below key financing terms are assumed:

<u>Original loan portfolio (PD: 0.8%)</u>

- Loan amount: US$ 800 million

- Average tenor: 7 years
- Average repayment profile: 15 years
- Average loan margin: 2% per annum

Senior Tranche (PD: 0.5%)

- Loan amount: US$ 560 million
- Average tenor: 7 years
- Average repayment profile: 15 years
- Average loan margin: 1.50% per annum

Equity Tranche (PD: 2.0%)

- Loan amount: US$ 240 million
- Average tenor: 7 years
- Average repayment profile: 15 years
- Average loan margin: 3.15% per annum

Note that the weighted average margins of the senior and equity tranches should not be higher than the margin of the original loan portfolio. The weighted average margins of the senior and equity tranche in the above example is 1.995% (= 70% × 1.50% + 30% × 3.15%), which is slightly lower than 2%.

Based on the above assumptions, the required RWA on the original loan portfolio should be as Table 2.29.

Table 2.29: RWA calculation on the original loan portfolio

	SA	**F-IRB**	**A-IRB**
PD	N/A	0.8%	0.8%
LGD	N/A	27.1%	17.5%
EAD	N/A	800	800

Maturity	N/A	2.5	5
R		0.200	0.200
b		0.147	0.147
K		0.043	0.036
Risk Weighting	100%	-	-
RWA	**800.0**	**434.0**	**361.1**

Note. R,b, and *K* are calculated based on Equation 2.1.

Table 2.30 shows the RWA requirement on the senior tranche after the securitization.

Table 2.30: RWA calculation on the senior tranche

	SA	**F-IRB**	**A-IRB**
PD	N/A	0.5%	0.5%
LGD	N/A	25.0%	15.0%
EAD	N/A	560	560
Maturity	N/A	2.5	5
R		0.213	0.213
b		0.167	0.167
K		0.031	0.026
Risk Weighting	100%	-	-
RWA	**560.0**	**216.6**	**184.2**

Note. R,b, and *K* are calculated based on Equation 2.1.

The results indicate that the RWA relief effect by securitization is significant to the banks that use the F-IRB or A-IRB approach, while the effect is meaningless to the banks that adopt the standardized approach. This is evidenced by the figures that the RWA reduction percentage in the standardized approach is 30%, the same as the split ratio between the senior tranche and the equity tranche. In contrast, the RWA reduction percentages in the F-IRB and A-IRB are 50.1% and 49.0%, respectively.

In order to determine whether CLO is a suitable option to relieve the RWA impact arising from Basel IV, profitability impact should also be considered, given reducing the notional loan amount means a reduction in interest income on the loans sold (i.e., the equity tranche). Referring to the principal and interest repayment schedule in Table 2.31, the bank expects around a US$40.8 million reduction in interest income by participating only in the senior tranche of CLO.

Table 2.31: Loan repayment schedule

	Original loan portfolio			Senior Tranche		
Period	Outstanding	Principal	Interest	Outstanding	Principal	Interest
0	800,000,000			560,000,000		
1	786,666,667	13,333,333	3,966,667	550,666,667	9,333,333	2,082,500
2	773,333,333	13,333,333	3,900,000	541,333,333	9,333,333	2,047,500
3	760,000,000	13,333,333	3,833,333	532,000,000	9,333,333	2,012,500
4	746,666,667	13,333,333	3,766,667	522,666,667	9,333,333	1,977,500
5	733,333,333	13,333,333	3,700,000	513,333,333	9,333,333	1,942,500
6	720,000,000	13,333,333	3,633,333	504,000,000	9,333,333	1,907,500
7	706,666,667	13,333,333	3,566,667	494,666,667	9,333,333	1,872,500
8	693,333,333	13,333,333	3,500,000	485,333,333	9,333,333	1,837,500
9	680,000,000	13,333,333	3,433,333	476,000,000	9,333,333	1,802,500
10	666,666,667	13,333,333	3,366,667	466,666,667	9,333,333	1,767,500
11	653,333,333	13,333,333	3,300,000	457,333,333	9,333,333	1,732,500
12	640,000,000	13,333,333	3,233,333	448,000,000	9,333,333	1,697,500
13	626,666,667	13,333,333	3,166,667	438,666,667	9,333,333	1,662,500
14	613,333,333	13,333,333	3,100,000	429,333,333	9,333,333	1,627,500
15	600,000,000	13,333,333	3,033,333	420,000,000	9,333,333	1,592,500
16	586,666,667	13,333,333	2,966,667	410,666,667	9,333,333	1,557,500
17	573,333,333	13,333,333	2,900,000	401,333,333	9,333,333	1,522,500
18	560,000,000	13,333,333	2,833,333	392,000,000	9,333,333	1,487,500
19	546,666,667	13,333,333	2,766,667	382,666,667	9,333,333	1,452,500
20	533,333,333	13,333,333	2,700,000	373,333,333	9,333,333	1,417,500
21	520,000,000	13,333,333	2,633,333	364,000,000	9,333,333	1,382,500
22	506,666,667	13,333,333	2,566,667	354,666,667	9,333,333	1,347,500
23	493,333,333	13,333,333	2,500,000	345,333,333	9,333,333	1,312,500
24	480,000,000	13,333,333	2,433,333	336,000,000	9,333,333	1,277,500
25	466,666,667	13,333,333	2,366,667	326,666,667	9,333,333	1,242,500
26	453,333,333	13,333,333	2,300,000	317,333,333	9,333,333	1,207,500
27	440,000,000	13,333,333	2,233,333	308,000,000	9,333,333	1,172,500
28	426,666,667	426,666,667	2,166,667	298,666,667	298,666,667	1,137,500
Sum			**85,866,667**			**45,080,000**

Return on equity (ROE) is the most commonly used metric to assess bank profitability. ROE is calculated by dividing the net profit achieved by the shareholders' equity. From ROE's perspective, CLO is not the best option to reduce RWA for the bank using the standardized approach. According to the above result, ROE is expected to decrease by 25% as the negative profitability effect (47.5%) exceeds the benefit of RWA reduction (30%) under the standardized approach. Meanwhile, ROE is boosted by 5% and 3% for the banks adopting the

F-IRB and A-IRB approaches, respectively, due to the positive RWA reduction effect exceeding the negative profitability effect (see Table 2.32).

Table 2.32: RWA impact from CLO

	SA	**F-IRB**	**A-IRB**
Δ RWA effect	-30.0%	-50.1%	-49.0%
Δ Profitability effect		-47.5%	
Δ ROE (post-CLO)	-25%	+4.8%	+2.9%

However, if external credit rating agencies rate the senior tranche, the risk weighting can be applied per Table 2.33. In this case, banks that use the standardized approach can also benefit from the RWA reduction, depending on the credit rating of the senior tranche.

Table 2.33: Risk Weight for Corporate Exposures

External rating	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to BB-	Below BB-
Risk weight	20%	50%	75%	100%	150%

Source: (CRE20 - Standardised approach: individual exposures)

However, there are some legal implications to the implementation of the proposed CLO on shipping loan portfolios in some jurisdictions. Unlike a typical CLO in the US or Europe, borrower involvement in the underlying loan portfolios is broad in various countries such as Panama, Liberia, Marshall Islands, etc. Most ship finance loan borrowers are located in countries that allow flying the flag of a country other than the country of ownership. In addition, borrowers are often guaranteed by their parents, the ship owners in many different countries. This means that the underlying loans in the portfolio are homogeneous in the sense that they are ship finance loans, but are not homogeneous assets from a legal perspective. Therefore, it can be difficult to create a CLO based on global ship financing loans. In practice, the CLO may need to be formed based on the underlying loans originating from the same jurisdictions and intended to be sold to investors in the same jurisdictions.

2.6.2. The future shape of ship financing with the regulatory changes

When Basel III was introduced to the banking market, many academics and practitioners expected the increasing role of non-financial institutions such as asset managers, private equity funds and leasing companies in the ship financing industry, which could fill the gap of traditional ship financing banks, which may have been left behind due to the stricter regulations withdraw business. The forecasts turned out to be half true in that some traditional ship financiers withdrew from the market and some active alternative investors in the shipping sector stood out, such as JP Morgan Asset Manager and the major Chinese leasing companies (ICBC Leasing, Bank of Communications Financial Leasing, China Development Bank Financial Leasing, etc.). However, it is also claimed that the forecasts are not correct as there are still many active traditional ship financing banks in the market, which are still the main source of financing for the ship owners. Another decisive factor in the withdrawal of some banks from the ship financing market was the high losses on their previous investments, which were hardly related to the strict regulations.

As analyzed in this paper, Basel IV will have a significant impact on ship finance banks using the A-IRB approach due to the LGD input floor. Assuming that the surviving ship financing banks have a solid loan portfolio, the LTV of the loan portfolio is likely to be low, with the estimated LGD being below 15%. Is the increased capital requirement due to Basel IV restrictions causing the remaining ship finance banks to downsize their business? It is highly unlikely that banks will downsize their shipping business. Instead, they can adjust their return target downwards in line with the increased capital requirements. The OECD estimates that 90% of trade goods are transported by sea. As demand for global cargo increases, maritime trade volumes are expected to triple by 2050. This is a huge market that banks cannot easily abandon. At the same time, shipping accounts for 2.6% of total greenhouse gas emissions, which could more than triple by 2050. This presents opportunities as there is much discussion and new technologies are being developed to address greenhouse gas issues, which could create a new expanded area for ship finance banks. Therefore, banks will try to find solutions to mitigate the increased capital requirements, such as the ideas presented in this chapter. Meanwhile, some banks currently using the A-IRB approach are expected to transition their approach to F-IRB or SA. Although the A-IRB approach would still provide more flexibility in estimating RWA parameters, there is a possibility that the actual results may differ between A-IRB and F-IRB or SA after the regulation of the Basel IV framework in certain legal areas may be similar. For example, the European Banking Authority requires European banks to include a certain margin of conservatism in their estimates.

2.7. Conclusion

There is considerable uncertainty regarding Basel IV and its influence on the strategic decisions of ship financing banks. In particular, the traditional ship finance banks in Europe that use the A-IRB approach will need to significantly increase their capital as the LGD input floor limits the banks' ability to estimate risk parameters based on their internal models. On the one hand, it ensures a level playing field for banks that use different approaches to credit risk assessment. On the other hand, this could result in the loss of banks' expertise in the shipping sector and create an incentive for a shift towards business models that lend money to riskier borrowers and structures. This paper addressed the question of whether the new LGD input floor adequately reflects the market situation in order to avoid overestimation of capital requirements under the A-IRB approach. Based on the hypothetical loan model and empirical data from Global Credit Data (GCD), the results suggest that the total LGD is more than 15%, which is consistent with the observed data from GCD that the actual LGD for shipping loans is around 14%. However, it is noteworthy that there is no statistical evidence that LGD is higher than 15% in cases with LTV less than 60%. This implies that there is a possibility that banks should reserve more capital, which may be unnecessary for low LTV loan portfolios, which could be a significant problem for banks.

In this paper, I have laid out three financing ideas that could minimize the RWA impact arising from Basel IV: (1) the utilization of export credit agency (ECA) financing, (2) engaging with insurance companies to cover a part of collateral values in a loan portfolio, and (3) securitizing a loan portfolio similar to the collateral loan obligations structure. The proposed ideas are tested based on a theoretical loan model, resulting in an RWA relief effect under Basel IV. In addition, it appears to be more effective for banks that adopt the internal ratings-based approach. Taking into account the contribution of ocean transportation in the global export market and the massive potential in view of decarbonization initiatives, ship financing banks are expected to remain the primary funding source for shipowners. However, it is likely that banks should downward adjust the expectation of profitability against the required capital while they strive to recoup the RWA impact in various ways, including the proposed idea. The analysis and proposed ideas in this paper can be widely applied to other asset classes such as aircraft, containers, rail, etc.

However, the question arises as to whether this is ultimately the right approach and whether it is consistent with the Basel Committee's intention for the new framework. Unlike the ECA financing option, which transfers a large portion of credit risk to sovereign risk, the other two financing options effectively shift credit risk to less regulated markets, which could harm financial stability. Bank regulation is the art of balancing the stability of banks and their role in promoting economic growth. In this respect, Basel IV should be examined with greater caution and carefully considered whether the benefits really outweigh the costs.

Chapter 3
Understanding the green premium: Financial perspectives in the shipping industry

3.1. Introduction

The shipping industry has been under increasing pressure to decarbonize in recent years, with regulatory bodies such as the International Maritime Organization (IMO) and industry players such as banks, insurers, and ship owners launching various initiatives toward this goal. The IMO initiative, for instance, aims to reduce the carbon intensity of international shipping, with a target of at least 40% reduction by 2030 and efforts towards 70% by 2050 compared to 2008 levels. Additionally, the initiative aims to reduce total annual greenhouse gas (GHG) emissions from international shipping by at least 50% by 2050 compared to 2008.

The Poseidon Principles is the representative initiative that has been widely recognized by many international banks, ship owners, and insurance companies. The Poseidon Principles establish a framework for assessing and disclosing the climate alignment of ship finance portfolios. They set a benchmark for what it means to be a responsible bank in the maritime sector and provide actionable guidance on how to achieve this. The Poseidon Principles are consistent with the policies and ambitions of the IMO, including its ambition for greenhouse gas emissions to peak as soon as possible and to reduce shipping's total annual GHG emissions by at least 50% by 2050.

These decarbonization initiatives have stimulated ship owners to delve into a wide range of potential solutions, one of which involves placing orders for vessels that possess the capability to operate on environmentally friendly alternative fuels like LNG, ammonia, methanol, and hydrogen. However, it is important to note that the shipbuilding cost for such vessels is significantly higher compared to conventional vessels that rely on bunker fuel. This disparity in cost necessitates that financiers allocate a greater amount of funding towards the construction of these new vessels, under the same Loan-to-Value (LTV) condition, in comparison to the financing of conventional vessels. To provide a concrete example, if a ship owner expresses the desire to procure an LNG dual fuel Capesize dry bulk carrier, it is estimated that an additional sum of approximately US$15 million is required to accommodate the LNG dual fuel function, as opposed to a traditional Capesize dry bulk carrier.

From the perspective of ship financiers, it is imperative that the additional costs incurred are adequately reflected in the fair market price, at least during the financing period. In this way, the potential risks associated with enforcement scenarios can be mitigated. Consider a scenario where the fair market value of an eco-friendly vessel surpasses that of conventional vessels in the sales and purchase markets. In such scenarios, financiers may take comfort in the understanding that the Loss Given Default (LGD) for a loan secured by an eco-friendly vessel would likely be relatively low. This subsequently acts as a motivating factor for ship financiers to promptly offer the necessary capital for eco-friendly vessels.

However, despite the increasing interest in sustainable financing for eco-friendly assets, it is worth noting that there is currently no international guidance or recommendation that enables banks to allocate less capital for what is commonly referred to as 'green financing.' Certain countries, such as the Netherlands, explicitly impose restrictions on providing benefits to green financing in terms of required capital calculation due to the limited availability of relevant data. This misalignment between decarbonization initiatives and the provision of liquidity underscores the importance of conducting a comprehensive study to ascertain whether green shipping financing indeed entails the nature of a low LGD.

Therefore, the main objective of this research is to comprehensively investigate and analyze the potential relationship between green ship financing and the associated LGD. It is important to note that a large amount of academic research has already been carried out in the asset management space, particularly focusing on comparing the performance of environmental, social and governance (ESG)/green funds and more conventional funds. However, it is important to recognize that few comprehensive studies have been conducted in the area of asset-backed financing, particularly with regard to the maritime industry.

The research conducted in this study has enormous potential to influence and guide regulators in their future considerations regarding the calculation of risk-weighted assets in the area of green financing in the shipping industry. The results of this research may prompt regulators to reassess and reconsider their existing approaches and strategies for calculating risk-weighted assets. This has the potential to bring about significant changes and transformations in the way green finance is perceived and managed in the shipping sector. By examining in-depth and thoroughly examining the complex relationship between green ship financing and the LGD concept, this study aims to shed light on the dynamics and intricacies of this relationship. The aim is to uncover the diverse ways in which ship financiers can finance environmentally friendly ships effectively and responsibly. Furthermore, this research strives to provide valuable insights and perspectives on how this funding can be channeled in a way that promotes sustainability, responsibility and efficiency. Through a comprehensive and detailed analysis of these aspects, this study aims to provide the shipping industry with a holistic and well-rounded perspective on financing environmentally friendly ships. Ultimately, the aim is to promote and facilitate the adoption and implementation of practices and approaches that are more aligned with the principles of sustainability and responsibility.

Therefore, this research has the potential to bring about significant and lasting changes in the way ship financiers approach environmentally friendly ships.

3.2. Literature review

Green financing in financial markets is a transformative approach that integrates environmental considerations into financial decision-making, aiming to support sustainable economic growth while addressing climate change and other environmental challenges. This approach involves a variety of financial instruments and policies designed to promote investments in environmentally friendly projects. The development and implementation of green finance are crucial for mobilizing the necessary capital to bridge the climate financing gap and foster a sustainable global economy. In terms of financial instruments, green bonds are a prominent tool in green finance, earmarked for projects with positive environmental impacts. They have gained traction as a means to channel capital towards sustainable projects, influencing corporate behavior and investor preferences (Khan *et al.*, 2024). Green finance also includes green investment funds and climate risk insurance, which help manage environmental risks and support sustainable development (Taneja and Reepu, 2024). While green financing presents numerous opportunities for promoting sustainable development, it also faces several challenges that need to be addressed to realize its full potential. The lack of standardized evaluation systems and transparency issues (Lin and Pan, 2024; Tang, 2024) are significant hurdles that can impede the effectiveness of green finance. The absence of clear definitions, standards, and regulations can slow down the impact and implementation of green finance. Therefore, Sigh (2024) emphasizes that the development of green finance requires collaboration among government bodies, financial institutions, and private sector entities to expand the market and mitigate risks.

Green ship financing

With the numerous literature reviews that have been conducted on green financing and sustainability across the different sectors and industries, it has become increasingly important to examine the ways in which these concepts can be applied to financing in the maritime industry. Whilst there are limited literature reviews that relate to green financing in the shipping industry, these are valuable resources to understand the various ship financing schemes aimed at reducing the environmental impact of the maritime industry. Kavussanos and Tsouknidis discuss the evolving regulatory framework for green shipping finance and the role of capital providers in reducing the environmental footprint of the shipping industry. They also explore initiatives and strategies aimed at making shipping more environmentally sustainable, providing valuable insights into the challenges and opportunities related to green financing in the shipping sector (Kavussanos and Tsouknidis, 2021).

Pangalos (2023) aims to explore potential routes for financial innovation in sustainability and alternative energy within the dry bulk shipping industry. It delves into the challenges and disruptions faced by the industry from a financial perspective. The paper draws on the theory of pecking order on debt and equity to conceptualize the relationship between modes of financing for maritime shipping companies. It offers insights into how financial innovation can contribute to making the dry bulk shipping industry more sustainable.

Rebelo (2020) pays attention to the ambiguity of the framework for green shipping from a legal perspective. The author advocated for the establishment of a globally recognized green-shipping vernacular or classification system to incentivize investors and address environmental concerns in the maritime transport sector. This paper highlights the importance of creating a common language and framework for green shipping to attract investment and promote sustainability. It addresses the need for clear terminology and standards in the industry, which can facilitate financing for environmentally friendly maritime projects.

One study synthesizes existing literature on green finance to identify important themes, including strategies to increase green financing, promoting green financing using technology and policy, the role of regulators and financial institutions in the green finance agenda, and the challenges of green financing (Ozili, 2022). This review highlights the need for continued research and exploration of innovative financing mechanisms that can support the transition to a more sustainable future.

Another literature review on green financing explores the potential benefits of corporate engagement in environmentally responsible practices in the context of green bonds and green loans (Gilchrist, Yu and Zhong, 2021). The authors underscore the importance of corporate social responsibility and the role that financial institutions can play in encouraging and supporting sustainable business practices. It also identifies potential challenges and areas for further research, including the need for greater transparency and accountability in corporate reporting and the development of standardized metrics for measuring the environmental impact of corporate activities.

Green premium in shipping

The "green premium" is a term used to refer to the added cost of using sustainable or low-emission fuels, technologies, or products, as compared to more traditional and polluting options. This term has been widely used in various industries, including shipping. While sustainable or low-emission fuels, technologies, or products are considered better for the environment, they may face higher costs for production and distribution, as well as investments in research and development required to produce them. In addition to these factors, the green premium may also be influenced by various other factors such as government incentives, taxes, and subsidies. Schinas and Sonechko concurred that a green premium exists within the shipping sector, as environmentally friendly technologies frequently incur higher expenses than conventional alternatives. This premium presents a hurdle for shipowners and operators keen on transitioning to greener vessels. They emphasize the necessity for practical and cost-effective financing solutions to address this disparity, proposing that alternative financial models, like the pay-as-you-use approach, can facilitate the greening of shipping by distributing risks and rewards among stakeholders (Schinas & Sonechko, 2022). Metzger found that the market is currently hesitant to pay for innovation or invest in green premium products during the decarbonization process of the shipping industry (Metzger, 2022). However, the paper also discusses various market-based measures and green shipping practices that could support the decarbonization process. These measures include the use of alternative fuels, such as hydrogen, and the implementation of energy-efficient technologies. A recent study by Moutzouris et al. (Moutzouris *et al.*, 2024) has validated the price premium associated with eco vessels in comparison to traditional vessels, particularly in the dry bulk shipping sector. The findings revealed that eco-friendly vessels command a 25% premium, whereas cash inflows are merely 9%-15% greater. The authors contend that this premium is attributed to their reduced environmental impact and compliance with international regulations aimed at reducing greenhouse gas emissions. This study aligns with the concept of a premium for green/eco vessels that my research also explores. The primary distinction lies in my research's emphasis on the premium that surpasses the additional costs of green vessels, while the previous study defined the premium as the market value disparity between eco vessels and conventional vessels.

In another literature review (MacAskill *et al.*, 2021), the existence of a green premium in the green bond market was investigated, and the concept of the green premium was also discussed. The study found that the literature investigating the green premium is diverse, which has resulted in ambiguity regarding a consensus over its existence. However, the study also found that there is a growing interest in green bonds and a potential market for green premium products.

A related study discusses the willingness of the shipping industry to pay for premium green fuels. Maersk's CEO highlighted that some customers are willing to pay a premium for low-carbon fuels, indicating a growing awareness and potential market for green premium products in the shipping industry. This awareness and the potential market could be further expanded through targeted marketing and education campaigns.

Furthermore, various industries have conducted other literature reviews on the green premium concept. For example, a study investigated green rental and price premia in real estate (Addae-Dapaah and Wilkinson, 2020), while another reviewed sustainable logistics practices (Ren *et al.*, 2020). There is one study particularly focused specifically on the green bond market (Sheng, Zheng and Zhong, 2021). The researchers explore the concept of green bond premiums and issuer heterogeneity in sustainable finance, aiming to understand whether a green bond premium exists and the variations in this premium among different issuers. The research highlights the importance of non-pecuniary motives in sustainable finance, particularly how the green bond premium can be an indicator of such motives. It discusses the lack of consensus in the field due to differences in interpretations.

These reviews in non-shipping industries provide important insights into the potential markets for green premium products across various industries and can help inform the development of targeted marketing and education campaigns.

Green financing and loss given default (LGD)

Research has been conducted to address the relationship between ESG ratings and the probability of default (Li, Zhang and Zhao, 2022). The study found that a higher ESG rating is associated with a lower probability of default. This finding has implications for investors who are looking to invest in companies with a lower probability of default. However, there is an ongoing discussion about the relationship between financial metrics and ESG performance (Velte, 2017). Some researchers have found that there are controversies arising from the ranking of companies in ESG scores and metrics. These controversies might result from differences in how different companies report their ESG data or in how different evaluators interpret the data.

Sanjai Bhagat ("An Inconvenient Truth About ESG Investing" 2022) discussed the potential drawbacks of ESG investing and suggested that the positive impact of ESG investing may be overstated. The author argues that there is a lack of straightforward evidence showing that ESG investing leads to better financial performance and that ESG ratings may be subjective and not always reliable. Additionally, the article notes that ESG investing may be subject to greenwashing and that companies may manipulate their ESG ratings to appear more socially responsible. Overall, the article encourages investors to exercise caution and skepticism when considering ESG investing.

Despite these controversies, one research has concluded that ESG disclosure alone might not necessarily drive financial performance. However, performance-based ESG measures, like greenhouse gas emission reduction, positively correlated with financial performance than ESG disclosure alone. This finding (Tensie, Ulrich and Casey, 2021) suggests that companies that perform well in terms of ESG measures are more likely to perform well financially. Such companies might be better able to attract investors who are looking for companies that are more likely to perform well in the future.

There are also regulatory developments aimed at encouraging banks to incorporate climate risk into their risk management practices, which could indirectly affect the calculation of risk-weighted assets. For instance, the European Banking Authority (EBA) proposed the introduction of a Green Supporting Factor (GSF) as a policy tool to support bank lending to green finance. The GSF would lower capital requirements for banks' green exposures and encourage banks to lend more to sustainable investments. The EBA has also published reports and guidelines on sustainable finance and the GSF, and it has reaffirmed its commitment to supporting green finance at the United Nations Climate Change Conference(*EBA reaffirms its commitment to support green finance in view of the UN Climate Change Conference*, 2021). However, there are differing opinions on the effectiveness of the GSF, with some arguing that it would weaken banks (Gregg, 2018) (Dankert *et al.*, 2018).

However, the integration of ESG factors in the calculation of risk-weighted assets in the banking industry is a relatively new concept, and there does not seem to be a clear consensus on how ESG factors should be incorporated into risk management practices.

According to a document published by MSCI, ESG factors can be considered as part of a broader set of risk factors that are used in the calculation of risk-weighted assets. The document outlines a methodology for calculating ESG metrics, which can be used to assess a company's exposure to various ESG risks (MSCI, 2020). On the contrary, it does not provide guidance on how ESG metrics should be incorporated into the calculation of risk-weighted assets specifically. There is some evidence to suggest that incorporating ESG factors into investment decisions may result in better risk-adjusted performance. For example, a study published in the Journal of Sustainable Finance and Investment found that an ESG portfolio outperformed a non-ESG portfolio on a risk-adjusted basis (Ashwin Kumar *et al.*, 2016). However, it is not clear how this finding would translate to the calculation of risk-weighted assets specifically.

3.3. Green ship financing

3.3.1. Introduction

Green financing is a form of financing that aims to support activities and projects that promote environmental sustainability. It is a financial mechanism designed to incentivize sustainable development priorities through the provision of loans, investments, insurance, and other financial products and services. The main goal of green financing is to increase the flow of financial resources from the public, private, and not-for-profit sectors towards sustainable development priorities, with a particular focus on improving environmental outcomes. By providing financial support to environmentally friendly activities, green financing helps to promote sustainable development and reduce the negative impact of human activities on the environment. This, in turn, helps ensure a more sustainable future for generations to come.

As per the United Nations Environment Programme, green financing involves increasing the level of financial flows from banking, micro-credit, insurance, and investment sectors towards sustainable development priorities (Green Financing, n.d.). It encompasses any structured financial activity created to ensure a better environmental outcome and includes green bonds, loans, and other financial instruments (Sean, 2020). Green financing can also include investing in environmentally friendly goods and services, building environmentally friendly infrastructure, and other activities that promote sustainability.

In recent years, the global green finance market has been experiencing rapid growth, with the value of green bonds traded approaching $2.36 trillion. This increase in the market can be attributed to a growing awareness of the importance of sustainability and the need to address climate change. As a result, investors are increasingly looking to invest in environmentally friendly projects and companies that prioritize sustainability. Furthermore, the European Central Bank has been actively promoting green finance and sustainable investments. This has resulted in an increase in the number of green bonds issued in Europe, with green bonds now accounting for a massive portion of the European bond market.

It is worth noting that in addition to the US, China, and France, other countries such as Japan, Germany, and the Netherlands are also emerging as major players in the global green finance market. This trend is expected to continue as more countries recognize the importance of sustainable investments and the need to transition to a low-carbon economy. In short, green financing refers to a broad spectrum of financial products and services that are specifically created to fund and promote environmentally responsible projects and initiatives. This can include things like renewable energy production, eco-friendly buildings, sustainable agriculture, and clean transportation. Green financing has become an increasingly crucial tool for governments, businesses, and individuals who are looking to support sustainable development goals and reduce their impact on the environment. By providing financial support for environmentally friendly projects, green financing helps to increase investment in sustainable development priorities and ultimately contributes to improving environmental outcomes and reducing the negative impact of human activity on the planet.

3.3.2. Definition of green ship

A green ship is a vessel that has been designed and built with consideration for the environment and has features that minimize its environmental impact during its entire life cycle, from construction to operation and eventual disposal. A green ship can also refer to a ship that has been retrofitted with environmentally friendly technologies and practices to reduce its environmental footprint.

The features and technologies that make a ship "green" can include various elements according to the report issued by the European Commission (COWI and CE Delft, 2021). Ships can be equipped with energy-efficient propulsion systems, such as hybrid or electric engines, that reduce fuel consumption and emissions. They also incorporate advanced waste management and water treatment systems to minimize pollution, along with innovative hull designs that reduce drag and improve fuel efficiency. Green ships often utilize renewable energy sources, such as solar panels or wind turbines, to power ship systems. Additionally, they employ environmentally friendly materials and coatings to reduce environmental impact. Finally, sustainable ship recycling practices are implemented to minimize waste and pollution at the end of a ship's life.

The definition of a green ship can vary depending on the specific standards and criteria used to evaluate its environmental performance. However, in general, a green ship in practice is designed and operated with a focus on reducing its environmental impact and promoting sustainability.

The EU Taxonomy is a classification system that aims to provide a common language and framework for identifying and classifying environmentally sustainable economic activities. It is part of the EU's efforts to create a sustainable finance framework that supports the transition to a low-carbon, sustainable economy. Although it is not a requirement for businesses to be taxonomy-aligned, it will be critical in the shipping industry as companies not meeting the Taxonomy requirements may face increasing difficulty in accessing new capital and financing, which is the key to developing the new technology and solutions necessary to transition the industry. According to the European Union Taxonomy, an economic activity is required to satisfy three fundamental criteria in order to be classified as environmentally sustainable.

Firstly, it must make a significant contribution to at least one of the established environmental goals. Secondly, it must not cause any substantial detriment to the other objectives. Lastly, it must adhere to the stipulations of certain minimum social safeguards.

In April 2021, the European Commission established technical screening criteria applicable to, among other sectors, the maritime transport industry. The maritime operations that are deemed to significantly enhance the environmental objectives, thereby satisfying the primary overarching criteria, comprise inland passenger and freight waterborne transportation, as well as their associated retrofitting initiatives. Furthermore, these operations incorporate sea and coastal freight waterborne transportation (which includes vessels utilized for port operations and ancillary activities), sea and coastal passenger waterborne transportation, in addition to the retrofitting processes for both freight and passenger vessels engaged in sea and coastal transportation.

Vessels dedicated to the transport of fossil fuels may never be considered to substantially contribute to the previously mentioned environmental objectives. The controversial point is that the vessels that burn fossil fuels may be classified as green assets only if they meet the strict criteria[1](Sea and coastal freight water transport, vessels for port operations and auxiliary

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a. [1] the vessels have zero direct (tailpipe) CO_2 emissions;
b. until 31 December 2025, hybrid and dual fuel vessels derive at least 25 % of their energy from zero direct (tailpipe) CO_2 emission fuels or plug-in power for their normal operation at sea and in ports;
c. where technologically and economically not feasible to comply with the criterion in point (a), until 31 December 2025, and only where it can be proved that the vessels are used exclusively for operating coastal and short sea services designed to enable modal shift of freight currently transported by land to sea, the vessels have direct (tailpipe) CO2 emissions, calculated using the International Maritime Organization (IMO) Energy Efficiency Design Index (EEDI), 50 % lower than the average reference CO2 emissions value defined for heavy duty vehicles (vehicle sub group 5-LH) in accordance with Article 11 of Regulation 2019/1242;
d. where technologically and economically not feasible to comply with the criterion in point (a), until 31 December 2025, the vessels have an attained Energy Efficiency Design Index (EEDI) value 10 %

activities, n.d.). Following the criteria does not allow most conventional vessels including LNG vessels to be classified as green vessels, which has been criticized by ship owners and investors given LNG vessels and dual fuel vessels powered by LNG or methanol are perceived as green vessels in practice. It is noted that the definition of green vessel in many of the green financing completed in shipping industries does not seem to follow the strict criteria set by EU Taxonomy, noting the underlying assets for the green financings are eco-friendly vessels, but not the vessels having zero direct CO_2 emissions (Giorgia *et al.*, 2022).

3.3.3. Type of green financing in shipping

Green financing in shipping refers to the use of financial instruments and mechanisms to support the construction, retrofitting, and operation of environmentally sustainable ships. The objective of green financing is to incentivize and accelerate the transition to a more sustainable shipping industry by providing financial incentives for environmentally friendly practices and technologies.

There are several forms of green financing available for the shipping industry, including:

- **Green loans:** These are loans specifically designed to finance environmentally sustainable projects, such as the construction or retrofitting of green ships. Green loans typically offer more favorable terms and conditions than traditional loans.
- **Green bonds:** These are fixed-income securities that are issued to finance environmentally sustainable projects. Green bonds can be used to finance the

below the EEDI requirements applicable on 1 April 2022(247) if the vessels are able to run on zero direct (tailpipe) CO2 emission fuels or on fuels from renewable sources.

construction or retrofitting of green ships, as well as other environmentally sustainable projects in the shipping industry.

- **Green leases:** This is a type of financing that involves the leasing of green ships or shipping-related equipment, with the option to purchase the equipment at the end of the lease term. Green lease financing can be used to support the adoption of environmentally sustainable practices in the shipping industry.
- **Green insurance:** This provides insurance coverage to shipping companies that operate green ships and may offer reduced premiums or other benefits to incentivize the use of sustainable ships.

The availability of green financing in shipping is increasing, with a growing number of financial institutions offering green loans, bonds, and other financing options for sustainable shipping projects. This is helping to accelerate the transition to a more sustainable shipping industry by providing the necessary funding for the development and deployment of environmentally friendly ships and technologies.

A sustainability-linked loan is a type of loan that is structured around specific sustainability performance targets that the borrower commits to achieving. This type of loan is similar to a green loan, but rather than being tied to a specific green project, it is linked to the borrower's overall sustainability performance.

In a sustainability-linked loan, the borrower and lender agree on specific sustainability targets, such as reducing greenhouse gas emissions, increasing the use of renewable energy, or improving social and governance practices. The borrower is then incentivized to achieve these targets through various mechanisms, such as a reduction in the interest rate or a bonus payment from the lender. The principal characteristics of a sustainability-linked loan are fundamentally anchored in several crucial components. Initially, the borrower is obligated to pledge adherence to specific sustainability objectives as a prerequisite for the loan. In order to incentivize the attainment of these objectives, a variety of incentive mechanisms are implemented, such as diminished interest rates or supplementary payments from the lender. The borrower's performance in relation to these objectives must undergo verification by an independent third party to ascertain compliance. Furthermore, the borrower is mandated to provide ongoing reports regarding their sustainability performance to both the lender and additional stakeholders.

Sustainability-linked loans are an innovative financing mechanism that can support the adoption of sustainability practices in a wide range of industries, including the shipping industry. They offer a flexible and scalable approach to financing sustainability initiatives and can be customized to meet the specific needs of the borrower and lender.

3.3.4. Restrictions of green financing

While financing for environmentally sustainable vessels can offer significant financial incentives for the advancement and implementation of eco-friendly maritime technologies, several crucial constraints and limitations warrant thorough examination. Environmentally sustainable vessels generally entail elevated initial expenditures due to the incorporation of advanced technologies and eco-conscious features, culminating in augmented construction or retrofitting costs alongside heightened financing expenses. Notwithstanding the increasing accessibility of green financing, it remains constrained in specific sectors and project categories, thereby engendering access difficulties for certain maritime enterprises. The financial yields associated with these investments may exhibit unpredictability and could take a protracted duration to materialize in comparison to traditional vessels, thereby complicating efforts to attract capital or secure advantageous financing conditions.

The dynamic nature of environmental regulations and green maritime technologies introduces further intricacy. The maritime sector is confronted with persistent regulatory transformations concerning environmental performance, while the technologies in question continue to evolve. This prevailing uncertainty may render investors more apprehensive, resulting in more cautious financing conditions. Moreover, the absence of uniformity in the assessment of environmental performance across diverse vessels complicates comparative analysis and evaluative processes, notwithstanding the presence of various standards and guidelines. Overall, green ship financing can provide an important incentive for the development of environmentally sustainable ships and technologies. However, several limitations and challenges must be considered when evaluating the potential benefits and risks of green financing in shipping.

3.3.5. Incentive of green financing in shipping

Green ship financing presents various incentives for enterprises to allocate resources towards environmentally sustainable maritime vessels and technologies. Corporations may access funding and financial alternatives that are often unattainable for conventional ships, thereby facilitating the financing of the construction or retrofitting of green vessels and other sustainable initiatives. Moreover, green financing frequently provides reduced financial costs or more advantageous conditions, such as extended repayment periods, rendering green investments more economically viable for corporations.

From an operational standpoint, green vessels generally incur lower operational expenses throughout their lifespan owing to diminished fuel consumption and reduced emissions, yielding considerable cost efficiencies for shipping enterprises. These ships also exhibit a diminished environmental footprint in comparison to traditional vessels, thereby assisting organizations in fulfilling regulatory obligations and enhancing their environmental performance. Furthermore, the commitment to investing in green vessels and other sustainable technologies can significantly bolster the reputation and brand equity of shipping companies, which is essential for attracting customers and investors.

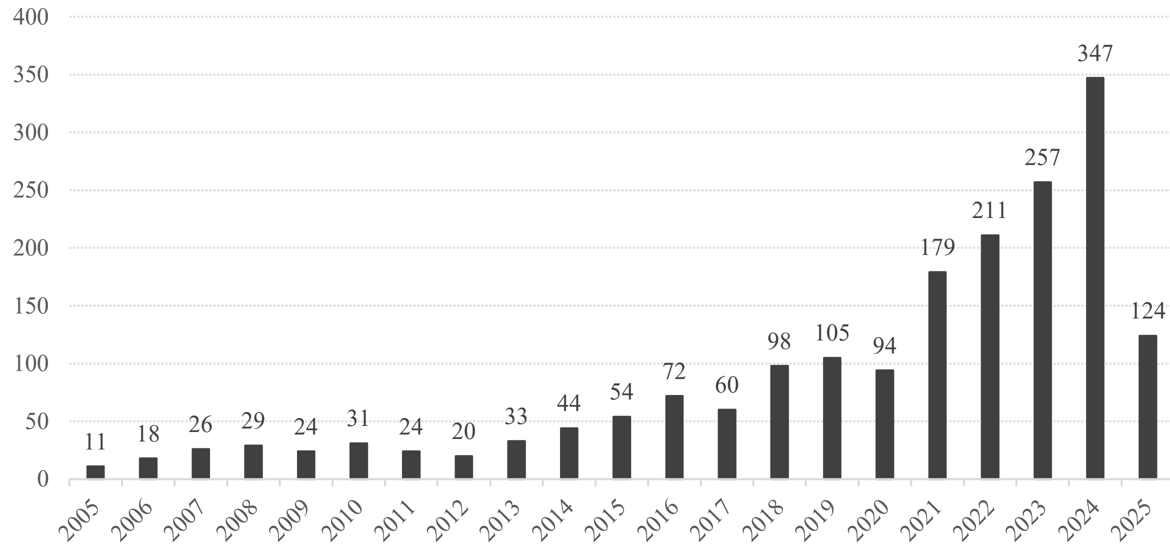
Overall, green ship financing can provide important incentives for shipping companies to invest in environmentally sustainable ships and technologies. These incentives can help to accelerate the transition to a more sustainable shipping industry, which is essential for achieving global climate and environmental goals.

3.4. Research model and results

3.4.1. Model development

As articulated in the preceding chapters, there is hardly any green vessel currently available that aligns with the criteria set forth by the EU taxonomy. Therefore, I reconceptualize the notion of a green vessel within this research to encompass a transitional vessel that is fitted with a dual fuel engine capable of operating on both conventional bunker fuel and alternative fuels including ammonia, battery, hydrogen, LNG, and methanol. However, it does not include the vessels that possess the capability to retrofit engines for alternative fuels at a subsequent phase, such as ammonia, LNG, and methanol, specifically referred to as ammonia-ready vessels, LNG-ready vessels, and methanol-ready vessels. This category of vessel is regarded as an environmentally sustainable vessel within the shipping industry, as it can be swiftly outfitted with a new engine designed to utilize alternative fuels once it achieves commercial viability. Nevertheless, this type of vessel bears significant similarities to conventional vessels in all respects until the new engine is installed, and it is also anticipated that several years will be required to develop a fully operational ammonia engine due to the necessary advancements in infrastructure to guarantee a reliable supply of alternative fuels. This is confirmed by the current new orders for the next few years (see Figure 3.1). GV denotes a green vessel in accordance with the revised definition presented in this chapter.

Figure 3.1: Alternative fuel vessels by year of build

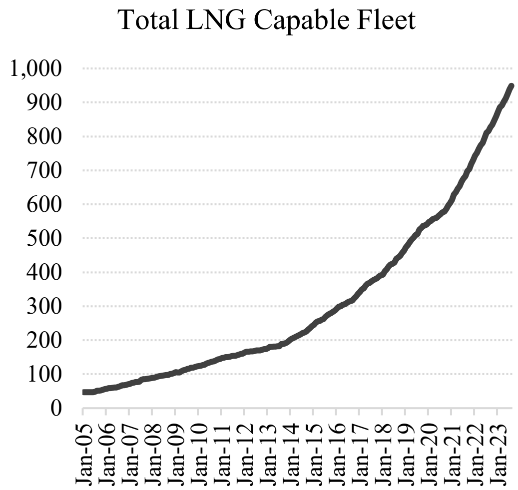


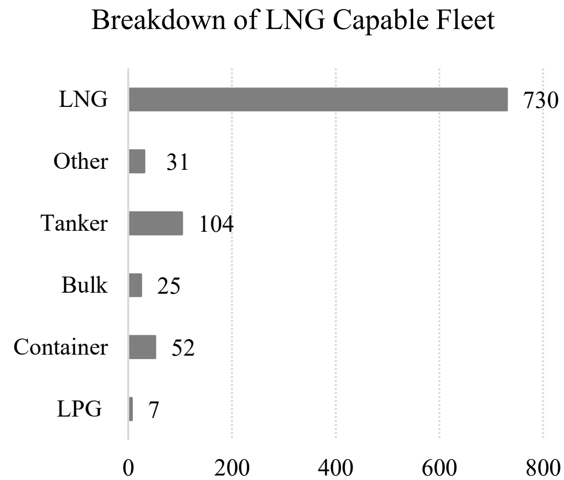
Source: DNV alternative fuels insight (Alternative Fuels Insight (AFI) for the shipping industry, n.d.)

3.4.1.1. Data selection

As of August 2023, 949 LNG capable vessels are trading, of which LNG vessels account for 76.9% (730 vessels), the remaining proportion consists of 52 containerships, 25 dry bulk carriers, 104 tankers, and 31 ferry/cruise/other special vessels (see Figure 3.2).

Figure 3.2: LNG Capable Fleet





Source: Clarksons Research

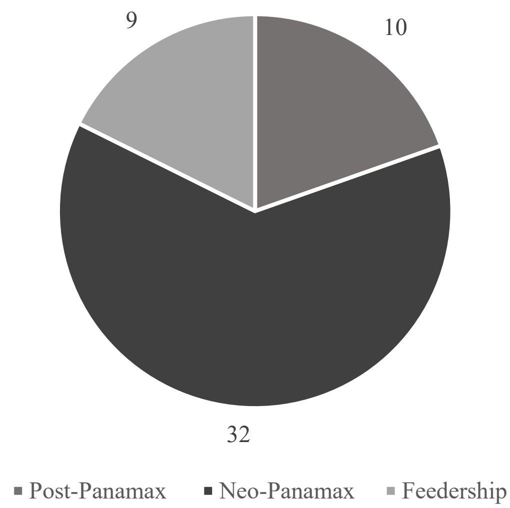
Across the various asset categories, there are currently only 19 MR tankers in operation that can run on methanol, while no containerships or bulk carriers that can run on ammonia, hybrid/battery, hydrogen, LPG or methanol are available. In this analysis, the GV pool includes all LNG-capable vessels except dedicated LNG vessels and those equipped to use methanol. LNG ships are not included in this pool because all of these ships use LNG as a fuel source, indicating that no LNG ship uses conventional bunker fuel for comparison.

3.4.1.2. The GV Pool for modeling

Containership – The detailed information for the containerships can be found in A. 1 in the Appendix

When analyzing the distribution of vessels by size, it is evident that a significant proportion of the pool is comprised of large vessels (> 15,000 TEU), as shown in Figure 3.3 below.

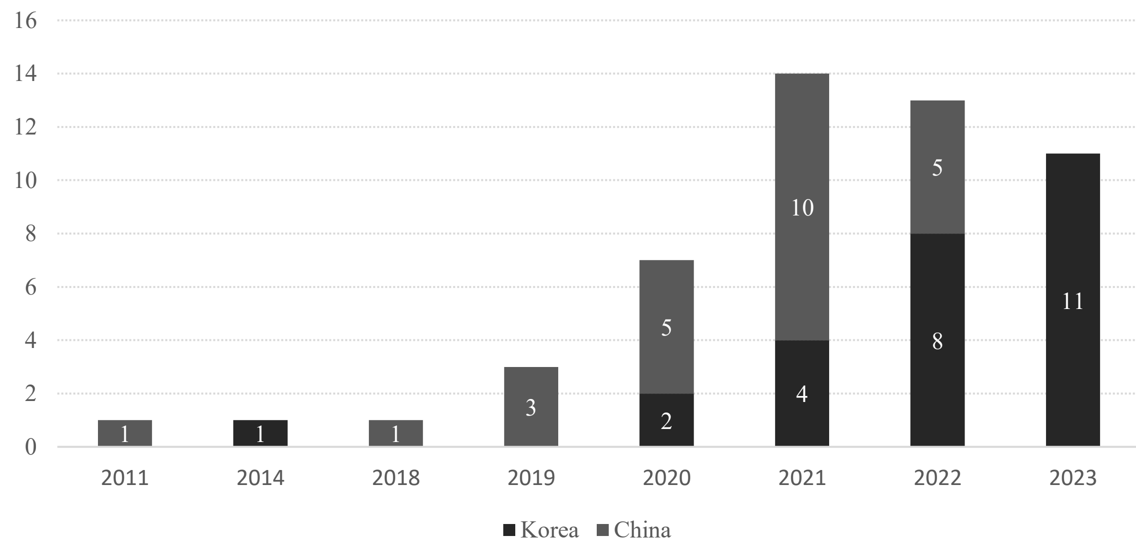
Figure 3.3: Vessel composition - LNG DF Containership



Source: Clarksons Research

The LNG DF containership commenced delivery in 2018 from shipyards located in both China and Korea (see Figure 3.4). In particular, the Seaboard Blue, delivered in 2011, was retrofitted with an LNG dual-fuel engine in August 2017, while the Brussels Express, delivered in 2014, was also retrofitted with an LNG dual-fuel engine in August 2020.

Figure 3.4*:* Shipyard and delivery year - LNG DF Containership

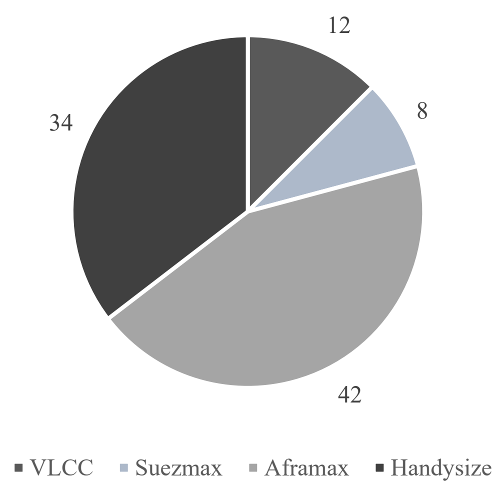


Source: Clarksons Research

Tanker - The detailed information for the tankers can be found in A. 2 in the Appendix.

The tanker is the most popular asset type for ship owners when it comes to the LNG DF specification. In contrast to the dry bulk sector, comparatively smaller-sized tankers (Aframax and Handysize) account for approximately 79% of the total LNG DF tankers, whereas the remaining 21% comprises larger tankers (VLCC and Suezmax), as demonstrated in Figure 3.5 below.

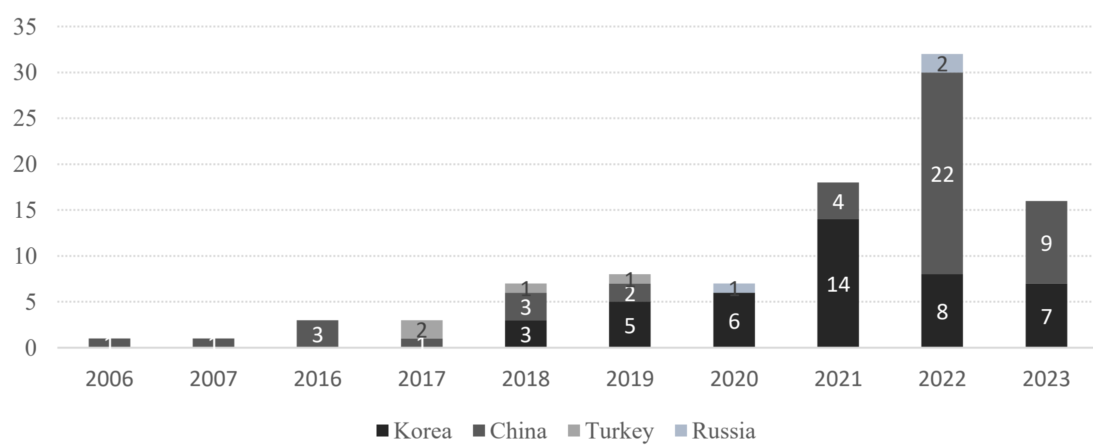
Figure 3.5: Vessel Composition - LNG DF Tanker



Source: Clarksons Research

Fure West, delivered in 2006, and Eure Viking, delivered in 2007 were retrofitted with an LNG DF engine in 2014 and 2011, respectively. The shipyards in Turkey and Russia provided four vessels and three vessels, respectively, which are leased by their respective national firms. In a manner akin to other asset categories, South Korea and China emerge as the principal nations contributing to the LNG DF tanker market (see Figure 3.6).

Figure 3.6: Shipyard and delivery year – LNG DF Tanker

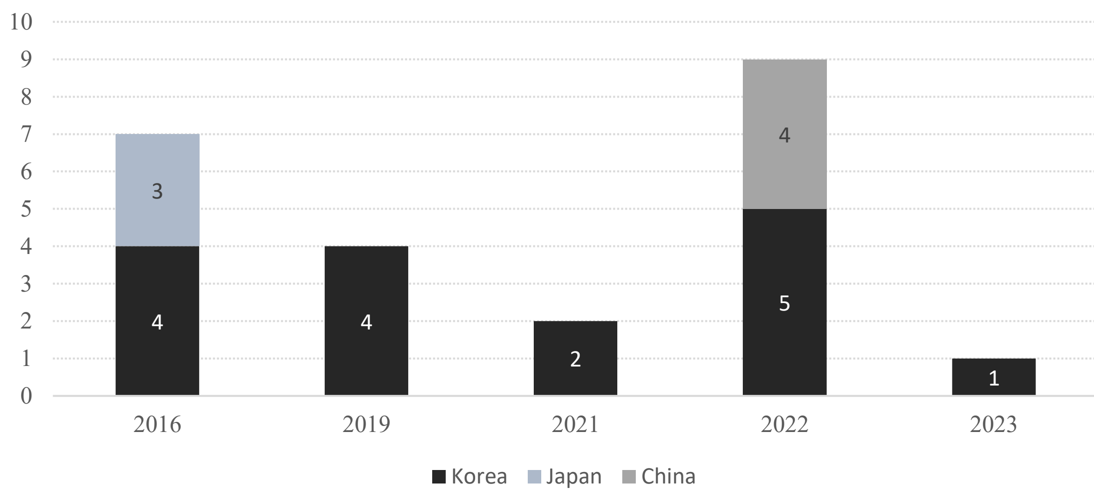


Source: Clarksons Research

Methanol DF Tanker - Detailed information for the methanol DF tankers can be found in A. 3 in the Appendix.

The tanker segment is the only category that has proactively adopted the methanol DF engine. There are currently 23 methanol DF tankers operating in international waters, most of which have been built by Korean shipyards since 2016 (see Figure 3.7).

Figure 3.7: Shipyard and delivery year – Methanol DF Tanker

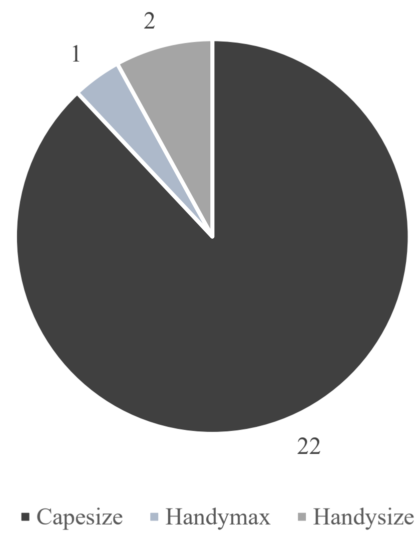


Source: Clarksons Research

Dry Bulk - The detailed information for the dry bulk carriers can be found in A. 4 in the Appendix

As of June 30, 2023, a total of 25 LNG DF dry bulk carriers have been delivered, with 22 of these vessels classified as Capesize, accounting for 88% of the total LNG DF dry bulk fleet, while the remaining vessels are categorized as small-sized vessels (less than 50,000 DWT) (see Figure 3.8). To date, no LNG DF vessels have been delivered in the Panamax category.

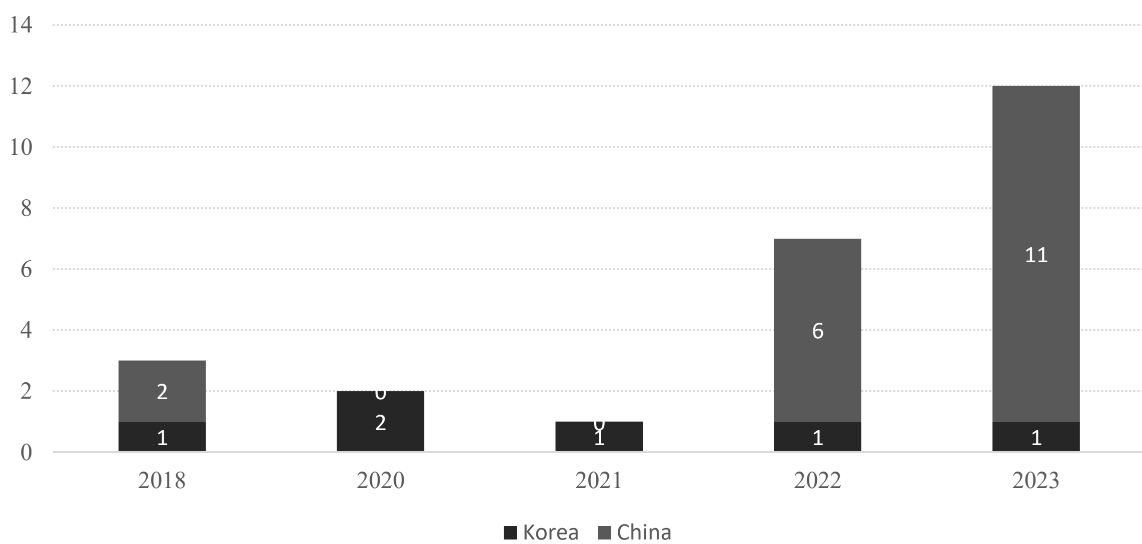
Figure 3.8: Vessel composition – LNG DF Dry bulk



Source: Clarksons Research

Except for the three small vessels delivered in 2018, the other Capesize vessels have been delivered mainly by the Korean shipyards since 2020 (see Figure 3.9).

Figure 3.9: Shipyard and delivery year – LNG DF Dry bulk



Source: Clarksons Research

3.4.2. Calculation methodology of green premium

There are different ways to estimate the green premium, which in this study is expressed as the added value generated by green elements in the GV compared to a conventional vessel. One method of determining the green premium is to assess the difference in the additional costs of the GV compared to that of a conventional vessel, as well as the discrepancy in fair market value between the GV and the traditional vessel. This can be equated to the following:

Equation 3.1: Premium Calculation – Method 1

$$Premium = Difference\left(FMV_{green}, FMV_{conventional}\right) - Difference(Cost_{green}, Cost_{convetional})$$

Where,

FMV_{green} is the fair market value for a GV. The fair market value may be assessed through valuation reports provided by external valuation firms or brokers. The FMV ought to be computed on the basis of a willing seller and a willing buyer, as well as a charter-free foundation.

$FMV_{conventional}$ is the fair market value for a conventional vessel.

$Cost_{green}$ is the shipbuilding cost for a GV.

$Cost_{convetional}$ is the shipbuilding cost for a conventional vessel.

Financing costs also could play a crucial role in assessing the green premium, especially when there is a marked difference in financing costs between green vessels and conventional vessels. Given the recent robust push for sustainable financing within the banking sector, financiers are likely to be inclined to offer more advantageous financing conditions for green vessels compared to conventional vessels. Nevertheless, the economic advantages associated with green financing in the shipping sector are not significant unless there is compelling evidence that financing for green vessels is more secure than that for conventional vessels. Therefore, it is assumed that there is no disparity in financing costs between green vessels and conventional vessels for modeling purposes.

If the premium exceeds zero (0), the additional value is acknowledged by market participants such as ship owners and charterers, indicating that the Loss Given Default (LGD) may be comparatively lower than traditional vessel financing, provided that all other conditions remain constant.

Since the fair market value of the vessel is also largely estimated through a discounted cash flow model based on the forecast cash flow, for example on time charter rates, it is helpful to check whether the time charter rate for the GV is significantly higher than the time charter rate for a conventional ship. If the sum of the present value of the difference between the time charter rate for the GV and the time charter rate for a conventional vessel is similar to the premium level calculated based on Equation 3.1 above, this represents an alternative method of proving the LGD for a green vessel the financing is comparatively low.

Equation 3.2: Premium Calculation – Method 2

$$Premium = \sum_{T=0}^{Maturity} Present\ Value\ \left(T/C_{green,T} - T/C_{conventional,T}\right)$$

Where,

$T/C_{green,T}$ is the time charter rate for a GV.

$T/C_{conventional,T}$ is the time charter rate for a conventional vessel.

T is the time charter period and *Maturity* refers to the final year of the time charter contract.

An alternative straightforward method for determining the green premium is to analyze the average variance in newbuilding prices alongside the average variance of market value differences for vessels with identical specifications, excluding green components such as LNG or methanol dual-fuel engines. Should the disparity between the two prices be statistically significant, the price differential can be interpreted as a green premium within the marketplace.

Equation 3.3: Premium Calculation – Method 3

$$Premium = Difference\left(NB_{green}, NB_{conventional}\right) -$$

$$Difference\left(FMV_{green}, FMV_{conventional}\right)$$

Where,

NB_{green} is the newbuilding price for a GV.

$NB_{conventional}$ is the newbuilding price for a conventional vessel.

FMV_{green} is the fair market value for a GV.

$FMV_{conventional}$ is the fair market value for a conventional vessel.

In this study, due to data accuracy considerations and challenges associated with data availability, the analysis is conducted using the methodology described in Equation 3.1. Ideally, all three approaches should reach the same conclusion, provided the necessary information is accessible. Certain data points, such as however, time charter rates and prices for new buildings are usually kept strictly confidential, which leads to a lack of transparency in many segments. Among the variables identified in the three approaches, fair market value is the most reliable measure because it can be verified through various reputable sources, including Clarksons Research, VesselsValue, MSI and Flagship.

However, there is still a problem with the methodology of Equation 3.1, namely estimating the additional shipbuilding costs incurred to accommodate the DF capability. This information shows a lack of transparency, and it appears that the additional costs vary depending on the type of assets involved. It is also noted that the cost of retrofitting may be higher than that of installing a DF engine during the vessel's initial design, as the retrofit may require significant modifications to the vessel.

According to the private source from Hyundai Heavy Industries, the estimated additional capital costs for the LNG DF engine is around US$24 million to US$38 million subject to the size of the containership (see Table 3.1).

Table 3.1: Additional capital costs for LNG DF for Containership

Containership	Additional CAPEX	% of NB Price (1)	% of NB Price (2)
8,000TEU	US$24m	21.0%	18.6%
13,000TEU	US$27m	21.5%	19.2%
16,000TEU	US$28m	20.1%	17.7%
24,000TEU	US$38m	20.9%	17.3%

Note. % of NB price (1) refers to the average newbuilding price from January 2020 based on Clarksons Research data, whereas % of NB Price (2) is based on the average newbuilding price from January 2023.

The above information is largely consistent with the report published by MSI, which states that new-build LNG DF container ships are currently 20-25% more expensive than their conventionally operated counterparts (Freight Waves, 2023). Clarksons data also suggests that the majority of orders for LNG-capable container ships are for vessels with a capacity of 12,000 to 16,999 20-foot units. Such newbuilds currently cost over $130 million, meaning many container ship owners are spending over $25 million per ship to add the LNG fuel option.

Referring to Fearnley Securities report (Pacific Green Technologies Group, 2023), the newbuild price of ten (10) 15,000 TEU LNG DF container ships ordered by CMA CGM represents an additional capital expenditure of US$20 million for a conventional 15,000 TEU container ship.

In terms of the tanker segment, one case study performed by Sea-LNG estimated that the additional capital costs for LNG retrofit for VLCC is US$27.2m (SEA\LNG 2019). According to Lois Zabrocky, CEO of International Seaways, at a Capital Link conference in March 2023, it requires another US$15m to US$20m for LNG DF capability if you order a VLCC in Korea. Putting together the information, the additional capital costs for LNG DF for VLCC ranges from 12.2% to 25.7% over the contract price of conventional VLCC which is subject to the benchmark newbuilding price (see Table 3.2).

Table 3.2: Additional capital costs for LNG DF for VLCC

	Additional CAPEX		
Newbuilding price	US$15m	US$20m	US$27.2m
US$105.78(1)	14.2%	18.9%	25.7%
US$123.25(2)	12.2%	16.2%	22.1%

Note. (1) refers to the average newbuilding price for VLCC from January 2020, while (2) refers to the average newbuilding price for VLCC from January 2023 based on Clarksons Research data.

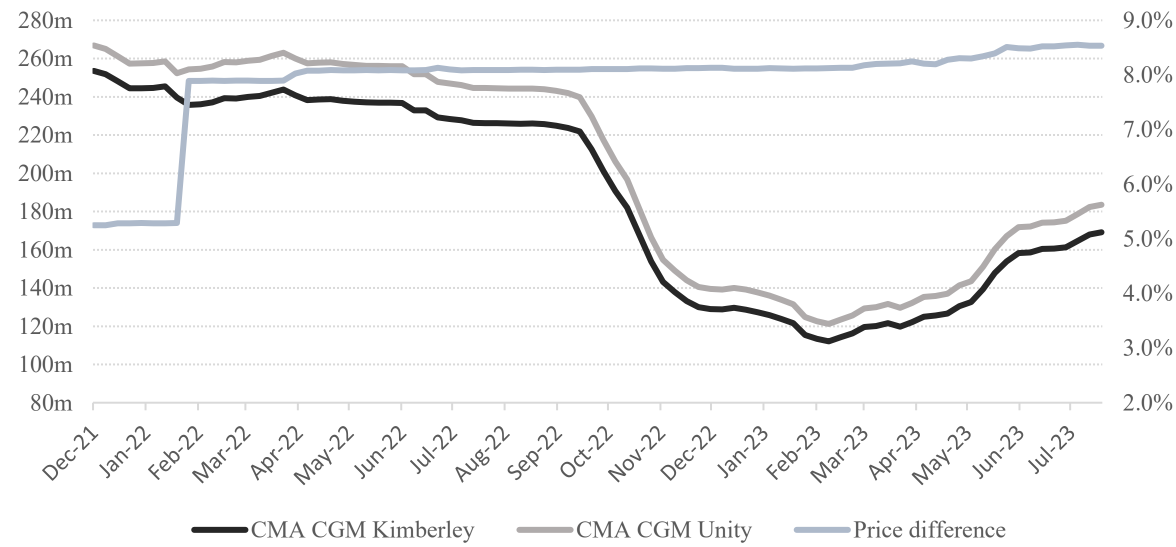
Meanwhile, it is challenging to locate publicly available information regarding the additional capital costs for LNG DF for dry bulk carriers, considering that this asset category represents the least common type of LNG DF capability among the various asset classifications. However, it is not an overly aggressive estimation to assume that the additional capital costs should be in the similar range for the container vessel and tanker in terms of the % of newbuilding price.

3.4.2.1. Valuation premium/penalty on Chinese-built vessel

As shown in the GV pool data, the vessels are built by different shipyards, predominantly either in China or Korea. To ensure uniformity in data for value comparison, it is essential to modify the market value should there exist a persistent value disparity between vessels constructed in China and those constructed in Korea with identical specifications. According to the study performed by Hyung-Sik at el (NamHyung-Sik, De Alwis and D'agostini, 2022), in most vessel classifications, Chinese-built ships were valued lower than other countries with a significant negative impact on the second-hand value of the vessel. Overall, the results indicate higher second-hand value for Korean and Japanese-built ships. One study also provides a 7% premium on Japanese-built vessels, while they discount 5% on the value of Chinese-built vessels (Maria, 2019).

The same finding can be verified by the comparison test using the vessels that have similar specifications, ages, and types except for the shipyard. For instance, in the containership space, two 15,000TEU vessels, CMA CGM Kimberly (built in December 2021 in Jiangnan Shanghai Changxing Heavy Industry) and CMA CGM Unity (built in December 2021 in Hyundai Heavy Industries) also confirm the value difference between Chinese-built vessel and Korean-built vessel. The newbuilding price difference between the two vessels ranges from US$9.1m to US$19.3m which represents around 5.2% – 8.6% premium value on the Korean-built vessel (see Figure 3.10).

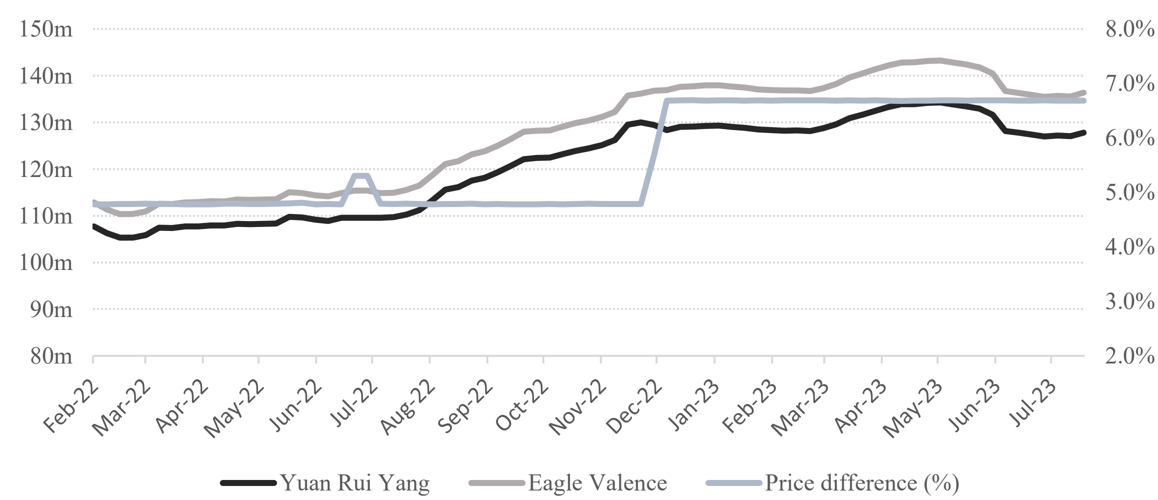
Figure 3.10: Comparison of Chinese-built vessel and Korean-built vessel - Containership



Source: VesselsValue

The two VLCCs which have the same specifications and age except for the shipyard, Yuan Rui Yang (built February 2022 by Dalian Shipbuilding Industry) and Eagle Valence (built February 2022 by Samsung Heavy Industries), show a consistent value difference, ranging from 4.8% to 6.7% (see Figure 3.11).

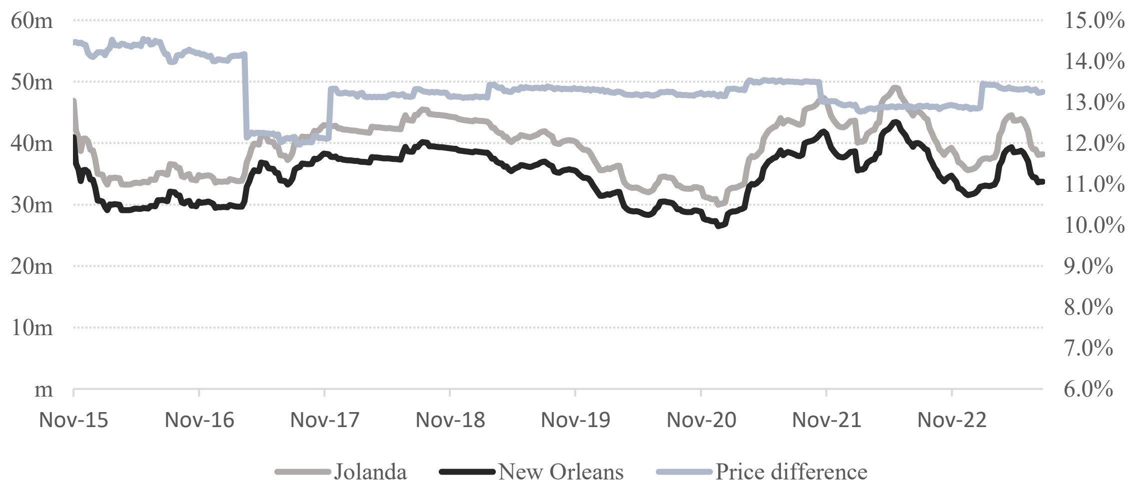
Figure 3.11: Comparison of Chinese-built vessel and Korean-built vessel - Tanker



Source: VesselsValue

The dry bulk shows a more significant value difference between the two yards. Based on the two 180,000 DWT Capesize bulk carriers, Jolanda (built October 2015 by Hyundai Samho Heavy Industries) and New Orleans (built November 2015 by Shanghai Waigaoqiao Shipbuilding), the price difference is at least 12% since the delivery of the vessels (see Figure 3.12).

Figure 3.12: Comparison of Chinese-built vessel and Korean-built vessel – Dry bulk



Source: VesselsValue

Referring to the valuation methodology applied by VesselsValue (*The Mathematics of Market Value*, 2019), the primary sources of data regarding vessel values are the sale and purchase (S&P) and newbuilding markets. Presuming the above historical secondhand values incorporate the same valuation methodology, the consistent value difference is supported by actual sale and purchase prices and newbuilding order prices.

For modeling purposes in this study, a Korean-built vessel is assigned a 5.0% premium at valuation to ensure a conservative approach regardless of asset category, particularly given the significant quality improvements observed among select Tier 1 Chinese shipyards.

In order to confirm if a 5.0% premium is statistically supported, I ran the *t*-test based on the data sets used for the above graphs.

Containership

Table 3.3: Value Comparison for Containership

						95% CI	
	T	*df*	*Sig. (2-tailed)*	*Sig. (1-tailed)*	*Mean*	*LL*	*UL*
Premium	31.2861	85	.0000***	.0000***	.0788	.0770	.0806

Note. CI = confidence interval; LL = lower limit; UL = upper limit. * $p < .05$. ** $p < .01$. *** $p < .001$. df = degree of freedom.

A one-tailed single sample T-test is performed to investigate if the average value difference between the two vessels is higher than 5%. The outcome confirms that the average value difference is significantly higher than 5%, t (85) = 31.2861, p = .000. This result is summarized in Table 3.3.

Tanker

The same finding is confirmed in the tanker segment. The outcome confirms that the average value difference is significantly higher than 5%, t (76) = 6.0056, p = .000 as summarized in Table 3.4.

Table 3.4: Value Comparison for Tanker

						95% CI	
	T	*df*	*Sig. (2-tailed)*	*Sig. (1-tailed)*	*Mean*	*LL*	*UL*
Premium	6.0056	76	.0000***	.0000***	.0563	.0542	.0585

Note. CI = confidence interval; LL = lower limit; UL = upper limit. * $p < .05$. ** $p < .01$. *** $p < .001$. df = degree of freedom.

Dry Bulk

The dry bulk segment shows more obvious results than other segments, confirming the average value difference between the Chinese-built dry bulk and Korean-built dry bulk is significantly different from 5%, t (403) = 294.6459, p = .000 as indicated in Table 3.5 below.

Table 3.5: Value Comparison for Dry Bulk Carrier

						95% CI	
	T	*df*	*Sig. (2-tailed)*	*Sig. (1-tailed)*	*Mean*	*LL*	*UL*
Premium	294.645	403	.0000***	.0000***	.1329	.1323	.1334

Note. CI = confidence interval; LL = lower limit; UL = upper limit. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. df = degree of freedom.

Conclusion

All data on the different types of assets statistically confirm that the value premium compared to the ship built in Korea is at least more than 5%. Based on this sample test, it appears that the premium in the dry bulk sector is much higher than in the other sectors. However, in adjusting the value in this document, the same 5% markup is conservatively applied to dry bulk carriers and the reason for the difference is not analyzed further as this is not the purpose of this research.

3.4.3. Green premium calculation

Equation 3.1 methodology is used to calculate the green premium. For the estimation of additional capital costs for LNG DF capability, it is assumed a 20% of the newbuilding price based on the various sources of information as discussed in Chapter 3.4.2. The historical newbuilding prices are extracted by Clarksons Research (Shipping Intelligence Network, n.d.). The historical market value data for the sample vessels is obtained from VesselsValue.

For the additional capital costs for methanol DF capability, it is assumed a 12% of the newbuilding prices based on the recent new orders from Maersk (Povl D, 2022) and the other sources (Jasmina, 2022), which indicates the additional capital costs would be in the range of 8% to 16% of a standard newbuilding cost.

3.4.3.1. Containership

As illustrated by Table 3.6 below, neo-Panamax containership (15,000TEU) accounts for the majority of LNG DF containerships delivered as of June 2023. Considering that 25 out of 51 vessels were delivered by the Chinese shipyard, the value should be adjusted as analyzed in Chapter 3.4.2.1. Due to the lack of information about the newbuilding price for feeder vessels and relatively small sample vessels, particularly for the recent deliveries, feeder vessels are excluded from the green premium calculation analysis.

Table 3.6: Summary of LNG DF Containerships

Vessel type	No. Vessel	Year of built				
		Before 2020	2020	2021	2022	2023
23,000 TEU	10	-	4	5	-	1
15,000 TEU	32	1	2	6	13	10
Feeder (<1,500 TEU)	9	5	1	3	-	-
Total	**51**	**6**	**7**	**14**	**13**	**11**

Source: Clarksons Research

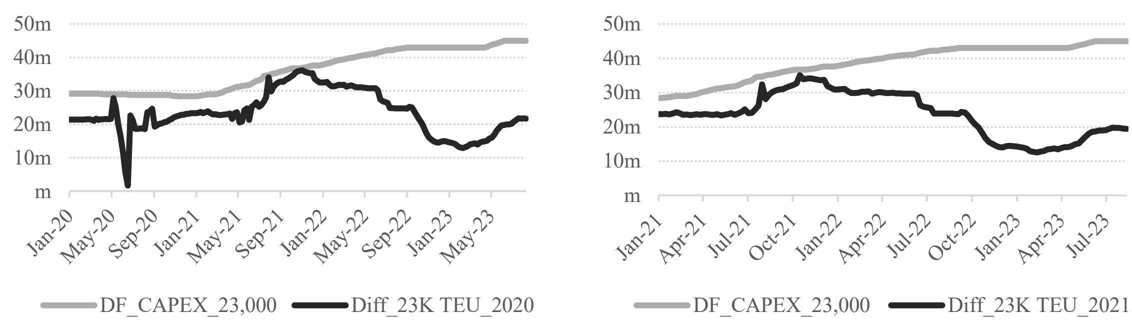
ULCV (>22,000 TEU)

Berlin Express, delivered June 2023, is carved out from the sample pool as there is insufficient time series data for comparison as of this study. For the 2020 built LNG DF containership, HMM Dublin is selected as the benchmark vessel which was delivered by Hanwha Ocean (ex- DSME) in May 2020, while MSC Amelia, built in June 2021 by Hanwha Ocean, is chosen as the benchmark vessel for the 2021 built LNG DF containership.

Referring to Figure 3.13 which visualizes the trend and valuation gap over time between the required capital costs for LNG DF capability and the average market value difference between the benchmark vessels and the remaining nine vessels, it does not appear to indicate any green premium over the LNG DF containerships.

Figure 3.13: Green premium Calculation for 23,000 TEU Containership

23,000 TEU Containership (2020 built)	23,000 TEU Containership (2021 built)



The null hypothesis posits that the valuation disparity between a green vessel and a conventional vessel is less than the extra cost associated with LNG dual fuel capacity for the conventional vessel (H_0: Diff_FMV – DF_CAPEX < 0), while the alternative hypothesis is the valuation disparity between a green vessel and a conventional vessel exceeds the extra cost associated with LNG dual fuel capacity for the conventional vessel (H_1: Diff_FMV – DF_CAPEX > 0). The statistical outcome also confirms that no green premium exists if the additional capital costs for LNG DF is 20% of the newbuilding price (see Table 3.7).

Table 3.7: T-test analysis for Green Premium Calculation for 23,000 TEU Containership

Asset type	Year	Obs	Mean		*SD*			
			Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test
23K TEU	2020	189	23.48	36.09	6.45	6.21	-12.60	-19.125^{-}
Containership	2021	137	23.70	38.83	6.46	5.09	-15.13	-18.125

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

Neo Panamax (14,000 – 15,000 TEU)

The same analysis is performed, which leads to the same conclusion that there is no green premium on LNG DF neo-Panamax containerships.

Figure 3.14: Green premium Calculation for 15,000 TEU Containership

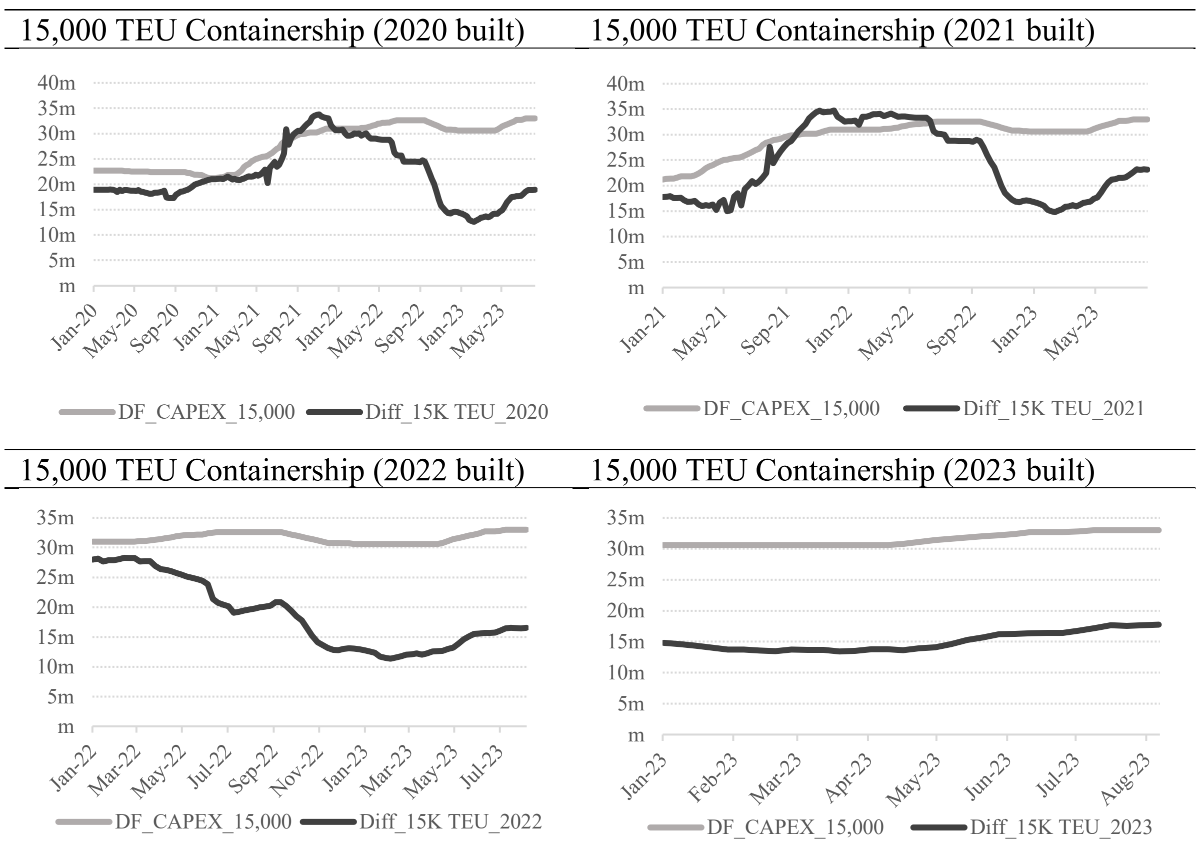


Table 3.8: T-test analysis for Green Premium Calculation for 15,000 TEU Containership

Asset type	Year	Obs	Mean		*SD*			
			Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test

	2020	189	21.93	27.69	5.75	4.33		-12.90
15K TEU	2021	137	24.23	29.72	7.10	3.29	-5.49	-18.125
Containership	2022	84	18.61	31.62	5.76	.844	-13.01	-21.160
	2023	32	15.04	31.50	1.52	1.01	-16.46	-150.80^{-}

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional CAPEX for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

Based on the above results, it is clear that there is no green premium for the LNG-DF container ships and that the difference in fair market value between LNG-DF container ships and conventional ships appears to change independently of the development of additional capital expenditure for the LNG DF capacity changed. In order to find out the external factors that influence the movement of the difference in fair market value between LNG-DF containerships and conventional ships, multiple regression analysis is carried out in accordance with the following Equation 3.4

Equation 3.4

$$Diff\_FMV = \beta_0 + \beta_1 X_{HSFO} + \beta_2 X_{LNG} + \beta_3 X_{CO2} + \beta_4 X_{Eearning} + \beta_5 X_{Secondhand} + \varepsilon$$

Where,

X_{HSFO} is High Sulphur Fuel Oil (HSFO) price quoted \$/ton.

X_{LNG} is Liquified Natural Gas (LNG) price quoted \$/ton.

X_{CO2} is CO_2 price quoted \$/ton.

$X_{Earning}$ is the average containership earnings quoted \$/day.

$X_{Secondhand}$ is the secondhand price index for the containership.

The historical data for the independent variables are extracted from Clarkosns Research.

Fuel costs significantly impact vessel valuation, as they constitute a major portion of operating expenses and influence the economic viability of different types of vessels. The choice of fuel type, fluctuations in fuel prices, and the adoption of alternative fuels all play crucial roles in determining the operational costs and, consequently, the valuation of vessels (Zainol et al., 2017). For instance, LNG-fueled vessels often have lower fuel costs compared to conventional vessels, although the initial investment is higher (Fokkema et al., 2017). While there is limited evidence that CO2 pricing directly impacts the value of ships, a study indicates that vessels outfitted with carbon capture and storage (CCS) systems can sequester CO2 emissions, potentially increasing their market worth as regulations tighten (Pérez-Bódalo et al., 2023). Furthermore, Rauca and Batrinca emphasized that the carbon intensity indicator (CII) serves as a metric for assessing a vessel's CO2 emission efficiency, which can influence operational choices and, in turn, affect the valuation of the vessel (Rauca & Batrinca, 2023). It is quite clear that there is a positive relationship between earnings and the value of a vessel, a point that Moutzouris and Nomikos also supports (Moutzouris & Nomikos, 2019).

Table 3.9: Multiple Regression Analysis for 23,000TEU containership built in 2020

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta *(β)*	
Constant	24.0616	2.3792	.	10.11
X_{HSFO}	-.0031	.0046	-.0353	-.066
X_{LNG}	-.0031	.0006	-.2815	-5.21^{***}
X_{CO2}	-.0939	.0254	-.1509	-3.69^{***}
$X_{Earning}$	.0003	.00003	1.1809	10.24^{***}
$X_{Secondhand}$	-.0480	.0391	-.1776	-1.23

Note. F (5,104)=147.68, $^{***}p < .001$, $R^2 = 0.8765$, Adj $R^2 = 0.8706$

The initial regression for the result of the 23,000TEU containerships built in 2020 shows that the HSFO price and the containership secondhand price are not statistically significant independent variables (see Table 3.9). Furthermore, a Variance Inflation Factor (VIF) test indicates that there is evidence of serious multicollinearity for the containership secondhand price variable (VIF=17.6). Therefore, another regression analysis is conducted after eliminating the two independent variables, the HSFO price and the containership secondhand price (see Table 3.10). The result shows that the valuation difference between LNG DF vessels and conventional vessels is negatively influenced by the price movement of LNG and CO_2 while there is a positive correlation with the earnings of containerships. Should the price of LNG escalate by $1 per ton, the disparity in fair market value between green vessels and conventional vessels would diminish by around US$3,500, whereas a $1 per ton increase in CO_2 pricing would lead to a reduction in the fair market value differential between green vessels and conventional vessels amounting to US$83,700. Conversely, an augmentation of the earning index by one point would expand the valuation disparity between green vessels and conventional vessels by approximately US$200. Among the three independent variables, standardized coefficients confirm that the revenue of containerships has a relatively larger influence on the valuation difference than the others.

Table 3.10: Revised Multiple Regression Analysis for 23,000TEU containership built in 2020

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta *(β)*	
Constant	20.1183	.5766	.	34.89
LNG	-.0035	.0004	-.3825	-7.13***
CO_2	-.0837	.0102	-.3525	-8.19***
Con_earnings	.0002	.00001	1.2612	23.89***

Note. F (3,184)=229.78, *** $p < .001$, $R^2 = 0.7893$, Adj $R^2 = 0.7859$

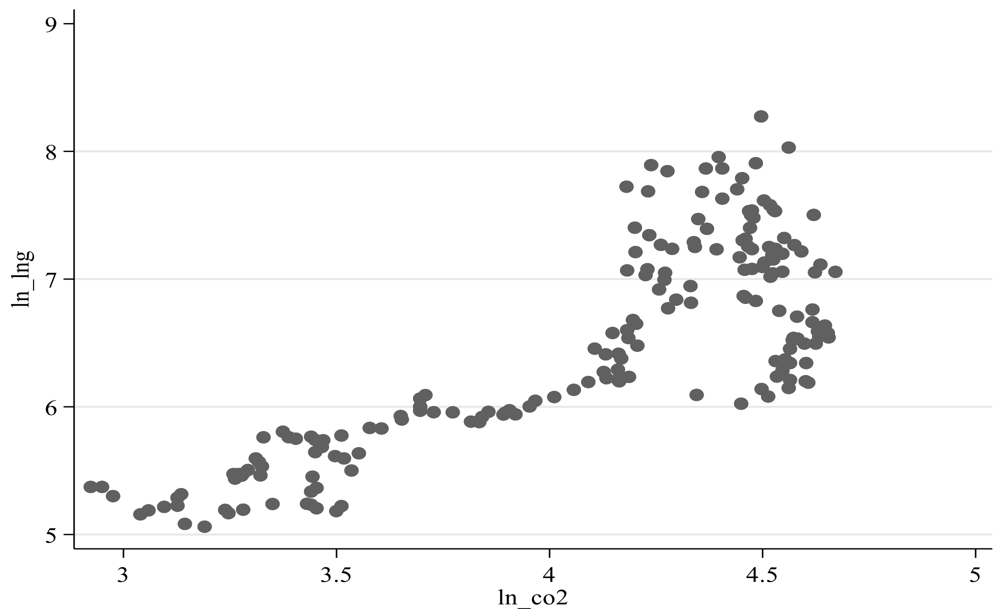
It is reasonable to conclude that the disparity in valuation would diminish concurrently with the increase in LNG prices, as ship operators would not prefer a LNG DF vessels due to the elevated bunker costs. Furthermore, it is rational to anticipate that the valuation difference will be wider as the average revenues of container vessels rise, as such an increase would furnish maritime operators with the necessary financial leeway to accommodate the heightened operational expenses associated with LNG DF vessels, in exchange for reductions in greenhouse gas emissions. However, it is not immediately apparent upon initial observation that the disparity in valuation narrows as CO_2 prices increase. Given that one of the advantages of operating a LNG DF vessel is the reduction of CO_2 emissions, it would be reasonable to anticipate that the value of such a vessel should appreciate, resulting in an expanded valuation disparity between the LNG DF vessel and conventional vessels. The plausible explanation for this phenomenon may be that the anticipated financial benefits stemming from reduced CO_2 emissions do not surpass the escalation of LNG bunker expenses; consequently, ship operators tend to favor conventional vessels in response to an increase in CO_2 pricing. This assertion can be substantiated if there exists a positive correlation between the prices of CO_2 and LNG. Referring to the result of a simple regression analysis conducted between the historical weekly LNG price and the CO_2 price from January 2020 to August 2023, there exists a distinct positive relationship between the two variables which are transformed by the natural logarithm to stabilize the variance of the price data and also shows that the LNG price increases by about 1.28 % if the price of CO_2 increases by 1% (see Table 3.11 and Figure 3.15). This finding substantiates my aforementioned plausible explanation.

Table 3.11: Regression analysis between LNG price and CO_2 price

Variable	Unstandardized Coefficients		Standardized Coefficients	T
	B	SE	Beta (β)	
Constant	1.2113	.2803	.	4.32
ln (CO_2)	1.2891	.0683	.8104	18.87^{***}

Note. F (1,186)=356.03, *** $p < .001$, $R^2 = 0.6568$, Adj $R^2 = 0.6550$

Figure 3.15: Relationship between LNG price and CO_2 price



The regression analysis is carried out in the same way for containerships of other sizes, the results of which are presented in Table 3.12.

Table 3.12: Multiple Regression Analysis for Other Containerships

23,000TEU containership built in 2021

Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta (β)	*T*
Constant	23.5987	.9294	.	25.39
LNG	-.0032	.0003	-.3413	-8.56***
CO_2	-.1247	.0115	-.3401	-10.84***
Con_earnings	.0002	.00001	1.0846	27.93***

Note. F (3,133)=324.24, *** $p < .001$, $R^2 = 0.8797$, Adj $R^2 = 0.8770$

15,000TEU containership built in 2020

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta (β)	
Constant	18.3657	.3519	.	52.18
LNG	-.0025	.0003	-.3085	-8.39***
CO_2	-.0785	.0062	-.3712	-12.58***
Con_earnings	.0002	.00001	1.2970	35.86***

Note. F (3,184)=558.75, *** $p < .001$, $R^2 = 0.9011$, Adj $R^2 = 0.8995$

15,000TEU containership built in 2021

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta (β)	
Constant	8.9930	1.0320	.	8.71
LNG	-.0005	.0004	-.0535	-1.33
CO_2	-.0352	.01277	-.0873	2.76***
Con_earnings	.0002	.00001	.9514	24.25***

Note. F (3,133)=316.61, *** $p < .001$, $R^2 = 0.8772$, Adj $R^2 = 0.8744$

15,000TEU containership built in 2022

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta (β)	
Constant	14.7307	2.6036	.	5.66
LNG	-.0025	.0004	-.3227	-5.56***
CO_2	-.0456	.0264	-.0794	-1.73***
Con_earnings	.0002	.00001	1.0903	20.58***

Note. F (3,80)=172.87, *** $p < .001$, $R^2 = 0.8664$, Adj $R^2 = 0.8613$

15,000TEU containership built in 2023

Variable	Unstandardized Coefficients		Standardized Coefficients	*T*
	B	SE	Beta (β)	
Constant	35.6053	6.5410	.	5.44
LNG	-.0076	.0015	-.7719	-4.98***

CO_2	-.0995	.0372	-.3532	-2.67***
Con_earnings	-.0002	.00001	-.2386	-1.50

Note. F (3,32)=11.22, *** $p < .001$, $R^2 = 0.5458$, Adj $R^2 = 0.4972$

According to the findings presented in Table 3.12, the price of LNG does not constitute a statistically significant independent variable for the 15,000 TEU containership constructed in 2021, and likewise, container earnings do not represent a statistically significant independent variable for the 15,000 TEU containership built in 2023. The anomalous results for the 2023 built containership case may be explained by the inadequacy of the sample size (merely 32 observations), which is substantiated by a low R^2 value. The other findings corroborate the conclusions that the disparity in valuation between LNG DF vessels and conventional vessels is adversely affected by the fluctuations in the prices of LNG and CO_2, whereas there exists a positive correlation with the revenues generated by containerships.

3.4.3.2. Tanker

Tankers are the most favored asset type for shipowners when it comes to DF propulsion as demonstrated by the number of vessels operating in waters (see Table 3.13). In addition, 23 vessels out of 57 handysize DF vessels are equipped with the methanol DF engine. Six (6) Suezmax tankers and four (4) Aframax tankers are shuttle tankers which are different from conventional crude/product oil carriers in terms of specification. Shuttle tankers are designed for offshore oil fields, transporting crude oil directly from offshore platforms to terminals or refineries, hence they are equipped with advanced dynamic positioning systems and thrusters for safe loading/unloading in challenging offshore conditions. Therefore, they are excluded from the green premium calculation analysis.

In terms of oil tanker types, there are two basic types in general, product tanker and crude tanker. Product tankers carry refined petroleum products like gasoline, diesel, and other lighter products, while crude tankers are specially designed for transporting unrefined crude oil extracted from oil fields. Product tankers are categorized according to their measurement in deadweight tonnage. Product tankers include Long Range (LR2 (85,000 DWT to 124,999 DWT) and LR1(60,000 DWT to 84,999 DWT)) product tanker, Medium Range (MR) tanker (42,000 DWT to 59,999 DWT), Handysize tanker (25,000 DWT to 41,999 DWT) and general-purpose tanker (10,000 DWT to 24,999 DWT). Crude tankers include Ultra Large Crude Carriers (ULCC, >320,000 DWT), Very Large Crude Carriers (VLCC, 200,000 DWT to 320,000 DWT), Suezmax tanker (125,000 DWT to 199,999 DWT), Aframax tanker (85,000 DWT to 124,999 DWT) and Panamax tanker (55,000 DWT to 84,999 DWT). ("Types of Oil Tankers - Handymax, Panamax, Aframax, Supertankers" n.d.)

Looking at the handysize DF tankers, many of them are small general-purpose tankers with less than 25,000 DWT size except for the methanol DF tankers which are typical MR tanker sizes. With the lack of information about the newbuilding price for small tankers, the green premium calculation for handysize vessels only focuses on twenty-three (23) methanol DF tankers.

Table 3.13: Summary of LNG / Methanol DF Tankers

Vessel type	No. Vessel	Year of built				
		Before 2020	2020	2021	2022	2023
VLCC	12	-	-	-	5	7
Suezmax	8	-	6	-	2	-
Aframax	42	8	1	10	16	7
Handysize	57	26	-	10	18	3
Total	**119**	**34**	**7**	**20**	**31**	**17**

Source: Clarksons Research

VLCC

The analysis is carried out with the two benchmark vessels, Erietta Latsi and Cassius. The vessels were delivered by Hyundai Heavy Industries in June 2022 and January 2023, respectively. As illustrated in Figure 3.16, there seems to be no green premium over LNG DF VLCC. This is confirmed by the statistical analysis as shown in Table 3.14.

Figure 3.16: Green premium Calculation for VLCC

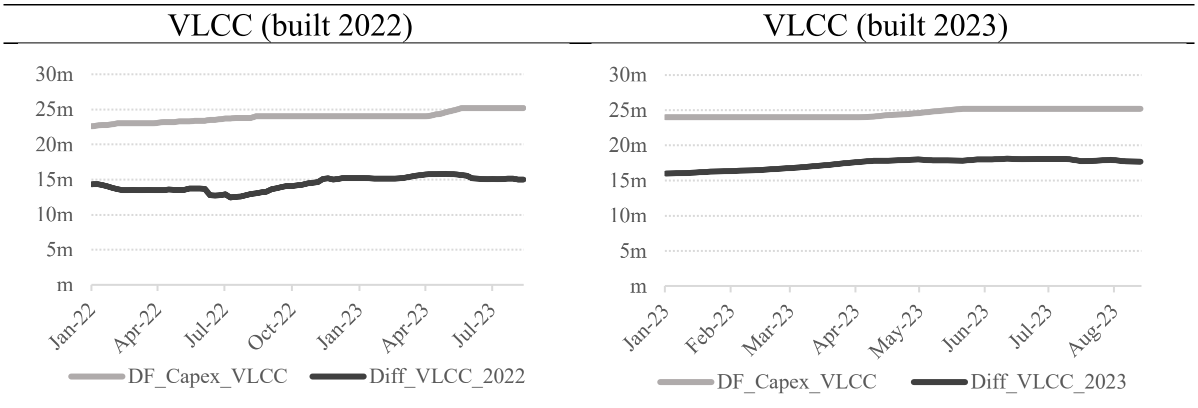


Table 3.14: T-test analysis for Green Premium Calculation for VLCC

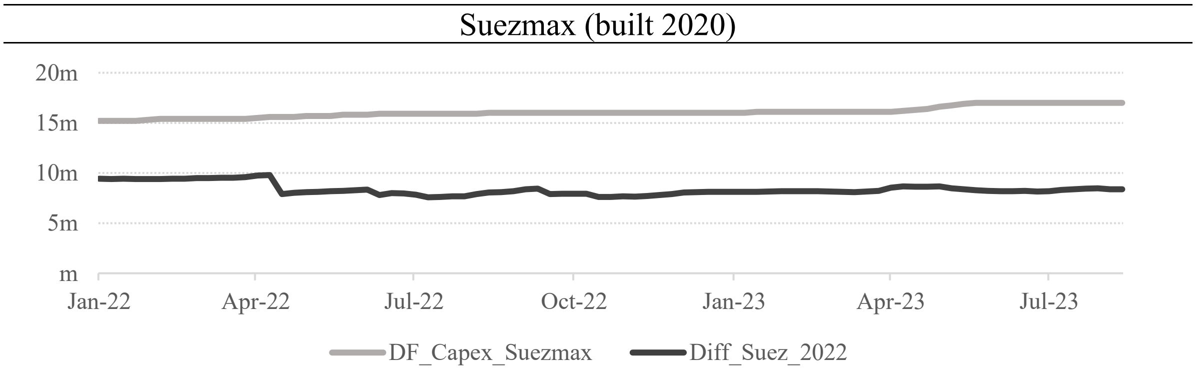
			Mean		*SD*			
Asset type	Year	Obs	Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test
VLCC	2022	85	14.38	23.93	.976	.712	-9.55	-111.45
	2023	33	17.38	24.56	.724	.566	-7.18	-92.319

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

Suezmax

Given two (2) LNG DF Suezmax vessels were built by a Chinese shipyard, the benchmark vessel, Emeraldway, is also selected which was delivered by Shanghai Waigaoqiao Shipyard in China in March 2022. The valuation difference between the benchmark vessel and LNG DF Suezmax since the inception from delivery has been substantially lower than the estimated CAPEX for the LNG DF capability (see Figure 3.17).

Figure 3.17: Green premium Calculation for Suezmax



The *T*-test result confirms the same interpretation as Figure 3.17 (see Table 3.15).

Table 3.15: T-test analysis for Green Premium Calculation for Suezmax

			Mean		*SD*			
Asset type	Year	Obs	Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test
Suezmax	2020	85	8.36	16.05	.586	.512	-7.69	-76.970

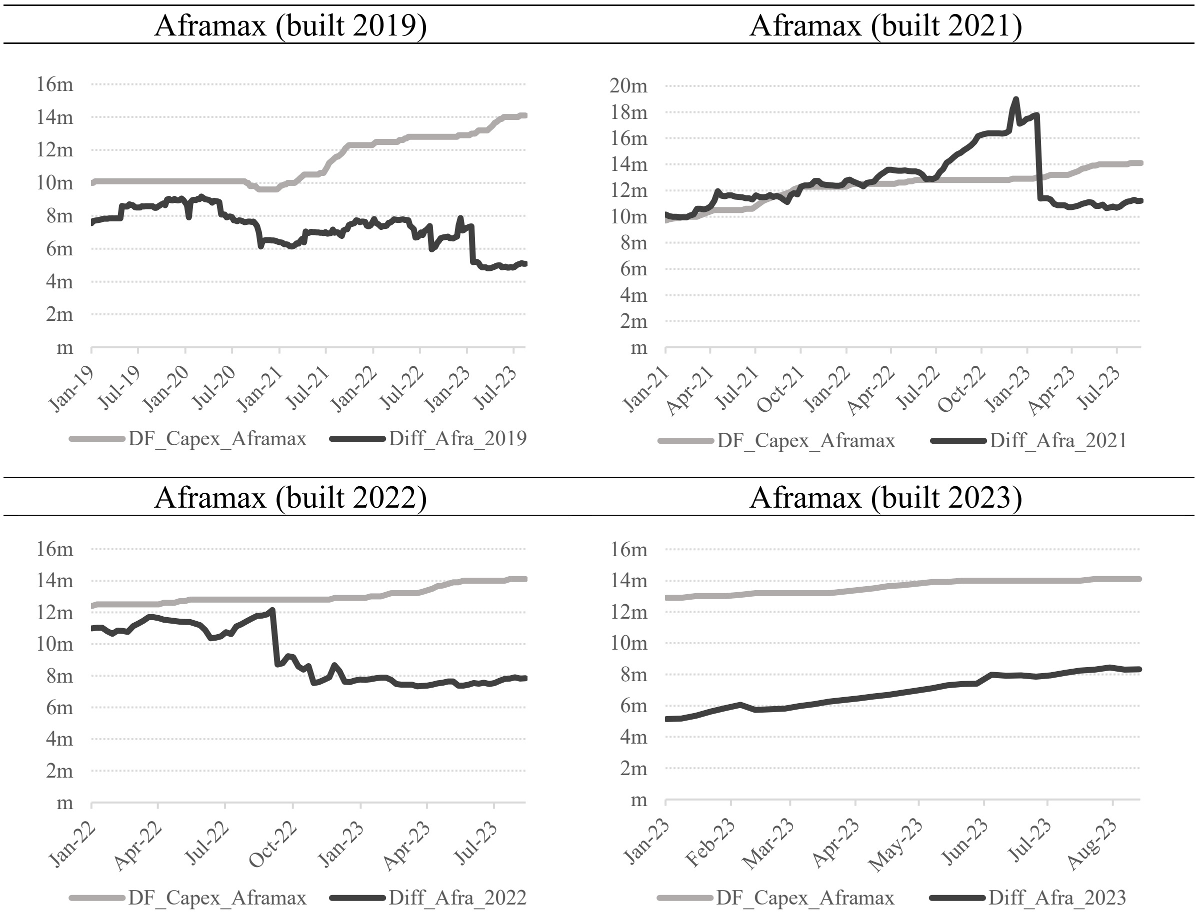
Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

Aframax

The only vessel delivered in 2020, Vladimir Monomakh, was built by the Russian shipyard, Zvezda Shipbuilding. As there is no comparable vessel to perform the analysis, this vessel is removed from the GV pool only for analysis purposes. Also, the vessels delivered before 2019 were excluded from the analysis, noting the additional CAPEX for LNG DF capability has reduced over time. Including those early adopted vessels could mislead the interpretation of the outcome unless the additional CAPEX for LNG DF capability is adjusted during the early days, which is not feasible due to the lack of information.

As the benchmark vessels, Eikeviken (built by Samsung Heavy Industries in January 2019), Jaarli (built by Hyundai Heavy Industries in September 2021), Ixora (built by New Times Shipbuilding in October 2022), and Navig8 Wolf (built by Dae Han Shipbuilding in January 2023) are selected. Referring to Figure 3.18, it seems there are certain periods where the green premium exists for the Aframax vessels built in 2021, whereas other vessels do not seem to show any green premium.

Figure 3.18: Green premium Calculation for Aframax



According to the *t*-test analysis performed in Table 3.16, it is statistically significant to confirm that there is a green premium on the LNG DF Aframax vessels built in 2021, with

p=0.0365. It is an interesting outcome, noting it can be interpreted that only LNG DF Aframax built in 2021 outperforms the conventional Aframax tanker built in the same year. However, the result is largely affected by the temporary uptick period from July 2022 to January 2023. If I narrow down the testing period from January 2023, it does not present any green premium. For other vessels, the outcome of statistical analysis aligns with graphical analysis (see Figure 3.18).

Table 3.16: T-test analysis for Green Premium Calculation for Aframax

			Mean		*SD*			
Asset type	Year	Obs	Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test
Aframax	2019	242	7.269	11.327	1.179	1.445	-4.05	-26.615
	2021	138	12.627	12.307	2.104	1.185	0.32	1.806*
	2022	85	9.254	13.054	1.748	.5229	-3.80	-16.307
	2023	33	6.889	13.595	1.058	.4359	-6.70	-59.668

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

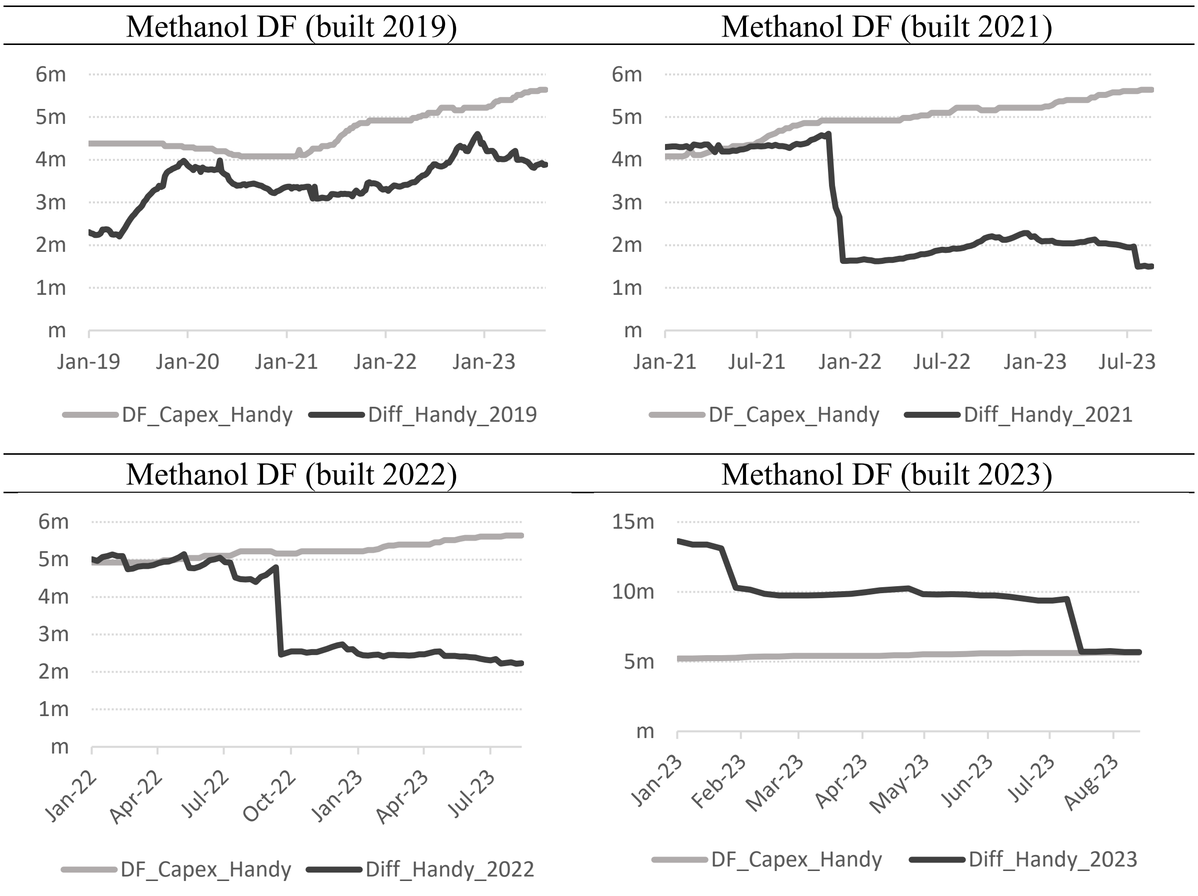
$^{*}p < .005$

Methanol DF – MR tanker

Sixteen (16) out of twenty-three (23) methanol DF tankers were built by Hyundai Mipo Dockyard, while three (3) vessels were delivered by the Japanese yard and four (4) vessels were built by the Chinese yard. In addition, the type of all the methanol DF tankers currently in water is MR product tanker. Therefore, the benchmark vessels are all conventional MR tankers which are Philoxenia (built by Hyundai Mipo Dockyard in May 2019), Clearocean Milano (built by Hyundai Heavy Industries in October 2021), Dee4 Mahogany (built by Hyundai Mipo Dockyard in September 2022) and Reliability (built by Dae Sun Shipbuilding in January 2023).

Interestingly, the methanol DF tanker built in 2023 seems to show a green premium since delivery although the premium has almost diminished in August 2023 (see Figure 3.19). On the other hand, the other vessels do not indicate any sign of green premium, which should be confirmed by statistical analysis.

Figure 3.19: Green premium Calculation for Methanol DF MR Tanker



Referring to Table 3.17, the most recently delivered methanol DF tanker indicates a slight sign of positive green premium, with p=0.1, which can be rejected with a 95% confidence level.

Table 3.17: T-test analysis for Green Premium Calculation for Methanol DF tankers

Asset type	Year	Obs	Mean Diff_FMV	Mean DF_CAPEX	*SD* Diff_FMV	*SD* DF_CAPEX	Diff	*t*-test
MR Tanker	2019	242	3.47	7.75	.526	.813	-4.28	-96.577
	2021	138	2.76	8.25	1.156	.746	-5.49	-35.769
	2022	85	3.49	8.72	1.202	.379	-5.23	-31.561
	2023	33	9.62	9.11	2.057	.226	0.51	1.308*

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

*$p < .001$

3.4.3.3. Dry Bulk

As illustrated by Table 3.18 below, the vessel type and the delivery year are different. In addition, 6 out of 25 vessels were delivered by the Korean shipyard, which means the value should be adjusted as analyzed in Chapter 3.4.2.1.

Table 3.18: Summary of LNG DF dry bulk vessels

Vessel type	**No. Vessel**	**Year of built 2018**	**2020**	**2021**	**2022**	**2023**
Cape (180K DWT)	9	-	2	1	2	4
Cape (210K DWT)	13	-	-	-	5	8
Panamax	-	-	-	-	-	-
Handymax	2	1	-	-	-	-
Handy	1	2	-	-	-	-
Total	**25**	**3**	**2**	**1**	**7**	**12**

Source: Clarksons Research

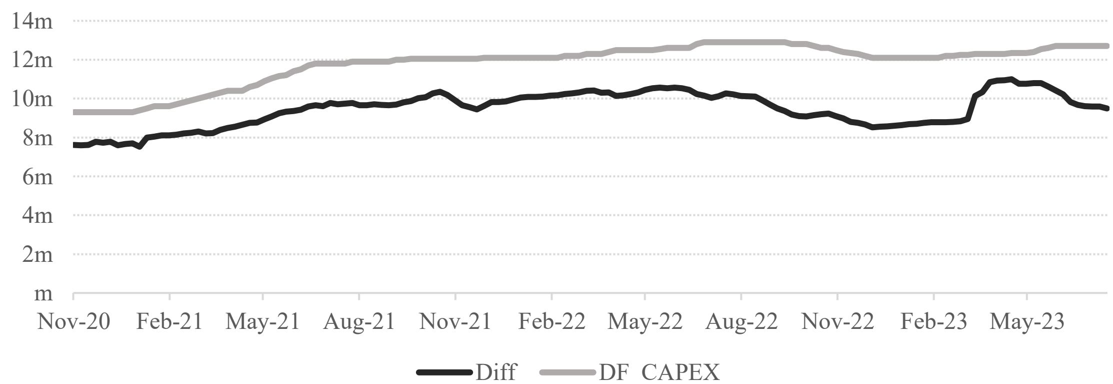
Capesize vessel (180,000 DWT – 210,000 DWT)

For the Capesize vessels delivered in 2020 and 2021, the 180,000 DWT Capesize dry bulk vessel, Ocean Dragon, is chosen as the benchmark vessel which was delivered in June 2020 by Namura Shipbuilding in Japan. By comparing the average market value of 3x LNG

DF vessels and the benchmark vessel, the value difference is derived by subtracting the market value of the benchmark vessel from the average market value of 3x LNG DF vessels, which is the same way as Equation 3.1.

The result is shown in the following Figure 3.20. Without further statistical analysis, it clearly indicates that there is no sign of green premium, given the expected additional CAPEX for LNG DF capability was always higher than the market value difference.

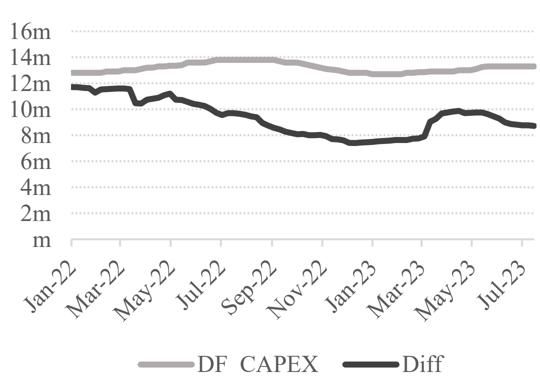
Figure 3.20: Green premium calculation for 2020-2021 Capesize vessel (180,000 DWT)

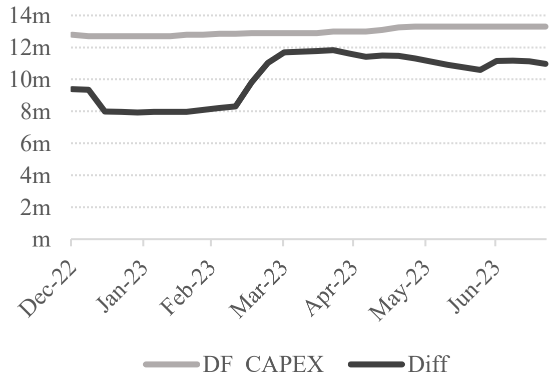


The same process was repeated for the other Capesize vessels delivered in 2022 and 2023. Maximus Australis, 210,000 DWT Capesize vessel built by Shanghai Waigaoqiao Shipbuilding in China in August 2022, Frontier Jasmine, 182,100 DWT Capesize vessel built by Namura Shipbuilding in Japan in July 2022, and Ocean Leader, 182,100 DWT Capesize vessel built by Namura Shipbuilding in Japan in January 2023 are selected as the benchmark vessels (see Figure 3.21).

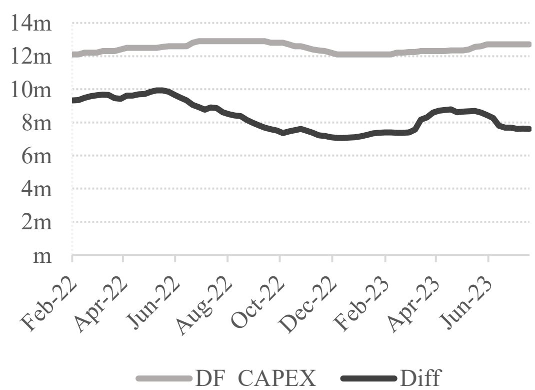
Figure 3.21: Green premium calculation for 2022-2023 Capesize vessel

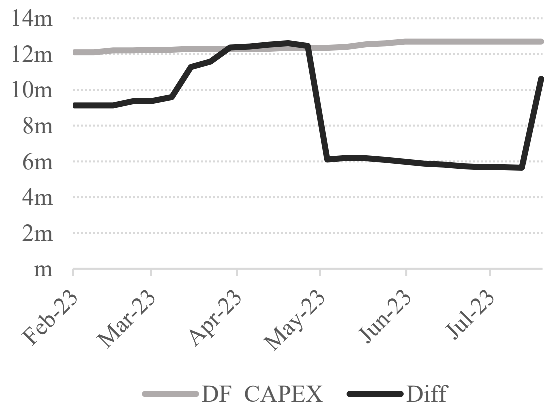
210,000 DWT Capesize (2022 built)	210,000 DWT Capesize (2023 built)





180,000 DWT Capesize (2022 built)	180,000 DWT Capesize (2023 built)





With running the paired t-test, the statistical outcome confirms no green premium exists if the additional capital costs for LNG DF is 20% of the newbuilding price (see Table 3.19).

Table 3.19: T-test analysis for Green Premium Calculation for Capesize Dry Bulk

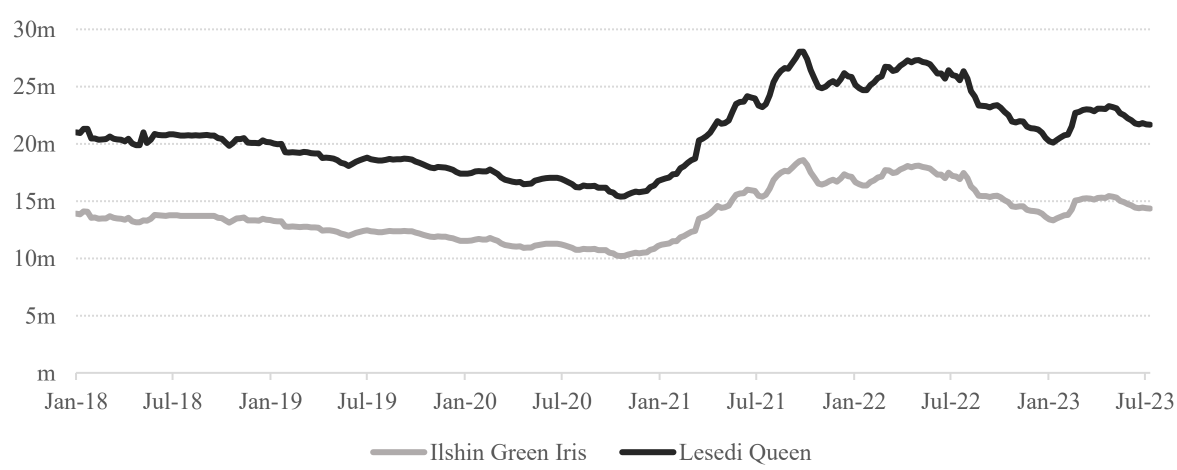
			Mean		*SD*			
Asset type	Year	Obs	Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX	Diff	*t*-test
180K DWT Cape	2020 & 2021	77	9.79	12.48	.743	.275	-2.69	-32.899
	2022	77	8.35	12.48	.922	.275	-4.13	-39.062
	2023	25	8.64	12.43	2.72	.215	-3.79	-6.565
210K DWT Cape	2022	81	9.37	13.19	1.37	.366	-3.82	-24.773
	2023	30	10.14	12.99	1.51	.237	-2.85	-11.520

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

Handymax vessel (40,000 DWT – 64,000 DWT)

The sample vessel, Ilshin Green Iris, is not a standard bulk carrier. It was specially built to carry limestone, which is an exceedingly rare type of vessel in the Handymax segment. Usually, the special type of vessel is trading at a discount in the sale and purchase market due to the lack of liquidity when it comes to monetizing the asset. This is proved by comparing the value of the standard equivalent size Handymax vessel Lesedi Queen, 50,400 DWT built by Oshima shipbuilding in February 2018 (see Figure 3.22). Therefore, in order to avoid any misleading results, no further analysis is performed for the Handymax vessel sample.

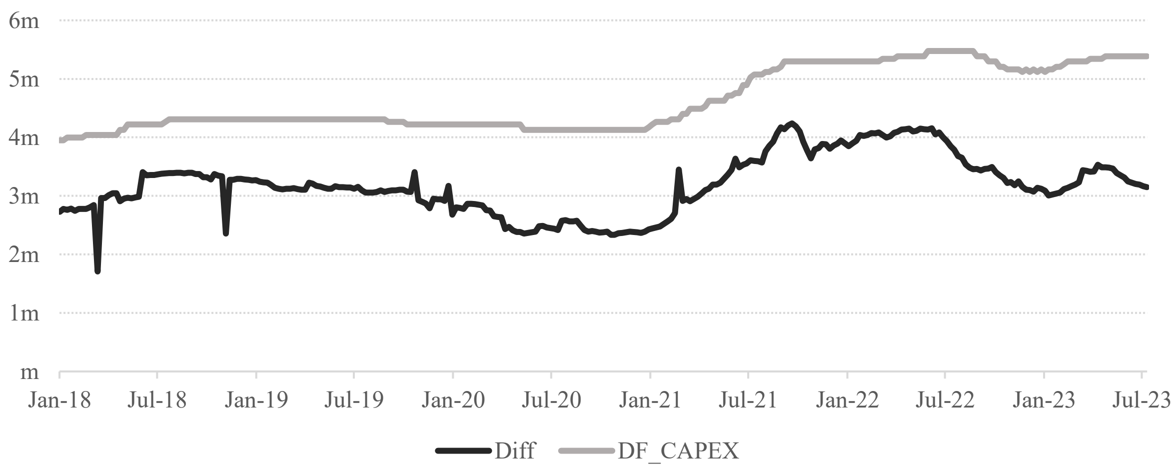
Figure 3.22: Value Comparison between Ilshin Green Iris and Lesedi Queen



Handysize vessel (15,000 DWT – 35,000 DWT)

Sentosa, a 24,000DWT Handy bulk carrier (open hatch) built by Yamanishi Zosen in Japan in May 2018, is picked as the benchmark vessel.

Figure 3.23: Green premium calculation for 2018 Handysize vessel



Similar to the Capesize dry bulk vessel, no green premium is confirmed by the t-test analysis for the handy dry bulk vessel if the additional capital costs for LNG DF is 20% of the newbuilding price (see Table 3.20).

Table 3.20: T-test analysis for Green Premium Calculation for Handysize Dry Bulk

Asset type	Year	Obs	Mean		*SD*		Diff	*t*-test
			Diff_FMV	DF_CAPEX	Diff_FMV	DF_CAPEX		
Handy	2018	289	3.19	4.63	.504	.527	-1.44	-68.383

Note. Diff_FMV refers to the valuation difference between the benchmark vessel and LNG DF vessels. DF_CAPEX means the additional capital costs for LNG DF capability. Diff refers to the difference in mean value between Diff_FMV and DF_CAPEX.

In comparison to the outcomes of containerships alongside those of tankers and dry bulk carriers, there is no evidence to support the existence of a green premium on LNG DF ships. Nevertheless, the pattern of the valuation gap between LNG DF vessels and conventional vessels differs from that of containerships and the other asset classes, namely tankers and bulk carriers. While the fluctuations in the valuation disparity between LNG DF containerships and conventional containerships can be attributed to LNG prices, CO_2 prices, and earnings from containerships, the same variations in tanker and bulk carriers cannot be explained by these same factors. Instead, it demonstrates that the gap between (1) the valuation difference between LNG DF vessels and conventional vessels and (2) capital costs for LNG DF stays consistent regardless of external factors. The likely reason is that the bunker fuel consumption of tankers and dry bulk carriers is lower than that of the large containerships, thus the fluctuation in bunker expenses or CO_2 charges would not have a considerably lesser effect on the value of those vessels when compared to the large containerships.

3.4.4. Volatility test

It is worthwhile to compare the volatility of two variables FMV_{green} and $FMV_{conventional}$ used in Equation 3.3. If the value of a green vessel is less volatile than a conventional vessel, particularly in the downturn market, it could also underpin the argument that the LGD for green vessel financing is relatively low. The degree of volatility can be measured through the standard deviation of each vessel. To investigate whether the standard deviation of GV and benchmark vessel is equal or not, an F-test is performed (see Table 3.23), which proves that there is no significant difference in terms of volatility between GV and conventional vessels except for the two cases, methanol DF MR tanker delivered in 2023 and handysize LNG DF dry bulk delivered in 2018.

Table 3.21: Summary Statistics of DF Vessels

Asset	Year	Mean	*SD*	Min	Max
Containership					
23K TEU containership	2020	238.0	60.7	146.6	337.5
	2021	262.1	59.4	164.0	342.2
15K TEU containership	2020	180.3	47.5	114.2	266.3
	2021	198.9	49.3	119.0	271.4
	2022	196.2	50.3	121.7	255.6
	2023	153.5	23.0	125.2	188.0
Tanker					

VLCC	2022	128.8	11.7	111.2	144.7
	2023	145.4	2.5	142.4	149.8
Suezmax	2022	81.7	6.0	70.7	89.8
Aframax	2019	62.3	11.3	46.4	87.0
	2021	74.1	13.3	50.8	100.2
	2022	79.6	9.0	64.6	97.1
	2023	91.9	2.8	87.4	96.4
	2019	41.7	4.8	34.8	54.0
MR tanker*	2021	44.5	5.5	37.4	55.9
	2022	50.4	3.6	44.2	57.8
	2023	54.0	3.3	48.2	61.4
Dry bulk					
Cape (210K DWT)	2022	69.6	7.8	56.6	82.1
	2023	68.5	7.8	57.9	77.9
Cape (180K DWT)	2020	62.8	6.0	49.3	72.4
	2021	66.9	5.2	57.2	74.3
	2022	63.0	5.7	55.4	71.5
	2023	62.1	6.5	53.3	70.0
Handy	2018	16.7	3.0	11.7	22.9

Note. MR tanker is powered by methanol DF engine.

Table 3.22: Summary Statistics of Benchmark Vessels

Asset	Year	Mean	*SD*	Min	Max
Containership					
23K TEU containership	2020	214.6	55.4	134.7	301.3
	2021	238.4	53.8	151.5	308.0
15K TEU containership	2020	158.3	42.0	96.1	232.5
	2021	174.6	42.5	104.2	236.7
	2022	177.6	45.0	110.4	228.0
	2023	138.4	21.5	111.5	170.3
Tanker					
VLCC	2022	114.4	10.8	97.7	128.9
	2023	128.0	2.2	125.3	131.9
Suezmax	2022	73.3	6.3	61.3	81.3
Aframax	2019	55.0	11.9	40.2	81.8
	2021	61.4	12.5	40.8	82.8
	2022	70.3	10.4	53.9	88.8
	2023	85.0	2.8	81.2	90.1
MR tanker	2019	38.2	4.5	31.7	49.4
	2021	41.7	6.3	33.2	53.6
	2022	46.9	4.4	39.3	55.1

	2023	44.2	1.4	42.0	47.7
Dry bulk					
Cape (210K DWT)	2022	60.2	6.5	49.2	70.6
	2023	58.3	6.3	49.5	66.1
Cape (180K DWT)	2020	53.3	5.2	41.7	61.8
	2021	54.6	4.4	46.5	61.8
	2022	57.9	5.9	50.7	66.4
	2023	59.9	5.9	51.8	67.7
Handy	2018	13.5	2.6	9.2	18.8

Table 3.23: F test on the Equality of Standard Deviations for GV and Conventional Vessels

Asset	Year	*df*	***F* statistics**	***P* value**
Containership				
23K TEU containership	2020	188	1.200	.213
	2021	136	1.216	.256
15K TEU containership	2020	188	1.274	.097
	2021	136	1.347	.083
	2022	83	1.249	.313
	2023	31	1.141	.716
Tanker				
VLCC	2022	85	1.168	.479
	2023	33	1.369	.379
Suezmax	2022	84	0.907	.656
Aframax	2019	241	0.895	.393
	2021	138	1.136	.456
	2022	84	0.738	.166
	2023	33	1.015	.966
MR tanker	2019	242	1.150	.278
	2021	138	0.764	.116
	2022	85	0.653	.051
	2023	33	5.618	$.000^{***}$
Dry bulk				
Cape (210K DWT)	2022	81	1.456	.093
	2023	29	1.508	.275
Cape (180K DWT)	2020	137	1.344	.085
	2021	89	1.393	.120
	2022	33	0.926	.826
	2023	29	1.203	.622
Handy	2018	288	1.374	$.007^{***}$

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

3.4.5. Discussion

As analyzed in the previous chapter, it is difficult to conclude that there is currently a green premium recognized by market participants in the shipping industry, assuming the additional capital costs for the LNG DF capability and the methanol DF capability is 20% and 12% of the newbuilding price, respectively. However, these assumptions allow us to reverse calculate the tipping point at which the green premium becomes statistically significant. In the first scenario is where the capital costs for LNG or methanol DF capability is cheaper than 20% or 12% of the newbuilding price, while in the second scenario, the FMV of GV exceeds the FMV of conventional vessels, resulting in a wider gap of value difference between the two GV and the conventional vessel.

Since the first scenario is not related to the premium recognized by market participants, it is more relevant for this study to further investigate the second scenario so that we can estimate how much more value should be recognized by market participants over the conventional vessel in order to confirm the green premium. The results are summarized in Table 3.24 to Table 3.27.

Table 3.24: Calculation of Inflection Point for LNG DF Containership

			Required additional value			
Asset type	Year	Inflection point	Mean	*SD*	Min	Max
23K TEU Containership	2020	12.5%	13.53**	2.331	10.65	16.875
	2021	11.5%	15.34**	2.642	12.07	19.12
15K TEU Containership	2020	15.0%	6.92**	1.084	5.30	8.25
	2021	15.5%	6.23**	.976	4.77	7.42
	2022	11.0%	12.46**	1.952	9.54	14.85
	2023	9.0%	15.23***	2.385	11.66	18.15

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 3.25: Calculation of Inflection Point for LNG DF Tanker

			Required additional value			

Asset type	Year	Inflection point	Mean	*SD*	Min	Max
VLCC	2022	11.5%	8.16***	1.16	6.80	10.71
	2023	14.0%	5.76**	.82	4.80	7.56
Suezmax	2020	10.0%	6.40***	.96	5.30	8.50
Aframax	2019	12.0%	4.25***	.57	3.60	5.64
	2021		Not Applicable			
	2022	13.5%	3.45***	.46	2.92	4.58
	2023	9.5%	5.58***	.75	4.72	7.40

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 3.26: Calculation of Inflection Point for Methanol DF Tanker

			Required additional value			
Asset type	Year	Inflection point	Mean	*SD*	Min	Max
MR Tanker	2019	8.5%	4.25***	.45	3.73	5.40
	2021	6.0%	5.17***	.55	4.55	6.58
	2022	7.0%	4.80***	.51	4.22	6.11
	2023		Not Applicable			

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 3.27: Calculation of Inflection Point for LNG DF Dry Bulk

			Required additional value			
Asset type	Year	Inflection point	Mean	*SD*	Min	Max
180K DWT Cape	2020 & 2021	15.4%	2.871**	.0633	2.783	2.967
	2022	13.0%	4.369**	.0963	4.235	4.515
	2023	12.0%	4.993**	.1101	4.84	5.16
210K DWT Cape	2022	13.5%	4.288***	.1889	4.127	4.485
	2023	14.5%	3.628***	.1006	3.492	3.795
Handy	2018	13.5%	1.507***	.1714	1.287	1.781

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

The interesting thing about the tables above is that the sooner the ship is delivered, the less additional market value is required to recognize the green premium. This translates to the additional capital expenditure for LNG or methanol DF capability increasing over time, exceeding the premium value of the dual-fuel vessels. However, this can also be interpreted to mean that the DF-equipped vessel has a more resilient value compared to a conventional vessel, meaning that the depreciation curve of an LNG or methanol DF vessel is less steep than the depreciation curve of a conventional ship. Considering that the additional capital expenditure for DF capability does not vary significantly, while the model assumes that the additional capital expenditure is linked to the price of new construction, which has increased in recent years, the latter interpretation should make more sense. However, due to the limited number of years of testing, this can be statistically verified with a few more years of data.

3.5. Conclusion

Based on the comprehensive and careful analysis in Chapter 3.4.2, which focuses particularly on the study of the green premium as well as the in-depth assessment of volatility, it is indeed challenging to reach a final conclusion that the risk associated with a green vessel is considered to be lower than that of a conventional vessel, especially taking into account the asset valuation aspect. This conclusion can be interpreted to mean that the Loss Given Default (LGD) for a green vessel should not show a significant difference compared to the LGD of a conventional vessel.

It should be duly noted that this result, while not entirely unexpected, should be approached with a degree of thoughtful consideration. This is mainly due to the ongoing consultations and negotiations on numerous environmental regulations that are still ongoing between various stakeholders. Consequently, shipowners, aware of the uncertainty and ambiguity surrounding the above regulations, are understandably reluctant to commit financial resources ahead of time without a clear and transparent understanding of the possible impacts.

The concept of a green vessel and green financing in the shipping industry has garnered significant attention from international organizations, banks, scholars, and practitioners. This increased focus on the subject is due to its growing popularity and recognition. However, it is important to note that there is currently no universally accepted definition of a green vessel, which has led to a lack of clarity when it comes to verifying the green premium associated with such vessels. In order to address this issue, this study aims to redefine the concept of green vessels in a manner that aligns with the perceptions of market participants. By doing so, it hopes to provide robust evidence of the existence of a green premium on these vessels, implying a low LGD compared to the financing of a conventional vessel.

Although the current lack of substantial evidence suggests that the existence of the green premium on the green vessel compared to the conventional vessel is minimal, it is possible that future regulatory changes could significantly influence this situation. These changes have the potential to create a green premium on the green vessel. A concrete example of such a regulatory change is the expected introduction of the EU Emissions Trading System (EU ETS) in shipping from 2024 onwards. This implementation is anticipated to have a considerable impact on the valuation of ships, as the price of CO_2 emissions is highly likely to be incorporated into the ship valuation process. Therefore, it is plausible that this regulatory change could lead to the emergence of a green premium on the green vessel.

To acquire a more comprehensive comprehension of the consequences of regulatory modifications, such as the EU ETS, on the maritime sector, further examination of market information is imperative. This study primarily concentrates on substantiating the presence of a green premium for green vessels by scrutinizing market trends and pricing data, intending to establish a potential correlation between such vessels and a diminished likelihood of loss given default. Through this analysis, we can ascertain whether the current regulations are achieving their intended impact and pinpoint areas that necessitate enhancement. Ultimately, this knowledge can be employed to inform policy-making decisions and propel progress toward a more sustainable future for the maritime industry.

Chapter 4
The evolution of shipping finance in light of GHG regulations

4.1. Introduction

The global shipping industry, which serves as a fundamental pillar of international trade and economic progress, is currently encountering an unparalleled challenge that revolves around the delicate equilibrium between ensuring economic feasibility and upholding environmental sustainability. Given its status as one of the primary sources of global greenhouse gas (GHG) emissions, the shipping sector is facing escalating scrutiny from various entities including regulators, stakeholders, and the general public. This escalating pressure is compelling the industry to deftly maneuver through a complex and rapidly evolving network of environmental regulations that are specifically crafted to mitigate its carbon footprint. The realm of shipping finance, conventionally centered on aspects like profitability and risk mitigation, now finds itself at a critical juncture due to recent developments. The implementation of stringent GHG regulations, particularly those outlined by the International Maritime Organization (IMO), is significantly reshaping the financial landscape of the maritime sector. These regulations, which encompass the IMO's ambitious objectives of reducing carbon intensity by 40% by 2030 and slashing total GHG emissions by a minimum of 50% by 2050 compared to levels recorded in 2008, necessitate substantial investments in cutting-edge technologies, fleet modernization, and the adoption of alternative fuel sources. The evolution of shipping finance in response to GHG regulations unfolds as a multifaceted narrative that encompasses various dimensions. This narrative includes the rise of green finance initiatives, the incorporation of environmental, social, and governance (ESG) criteria into investment strategies, and the creation of innovative financial frameworks tailored to bolster sustainable shipping practices. Both financial institutions and shipowners are currently grappling with the imperative to realign their approaches with these environmental mandates, which are increasingly viewed as indispensable components for achieving sustained economic prosperity and resilience in the long term.

This study presents a few ship financing solutions to respond to the changed environmental regulations and identifies the most optimized financial solutions for shipowners and financial institutions through specific financial modeling. Additionally, it examines to what level the CO_2 price needs to reach, focusing on the recently implemented or planned EU ETS and FuelEU Maritime, to steer investments towards eco-friendly ships and the use of alternative fuels as intended by the IMO.

Fundamentally, the evolution of shipping finance under the influence of GHG regulations signifies a pivotal moment for the industry, requiring a re-evaluation of traditional financial paradigms and emphasizing the critical role of innovative thinking in accomplishing both environmental objectives and economic aspirations. This research endeavor seeks to enrich the ongoing dialogue on sustainable shipping by shedding light on the crucial role played by finance in facilitating the industry's transition towards lower emissions and heightened environmental stewardship.

This paper sets out the objective of making a multitude of significant contributions to enhancing the comprehension of the ever-evolving relationship between shipping finance and greenhouse gas (GHG) regulations. Through the provision of an in-depth and thorough analysis, the study aims to offer valuable insights that have the potential to enlighten stakeholders operating within both the maritime and financial sectors.

To begin with, the paper aims to explain in great detail the specific ways in which GHG regulations are currently restructuring the financial terrain of the shipping industry. By carefully analyzing how regulatory frameworks influence investment decisions and capital allocation, the study aims to provide a detailed account of the regulatory pressures steering the sector toward more environmentally friendly practices. This understanding is essential for policymakers, regulators, and industry leaders as they manage the complexities of implementing and adhering to these regulations.

The subsequent focus of the paper involves the provision of practical insights through detailed case studies on how different actors within the shipping industry are reacting to GHG regulations. These case studies are aimed at illustrating the diverse strategies that have been embraced by shipowners, financial institutions, and other relevant stakeholders, with the aim of offering valuable lessons and exemplars of best practices that can be widely adopted across the sector. By grounding the theoretical analysis in concrete outcomes through real-world examples, the paper aims to provide a blueprint that can guide other entities grappling with similar challenges.

Moreover, by synthesizing the research findings and offering strategic recommendations, the paper tries to lay down a framework for future research endeavors and policy development in the field. It pinpoints specific areas where further investigation is warranted and puts forth policy measures that could potentially bolster the industry's ongoing shift toward sustainability. This contribution is particularly invaluable for academics, researchers, and policymakers who are eager to deepen their insights into the intricate interplay between finance and environmental regulations within the maritime realm.

Lastly, the paper delves into an exploration of the roles and interactions of the various stakeholders within the shipping finance ecosystem. It delves into how financiers, shipowners, regulators, and other pertinent entities are mutually influencing and being influenced by GHG regulations. This exploration is intended to provide a nuanced perspective on the dynamics at play among stakeholders, offering insights that could pave the way for more collaborative and effective approaches toward achieving regulatory compliance and sustainability objectives.

Overall, this paper seeks to bridge the gap between regulatory imperatives and financial practices in the shipping industry, offering a roadmap for how the sector can navigate the challenges and opportunities presented by GHG regulations. It aims to contribute to the broader discourse on sustainable finance and the future of maritime transportation, ultimately supporting the industry's evolution towards a more environmentally responsible paradigm.

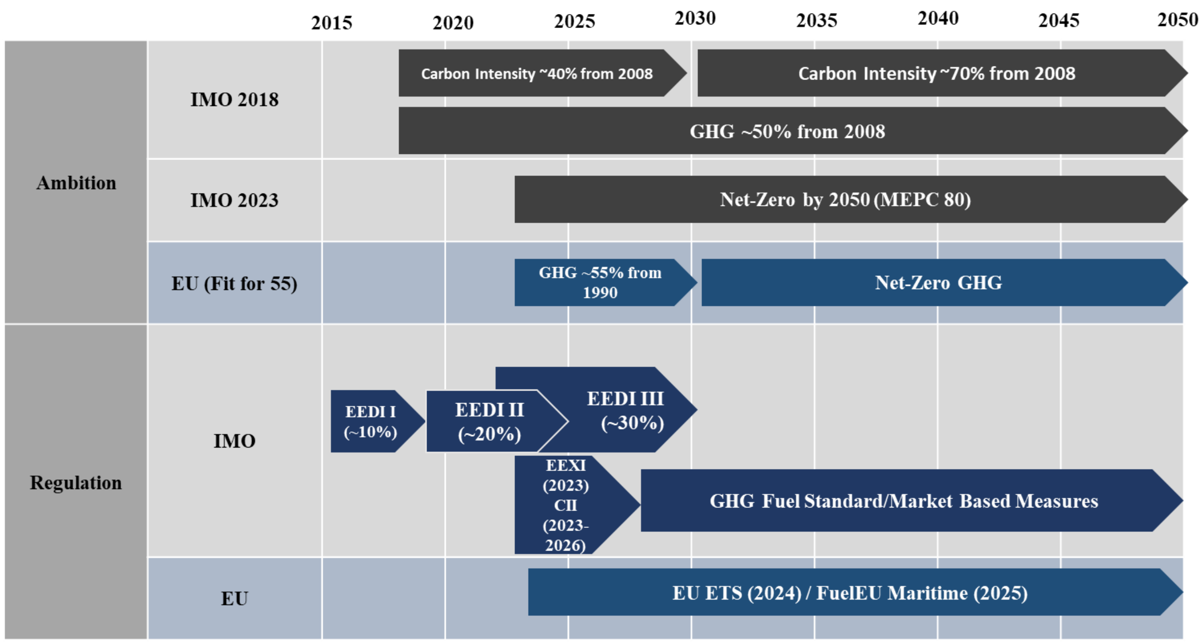
4.2. Understanding GHG regulations in the maritime industry

4.2.1. Overview

The International Maritime Organization (IMO) and the European Union (EU) are the predominant entities driving initiatives for decarbonization, with their relationship characterized by a combination of collaboration, alignment, and occasional divergence in regulatory strategies. Specifically, the IMO serves as the principal global authority tasked with establishing standards for maritime safety, security, environmental performance, and decarbonization. Conversely, the EU, holding membership in the IMO, actively engages in shaping these regulations.

In order to maintain consistency with worldwide standards, the EU commonly harmonizes its regulations with those set forth by the IMO. Notably, the EU's rules concerning sulfur levels in marine fuels and energy efficiency frequently mirror those established by the IMO. Furthermore, the EU extends support to the IMO's efforts in reducing greenhouse gas (GHG) emissions by promoting ambitious global targets and initiatives within the IMO's framework. Financial and technical assistance for global maritime decarbonization endeavors, including those spearheaded by the IMO, are provided by the EU. This assistance encompasses funding for the advancement of low-carbon technologies and alternative fuels.
Although the EU typically conforms to the IMO's regulations, there are instances where it enforces stricter or more ambitious measures within its own jurisdiction. For instance, the EU's Emissions Trading System (ETS) incorporates maritime emissions, surpassing the existing IMO mandates. Often advocating for expedited and more assertive timelines for decarbonization in contrast to the IMO, the EU must account for the varied interests and capabilities of a diverse array of member states, including developing nations. The differing

pace of regulatory actions between the EU and IMO may result in potential conflicts or overlaps in regulations, especially when the EU's regional directives impose additional obligations on shipping companies already subject to IMO regulations. This complexity could lead to heightened compliance costs for the industry.



Source: KR Decarbonization magazine Vol. 07

4.2.2. IMO’s initiatives and regulations for decarbonization in the maritime industry

IMO has established a global framework since 2018 for reducing greenhouse gas emissions from the maritime industry, aligning with international efforts to combat climate change. The object is to reduce the carbon intensity of international shipping by at least 40% by 2030, aiming for a 70% reduction by 2050 compared to 2008 levels. It also aims to peak GHG emissions IMO has established a global framework since 2018 for reducing greenhouse gas emissions from the maritime industry, aligning with international efforts to combat climate change. The object of international shipping as soon as possible and to reduce total annual GHG emissions by at least 50% by 2050 compared to 2008 levels. The approach to mitigating GHG emissions in the maritime industry encompasses short-term (2018-2023), mid-term (2023-2030), and long-term (2030 and beyond) objectives, focusing on technical feasibility, economic viability, and social acceptance. Key actions include enhancements in energy efficiency, adoption of cutting-edge technologies, and utilization of zero-emission vessels and fuels. There is a strong emphasis on substantial investments in research and development, capacity enhancement, and technical collaboration, particularly for developing nations. A robust system for monitoring and evaluation ensures compliance with scientific and technological progress.

The execution of the Initial GHG Strategy entails a series of steps and measures. Immediate actions include enhancing the current energy efficiency framework (EEDI and SEEMP), implementing operational measures like the Carbon Intensity Indicator (CII), and encouraging the use of energy-efficient technologies and practices. Medium-term actions involve examining market-based measures (MBMs) such as carbon pricing or emission trading schemes and promoting the advancement and deployment of alternative fuels and propulsion systems, such as hydrogen, ammonia, and battery technology. Long-term actions concentrate on the advancement and adoption of zero-emission vessels, aiding the shift to a carbon-neutral maritime industry through inventive solutions and global collaboration. Strategic approaches encompass stimulating innovation in low-carbon and zero-carbon technologies, formulating and enforcing robust policies to bolster GHG reduction, and enhancing international collaboration and alliances to accomplish shared objectives. The supervision and evaluation procedure entails the IMO conducting periodic assessments of the strategy to gauge progress and adjust to emerging challenges and opportunities. An updated strategy is slated for adoption in 2023, building upon the insights gained and accomplishments of the Initial Strategy.

4.2.2.1. Key IMO Regulations and Measures

Energy Efficiency Design Index (EEDI)

The EEDI, adopted in 2011 and has become mandatory for new ships since 2013, aims to promote the use of energy-efficient technologies and practices in the design and construction of new ships. It sets a minimum energy efficiency level per capacity mile (e.g., ton-mile) for different types of vessels. EEDI is calculated using a specific formula that takes into account several factors which are (1) the power of the main and auxiliary engines, the fuel consumption of the engines, ship's capacity, usually measured in deadweight tonnage (DWT) or gross tonnage (GT), speed of the ship and energy-saving technologies onboard, such as waste heat recovery systems or wind-assisted propulsion. The basic formula is, $EEDI = \frac{\text{CO2 Emissions}}{\text{Transport work (tons or passengers) } X\ Distance\ (nautical\ miles)}$ whereas the result is expressed in grams of CO_2 per ton-mile or passenger-mile.

EEDI applies to new ships of 400 gross tonnage and above that are engaged in international voyages. The requirement covers various ship types, including bulk carriers, tankers, container ships, gas carriers, and more. EEDI is implemented in phases, with progressively stricter requirements. Phase 0 started in 2013 and set the baseline. Phase 1, which lasted from 2015 to 2019, required a 10% improvement in energy efficiency compared to the baseline. Phase 2, covering the period from 2020 to 2024, requires a 20% improvement. From 2025 onwards, Phase 3 mandates a 30% improvement for most ship types, with some types facing even stricter targets.

Verification of EEDI compliance is conducted through a technical file prepared by the shipyard, reviewed by the ship's classification society, and approved by the flag state administration. Ships that meet EEDI requirements are issued an International Energy Efficiency (IEE) Certificate, which must be kept onboard. EEDI encourages the adoption of innovative design features and technologies that improve fuel efficiency, such as optimized hull designs, more efficient engines, and the use of alternative fuels. Ships with lower EEDI scores, indicating higher efficiency, can gain a competitive advantage in the market by offering lower operating costs and complying with stricter environmental regulations.

Some critics argue that the technology needed to meet future EEDI requirements is not yet fully mature or commercially viable for all ship types. Additionally, EEDI focuses on design efficiency but does not account for how efficiently a ship is operated in practice, which can also have a significant impact on overall emissions.

Energy Efficiency Existing Ship Index (EEXI)

The primary goal of the EEXI, adopted as part of amendments to MARPOL Annex VI in 2021 and applied from 2023, is to reduce the carbon intensity of the global fleet by ensuring that existing ships meet specific energy efficiency standards. The EEXI is designed to assess and improve the energy efficiency of existing ships, similar to how the Energy Efficiency Design Index (EEDI) applies to new ships.

The EEXI applies to all existing ships of 400 gross tonnage and above that are engaged in international voyages. It covers a wide range of ship types, including bulk carriers, tankers, container ships, general cargo ships, and gas carriers. The EEXI calculation is similar to the EEDI formula used for new ships, taking into account the ship's design parameters, engine power, fuel type, and installed energy-saving technologies. It is expressed in grams of CO_2 per ton-mile. The EEXI calculation includes a "reduction factor" that specifies how much more efficient a ship must be compared to a baseline, which is typically based on the average efficiency of ships in the same category in 2008.

Shipowners can comply with the EEXI requirements by implementing technical measures to improve the energy efficiency of their vessels. These may include reducing the maximum engine power to lower fuel consumption, installing devices like propeller modifications, air lubrication systems, or hull modifications, and switching to lower-carbon or alternative fuels to improve a ship's EEXI rating. Shipowners must prepare an EEXI technical file, which documents the ship's energy efficiency characteristics and how it complies with the EEXI requirements. This file must be reviewed and approved by the ship's classification society or flag state.

The ship's classification society or an authorized organization verifies the EEXI technical file to ensure compliance. This process typically involves checking the ship's design and operational parameters against the EEXI standards. Ships that meet the EEXI requirements are issued an International Energy Efficiency (IEE) Certificate, which must be kept onboard.

The EEXI may require some ships to operate at reduced speeds or with limited engine power to meet the efficiency standards, affecting their operational flexibility. The EEXI is expected to drive demand for retrofitting existing ships with energy-saving technologies, leading to increased activity in the ship repair and modification market. By improving the energy efficiency of existing ships, the EEXI contributes to reducing the overall carbon footprint of the shipping industry. Implementing the required technical measures can be costly, especially for older ships, which may face challenges in achieving compliance without significant investment. Some older, less efficient ships may be phased out or scrapped if they cannot economically comply with the EEXI requirements, leading to a potential reduction in the global fleet size.

Carbon Intensity Indicator (CII)

The primary goal of the CII, adopted in 2021 as part of the broader IMO strategy to reduce GHG emissions and has come into force in 2023, is to reduce the carbon intensity of the global fleet by requiring ships to continuously improve their operational efficiency and reduce their emissions relative to the amount of cargo they transport over a given distance.

The CII is calculated by measuring the grams of CO_2 emitted per deadweight ton (DWT) per nautical mile (g CO_2/DWT-nm). This metric assesses the efficiency of a ship's operations, taking into account factors such as fuel consumption, distance travelled, and cargo carried. The CII calculation uses data collected under the IMO's Data Collection System (DCS), which includes information on fuel consumption, distance sailed, and cargo carried.

The CII applies to ships of 5,000 gross tonnage and above that are engaged in international voyages. This includes a wide range of ship types such as bulk carriers, tankers, container ships, and general cargo vessels. Ships must calculate and report their CII annually, and they are assessed against a reference line based on the average performance of similar ships.

Ships are given an annual CII rating on a scale from A to E, where A indicates superior performance (most efficient), B indicates performance better than average, C indicates average performance (compliant with the required standards), D indicates performance below average (non-compliant, but with limited tolerance), and E indicates inferior performance (least efficient and non-compliant). Ships rated D or E must develop a corrective action plan to improve their performance and raise their rating to at least C in subsequent years. If a ship is rated D for three consecutive years or E in any single year, it must submit a corrective action plan to the relevant authorities (such as the flag state or classification society) outlining how it will improve its CII rating. Compliance with the CII requirements is linked to the issuance and maintenance of the ship's International Energy Efficiency (IEE) Certificate. Non-compliance could lead to penalties or restrictions on the ship's operation. Shipowners and operators may need to adjust their operations to achieve better CII ratings. This could involve optimizing voyage planning, reducing speeds (slow steaming), or improving energy management practices onboard. The CII creates a continuous incentive for ships to improve their operational efficiency over time, contributing to the IMO's broader goal of reducing GHG emissions from shipping.

While the Energy Efficiency Existing Ship Index (EEXI) sets design-based standards for existing ships, the CII focuses on operational efficiency. Together, these measures provide a comprehensive approach to reducing the carbon footprint of ships throughout their lifecycle. The CII is a key element of the IMO's Initial GHG Strategy, which aims to reduce the carbon intensity of international shipping by at least 40% by 2030, compared to 2008 levels.

Achieving a good CII rating can be challenging, particularly for ships operating in difficult trading conditions or for those with irregular operational profiles. Ships with lower CII ratings may face commercial disadvantages, as charterers and customers increasingly prioritize environmentally friendly vessels. The CII is a significant regulatory tool that encourages the maritime industry to adopt more sustainable practices and to continuously improve the carbon efficiency of their operations, thereby contributing to global efforts to combat climate change.

Comparison of EEDI, EEXI and CII

The Energy Efficiency Design Index (EEDI) is concerned with the design phase of new ships, the Energy Efficiency Existing Ship Index (EEXI) focuses on the energy efficiency of existing ships, including retrofits, and the Carbon Intensity Indicator (CII) is all about operational efficiency and how a ship is run day-to-day. EEDI and EEXI are more about meeting set design or retrofit standards, whereas CII is about continuous operational performance and improvement. EEDI and EEXI primarily address design and structural efficiency, while CII addresses real-world, operational emissions (see Table 4.1).

Table 4.1: Comparison Summary for EEDI, EEXI and CII

Feature	EEDI	EEXI	CII
Target Ships	New ships	Existing ships	Existing ships
Applicable tonnage	400 GT and above	400 GT and above	5,000 GT and above
Main focus	Design efficiency	Energy efficiency of existing ships	Operational carbon intensity
Stage of Application	Design and construction	Retrofit and operational adjustments	Operational phase
Implementation Year	2013 onwards (various phases)	2023 onwards	2023 onwards
Compliance Mechanism	Design meets specified efficiency standards	Ships must meet or exceed EEXI standards	Annual CII rating and compliance through corrective actions if needed
Rating System	No rating system, binary compliance	No rating system, binary compliance	A-E rating scale, with corrective actions required for low ratings

Future Developments

The IMO continues to refine and develop its energy efficiency measures, aiming for further reductions in GHG emissions. Future measures may include the further tightening of EEDI and EEXI standards, the development of new market-based measures (MBMs) to provide economic incentives for reducing emissions, and an increased focus on innovative technologies and alternative fuels to enhance energy efficiency and reduce carbon intensity.

Market-based measures (MBMs) in the maritime industry are economic mechanisms designed to incentivize the reduction of greenhouse gas (GHG) emissions by placing a financial cost on emissions or providing economic benefits for low-carbon practices. These measures are part of the broader efforts to decarbonize the shipping industry and align it with global climate goals.

The primary purpose of MBMs is to incentivize emission reductions by creating a financial incentive for shipowners and operators to reduce their carbon emissions. This is achieved by making it more costly to emit GHGs. Additionally, revenues generated from MBMs can be used to fund research, development, and deployment of low-carbon technologies, as well as to support climate adaptation and mitigation efforts in developing countries.

There are various types of MBMs. Carbon pricing includes a carbon tax, which is a direct tax on the carbon content of fuels used in shipping, providing a clear cost for emissions and encouraging operators to switch to cleaner fuels or improve efficiency. Another type is the emissions trading system (ETS), a cap-and-trade system where shipping companies must purchase emission allowances to cover their CO_2 emissions. Companies that reduce emissions below their allowances can sell surplus allowances, creating a financial incentive for efficiency. A fuel levy is another measure, that imposes a fee on bunker fuels based on their carbon content, providing a price signal to reduce fuel consumption and GHG emissions (Kosmas and Acciaro, 2017). Incentive schemes include subsidies and grants for adopting energy-efficient technologies or using alternative fuels, such as grants for retrofitting ships or subsidies for using low-carbon or zero-carbon fuels like hydrogen or ammonia. Environmental Ship Index (ESI) discounts can also be offered by ports or other maritime infrastructure providers, offering discounts on port fees or other services to ships with lower emissions or those that meet certain environmental criteria.

The European Union Emissions Trading System (EU ETS) is a key market-based measure in discussion. The EU has decided to include maritime emissions in its existing ETS starting from 2024, covering CO_2 emissions from ships over 5,000 gross tonnage on voyages within the European Economic Area (EEA), as well as 50% of emissions from voyages to and from the EEA. The IMO has also been discussing the potential introduction of a global MBM, with various proposals under consideration, including a global carbon levy or an international emissions trading system. However, consensus among member states has been challenging, and discussions are ongoing.

MBMs are often seen as cost-effective ways to reduce emissions, as they provide flexibility for shipowners and operators to choose the most economically viable way to reduce their carbon footprint. By creating a financial cost for emissions, MBMs encourage the development and adoption of new technologies and practices that reduce GHG emissions. Additionally, MBMs can generate significant revenue, which can be reinvested in the maritime industry to support the transition to a low-carbon future, as well as in broader climate action initiatives.

However, there are challenges and criticisms of MBMs. One of the main challenges is the potential for a patchwork of regional MBMs, like the EU ETS, which could create compliance complexities and competitive disadvantages for operators depending on where they operate. Developing countries are concerned about the impact of MBMs on their economies, particularly those heavily reliant on maritime trade. There are calls for measures to ensure that MBMs are fair and equitable. The introduction of MBMs can also create uncertainty in the market, particularly regarding future fuel costs and the availability of allowances in cap-and-trade systems.

The adoption of MBMs in the maritime industry is still evolving. While the EU is moving forward with its ETS, the IMO is working towards finding a consensus on a global approach. The industry is closely watching these developments, as they will have significant implications for the cost of shipping and the pace of decarbonization. Market-based measures are seen as an essential tool in the effort to reduce GHG emissions from shipping, complementing technical and operational measures, and driving the industry towards a more sustainable future.

4.2.3. EU's initiatives and regulations for decarbonization in the maritime industry

The European Union (EU) has implemented a series of initiatives and regulations aimed at decarbonizing the maritime industry as part of its broader European Green Deal and Fit for 55 strategies which are key components of the EU's ambitious plan to transition to a sustainable, low-carbon economy. These initiatives are designed to make Europe the first climate-neutral continent by 2050, while also achieving significant greenhouse gas (GHG) emissions reductions by 2030. These efforts are designed to reduce greenhouse gas (GHG) emissions, improve energy efficiency, and promote the use of alternative fuels within the shipping sector.

The European Green Deal is a comprehensive roadmap for making the EU's economy sustainable by transforming climate and environmental challenges into opportunities across all policy areas. The central goal is to make the EU climate-neutral by 2050, meaning that the EU’s net GHG emissions will be reduced to zero. This involves cutting emissions, investing in green technologies, and protecting the natural environment. Key pillars include climate action, which aims to reduce GHG emissions, increase the use of renewable energy, and enhance energy efficiency; the circular economy, which promotes sustainable resource management, waste reduction, and recycling; biodiversity, which protects ecosystems, restores damaged environments, and halts biodiversity loss; sustainable agriculture, which encourages the use of environmentally friendly farming practices through the Farm to Fork strategy; and zero pollution, which targets air, water, and soil pollution, with specific actions to reduce contaminants. The Green Deal includes mechanisms to ensure that the transition to a green economy is fair and inclusive, particularly for regions and workers who may be adversely affected by the shift away from fossil fuels.

The Fit for 55 package is a set of legislative proposals designed to achieve a 55% reduction in GHG emissions by 2030, compared to 1990 levels. This target is part of the broader goal set by the European Climate Law, which is enshrined in the European Green Deal. Key components include a revised Emissions Trading System (ETS), which extends the ETS to more sectors, including maritime and road transport, and tightens the cap on emissions to drive further reductions; the Carbon Border Adjustment Mechanism (CBAM), which introduces a carbon border tax on imports from countries with lower environmental standards to prevent "carbon leakage" and protect EU industries; the Renewable Energy Directive (RED), which sets higher targets for the share of renewable energy in the EU's energy mix and encourages the deployment of renewables across all sectors, including transport and industry; the Energy Efficiency Directive (EED), which strengthens energy efficiency targets and measures to reduce energy consumption across the EU; the Effort Sharing Regulation (ESR), which sets national targets for sectors not covered by the ETS, such as agriculture, waste, and building emissions; the Alternative Fuels Infrastructure Regulation, which supports the expansion of infrastructure for electric vehicles, hydrogen, and other alternative fuels across the EU; and the Social Climate Fund, which was created to address the social impact of the transition, particularly for vulnerable households, small businesses, and transport users.

The Green Deal and Fit for 55 are designed to work together to create a comprehensive framework for the EU's transition to a low-carbon economy. While the Green Deal sets the overarching goals and vision, the Fit for 55 package provides the legislative tools and targets necessary to achieve those goals. These strategies affect multiple sectors, including energy, transport, agriculture, industry, and buildings. They aim to ensure that all sectors contribute to the overall reduction in emissions and the shift towards sustainability. Both initiatives are also seen as drivers of economic growth and innovation. By investing in green technologies and infrastructure, the EU aims to create jobs, boost competitiveness, and secure long-term economic resilience.

4.2.4. Key EU initiatives and regulations

4.2.4.1. Introduction of the EU ETS

The European Union Emissions Trading System (EU ETS) is a cornerstone of the EU's climate policy, designed to reduce greenhouse gas emissions cost-effectively. It was the world's first major carbon market and remains the largest one, covering about 40% of the EU's total greenhouse gas emissions. The EU ETS aims to reduce greenhouse gas emissions from high-emission industries and power generation sectors by creating a financial incentive to cut emissions. It works on the "cap-and-trade" principle, where a cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap-and-trade system involves setting a cap on the total amount of GHGs that can be emitted by the sectors covered by the ETS. This cap is reduced over time to ensure that total emissions fall. Within this cap, companies receive or buy emission allowances, which they can trade with one another as needed. One allowance gives the holder the right to emit one ton of CO_2 or the equivalent amount of another greenhouse gas. Companies that reduce their emissions can sell their excess allowances to others that are struggling to stay within their limits, creating a financial incentive to cut emissions. At the end of each year, companies must surrender enough allowances to cover their emissions. If a company emits more than it holds in allowances, it faces significant fines (EU Emissions Trading System (EU ETS) - European Commission, n.d.).

The EU ETS has evolved through several trading phases. Phase 1 (2005-2007) was the pilot phase, primarily for testing the system, and involved only CO_2 emissions from power and heat generation, and some industrial sectors. Phase 2 (2008-2012) was aligned with the first commitment period of the Kyoto Protocol and expanded to more sectors and gases. Phase

3 (2013-2020) introduced a single EU-wide cap on emissions, replacing national caps, and made auctioning of allowances the default method of allocation. Phase 4 (2021-2030) is the current phase, with a more ambitious emissions reduction target of 55% by 2030 compared to 1990 levels. This phase includes a steeper annual reduction in the cap and increased use of auctioning.

The EU ETS covers sectors such as power and heat generation, energy-intensive industrial sectors (e.g., oil refineries, steelworks, cement production), and commercial aviation within the European Economic Area (EEA). Starting from 2024, maritime transport emissions will also be included under the ETS. The Market Stability Reserve (MSR), introduced in 2019, addresses the surplus of allowances that has accumulated in the market, helping to make the EU ETS more resilient to shocks by adjusting the supply of allowances to be auctioned. Recent developments include the Fit for 55 Package, which consists of legislative proposals to reform the EU ETS to align it with the EU's new climate target of reducing GHG emissions by at least 55% by 2030. This includes expanding the scope of the ETS, increasing the annual reduction in the cap, and strengthening the MSR.

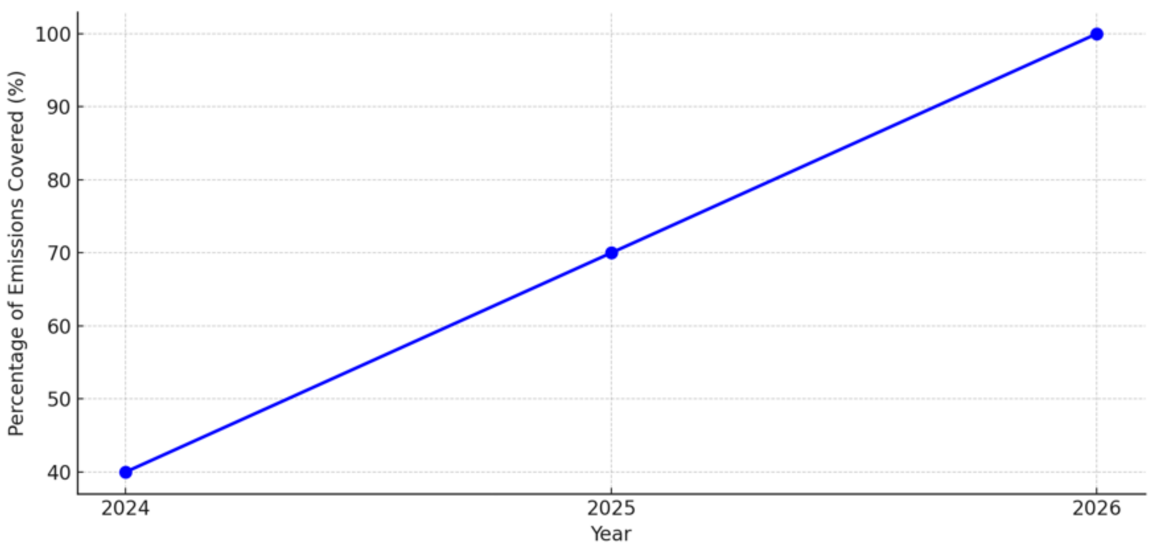
While the EU ETS has been successful in reducing emissions, it has faced criticism over issues like the initial over-allocation of allowances, which led to a low carbon price and reduced the incentive to invest in low-carbon technologies. Reforms in recent years have sought to address these issues.

4.2.4.2. EU ETS in the maritime sector

The inclusion of the maritime sector in the European Union Emissions Trading System (EU ETS) is a significant step toward reducing greenhouse gas emissions from shipping, a sector that has traditionally been outside the scope of many environmental regulations. The maritime sector will be phased into the EU ETS starting from 2024. The ETS will apply to CO_2 emissions from large ships over 5,000 gross tonnage, which are responsible for about 90% of CO_2 emissions from the sector. This includes emissions from intra-EU voyages, as well as 50% of emissions from voyages between an EU port and a non-EU port, and emissions occurring at berth in EU ports (Reducing emissions from the shipping sector - European Commission, n.d.).

The EU ETS has started by covering 40% of the verified emissions from applicable voyages in 2024. By 2025, coverage will increase to 70% of verified emissions. From 2026 and beyond, full coverage of 100% verified emissions will be required (see Figure 4.1).

Figure 4.1: Phased Implementation of EU ETS coverage in the Maritime Sector



Shipping companies must obtain and surrender emission allowances equivalent to their CO_2 emissions. These allowances can be bought at auction, allocated, or purchased on the secondary market. Ships must monitor and report their CO_2 emissions, fuel consumption, and other relevant data annually. This data is verified by an independent third party before it is submitted to the European Commission. After the end of each year, ship operators are required to surrender allowances equal to the verified emissions. Failure to surrender sufficient allowances can result in penalties.

A portion of the allowances may be allocated for free to address concerns about carbon leakage and the competitiveness of the EU maritime sector. However, most allowances will be auctioned, reflecting the "polluter pays" principle. Shipping companies will need to purchase most of their emission allowances, European Union Allowances (EUA)[2], through auctions, which creates a financial incentive to reduce emissions and adopt more efficient technologies. Inclusion in the EU ETS will likely increase operating costs for shipping companies, as they will need to purchase allowances to cover their emissions. This could encourage the adoption of energy efficiency measures, alternative fuels, and other strategies to reduce emissions and, consequently, the need for allowances. The cost of carbon under the ETS could influence shipping routes, the choice of fuel, and overall operational strategies. For example, operators may prefer shorter routes or slower steaming (reducing speed to save fuel) to minimize emissions. With the introduction of the EU ETS to the shipping industry, Europe's largest shipping lines may have to incur a total of 516 million euros in costs to buy emission allowances by September 2025 according to Bloomberg New Energy Finance which forecasts that the carbon price will rise to €160 per ton by 2030 from the current € 80 per ton. The same source of information analyzed that the top 10 shipping emitters in Europe own

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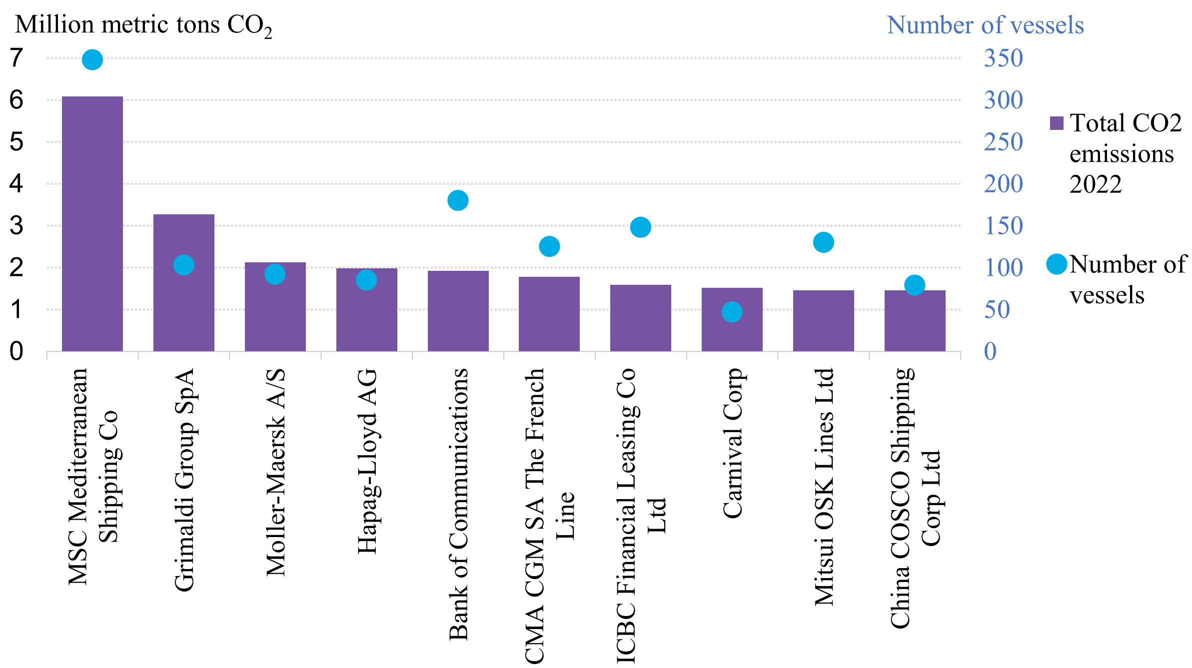
[2] EUAs are permits that allow the holder to emit one ton of carbon dioxide (CO2) or the equivalent amount of another greenhouse gas. They are the currency of the EU ETS. Companies receive or purchase EUAs, which they must hold in a quantity equal to their emissions. At the end of each year, companies must surrender enough allowances to cover their emissions or face significant fines. EUAs can be traded between companies. If a company reduces its emissions, it can sell its excess allowances to another company that needs them. This creates a financial incentive for companies to reduce their emissions.

1,258 ships and their voyages emitted 23 million tons of carbon dioxide in 2022, accounting for 18% of Europe's total shipping emissions (see Figure 4.2).

Figure 4.2: Top 10 emitters by beneficial owner



Source: Bloomberg New Energy Finance, European Maritime Safety Agency (EMSA), Bloomberg terminal

The EU ETS is expected to drive innovation in the maritime sector, encouraging investment in cleaner technologies such as wind-assisted propulsion, LNG (liquefied natural gas), hydrogen, or ammonia as alternative fuels, and energy-efficient ship designs.

The EU's Monitoring, Reporting, and Verification (MRV) regulation, which has been in place since 2018, requires ships to monitor and report their CO_2 emissions from voyages to, from, and within the EU. This data provides the basis for the ETS compliance process. The EU is also promoting the development of alternative fuels and the necessary infrastructure, such as refueling stations for LNG and hydrogen, to support the maritime sector's transition to low-carbon operations. One challenge is the potential for conflict with international regulations, particularly those developed by the International Maritime Organization (IMO). While the EU ETS applies regionally, the IMO is working on global measures to reduce maritime emissions. Coordination between the two will be crucial to avoid regulatory overlap and ensure global competitiveness. There are concerns that the EU ETS could increase shipping costs for goods entering and leaving the EU, potentially affecting global trade patterns and the competitiveness of EU ports.

4.2.4.3. FuelEU Maritime

The FuelEU Maritime initiative is a key component of the European Union's strategy to reduce greenhouse gas (GHG) emissions from the maritime sector, aligning with the broader goals of the European Green Deal and the Fit for 55 package. The initiative is designed to promote the use of sustainable alternative fuels in shipping, thereby helping the sector transition to cleaner energy sources and significantly reducing its carbon footprint.

The primary goal is to reduce the carbon intensity of the energy used by ships, leading to a substantial decrease in overall emissions from the maritime sector. FuelEU Maritime seeks to encourage the adoption of alternative fuels that have a lower environmental impact, such as biofuels, hydrogen, ammonia, and electricity.

The initiative applies to ships above 5,000 gross tonnage that call at EU ports, regardless of the flag they fly. This includes both EU and non-EU-flagged vessels operating within EU waters. It covers all voyages within the EU, as well as 50% of voyages that begin or end outside the EU. The initiative sets out a series of GHG intensity reduction targets for ships, beginning in 2025 with a 2% GHG reduction and becoming progressively stricter over the years, reaching the GHG reduction of 80% of the energy used in 2050 compared to a 2020 baseline. The targets cover not only CO_2 but also methane and nitrous oxide emissions over the full lifecycle of the fuels used onboard, on a Well-to-Wake (WtW) basis (Decarbonising maritime transport – FuelEU Maritime - European Commission, n.d.). The EU's starting GHG fuel intensity was set at 91.16g CO_2/MJ which is based on EU analysis of the 2020 EU MRV data (see Table 4.2).

Table 4.2: GHG Intensity Threshold

Year	2020	2025	2030	2035	2040	2045	2050
Reduction	-	-2%	-6%	-14.5%	-31%	-62%	-80%
GHG intensity (g CO2/MJ)	91.16	89.34	85.69	77.97	62.90	34.64	18.23

Source: *ABS* (FuelEU Maritime, n.d.)

GHG intensity is calculated as follows Equation 4.1, representing the total GHG emissions per unit of energy, adjusted by a factor for wind assistance (Office of the European Union, n.d.).

Equation 4.1:

$$\text{GHG intensity} = \frac{\sum \mathbf{CO2}}{\mathbf{MJ}} = f_{\text{wind}} \text{ x } (WT + TW)$$

Where,

WT is a traditional propulsion contribution, calculated by summing the products of fuel mass, CO_2 emission factors, and energy content values across different fuel types and energy sources.

TW is wind-assisted propulsion contribution, adjusted for efficiency losses due to slip (the difference between actual and theoretical ship speed).

$ʄ_{wind}$ is a reward factor for wind-assisted propulsion, incentivizing the use of renewable methods.

The model underscores the potential for significant reductions in GHG emissions through enhanced efficiency and renewable energy integration in maritime operations and suggests a policy or technological incentive to reduce GHG emissions by incorporating renewable energy sources evidenced by the integration of $ʄ_{wind}$.

If wind-assisted propulsion is installed on board, a reward factor can be applied, determined as follows:

Reward factor for wind-assisted propulsion ($ʄ_{wind}$)	$\frac{Power\_wind}{Power\_Propulsion}$
0.99	0.05
0.97	0.1
0.95	≥ 0.15

This means GHG intensity can be decreased by 5% if the wind contributes more than 15% of the propulsion power.

According to the shipbroker SSY, the penalty for VLSFO is expected to reach approximately $30 per ton and is projected to rise to $1,000 per ton by the year 2050 for international voyages. This serves as an incentive for shipowners who are early adopters, capable of capitalizing on the greater surplus potential of compliance with zero or low-carbon fuels in the upcoming decade ('FuelEU Maritime_SSY', n.d.). Ship operators are free to choose the technology or fuel they use to meet the targets, providing flexibility in how they achieve compliance. This can include the use of low-carbon or zero-carbon fuels, energy efficiency improvements, or innovative propulsion technologies.

Ships must monitor and report their fuel use and emissions. The data collected will be used to assess compliance with the carbon intensity targets. Ships that fail to meet the required targets may face penalties, which could include financial fines or restrictions on access to EU ports.

The FuelEU Maritime initiative complements the inclusion of maritime emissions in the EU Emissions Trading System (ETS) by providing an additional regulatory mechanism focused specifically on fuel use. The initiative is aligned with the Alternative Fuels Infrastructure Directive (AFID), which supports the development of the necessary infrastructure for alternative fuels in EU ports, ensuring that ships can access the fuels needed to meet their carbon intensity targets.

The initiative is expected to drive significant reductions in emissions from the maritime sector, contributing to the EU's overall climate goals. By setting clear regulatory targets, FuelEU Maritime is likely to accelerate the development and deployment of sustainable fuels and technologies in the shipping industry. The success of the initiative will depend on the availability and commercial viability of alternative fuels and technologies. A study demonstrates that while fossil fuels such as LPG can satisfy initial regulatory requirements, the shift towards sustainable energy sources is crucial to accomplish more substantial reductions in emissions by the year 2050. This highlights the importance of incorporating renewable e-fuels after the year 2040 (Christodoulou and Cullinane, 2022).

4.3. Literature review

Maritime transport is a critical sector for global trade and the economy, particularly for island communities that depend on it for connectivity and the transportation of goods and passengers. However, the sector is also a significant contributor to atmospheric pollutants such as PM, SOx, and NOx, which adversely affect air quality and public health. The EU has recognized the need to decarbonize maritime shipping as part of its broader climate policy, aiming for carbon neutrality by 2050. This is reflected in several initiatives, one of which is the FuelEU Maritime regulation, which emerged from a policy window opened by the Paris Agreement and the European Green Deal. The regulation has faced challenges, with different stakeholders advocating for varying approaches to emission reductions. The European Commission proposed a technology-neutral, goal-based approach, while NGOs like Transport & Environment pushed for technology-specific measures to achieve zero-carbon fuels. Additionally, the shipping industry, responsible for about 3% of global anthropogenic CO_2 emissions (Eide *et al.*, 2011), is under international pressure to cut emissions by 40% by 2030 and 70% by 2050. Climate change poses further risks to maritime transport, particularly for islands vulnerable to rising sea levels and extreme weather events, which could disrupt operations. Adopting a low-emission pathway is crucial to mitigate these risks and maintain operational resilience. Overall, the EU's climate policy for maritime transport involves a complex interplay of regulatory measures, stakeholder interests, and adaptation strategies to ensure both environmental sustainability and economic viability.

Historical pathway to decarbonization in shipping

The historical pathway to decarbonization in shipping has evolved significantly over the years, driven by the International Maritime Organization's (IMO) ambitious carbon reduction targets and the growing awareness of the substantial environmental impact of maritime transport. Initially, the primary focus was on improving fuel efficiency and reducing emissions through a variety of operational measures. These included slow steaming (Cariou, 2011), which involves operating ships at lower speeds to save fuel, and the utilization of shore power, which allows ships to turn off their engines and plug into the local electric grid while docked (Zhao *et al.*, 2023). These early efforts marked the beginning of a broader movement towards cleaner maritime operations.

As the industry matured and technological advancements were made, the focus gradually shifted towards the adoption of alternative fuels. These fuels, including LNG (liquefied natural gas), methanol, ammonia, and hydrogen, offer promising opportunities for reducing emissions. However, they also present a range of challenges, such as technical uncertainties related to their use, financial constraints due to higher costs, and the need for extensive infrastructure development to support widespread adoption (Lee *et al.*, 2024). The production of green fuels, such as green hydrogen, green ammonia, and green methanol, from renewable energy sources has been identified as a crucial step in this transition. Despite their potential, the high production costs and the need for significant technological advancements remain major hurdles that the industry must overcome (Shi *et al.*, 2023).

In the near term, standalone decarbonization technologies can achieve up to 20% emissions reduction. However, to meet the more stringent IMO 2050 targets, a combination of solutions will be essential. This includes not only the adoption of alternative fuels but also improvements in energy efficiency, the development of new technologies, and changes in operational practices (Farrukh *et al.*, 2023). Collaborative governance, which involves cooperation between various stakeholders, innovative niche strategies, and a holistic approach that considers the entire lifecycle of maritime operations, is necessary to fully leverage the current window of opportunity for transitioning to sustainable fuel options (Lee *et al.*, 2024). Additionally, participatory approaches that involve input and collaboration from a wide range of stakeholders, along with robust policy development, are crucial. Initiatives like the 'Zero-Net Emissions, Resilient Maritime Hubs in Cyprus' project exemplify the importance of regulatory support, education, and technological development. These initiatives highlight how coordinated efforts can lead to significant progress in achieving decarbonization goals (Nisiforou *et al.*, 2022). Overall, the pathway to decarbonization in shipping is multifaceted, requiring coordinated efforts across technological, social, industrial, and cultural dimensions to achieve a sustainable future. The journey towards a greener maritime industry is complex, but with concerted efforts and innovative approaches, it is an achievable goal.

Arguments about IMO's greenhouse gas emissions regulations

The effectiveness of the IMO GHG environmental regulations presents both advantages and challenges. On the positive side, the 2023 IMO Strategy on the Reduction of GHG Emissions from Ships sets ambitious decarbonization targets, aiming for a 51.5–62.5% reduction in emission intensity by 2030, which is significantly higher than the previously recommended 40% target. This strategy emphasizes the need for substantial penetration of alternative fuels, such as sustainable biodiesel and LNG, and the potential roles of e-methanol and e-ammonia in the long term, thereby providing a clear pathway for the shipping sector to transition towards zero GHG emissions (Zhang *et al.*, 2024). This comprehensive approach not only encourages the adoption of cleaner technologies but also promotes innovation within the maritime industry to meet these stringent goals. Additionally, the IMO's technical and operational measures, which are mandatory for all ships regardless of their flag, demonstrate a strong commitment to global "green shipping" (Zhang, 2016). These measures include energy efficiency design requirements and operational practices that aim to minimize the environmental impact of shipping activities.

However, there are notable challenges. The principle of Common but Differentiated Responsibility (CBDR) under the UNFCCC conflicts with the IMO's non-discrimination principle, creating legal and practical difficulties in the implementation of these regulations (Zhang, 2016) (Lee and Doo, 2011). This conflict complicates the enforcement of uniform standards across countries with varying levels of economic development and capacity to invest in new technologies. Furthermore, the lack of concrete reduction goals and implementation plans in earlier frameworks, such as the UNFCCC, has historically undermined the effectiveness of global efforts to curb GHG emissions from ships (Doo and Lee, 2013). These earlier shortcomings highlight the importance of clear, actionable targets and robust monitoring mechanisms. The ongoing development of market-based measures within the IMO is also hindered by deep divisions among member states, making it difficult to reach a consensus and implement these measures effectively (Zhang, 2016). Disagreements over the design and fairness of such measures can stall progress and delay the adoption of necessary policies.

Therefore, while the IMO's GHG regulations represent a significant step forward in addressing maritime emissions, their effectiveness is contingent upon resolving these legal conflicts and achieving broader international cooperation and agreement. Continued dialogue and collaboration among member states, along with supportive policies and financial mechanisms, will be crucial in overcoming these hurdles and ensuring that the shipping industry can meet its decarbonization targets.

New regulations for decarbonization in shipping

One of the notable regulations in the maritime sector that has recently been introduced is the European Union Emissions Trading System (EU ETS). The inclusion of the maritime sector in the EU ETS presents several pros and cons. On the positive side, the EU ETS incentivizes investment in green technologies, which can significantly reduce the carbon footprint of the shipping industry (Christodoulou and Cullinane, 2024). Creating financial incentives encourages the abandonment of traditional, more polluting fuels, pushing the industry towards alternative, more sustainable options like methanol, which has been shown to produce the least CO_2 emissions among various fuels (Sun *et al.*, 2024). Additionally, the EU ETS can act as a powerful catalyst for the development and rapid adoption of innovative technologies. For example, advanced sail designs and other cutting-edge solutions could further enhance the environmental benefits by optimizing fuel efficiency and reducing emissions (Oxford Analytica 2023).

However, there are notable drawbacks that warrant careful consideration. The enforcement of the EU ETS may lead to evasive port calls, where shipping operators might prefer non-EEA transshipment hubs to avoid the costs associated with EU Allowances (EUAs). This could potentially increase overall carbon emissions and cause carbon leakage, undermining the system's environmental objectives (Lagouvardou and Psaraftis, 2022). Such evasive actions could also result in significant economic losses for EEA transshipment hubs and diminish the effectiveness of the EU ETS itself. Furthermore, the economic implications of high taxation and the risk of voyage evasion could undermine the system's overall effectiveness and lead to unintended consequences (KIRVAL and ÇALIŞKAN, 2022). Therefore, there is a view that a carbon tax is simpler and more cost-effective than an ETS for the shipping sector, given ETS requires complex administrative and monitoring frameworks, which could burden the industry (Garcia, Foerster and Lin, 2021). In relation to the power industry that has already implemented an Emissions Trading Scheme, the additional expenses could potentially be transferred to the consumer as unforeseen consequences (Laing *et al.*, 2014).

The relationship between sailing speed and CO_2 emissions, which follows a U-shaped curve, further complicates the situation. It indicates that speed reduction is only effective beyond a certain threshold, adding complexity to cost and carbon control strategies under the EU ETS (Sun *et al.*, 2024). Despite these challenges, the EU ETS remains a crucial step towards decarbonizing the shipping industry. Its success will depend on careful management and strategic adjustments. For instance, the development of a global ETS by the International Maritime Organization (IMO) could ensure a level playing field and prevent carbon leakage, thereby enhancing the overall efficacy of the system (Christodoulou and Cullinane, 2024) (KIRVAL and ÇALIŞKAN, 2022).

The other remarkable decarbonization regulation in shipping is the FuelEU Maritime initiative, which is an integral part of the EU 'Fit for 55' package and is designed to reduce CO_2 emissions from shipping by promoting the use of cleaner marine fuels. This initiative holds great promise as it aims to significantly lower the maritime sector's carbon footprint, thereby contributing to the broader goal of a climate-neutral Europe by the year 2050. One of the most notable advantages of this initiative is its potential to bring about considerable reductions in greenhouse gas emissions, which is crucial for the environmental sustainability of the shipping industry.

To achieve these ambitious targets, the initiative utilizes the EU's Monitoring, Reporting, Verification (MRV) database, a comprehensive system that effectively tracks fuel consumption and CO_2 emissions. This database provides valuable data, enabling stakeholders and policymakers to make well-informed decisions based on accurate and up-to-date information. By leveraging this tool, the initiative can ensure greater transparency and accountability within the maritime sector (Christodoulou and Cullinane, 2022).

Furthermore, the FuelEU Maritime initiative encourages the adoption of alternative fuels, such as polyoxymethylene dimethyl ethers (PODE). These alternative fuels have demonstrated impressive results in reducing particulate matter (PM) and CO_2 emissions by up to 86.8% and 56.3%, respectively. Importantly, this reduction is achieved without compromising the power output of marine diesel engines, making PODE a viable option for cleaner shipping. However, despite these significant benefits, there are also some drawbacks to consider. The increased effective fuel consumption associated with PODE, which can rise by up to 132%, may result in higher operational costs for shipping companies. This presents an economic challenge that must be addressed to ensure the widespread adoption of alternative fuels (Changxiong *et al.*, 2023). Additionally, while the initiative aims to reduce environmental pollution, the transition to new fuel types may pose technical challenges. Retrofitting existing vessels and upgrading infrastructure will require substantial investments, which could be a barrier for some stakeholders.

Moreover, the development of new marine fuel oils, such as those comprising normal and reduced pressure slag oil, wax oil, diesel oil, and oil slurry, further underscores the complexity of meeting both national and international standards. These developments highlight the need for a balanced approach that addresses environmental concerns while ensuring compliance with regulatory requirements.

Principal-agent problems in decarbonization for the shipping industry

The principal-agent problem in shipping is a multifaceted issue that arises due to misaligned incentives and information asymmetries between different stakeholders, such as policymakers, shipping companies, and port authorities. This problem is evident in various aspects of the shipping industry, including the transition to alternative fuels, digital transformation, and carbon emission reduction. In reference to the study (Agnolucci, Smith and Rehmatulla, 2014) regarding how financial savings from energy-efficient ships are distributed between ship owners and those hiring the ships, it explores the principal-agent problem in the time charter market, similar to the tenant-landlord issue in real estate. The researchers ascertain that, on average, merely 40% of the financial benefits resulting from energy efficiency are realized by ship owners, which adversely impacts their investment motivation and, in turn, shapes the nature of emission reduction strategies implemented at both global and regional scales. A comparable conclusion was drawn from an additional study (Adland *et al.*, 2017) that examines the principal-agent dilemma within the time charter market, concentrating on the extent to which energy-efficient dry bulk vessels are awarded a freight rate premium that accurately reflects their fuel savings. The results reveal that merely a small fraction (14% for Panamax and 27% for Capesize) of fuel savings is incorporated into elevated time charter rates, a figure that is considerably lower than prior estimations and diminishes during periods of high demand when fuel-inefficient ships may secure higher rates. The authors caution that a deficiency in information and the presence of asymmetric information regarding actual operational performance could lead to a market failure, wherein energy efficiency is not adequately priced.

A recent study (Dirzka and Acciaro, 2021) exploring principal-agent problems in decarbonizing container shipping reached a similar conclusion that chartering under time-charter contracts leads to 8% higher carbon emissions compared to owned vessels, highlighting the charter market does not adequately reward energy-efficient vessels. The authors also study carbon pricing's impact on charter operations, revealing significant potential financial consequences for charterers, varying with price levels. Simulations indicate that carbon pricing could result in substantial annual costs for chartered vessels, potentially swaying decisions between chartering and operating owned vessels. The research emphasizes the importance of including emissions data in charter contracts to enhance transparency and encourage the adoption of low-carbon solutions in the shipping industry.

Changes in the ship financing environment due to GHG regulations

The ship financing industry is undergoing significant changes due to the implementation of greenhouse gas (GHG) regulations, driven by the urgent need to mitigate climate change impacts. The International Maritime Organization (IMO) has introduced stringent decarbonization regulations, which are set to be fully enforced from 2023, compelling maritime companies to adopt greener practices and more sustainable operational methods. These regulations necessitate substantial capital investments in alternative fuels, green energy, and fleet upgrades, posing a significant financial challenge for shipping companies that traditionally operate on narrow margins and have limited resources for such large-scale transformations (Pangalos, 2023).

As a result, the financing landscape is evolving to accommodate these new requirements, with a growing emphasis on green financing schemes and the role of capital providers in reducing the industry's environmental footprint (Song, n.d.). Regulatory bodies and private companies are increasingly promoting initiatives to support the transition to sustainable shipping through various financial instruments. These instruments include tightened Energy Efficiency Design Index (EEDI) limits, which require new ships to be more energy-efficient, port discounts for greener ships, Emissions Trading Systems that create a market for carbon credits, and potential carbon taxes that would impose additional costs on carbon-intensive operations (Koopman, 2018).

The European Union, in particular, has taken a proactive stance, implementing regional measures to complement the IMO's efforts. These measures not only influence regional shipping practices but also have a global impact, encouraging other regions to adopt similar standards and practices (Piccolo, n.d.).

The financial sector is also adapting by developing frameworks to assess and mitigate carbon risks. These frameworks include evaluating the impact of direct and indirect regulations on shipowners' operations and economic value. Financial institutions are increasingly incorporating Environmental, Social, and Governance (ESG) factors into their investment criteria, recognizing that these are now critical in attracting investment and ensuring long-term returns (Koopman, 2018).

Consequently, maritime companies are encouraged to adopt a cautious and strategic approach, balancing equity and debt financing, and investing in fuel-efficient technologies. Such investments not only enhance their competitive position in the market but also help mitigate future regulatory risks and ensure compliance with evolving environmental standards (Koopman, 2018; Pangalos, 2023). This comprehensive approach to financing and operations underscores the industry's commitment to sustainability and its role in addressing global climate challenges.

4.4. Implication of GHG regulations on ship financing

4.4.1. Impact on shipowners

Increased compliance costs

Compliance costs are expected to increase as shipowners may need to invest in retrofitting existing vessels with energy-efficient technologies, such as exhaust gas cleaning systems (scrubbers), energy-saving devices, or alternative fuel systems like LNG or hydrogen. New ships will need to comply with stricter design efficiency standards (e.g., the Energy Efficiency Design Index), leading to higher construction costs as shipowners invest in more advanced and greener technologies.

In order to meet carbon intensity targets, shipowners may have to operate vessels at reduced speeds (slow steaming), impacting shipping schedules and logistics. They might also need to invest in software and technology for better route planning to reduce fuel consumption and emissions.

Fuel transition challenges

Transitioning to low-carbon or zero-carbon fuels (such as LNG, ammonia, or methanol) is a significant challenge. These fuels are often more expensive and may require new infrastructure and onboard storage solutions. The global availability of alternative fuels and the required bunkering infrastructure are still developing, which could limit operational flexibility. Higher costs associated with fuel, retrofitting, and compliance may lead to increased operational expenses, impacting profitability. Shipowners with more efficient and greener fleets might gain a competitive advantage in the market, as customers and charterers increasingly prefer environmentally responsible partners.

Access to finance

Financing may become more challenging for shipowners who do not comply with GHG regulations, as financial institutions are increasingly adopting Environmental, Social, and Governance (ESG) criteria.

Regulatory compliance and monitoring

Compliance with regulations such as the IMO's Carbon Intensity Indicator (CII) and the European Union's Emissions Trading System (ETS) requires continuous monitoring and reporting, adding administrative burdens and costs. Non-compliance with GHG regulations can lead to penalties, while incentives may be offered for early adoption of greener technologies.

Shipowners will need to strategically plan the modernization of their fleet to remain compliant with future regulations. This might include phasing out older, less efficient vessels and investing in new, environmentally friendly ships. Collaboration with technology providers, fuel suppliers, and other stakeholders will be crucial to navigating the transition to greener operations.

4.4.2. Impact on financiers

The implementation of regulations on greenhouse gas (GHG) emissions in the maritime industry has a substantial effect on financiers, such as banks, investors, and other financial entities. These regulations change the risk environment and present novel difficulties and prospects for those involved in financing maritime assets.

Increased risk assessment

Financial institutions must now take into account environmental risks when conducting credit and investment evaluations. This involves assessing the environmental impact of shipping companies, including their carbon footprint and adherence to greenhouse gas (GHG) regulations. There is a concern regarding stranded assets risk, where vessels that do not meet the new GHG standards may lose value and liquidity. It is crucial for financiers to effectively manage this risk to mitigate potential financial losses (Li et al., 2024).

Failure to comply with GHG regulations could result in operational disruptions, increased costs, and penalties for shipping companies, thus elevating their credit risk (Koopman, 2018). This scenario may lead to higher default rates and negatively impact the overall financial stability of these businesses.

Shifts in financing criteria

The integration of Environmental, Social, and Governance (ESG) criteria is increasingly crucial in decision-making processes related to financing. Companies that demonstrate robust sustainability practices and adherence to GHG regulations are more likely to attract support from financiers (Handl, 2023).

A rising inclination can be observed towards green financing avenues, such as green loans, bonds, or sustainability-linked loans, which present advantageous conditions for investments in energy-efficient or low-emission vessels. Financiers endorsing the advancement and acceptance of green technologies within the maritime industry may secure a competitive advantage. The need for financing solutions enabling shipowners to comply with GHG regulations via retrofitting, new constructions, or alternative fuel sources is on the rise.

Regulatory and reporting compliance

Financial institutions may be required to adhere to regulations like the Poseidon Principles, which aim to align ship finance portfolios with climate objectives. This necessitates financiers to oversee and disclose the climate effects of their investments in shipping. Financiers are expected to meet stricter reporting standards to prove the alignment of their portfolios with greenhouse gas (GHG) reduction goals. This could heighten the administrative workload and necessitate investments in data collection and reporting systems (Kavussanos & Tsouknidis, 2021).

4.4.3. Decision-making process for the optimal financing solution

Shipowners are evidently in need of funding to adhere to GHG regulations. The challenges imposed by these regulations require a substantial amount of financial resources for compliance. In order to effectively tackle these challenges, financiers must offer optimal financing solutions that meet the specific needs of both shipowners and financiers. This becomes especially critical under the new Basel IV regulations, which bring forth additional complexities and requirements. Through the development of customized financing strategies, financiers can guarantee that shipowners are equipped with the essential resources to fulfill regulatory obligations while also protecting their own financial interests. Decarbonization is regarded as the most pressing challenge in the maritime industry within the framework of GHG regulations. Therefore, it serves as the primary focal point of this study for the upcoming chapters.

4.4.4. Shipowners' perspective

Shipowners have four alternatives to consider, namely (1) acquiring a new eco-friendly vessel that is capable of being propelled by alternative fuels, (2) purchasing a secondhand eco-friendly vessel that is capable of being propelled by alternative fuels (3) procuring European Union Allowances (EUA), and (4) investing in retrofitting an existing vessel. Ordering a new vessel does not provide an immediate solution to addressing decarbonization challenges, as it typically entails a delivery timeline of several years based on shipyard orderbook availability. Furthermore, the acquisition of a secondhand eco-friendly vessel necessitates a distinct economic evaluation when contrasted with obtaining EUA and investing in retrofitting, as it requires a thorough profitability assessment between traditional and eco-friendly vessels. Hence, the analysis in this chapter will concentrate on examining the financial aspects related to the acquisition of EUA compared to the investment in retrofitting existing vessels. In the context of vessel retrofitting, this case analysis supposes an investment in the LNG dual fuel engine, whereas retrofitting with methanol or ammonia dual fuel also presents a feasible alternative where the same methodology may be utilized.

4.4.4.1. Case 1: No financing is required

If the ship owner possesses adequate financial resources to evaluate various solutions without being constrained by the need for financing, the determining factor will be the level of CO_2 reduction achieved per unit of investment. When comparing the accumulated CO_2 savings over the economic lifespan of a retrofit investment to the corresponding EUA amount, one can determine the superior alternative between the two, albeit based on a few underlying assumptions.

Assumptions

- **CAPEX for LNG retrofit:** According to Wartsila, it would cost US$20 million to US$35 million to retrofit a typical large vessel, which includes the cost of converting the engines to dual-fuel capability and installing LNG storage tanks and associated systems.
- **Economic life of LNG retrofit:** This is subject to the remaining economic life of the vessel. In this analysis, 10 years, 15 years, and 20 years are used based on the assumption that the economic life of a new LNG vessel is 25 – 30 years and the retrofit investment is made for older than 5-year-old vessels.
- **Installation period for retrofitting:** The time required to retrofit an existing engine to an LNG dual-fuel engine can vary significantly based on several factors, such as the type and size of the engine, the complexity of the retrofit, the availability of parts and labor, and the specific requirements of the vessel. The extended duration of the retrofit process results in increased financial loss for the ship owner from the vessel's operations. Therefore, it is imperative to account for this opportunity cost as well. In this examination, it is assumed that the actual retrofitting process will require a

duration of 3 months, with the opportunity cost incorporated into the economic life assumption by reducing the economic life by a period of 3 months.

- **Bunker (HSFO) consumption (Conventional, ton/day):** For the dry bulk carriers, it is estimated that handysize bulk carriers (10,000 – 35,000DWT) consume approximately 15-25 tons of high-sulfur fuel oil (HSFO) per day at a speed of 13-14 knots, while the large size bulk carriers such as Capesize bulk carriers (over 150,000 DWT) burns approximately 50-70 tons per day. For the tanker, the daily bunker consumption is estimated from 15 tons (handysize tanker) to over 150 tons (ULCC, ultra large crude carrier), whereas containerships are expected to burn at least 20 tons (feeder ship) up to over 300 tons (ULCV, ultra large container vessel).
- **Bunker (LNG) consumption (LNG dual fuel, ton/day):** To estimate daily LNG consumption, you need to know how much LNG is required to provide the same energy as HSFO. HSFO has an energy content of approximately 40.5 MJ/kg, whereas LNG has an energy content of approximately 50 MJ/kg. For instance, if a vessel consumes 1 ton of HSFO, the energy provided is 40.5 MJ. To provide the same energy, the amount of LNG required is calculated by dividing the energy content of HSFO by that of LNG.

$$\textbf{Equivalent LNG (ton)} = \frac{\mathbf{40.5}\ \boldsymbol{MJ}}{\mathbf{50}\ \boldsymbol{MJ}} = 0.81 \text{ tons of LNG}$$

Thus, for every ton of HSFO, approximately 0.81 tons of LNG is required to provide the same energy. It is noted that the difference in energy content between HSFO and Very Low-Sulfur Fuel Oil (VLSFO) is minimal and is not significant enough to drastically impact fuel efficiency. Therefore, HSFO is used as the proxy of the conventional bunker in this analysis.

- **CO_2 emissions (ton / ton of HSFO):** HSFO typically contains about 85% carbon by weight. The emission factor for CO_2 from burning carbon is approximately 3.67 tons of CO_2 per ton of carbon burned (this factor is derived from the molecular weights of carbon (12) and CO_2 (44), where $44/12 \approx 3.67$). For HSFO CO_2 emissions:

  CO_2 Emissions (tons) = $0.85 \times 3.67 \approx 3.12$ tons of CO_2 per ton of HSFO burned

  In summary, burning one ton of HSFO emits approximately 3.12 tons of CO_2. This is in line with the CO_2 emission factors defined by EU MRV regulations for the EU-ETS.

Type of fuel	Reference	Emission factor (CO_2)
HSFO	ISO8217 Grades RME to RMK	3.114
LSFO	ISO8217 Grades RMA to RMD	3.151
MGO	ISO8217 Grades DMX to DMB	3.206

Source: Annex I of the MRV regulation

- **CO_2 emissions (ton / ton of LNG):** Methane (CH_4), the main component of LNG, has a carbon content of about 75% by mass. The CO_2 emission factor for methane is about 2.75 tons of CO_2 per ton of carbon burned (based on the molecular weights of carbon (16) and CO_2 (44), where $44/16 \approx 2.75$). For LNG CO_2 emissions:

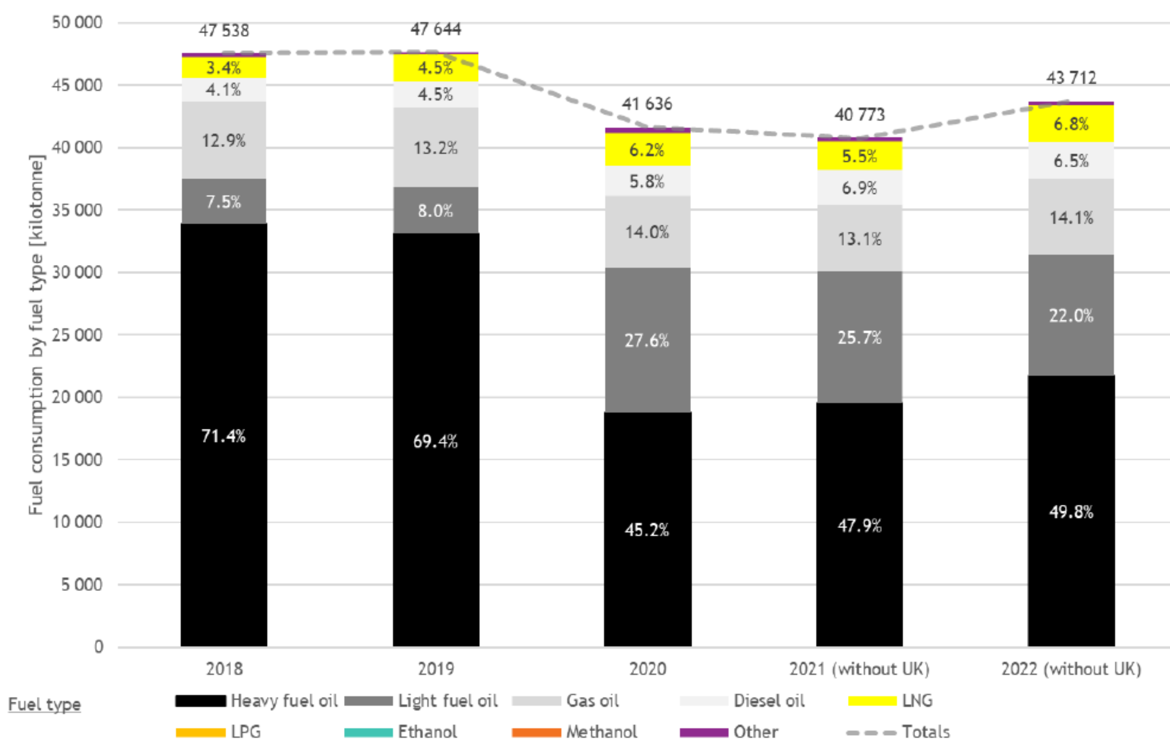
  CO_2 Emissions (tons) = $0.75 \times 2.75 \approx 2.06$ tons of CO_2 per ton of LNG burned

  In conclusion, the consumption of one ton of LNG generates an estimated 2.06 tons of CO_2, which constitutes roughly 66% of the CO_2 emissions produced by HSFO.

- **CO_2 price (EUA):** According to the EUA pricing data from January 2023 through June 2024, the price fluctuated between approximately US$55 and US$103 per ton of CO_2.

According to the 2023 report from the European Commission regarding CO_2 emissions from maritime transport (*Full-length report Accompanying the document Report from the Commission 2023 Report from the European Commission on CO2 Emissions from Maritime Transport*, 2024), it indicates that traditional bunker fuels still represent the largest portion of total fuel consumption (92.4% in 2022), whereas the use of LNG and other alternative fuels remains minimal, despite the fact that LNG consumption by the fleet increased by 82.6% from 2018 to 2022, with its proportion of the total rising from 3.4% in 2018 to 6.8% in 2022 (see Figure 4.3).

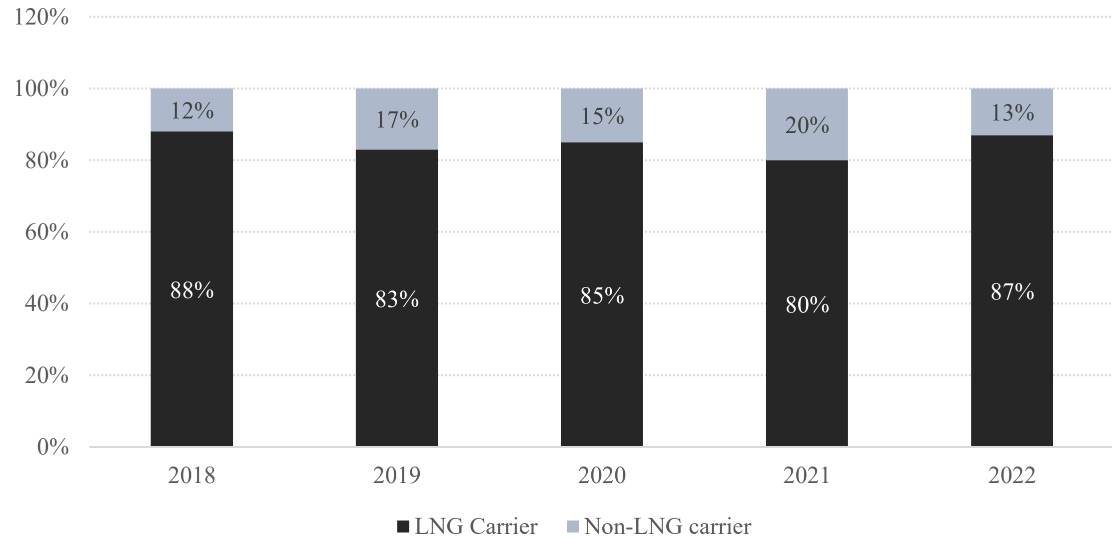
Figure 4.3: Total fleet fuel consumption by fuel type for the period 2018-2022



Source: 2023 report from the European Commission regarding CO_2 emissions from maritime transport

Of the total LNG consumption, 87% of LNG consumption was used by LNG carriers, which means the volume used by non-LNG carriers remains negligible (see Figure 4.4).

Figure 4.4: LNG consumption for the period 2018-2022



Source: 2023 report from the European Commission regarding CO_2 emissions from maritime transport

In reference to the CO_2 emission data published by European Maritime Safety Agency (EMSA) for the vessels that are required to submit the CO_2 information for EU ETS (THETIS-MRV), CO_2 emission is highly correlated with the fuel consumption and operation distance regardless of asset type, which is supported by the regression analysis performed for containerships, dry bulk carriers and tankers based on the data from 2018 to 2023 (see Table 4.3 to Table 4.5).

Table 4.3: Regression analysis for CO_2 consumption for containerships

Year	Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta *(β)*	*T*	*Fit*
2023	Constant	20.0280	23.5856	.	0.85	R^2 = 0.9987
	Fuel	3.1014	.0036	.9967	850.77***	
	Distance	.0025	.0008	.0036	3.14***	
2022	Constant	138.8083	94.9717	.	1.46	R^2 = 0.9842
	Fuel	3.0760	.0126	.9915	243.57***	
	Distance	.0005	.0030	.0007	0.19	

2021	Constant	59.2821	40.7347	.	1.46	R^2 = 0.9977
	Fuel	3.1037	.0049	.9967	623.63***	
	Distance	.0024	.0012	.0030	1.88	
2020	Constant	-129.7111	43.7352	.	-2.97	R^2 = 0.9999
	Fuel	3.0991	.0070	.9859	441.08***	
	Distance	.0113	.0013	.0018	8.22***	
2019	Constant	-11.2730	4.8614	.	-2.32	R^2 = 0.9999
	Fuel	3.1160	.0005	.9980	5,391.31***	
	Distance	.0020	.0005	.0027	14.80***	
2018	Constant	-14.0729	4.3605	.	-3.23	R^2 = 0.9999
	Fuel	3.1158	.0005	.9980	6,336.27***	
	Distance	.0021	.0001	.0026	16.93***	

Note. *** $p < .001$

Table 4.4: Regression analysis for CO_2 consumption for dry bulk carriers

Year	Variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta (β)	*T*	*Fit*
2023	Constant	2.9227	1.1566	.	2.53	R^2 = 0.9998
	Fuel	3.1197	.0014	.9954	2,091.02***	
	Distance	.0015	.0001	.0049	10.42***	
2022	Constant	2.6799	.9600	.	2.79	R^2 = 0.9999
	Fuel	3.1207	.0009	.9949	3,151.88***	
	Distance	.0018	.0001	.0057	18.34***	
2021	Constant	.2339	1.3248	.	0.18	R^2 = 0.9998
	Fuel	3.1158	.0013	.9926	2,325.30***	
	Distance	.0027	.0001	.0084	19.72***	
2020	Constant	-31.1174	8.1599	.	-3.81	R^2 = 0.8797
	Fuel	3.1273	.0086	.9878	360.07***	
	Distance	.0041	.0008	.0136	4.97***	
2019	Constant	-1.8092	10.8022	.	-0.17	R^2 = 0.9908
	Fuel	3.1717	.0103	1.0022	305.02***	
	Distance	-.0025	.0010	-.0079	-2.41**	
2018	Constant	-11.3012	8.5334	.	-1.32	R^2 = 0.9983
	Fuel	3.1939	.0026	1.0032	1,217.08***	
	Distance	-.0047	.0004	-.0081	-9.83***	

Note. ** $p < .005$, *** $p < .001$

Table 4.5: Regression analysis for CO_2 consumption for tankers

Year	Variable	Unstandardized Coefficients		Standardized Coefficients	*T*	*Fit*
		B	SE	Beta (β)		
2023	Constant	1.0158	4.8557	.	0.21	R^2 = 0.9997
	Fuel	3.1271	.0023	.9974	1,318.79***	
	Distance	.0013	.0003	.0028	3.75***	
2022	Constant	-10.2205	3.6146	.	-2.83	R^2 = 0.9998
	Fuel	3.1406	.0017	.9982	1,774.33***	
	Distance	.0009	.0002	.0019	3.50***	
2021	Constant	10.9164	6.9918	.	1.56	R^2 = 0.9994
	Fuel	3.1248	.0032	.9960	966.07***	
	Distance	.0020	.0004	.0044	4.32***	
2020	Constant	34.9705	22.0205	.	1.59	R^2 = 0.8797
	Fuel	3.1127	.0187	.9980	165.64***	
	Distance	.0008	.0021	.0022	0.38	
2019	Constant	-31.0456	32.2571	.	-0.96	R^2 = 0.9889
	Fuel	3.1384	.0120	.9892	260.63***	
	Distance	.0032	.0018	.0066	1.75***	
2018	Constant	10.9540	38.5458	.	0.28	R^2 = 0.9867
	Fuel	3.1642	.0141	.9978	222.87***	
	Distance	-.0029	.0023	-.0056	-1.27	

Note. F (3,133)=324.24, *** $p < .001$, R^2 = 0.8797, Adj R^2 = 0.8770

In addition, the unstandardized coefficient of fuel consumption, which is approximately 3.12 irrespective of the asset type further substantiates that most of the fuels utilized are conventional bunker fuel. The standardized coefficients among the various asset classes evidently demonstrate that fuel consumption is the most significant factor affecting CO2 emissions. This unstandardized coefficient is in line with the CO_2 emission factors defined by EU MRV regulations for the EU-ETS listed as below table.

Type of fuel	Reference	Emission factor (CO_2)
HSFO	ISO8217 Grades RME to RMK	3.114
LSFO	ISO8217 Grades RMA to RMD	3.151
MGO	ISO8217 Grades DMX to DMB	3.206

Source: Annex I of the MRV regulation The high R^2 indicates a potential issue with multicollinearity; therefore, a VIF test is conducted, which confirms the absence of significant multicollinearity, with VIF values ranging from 1.92 to 4.8.

In light of the aforementioned assumptions, the projected CO_2 savings accrued throughout the economic lifespan of the LNG retrofit are anticipated to rise in conjunction with the increase in daily bunker consumption, indicating that larger vessels are likely to reap greater advantages from the LNG retrofit. The correlation can be articulated by the following Equation 4.2 which is also visualized as Figure 4.5.

Equation 4.2:

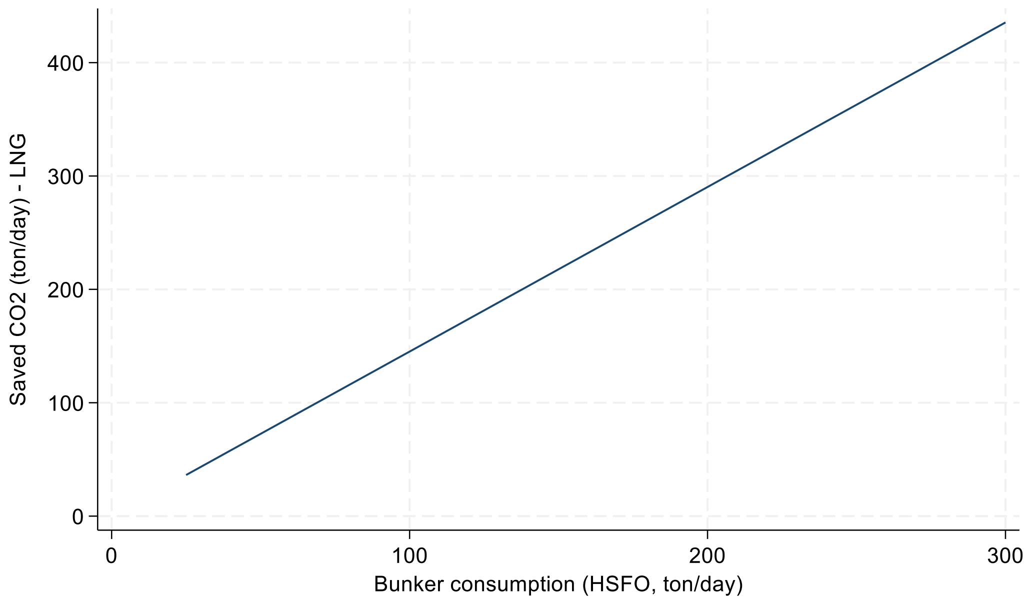
$$Y_{CO2\_savings} = 1.4514 \text{ x } X_{\text{bunker consumption}}$$

Where,

$Y_{CO2\_savings}$ refers to the total volume of daily CO_2 savings measured in tons as a result of utilizing LNG that delivers an equivalent energy output of one ton of HSFO.

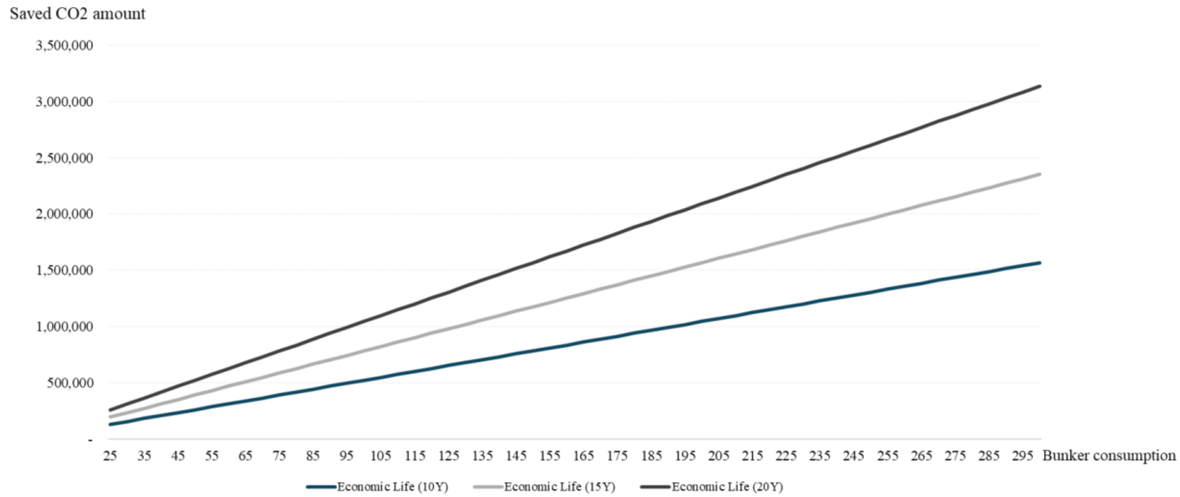
$X_{\text{bunker consumption}}$ refers to the daily bunker consumption (HSFO)

Figure 4.5: Linear relationship between CO_2 savings and bunker consumption



It is imperative to acknowledge that the sooner the retrofit is executed, the more substantial the benefits are anticipated to be (see Figure 4.6). For instance, a vessel retrofitted to utilize LNG has the potential to reduce CO_2 emissions by 26,125 tons annually in comparison to a conventional vessel operating on HSFO. Should the economic lifespan of the LNG retrofit extend to 20 years, the total accumulated savings in CO_2 emissions would amount to 470,254 tons (= 26,125 x 20).

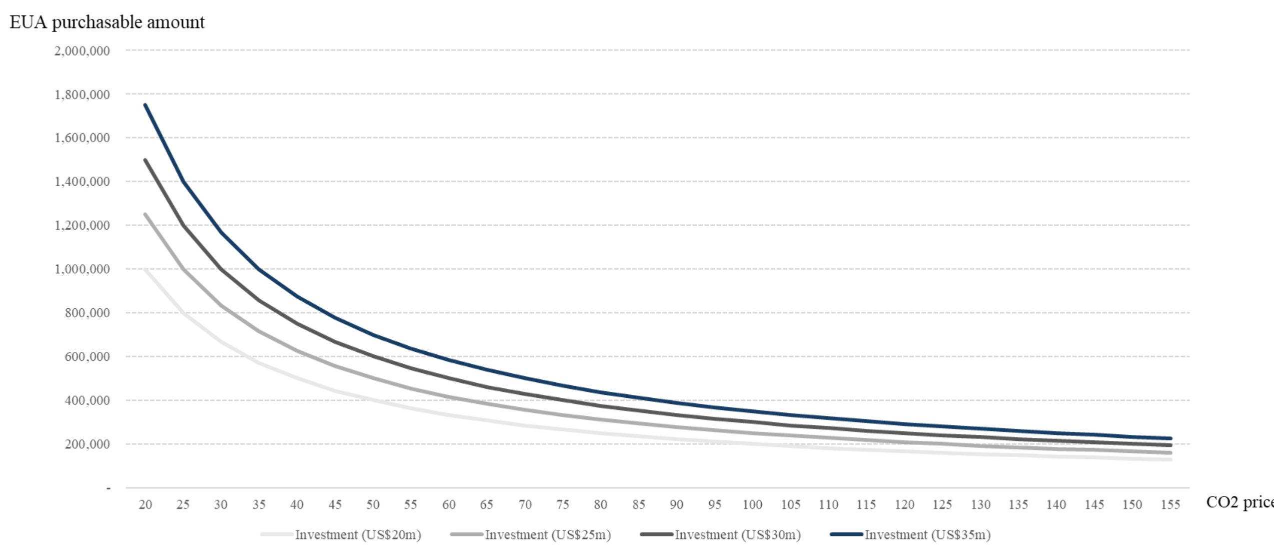
Figure 4.6: CO_2 savings amount as per the varying economic life of LNG retrofitting



Note. CO_2 savings are quantified in tons, while bunker usage is assessed in tons per day.

Separately, the eligible EUA for acquisition is subject to the investment capital and the prevailing CO_2 price at the moment of investment (see Figure 4.7). For instance, it is feasible to acquire 419,463 tons of CO_2 if the investment capital amounts to US$25 million and the CO_2 price is set at $60 per ton.

Figure 4.7: Eligible EUA for acquisition in accordance with the CO_2 price



Note. The EUA purchase amount signifies the cumulative quantity of EUAs, whereas the CO2 price is evaluated in dollars per ton.

In the scenario where a shipowner operates a dry bulk carrier that consumes 50 tons of bunker (HSFO) daily and is contemplating LNG retrofitting, the decision should be predicated upon (1) the anticipated economic lifespan of the LNG retrofit, (2) the current or projected CO_2 pricing, and (3) the required investment capital. Should the economic lifespan of the LNG retrofit extend to 15 years with an investment capital of US$25 million, pursuing LNG retrofitting becomes financially advantageous provided that the CO_2 price exceeds roughly US$65 per ton. Conversely, if the CO_2 price falls below US$65 per ton, acquiring EUAs from the market would be a more prudent course of action (refer to the grey highlighted parts in Table 4.6).

Table 4.6: Example of the decision-making process for the shipowner

	Saved CO_2 amount (ton)		
Bunker consumption (day)	**Economic life (10Y)**	**Economic life (15Y)**	**Economic life (20Y)**
25	130,626	195,939	261,252
30	156,751	235,127	313,502
35	182,876	274,315	365,753
40	209,002	313,502	418,003
45	235,127	352,690	470,254
50	261,252	391,878	522,504
55	287,377	431,066	574,754
60	313,502	470,254	627,005
65	339,628	509,441	679,255
70	365,753	548,629	731,506
75	391,878	587,817	783,756
80	418,003	627,005	836,006
85	444,128	666,193	888,257
90	470,254	705,380	940,507
95	496,379	744,568	992,758
100	522,504	783,756	1,045,008
105	548,629	822,944	1,097,258
110	574,754	862,132	1,149,509
115	600,880	901,319	1,201,759

120	627,005	940,507	1,254,010
125	653,130	979,695	1,306,260
130	679,255	1,018,883	1,358,510
135	705,380	1,058,071	1,410,761
140	731,506	1,097,258	1,463,011
145	757,631	1,136,446	1,515,262
150	783,756	1,175,634	1,567,512

EUA Purchase amount				
CO_2 price (ton)	**Investment (US$20m)**	**Investment (US$25m)**	**Investment (US$30m)**	**Investment (US$35m)**
20	1,000,000	1,250,000	1,500,000	1,750,000
25	800,000	1,000,000	1,200,000	1,400,000
30	666,667	833,333	1,000,000	1,166,667
35	571,429	714,286	857,143	1,000,000
40	500,000	625,000	750,000	875,000
45	444,444	555,556	666,667	777,778
50	400,000	500,000	600,000	700,000
55	363,636	454,545	545,455	636,364
60	333,333	416,667	500,000	583,333
65	307,692	384,615	461,538	538,462
70	285,714	357,143	428,571	500,000
75	266,667	333,333	400,000	466,667
80	250,000	312,500	375,000	437,500
85	235,294	294,118	352,941	411,765
90	222,222	277,778	333,333	388,889
95	210,526	263,158	315,789	368,421
100	200,000	250,000	300,000	350,000
105	190,476	238,095	285,714	333,333
110	181,818	227,273	272,727	318,182
115	173,913	217,391	260,870	304,348
120	166,667	208,333	250,000	291,667
125	160,000	200,000	240,000	280,000
130	153,846	192,308	230,769	269,231
135	148,148	185,185	222,222	259,259
140	142,857	178,571	214,286	250,000
145	137,931	172,414	206,897	241,379

4.4.4.2. Case 2: Financing is required

Should the ship owner necessitate financing for the investment, the determination regarding the investment should be predicated on the return on equity (ROE) methodology, considering that the equity contribution will vary in accordance with the loan-to-value (LTV) ratio of the investment.

Assuming that the LTV of both the retrofit investment and the EUA acquisition remains consistent, the decision-making process hinges exclusively on the evaluation of the total CO_2 savings generated by each investment alternative. For example, if the quantity of CO_2 saved through the retrofit investment exceeds the number of eligible EUAs available for acquisition at an equivalent expenditure, it is rational to opt for the retrofitting investment.

In instances where the LTV of the retrofit investment exceeds that of the EUA acquisition, or conversely, the decision-making process becomes increasingly complex. Should the cumulative CO_2 savings resulting from the retrofit investment exceed the number of eligible EUAs available for acquisition, the retrofit investment is the optimal decision, as it basically means it gets a greater return with less equity contributions. Even when the volume of CO_2 savings is comparable for both investments, the retrofitting investment remains the superior choice for the same rationale.

However, it requires meticulous assessment on an individual basis when the quantity of qualifying EUAs available for acquisition surpasses the aggregate CO_2 reductions resulting from the retrofit investment. This is the juncture at which the ROE methodology becomes essential (see Equation 4.3).

Equation 4.3

$$\frac{The\ aggregate\ CO2\ savings\ (Retrofit)}{Equity\ contribution\ (Retrofit)} - \frac{The\ eligible\ EUAs\ available\ for\ acquisition}{Equity\ contribution\ (EUA)} > 0 \rightarrow \text{Retrofit}$$

$$\frac{The\ aggregate\ CO2\ savings\ (Retrofit)}{Equity\ contribution\ (Retrofit)} - \frac{The\ eligible\ EUAs\ available\ for\ acquisition}{Equity\ contribution\ (EUA)} = 0 \rightarrow \text{Indifferent}$$

$$\frac{The\ aggregate\ CO2\ savings\ (Retrofit)}{Equity\ contribution\ (Retrofit)} - \frac{The\ eligible\ EUAs\ available\ for\ acquisition}{Equity\ contribution\ (EUA)} < 0 \rightarrow \text{EUA}$$

To illustrate, it is presumed that a secured term loan may be extended under the simplified financing terms outlined below, irrespective of the investment alternatives selected by the shipowner.

- LTV: 70%
- Tenor: 5 years
- Repayment profile: 10 years
- Margin: 7% fixed

The other assumptions continue to hold steady in the aforementioned Case 1.

Assuming an investment of US$25 million is allocated toward either retrofitting or acquiring EUAs, the ROE for the retrofit investment escalates as the vessel's size increases (i.e., the daily fuel consumption rises), whereas the ROE for EUA acquisition is inversely related to the market price of CO_2 (see Figure 4.8 and Figure 4.9).

Figure 4.8: ROE for the retrofit investment

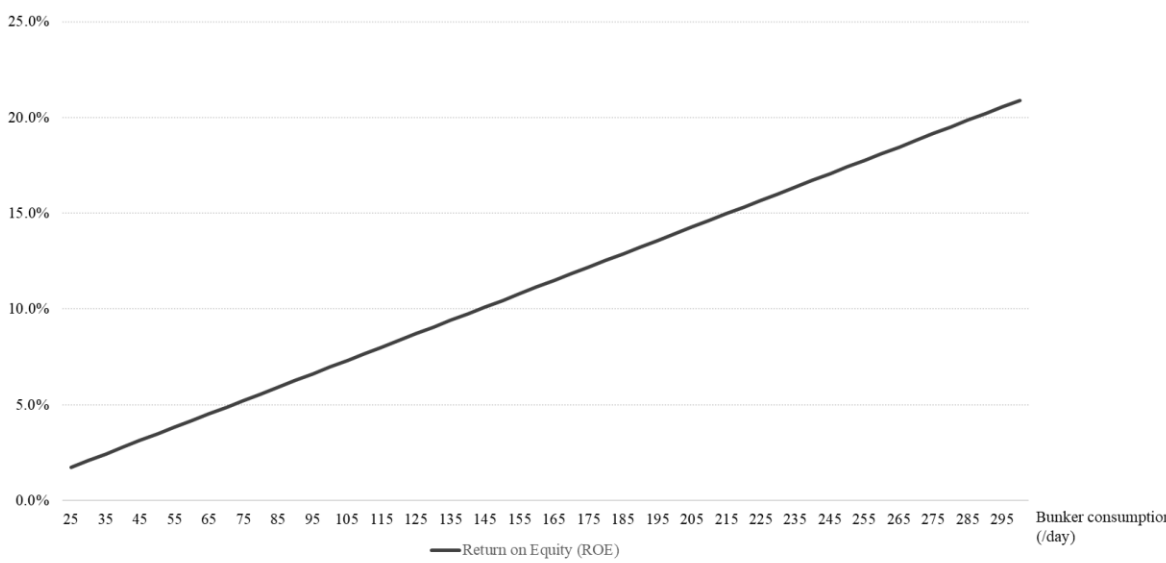
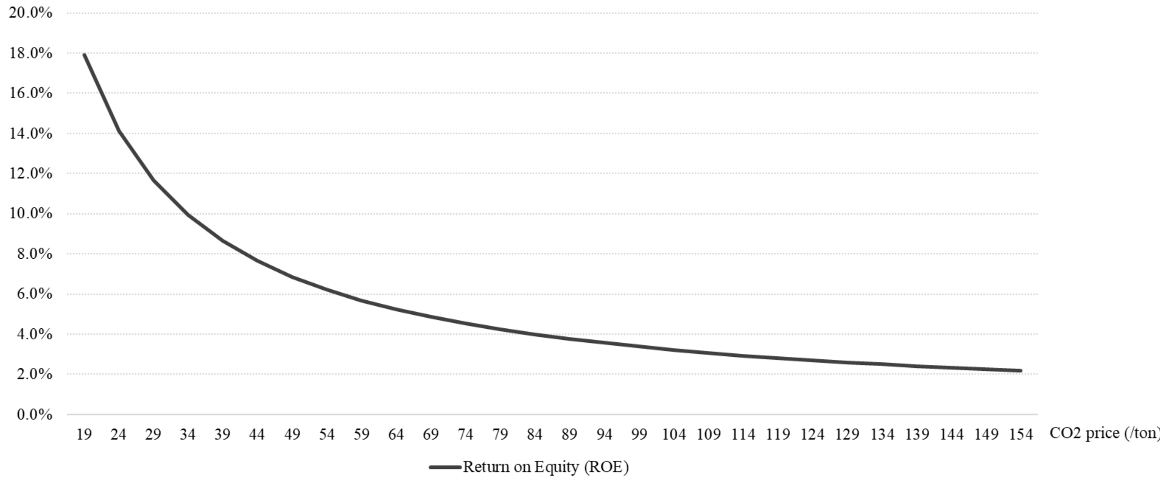


Figure 4.9: ROE for EUA acquisition



Should the identified vessel for the investment in this example be Capesize dry bulk carriers, which utilize between 50 to 70 tons of HSFO per day, the ROE is projected to fall within the range of 3.5% to 4.5%. Consequently, it is prudent to consider the retrofit investment rather than acquiring EUAs in the market if the prevailing market price for CO_2 exceeds US$74 per ton. Conversely, it becomes more advantageous to procure EUAs from the market when the CO_2 price is below USD 74.

4.4.4.3. Comparison with Methanol and Ammonia retrofit

As indicated in the preceding chapters, the methodology for calculating the feasibility of the retrofit of methanol and ammonia is consistent with that of the LNG retrofit case. For example, methanol possesses an energy content of 19.9 MJ/Kg, which is nearly half of that of HSFO, recorded at 40.5 MJ/Kg; moreover, methanol generates 1.38 tons of CO_2 emissions per ton combusted, representing 55.8% of the CO_2 emissions produced by HSFO per ton burned. This can be articulated through the subsequent Equation 4.4 and depicted in Figure 4.10.

Equation 4.4:

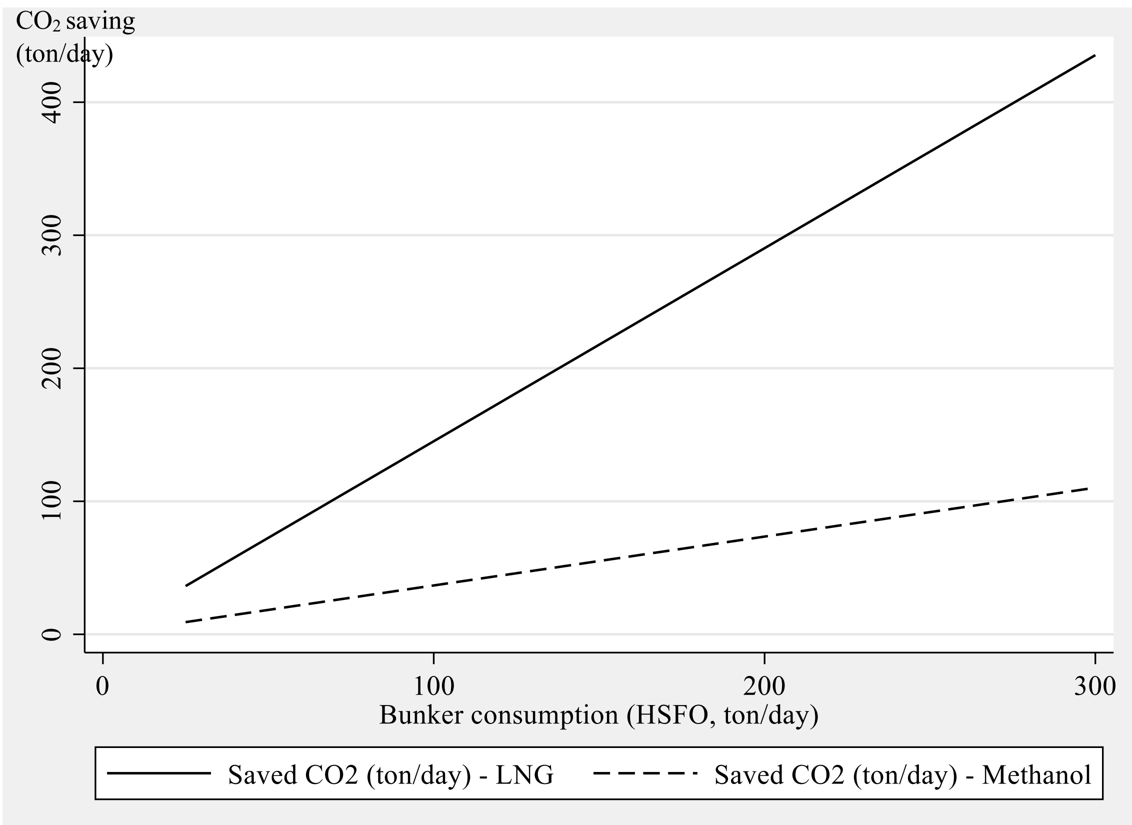
$$Y_{CO2\_savings} = 0.3675 \text{ x } X_{bunker\ consumption}$$

Where,

$Y_{CO2\_savings}$ refers to the total volume of daily CO_2 savings measured in tons as a result of utilizing methanol which delivers an equivalent energy output of one ton of HSFO.

$X_{bunker\ consumption}$ refers to the daily bunker (HSFO) consumption.

Figure 4.10: The CO_2 saving effect comparison between LNG and Methanol



It is unequivocally demonstrated that the LNG retrofit presents a superior solution compared to the methanol retrofit concerning the efficacy of CO_2 savings while disregarding additional challenges such as handling and storage challenges, cost and availability, safety concerns, and other environmental impacts. Currently, methanol is primarily produced from fossil fuels like natural gas and coal, which limits its environmental benefits. While renewable production methods exist, they are not yet widespread or cost-effective. The existing fuel infrastructure is designed for conventional fuels, necessitating substantial investments to adapt or build methanol-specific facilities.

Combustion and engine compatibility issues also arise with methanol use. Internal combustion engines require modifications to run efficiently on methanol, including changes to fuel injection systems and materials to handle its corrosive nature. Methanol's lower vapor pressure can cause cold start problems, particularly in colder climates, adding to operational complexity.

Environmental and safety concerns surround methanol use. It is toxic to humans and animals, presenting significant safety challenges in handling, storage, and transport. While methanol burns cleaner than many conventional fuels, it can still emit harmful compounds, especially if combustion is incomplete. Its carbon footprint depends on the production method, with green methanol offering the potential for reduced emissions.

Fuel availability and distribution present additional challenges. The global supply of methanol is currently limited compared to traditional fuels. Expanding production and distribution networks requires significant investment and time. Transporting methanol necessitates careful handling due to its corrosive and toxic nature, further complicating the development of a reliable and widespread distribution network.

On the contrary, Ammonia does not produce CO_2 during combustion, which represents a significant advantage in mitigating greenhouse gas emissions; however, Ammonia requires considerably greater quantities of fuel by both weight and volume to produce the equivalent energy output as HSFO, given that its energy content stands at 18.6 MJ/Kg. Ammonia also presents several challenges as a potential fuel source. It requires specialized storage conditions, needing to be kept under pressure or at low temperatures to remain liquid. This necessitates robust infrastructure like cryogenic tanks, which are expensive to build and maintain. Ammonia's highly corrosive nature, particularly to materials such as copper and brass, further complicates storage and transport, requiring specialized materials and coatings.

Safety is a significant concern with ammonia. It's toxic and can cause severe respiratory issues if inhaled. Its corrosive properties can damage equipment and infrastructure. Consequently, rigorous safety protocols are necessary for its storage, transport, and handling, adding complexity and cost.

From a technical perspective, ammonia poses challenges in combustion and engine technology. It has a lower flame speed and higher ignition temperature compared to conventional fuels, making it difficult to ignite and burn efficiently. This can result in incomplete combustion, lower engine efficiency, and potentially higher emissions of nitrogen oxides (NOx). Existing engines require significant modifications to use ammonia as fuel, including optimizing ignition systems and combustion chambers, which is both costly and technically challenging. While ammonia doesn't produce CO_2 during combustion, it can lead to high NOx emissions, which are harmful to human health and the environment. These emissions must be controlled using technologies like selective catalytic reduction, adding further complexity and cost.

The production and supply chain for ammonia as a fuel also present obstacles. Currently, most ammonia is produced from natural gas through the energy-intensive Haber-Bosch process, which emits significant amounts of CO_2. Transitioning to green ammonia production using renewable energy sources is necessary for sustainability, but this process is still expensive and not widely available. Moreover, the existing infrastructure for ammonia is primarily designed for its use in fertilizers and chemicals, not as a fuel. Developing the necessary infrastructure for widespread use as a fuel requires substantial investment. Economic viability is another hurdle. The production, storage, and handling of ammonia are currently more expensive than many conventional fuels. For ammonia to become economically competitive, its cost as a fuel needs to decrease significantly. The lack of a mature market for ammonia as a fuel also creates uncertainties regarding long-term supply and pricing. Finally, regulatory and environmental challenges exist. Ammonia is classified as a hazardous material due to its toxicity and corrosiveness, leading to stringent regulations governing its transport, storage, and use. These regulations can create barriers to adoption. While ammonia combustion doesn't produce CO_2, any accidental release into the environment can harm ecosystems, especially aquatic life. The management of high NOx emissions also remains a significant environmental concern.

4.4.5. Financiers' perspective

From the financier's viewpoint, the ideal investment entails generating a higher return while minimizing capital allocation in accordance with Basel regulations, which effectively embodies the concept of ROE. The determination of capital allocation is predicated upon the requisite amount of risk-weighted assets (RWA) that must be reserved; therefore, the objective of minimizing capital allocation equivalently translates to minimizing RWA.

In accordance with the regulatory framework for the capital deficiency of banks set by the Basel Committee, there exist two primary methodologies for calculating Risk-Weighted

Assets (RWA) pertaining to credit risk within the banking book, namely (1) the standardized approach (SA) and (2) the internal ratings-based (IRB) approach. The IRB approach is further categorized into two distinct sub-groups: the foundation IRB (F-IRB) approach and the advanced IRB (A-IRB) approach.

The fundamental distinction between the SA and IRB approaches lies in the fact that the SA mandates that banks utilize a defined risk weighting for the computation of RWA, which is contingent upon the asset class and is typically associated with external ratings. In contrast, the IRB approach permits banks to apply their internal rating systems for assessing credit risk, provided that explicit authorization is obtained for their respective estimations of risk parameters, such as Probability of Default (PD), Loss Given Default (LGD), and Exposure at Default (EAD) (Akkizidis and Kalyvas, 2018). The differentiation between F-IRB and A-IRB resides in the fact that F-IRB relies exclusively on internal estimates of PD, whereas under A-IRB, PD, LGD, and EAD may be estimated using the internal rating model developed by the banks. Shipping finance is categorized as object finance, a sub-asset class within the specialized lending (SL) asset class under the Internal Ratings-Based (IRB) approach as stipulated by the amendment of the Third Basel Capital Accord called Basel III post-crisis regulatory reforms, namely Basel IV. Consequently, the IRB methodology will be employed in this chapter.

In accordance with the IRB approach under Basel IV, RWA for corporate, sovereign, and bank exposures not in default is derived based on the Equation 4.5 formula (CRE31 - IRB approach: risk weight functions)):

Equation 4.5: RWA calculation formula under the IRB approach

$$Correlation = R = 0.12 \cdot \frac{\left(1-e^{-50 \cdot PD}\right)}{\left(1-e^{-50}\right)} + 0.24 \cdot \left(1 - \frac{\left(1-e^{-50 \cdot PD}\right)}{\left(1-e^{-50}\right)}\right)$$

$$Maturity\ adjustment = b = \left[0.11852 - 0.05478 \cdot \ln\left(PD\right)\right]^2$$

$$Capital\ requirement = K = \left[LGD \cdot N\left[\frac{G\left(PD\right)}{\sqrt{\left(1-R\right)}} + \sqrt{\frac{R}{1-R}} \cdot G\left(0.999\right)\right] - PD \cdot LGD\right] \cdot \frac{\left(1+\left(M-2.5\right) \cdot b\right)}{\left(1-1.5 \cdot b\right)}$$

$$RWA = K \cdot 12.5 \cdot EAD$$

Where,

ln denotes the natural logarithm

N(X) denotes the cumulative distribution function for a standard normal random variable.

G(z) denotes the inverse cumulative distribution function for a standard normal random variable.

Assumptions

To streamline the financing model in this chapter, it is assumed that the returns derived from financing for both retrofit investments and EUA acquisitions are equivalent, indicating that the financing alternative with the lower RWA is the most advantageous choice for the financier.

The probability of default (PD) for the borrower is assessed utilizing Standard & Poor's default data (see Table 4.7), predominantly ranging from a BB- external rating to BBB+, considering that the most elevated credit rating assigned to a shipping company to date is BBB+ (A.P. Moller-Maersk A/S).

Table 4.7: One-year average global corporate default rates by rating modifiers (%)

AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B

0	0	0.01	0.02	0.04	0.04	0.06	0.11	0.2	0.22	0.45	0.65	1.12	1.99	5.35

Source: S&P (Default, Transition, and Recovery: 2023 Annual Global Corporate Default And Rating Transition Study | S&P Global Ratings, n.d.)

It is presumed that financial institutions extend 1-year unsecured loans for the procurement of EUA, whereas the retrofitting equipment is offered as security collateral in conjunction with a vessel to the financial institutions so that the borrower would obtain a 5-year secured term loan. Although a study suggests that EUAs should be regarded as a new asset class akin to commodities (Medina and Pardo, 2022), there remains a lack of market consensus regarding the ability of EUAs to serve as physical collateral, similar to a vessel for financing; therefore, this analysis presumes unsecured financing. For the purposes of this chapter, the value of retrofitting equipment is estimated at US$100 million.

4.4.5.1. F-IRB approach

Under the F-IRB methodology, the LGD for unsecured loans is established at 40%, whereas the LGD for secured loans is determined at 25%, with a maturity period consistently set at 2.5 years, independent of the actual loan tenor.

Assuming a loan with a 70% LTV is allocated to a borrower with BBB- credit rating for the retrofit investment while an equivalent amount is designated for the EUA acquisition, the RWA calculation in accordance with F-IRB methodology is presented in the following Table 4.8. The risk-weighted asset (RWA) is computed on the premise that the financing terms, including LTV, are the same for both the financing of EUA acquisition and retrofit investment. However, in practice, there is a possibility that the LTV for EUA acquisition might be lower than that for retrofitting financing, depending on the perceived reliability of EUA as collateral, which does not necessarily reflect a consensus among banks. Furthermore, retrofit equipment cannot be considered as first lien collateral if the financier for the vessel differs from the financier of the retrofit for the vessel. In such instances, subordinate LGD should be utilized instead of secured LGD, which is significantly higher (40%) compared to the secured LGD (25%) because the vessel collateral is usually registered as the first lien collateral.

Nonetheless, the analysis in the research overlooks these variations to examine how RWA shifts as LTV rises while other variables remain constant, which is the primary focus of the estimation.

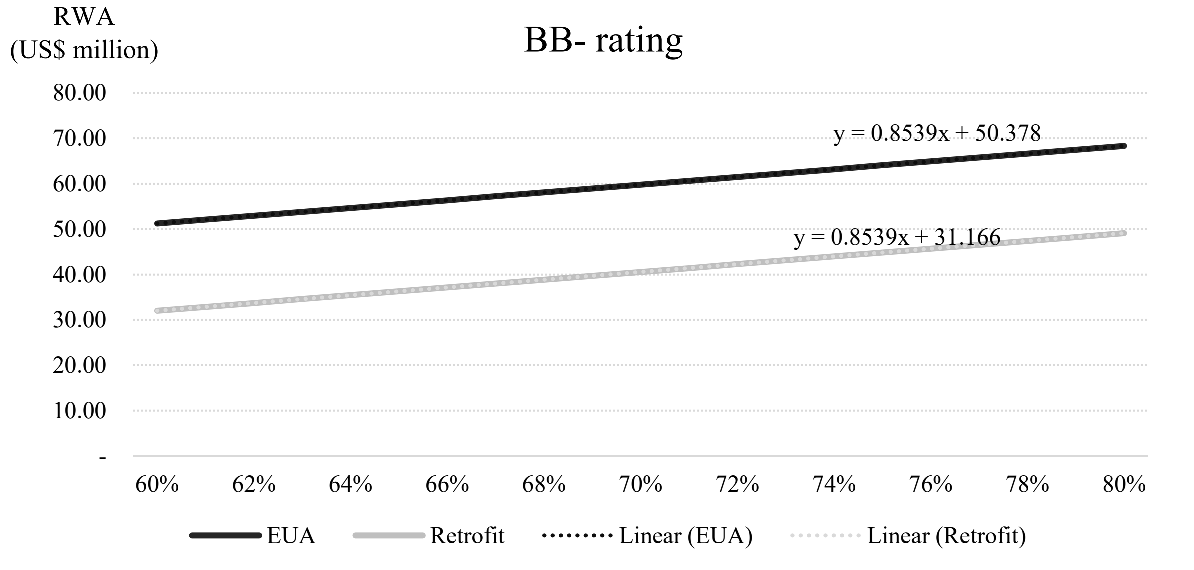
Table 4.8: RWA calculations in accordance with the F-IRB approach

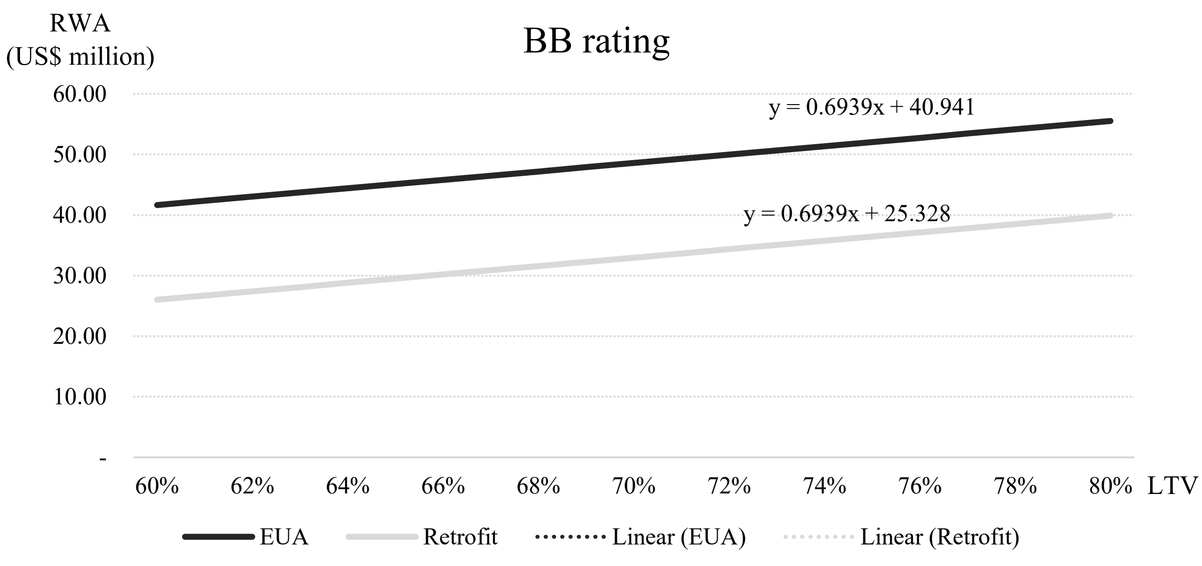
	EUA	**Retrofit**
PD	0.22%	0.22%
LGD	40.0%	27.1%
EAD	70	70
Maturity	2.5	2.5
R	0.228	0.228
b	0.206	0.206
K	0.033	0.022
Risk Weighting	-	-
RWA (US$ million)	**28.76**	**19.51**

Note. R,b, and *K* are calculated based on Equation 4.5.

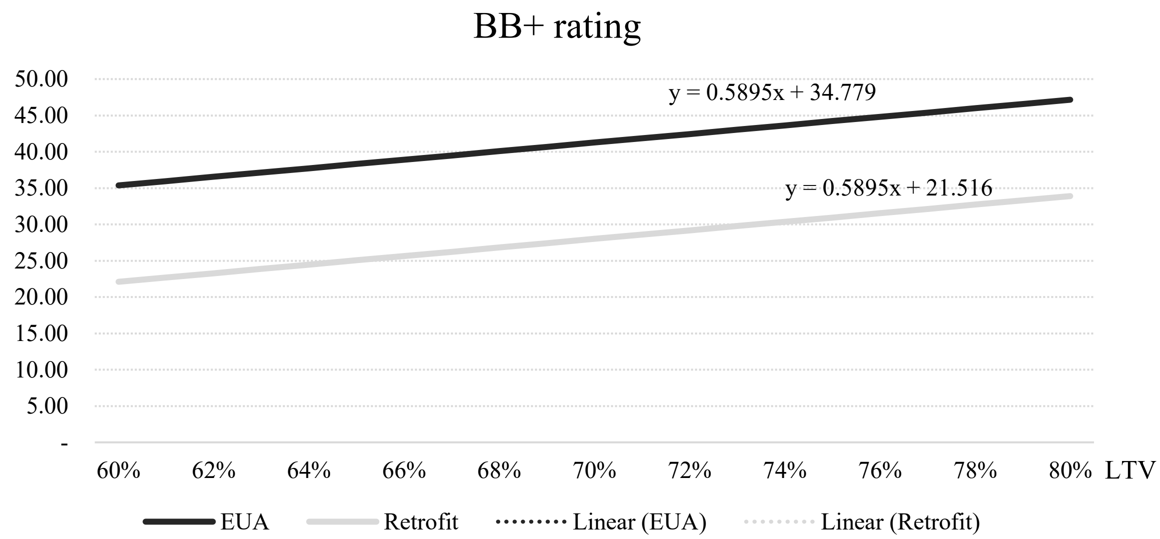
The figures presented below (see Figure 4.11) illustrate the projected RWA associated with the financing of both EUA acquisition and retrofit investments as the LTV ratio escalates in accordance with various credit ratings, which correspond to differing PD.

Figure 4.11: RWA calculation with various LTV and credit ratings

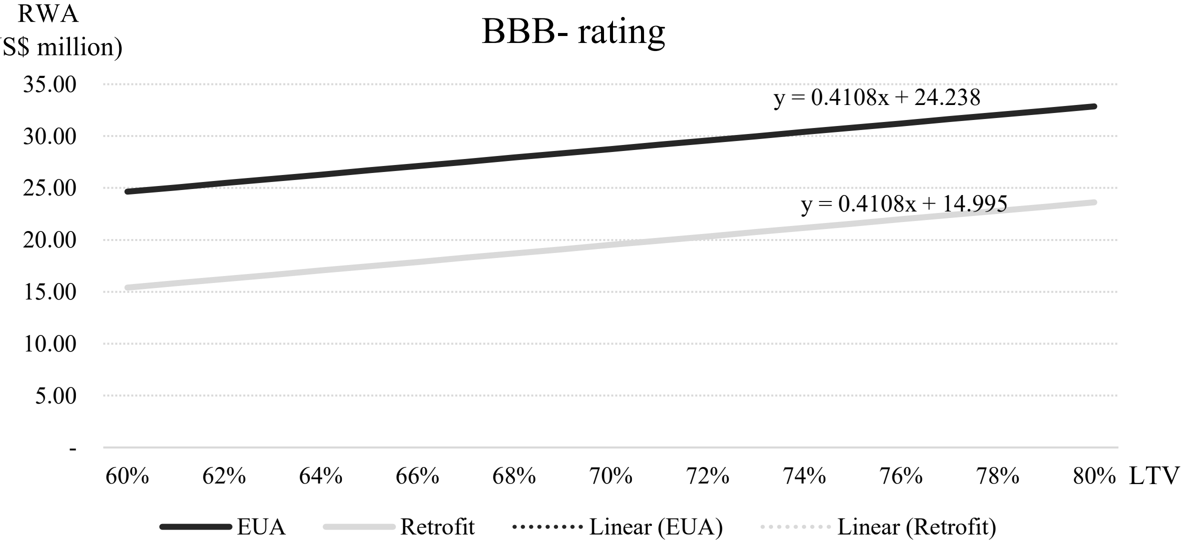




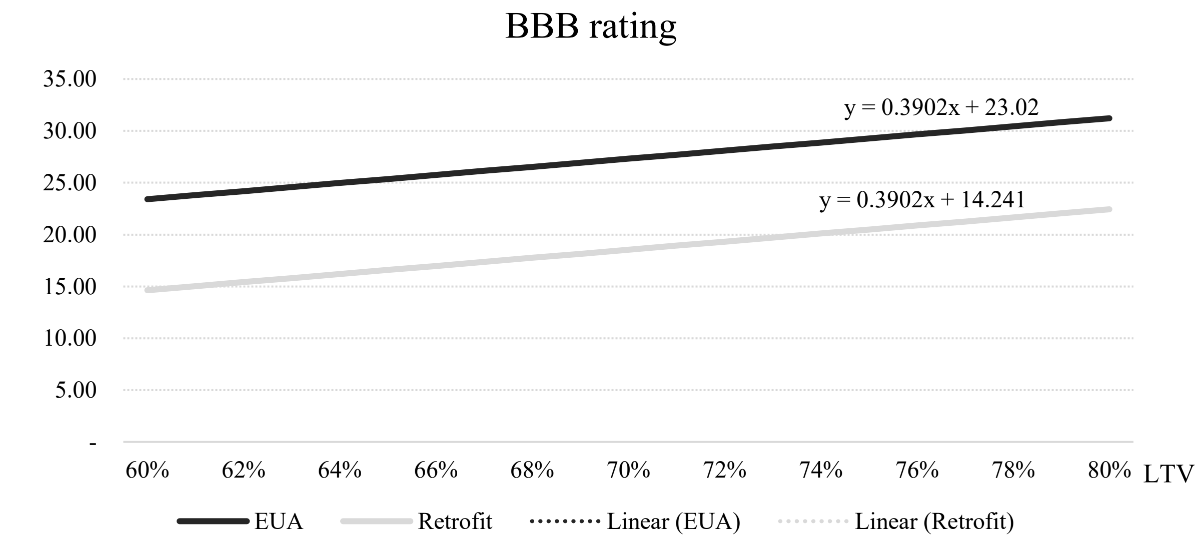
RWA
(US$ million)

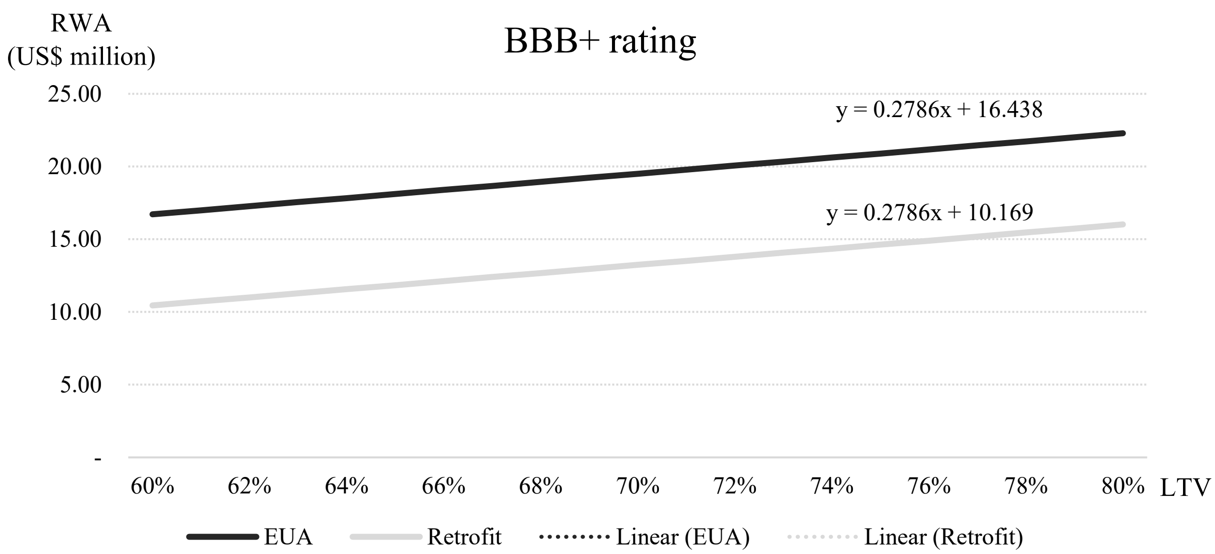


RWA
(US$ million)



RWA
(US$ million)

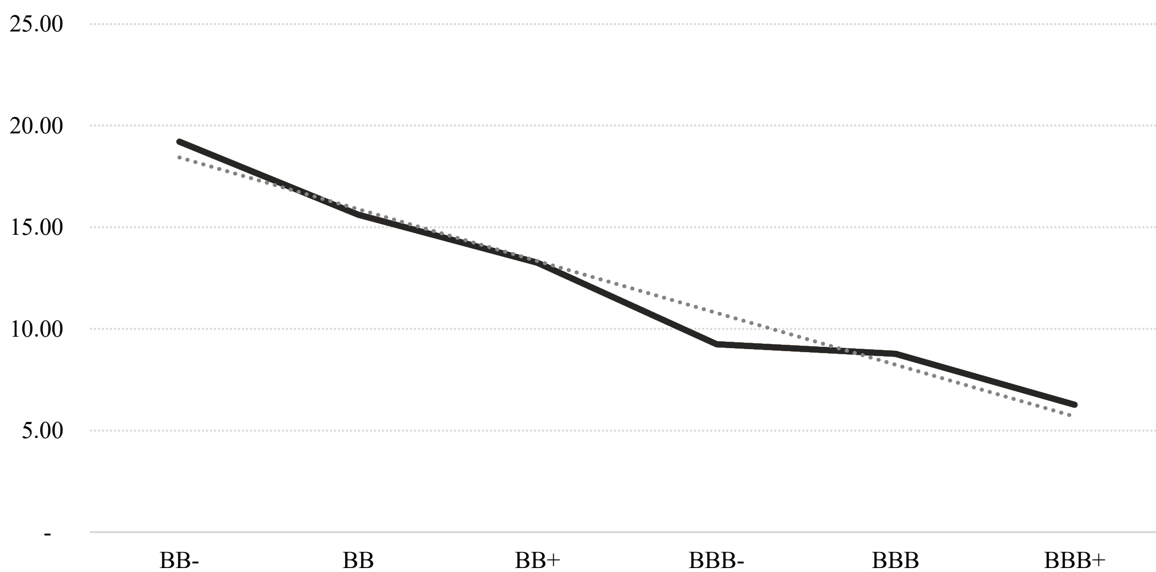




The findings suggest that it is always advantageous for the financier to extend financing for the retrofit investment, irrespective of the LTV ratio or the PD of the borrower, in accordance with the F-IRB methodology. In other words, secured financing is consistently favorable compared to unsecured financing for the lender.

However, it equally illustrates that the RWA disparity between retrofitting investments and EUA procurement exhibits a diminishing trend as the creditworthiness of the borrower enhances (see Figure 4.12). This indicates a reduced motivation for the financier to advocate for secured financing for borrowers with robust credit profiles, whereas unsecured financing becomes increasingly challenging for borrowers with weaker credit unless they are willing to incur significantly elevated margins compared to secured financing to offset the increased RWA.

Figure 4.12: RWA gap analysis between retrofit financing and EUA purchase financing



Note. The Y-axis refers to RWA in US$ million. The X-axis refers to the credit rating of borrowers

4.4.5.2. A-IRB approach

Under the A-IRB methodology, the LGD for unsecured loans is floored at 25%, while the LGD for secured loans is set with a minimum threshold of 15%, and the maturity period is limited to a maximum of 5 years. The unsecured LGD is assumed at 40% in this example for easy comparison with the results from the F-IRB case in chapter 4.4.5.1.

Utilizing the same scenario involving the F-IRB case, wherein a loan with a 70% LTV is allocated to a borrower with BBB- credit rating for the retrofit investment while an equivalent amount is designated for the EUA acquisition, the RWA calculation pursuant to A-IRB methodology is presented in the following Table 4.9.

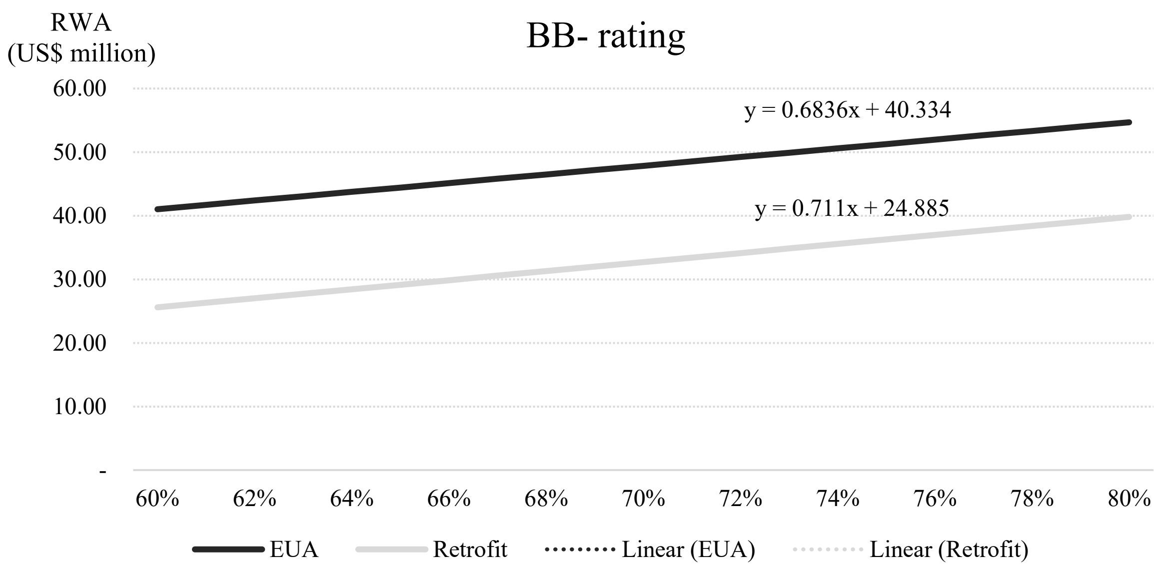
Table 4.9: RWA calculations in accordance with the A-IRB approach

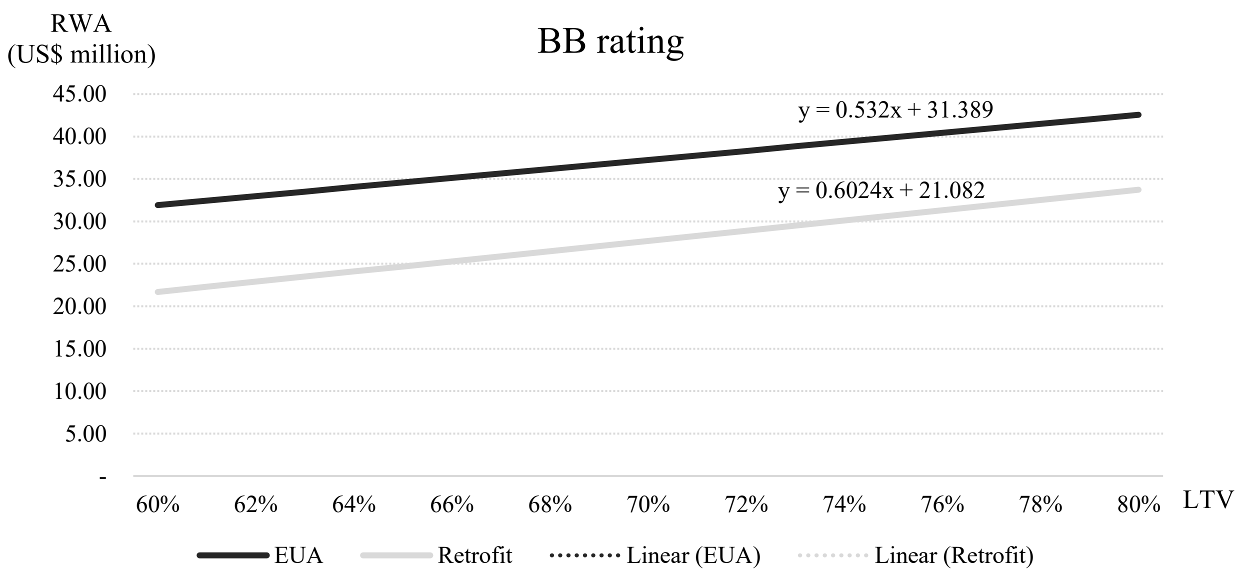
	EUA	**Retrofit**
PD	0.22%	0.22%
LGD	40.0%	16.4%
EAD	70	70
Maturity	1	5
R	0.228	0.228
b	0.206	0.206
K	0.023	0.020
Risk Weighting	-	-
RWA (US$ million)	**19.88**	**17.89**

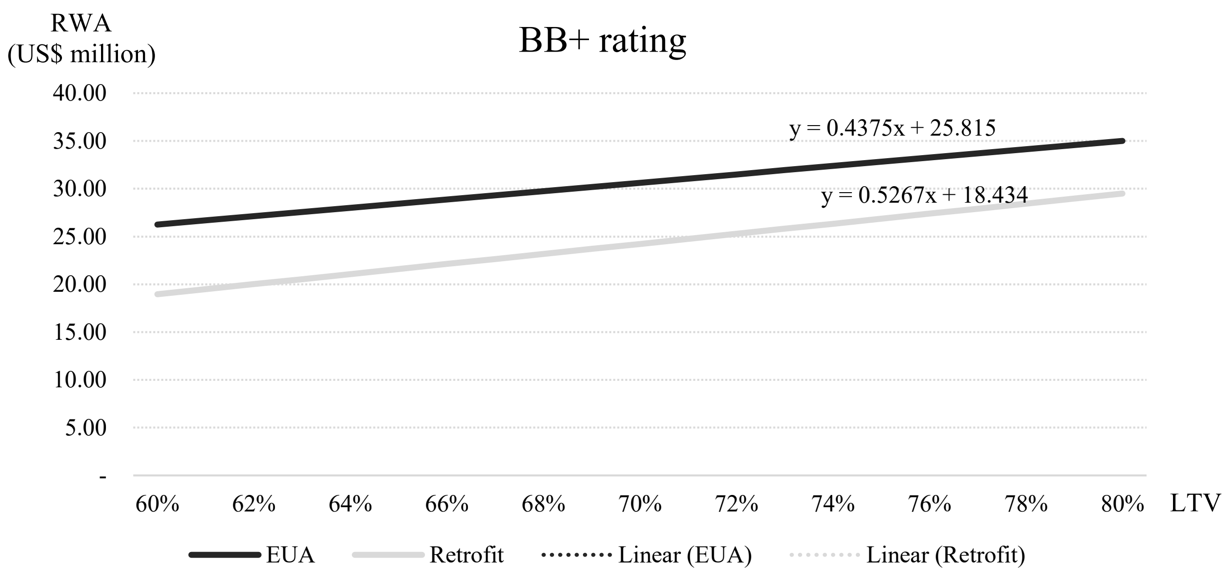
Note. R,b, and *K* are calculated based on Equation 4.5.

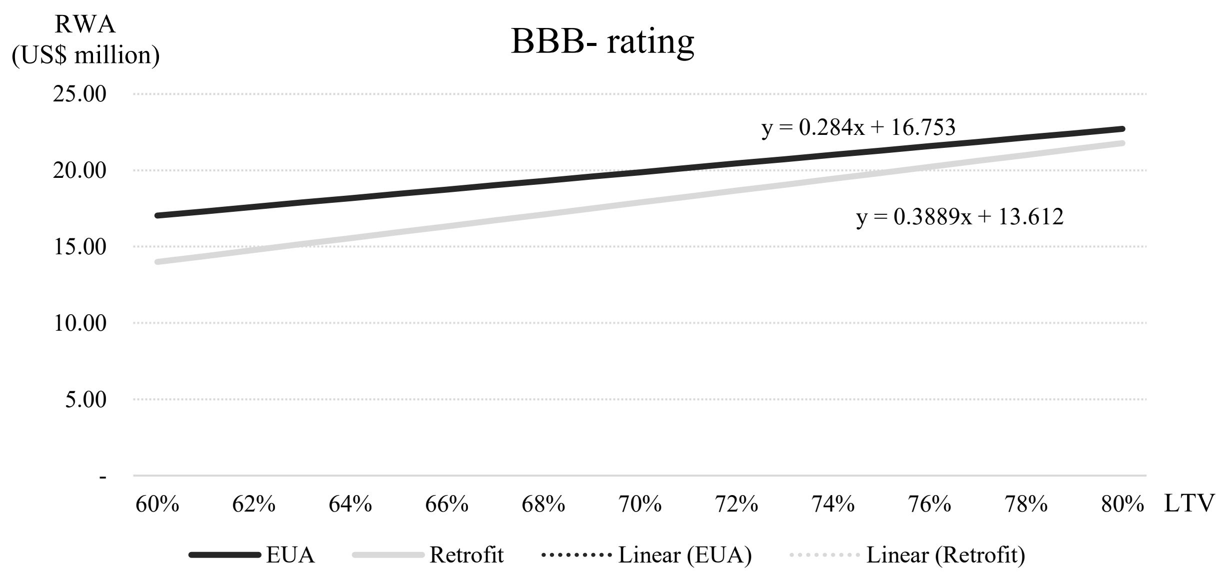
The figures presented below (see Figure 4.13) illustrate the projected RWA associated with the financing of both EUA acquisition and retrofit investments as the LTV ratio escalates in accordance with various credit ratings, which correspond to differing PD.

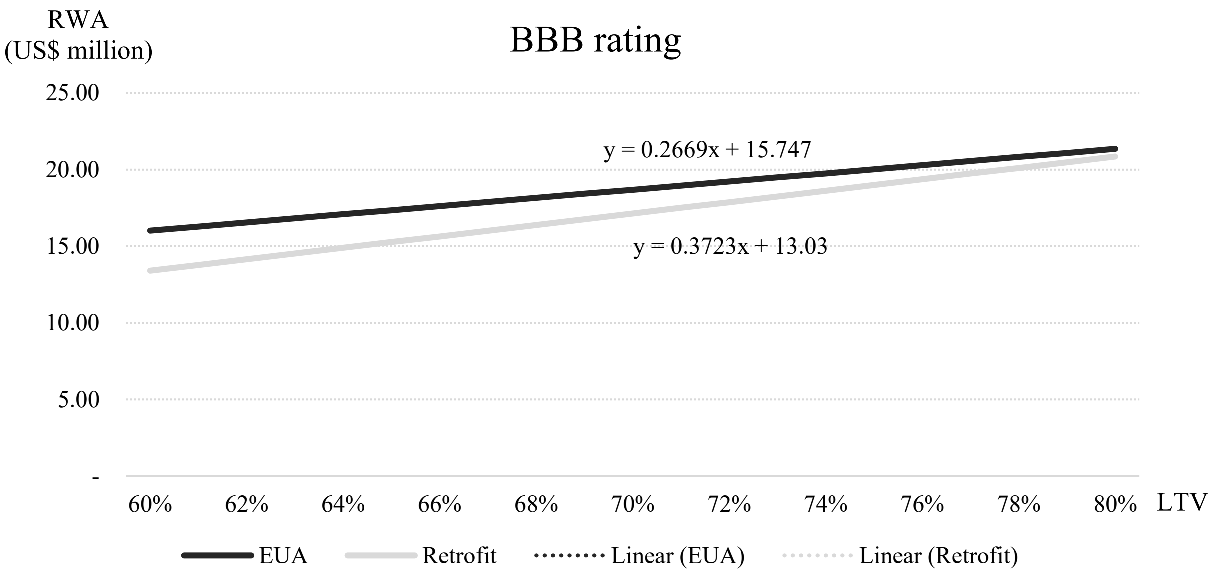
Figure 4.13: RWA calculation with various LTV and credit ratings

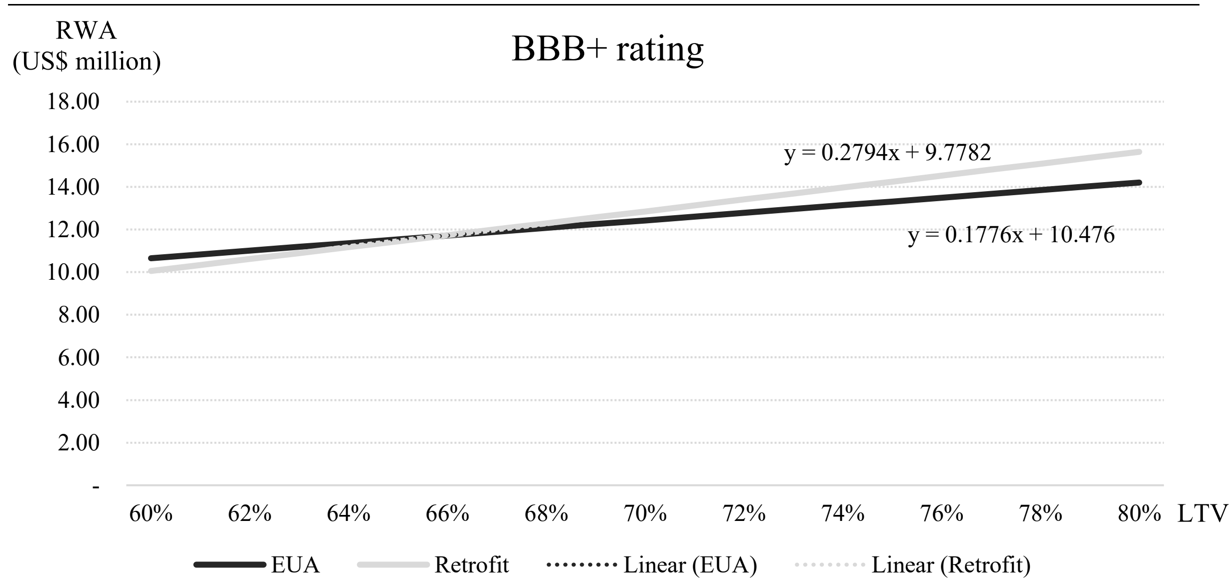

RWA
(US$ million)
BB- rating
y = 0.6836x + 40.334
y = 0.711x + 24.885
60.00
50.00
40.00
30.00
20.00
10.00
-
60%
62%
64%
66%
68%
70%
72%
74%
76%
78%
80%
EUA
Retrofit
Linear (EUA)
Linear (Retrofit)


RWA
(US$ million)
BB rating
y = 0.532x + 31.389
y = 0.6024x + 21.082
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
60%
62%
64%
66%
68%
70%
72%
74%
76%
78%
80%
LTV
EUA
Retrofit
Linear (EUA)
Linear (Retrofit)


RWA
(US$ million)
BB+ rating
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
y = 0.4375x + 25.815
y = 0.5267x + 18.434
60%
62%
64%
66%
68%
70%
72%
74%
76%
78%
80%
LTV
EUA
Retrofit
Linear (EUA)
Linear (Retrofit)


RWA
(US$ million)
BBB- rating
25.00
20.00
15.00
10.00
5.00
-
y = 0.284x + 16.753
y = 0.3889x + 13.612
60%
62%
64%
66%
68%
70%
72%
74%
76%
78%
80%
LTV
EUA
Retrofit
Linear (EUA)
Linear (Retrofit)

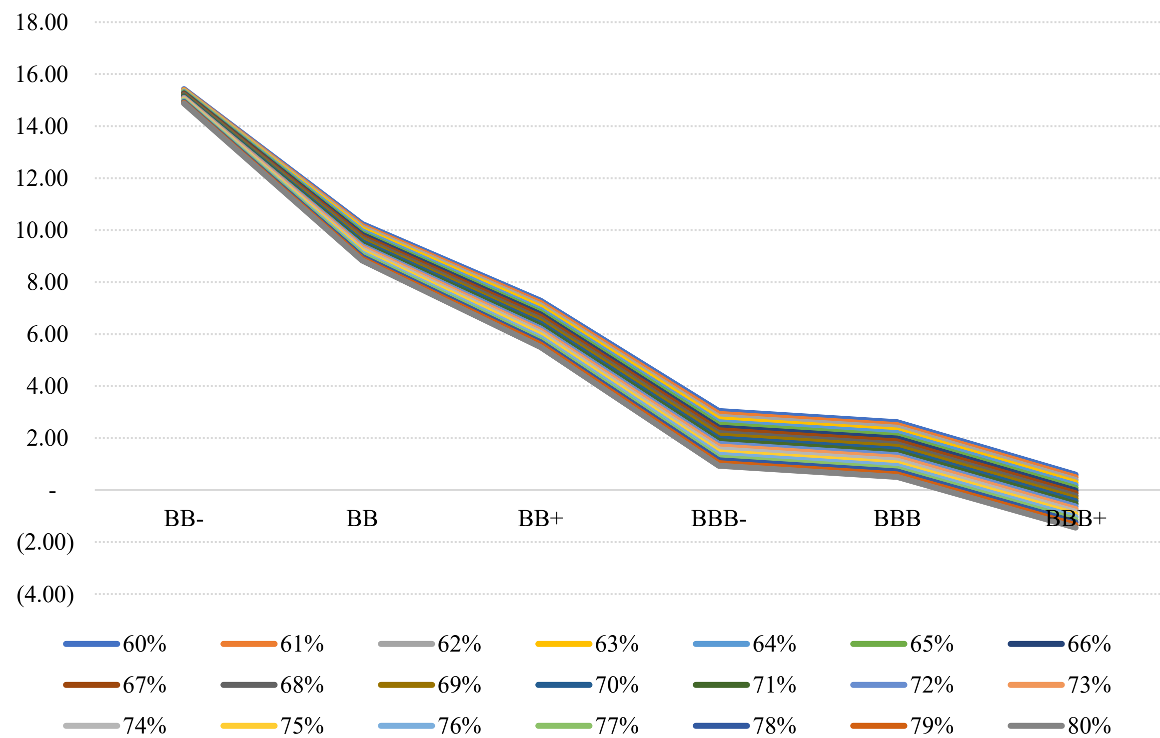




It is important to note that the advantages of secured lending in terms of RWA gradually decline as the borrower's credit rating improves. Furthermore, the rate of RWA increase corresponding to a rise in LTV ratios is more pronounced in secured financing compared to unsecured financing, which contrasts with the results derived from the F-IRB methodology. This distinction becomes increasingly apparent when the borrower's creditworthiness is robust; for instance, it is advisable for the lender to contemplate unsecured lending for EUA acquisition for a borrower with a BBB+ rating if the LTV related to retrofit investment surpasses 66%.

This implies that the RWA calculation pursuant to the A-IRB approach exhibits reduced sensitivity regarding the LTV ratio for secured loans in relation to the borrower's credit quality (i.e., borrowers with low PD).

Figure 4.14: RWA gap analysis between retrofit financing and EUA purchase financing



Note. The Y-axis refers to RWA in US$ million. The X-axis refers to the credit rating of borrowers.

Conclusion

The optimal financing arrangement should ensure that the interests of both the shipowner and the financier are harmonized. In instances where the borrower's credit rating is comparatively low, there is a tendency to reduce the equity contributions required for a prospective investment while simultaneously maximizing the anticipated return. Conversely, financiers typically require substantial equity contributions (i.e., a low LTV ratio for secured financing) from borrowers with weaker credit profiles in order to optimize their capital allocation. If EUA can also be utilized as collateral for secured financing in the future, the decision-making process can be streamlined for both the shipowner and the financier, which ultimately hinges on the prevailing market price of CO_2. Therefore, the subsequent chapter will examine the appropriate CO_2 pricing necessary to render investments in decarbonization economically viable.

4.5. Estimation of CO_2 price for investments in retrofitting

As analyzed in the preceding Chapter 4.4, the investment decision is contingent upon the owners' perspective regarding the market CO_2 price. Should the breakeven CO_2 price at the moment of investment be ascertainable, it would significantly aid the owners in their decision-making process. In this study, I propose two methodologies for determining the breakeven CO_2 price.

4.5.1. CO_2 price calculation from retrofit investment

The first methodology is derived from the subsequent equations for retrofit investment, which can also be categorized into two scenarios: one that excludes the necessity for financing and another that incorporates financing costs (see Equation 4.6 and Equation 4.7).

Equation 4.6: Breakeven CO_2 price calculation with no financing involved.

$$CO_2 \text{ Price} = \boldsymbol{Annual\ depreciation} \big/ \boldsymbol{Saved\ CO2\ amount\ per\ annum}$$

Equation 4.7: Breakeven CO_2 price calculation with financing involved.

$$CO_2 \text{ Price} = (\boldsymbol{Annual\ depreciation} + \boldsymbol{Financing\ cost}) \big/ \boldsymbol{Saved\ CO2\ amount\ per\ annum}$$

Where,

Annual depreciation is determined by dividing the total investment by the expected economic lifespan of the retrofit. The annual CO_2 savings are calculated utilizing the same assumptions established in Chapter 4.4.4.1.

4.5.2. Case 1: No financing is required

The annual depreciation is subject to both the investment amount and the economic lifespan of the retrofitted equipment; therefore, multiple scenarios are illustrated in the subsequent figures, reflecting diverse investment amounts ranging from US$20 million to US$35 million, alongside economic lifespans extending from 10 years to 20 years (see Figure 4.15, Figure 4.16 and Figure 4.17).

Figure 4.15: Breakeven CO_2 Price with 10-year economic life assumption

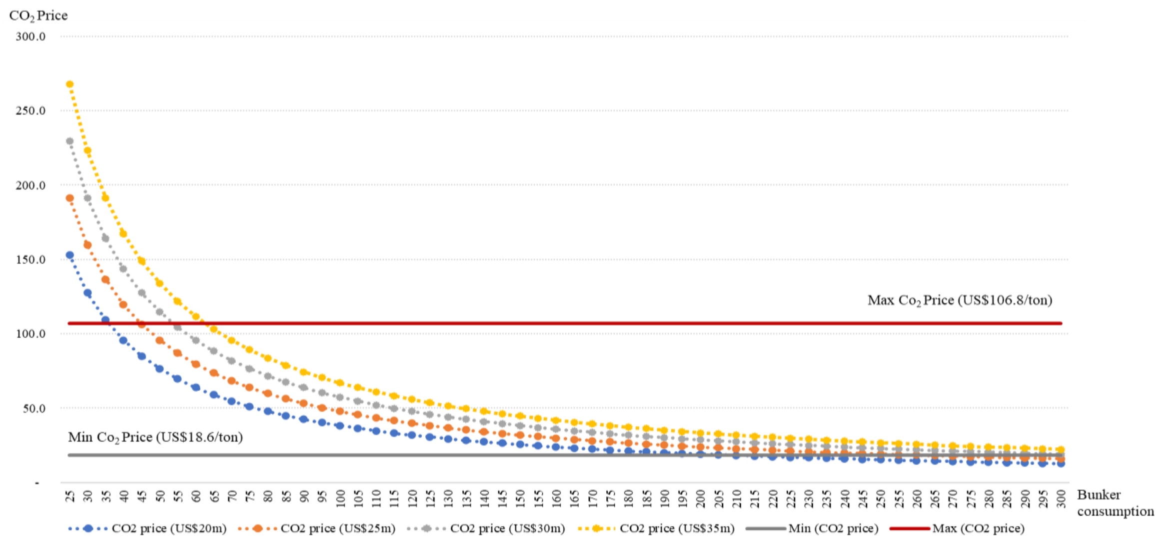


Figure 4.16: Breakeven CO_2 Price with 15-year economic life assumption

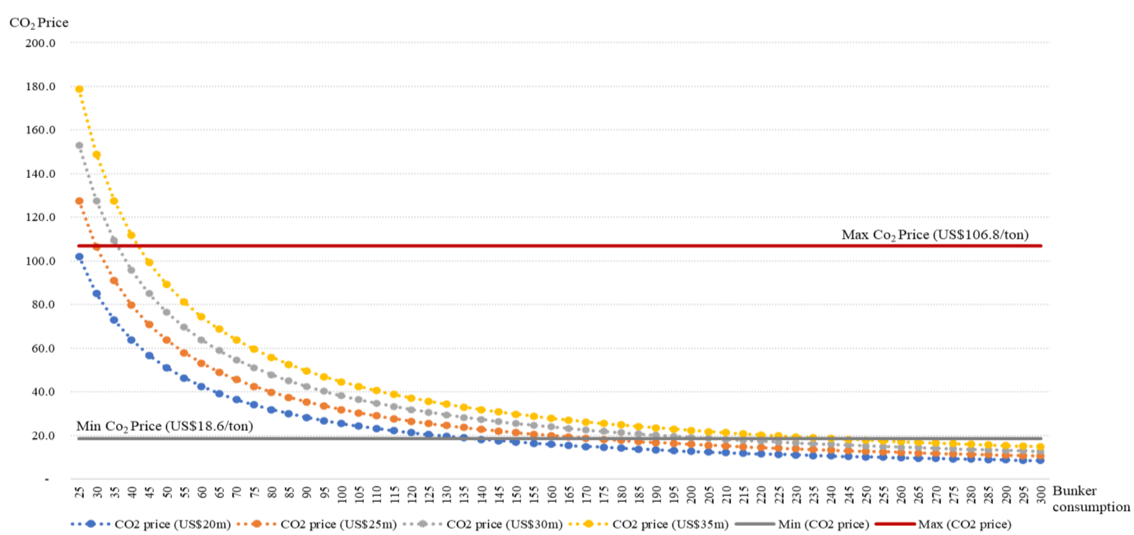
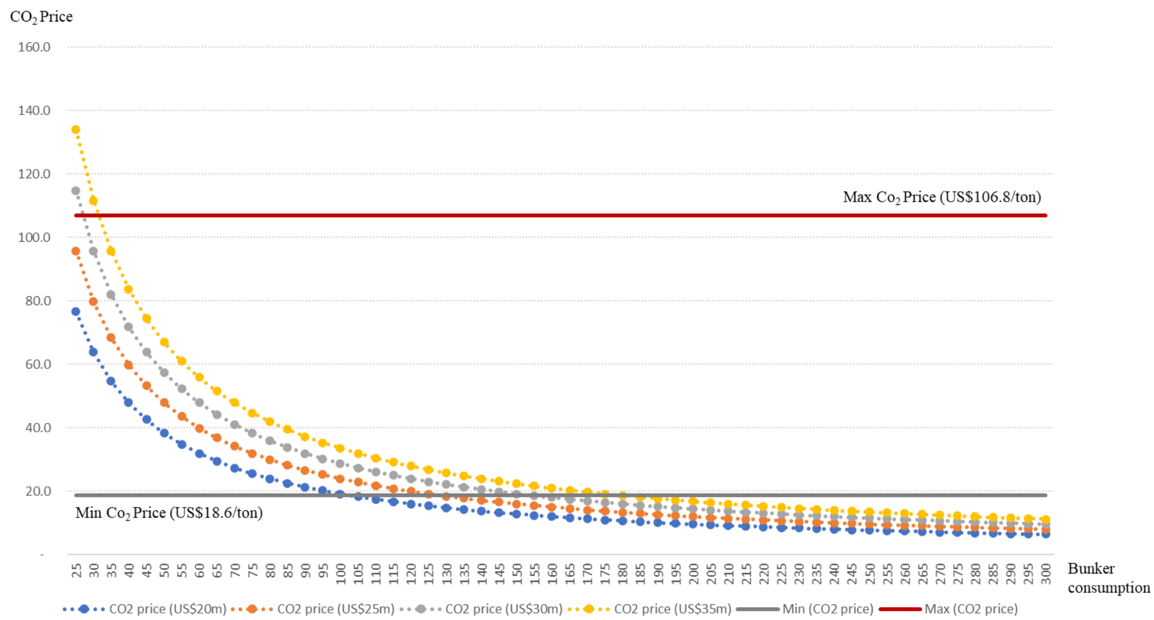


Figure 4.17: Breakeven CO_2 Price with 20-year economic life assumption



It is evident that the breakeven CO_2 price diminishes as the necessary daily bunker consumption increases (i.e., the vessel size expands) and the economic lifespan of the retrofit extends. For example, the breakeven CO_2 price for a Capesize bulk carrier consuming between 50 to 70 tons of bunker fuel daily is projected to be between US$54.7 per ton and US$76.6 per ton if the expected economic lifespan of retrofit is 10 years and the anticipated retrofit investment is US$20 million, which is expected to escalate to a range of US$95.7 per ton to US$134.0 per ton when the anticipated retrofit investment increases to US$35 million.

Considering the current CO2 price (EUA price) of approximately US$70 per ton as of July 2024, it is prudent to consider retrofitting for vessels that consume over 55 tons per day if the projected investment is US$20 million. Should the expected investment escalate to US$35 million, the vessel would need to utilize a minimum of 95 tons of bunker fuel to ensure the profitability of the retrofit investment (see Table 4.10). The baseline requirement for daily bunker consumption is diminished from 30 tons (US$20 million investment) to 50 tons

(US$35 million investment) should the operational lifespan of retrofitting be prolonged to 20 years.

Table 4.10: Breakeven CO_2 Price with 10-year economic life assumption

Bunker consumption (ton/day)	**CO_2 Price (US$20m)**	**CO_2 Price (US$25m)**	**CO_2 Price (US$25m)**	**CO_2 Price (US$30m)**
25	153.1	191.4	229.7	267.9
30	127.6	159.5	191.4	223.3
35	109.4	136.7	164.0	191.4
40	95.7	119.6	143.5	167.5
45	85.1	106.3	127.6	148.9
50	76.6	95.7	114.8	134.0
55	**69.6**	87.0	104.4	121.8
60	63.8	79.7	95.7	111.6
65	58.9	73.6	88.3	103.1
70	54.7	**68.4**	82.0	95.7
75	51.0	63.8	76.6	89.3
80	47.8	59.8	71.8	83.7
85	45.0	56.3	**67.5**	78.8
90	42.5	53.2	63.8	74.4
95	40.3	50.4	60.4	**70.5**
100	38.3	47.8	57.4	67.0

4.5.3. Case 2: Financing is required

In addition to the yearly depreciation and the economic lifespan of the retrofitted equipment, the financing cost plays a crucial role in determining the breakeven CO_2 price when the investment necessitates financing. The financing cost also varies according to the investment amount, even in instances where other financing terms remain constant. In this case analysis, the financing cost is computed based on the following financing assumptions.

- LTV: 70% of the total investment amount
- Tenor: 5 years
- Repayment profile: 10 years
- Margin: 7% fixed

Consistent with Case 1 mentioned previously, multiple scenarios are presented in the subsequent figures, showcasing various investment amounts ranging from US$20 million to US$35 million, along with economic lifespans varying from 10 years to 20 years.

Figure 4.18: Breakeven CO_2 Price with 10-year economic life assumption

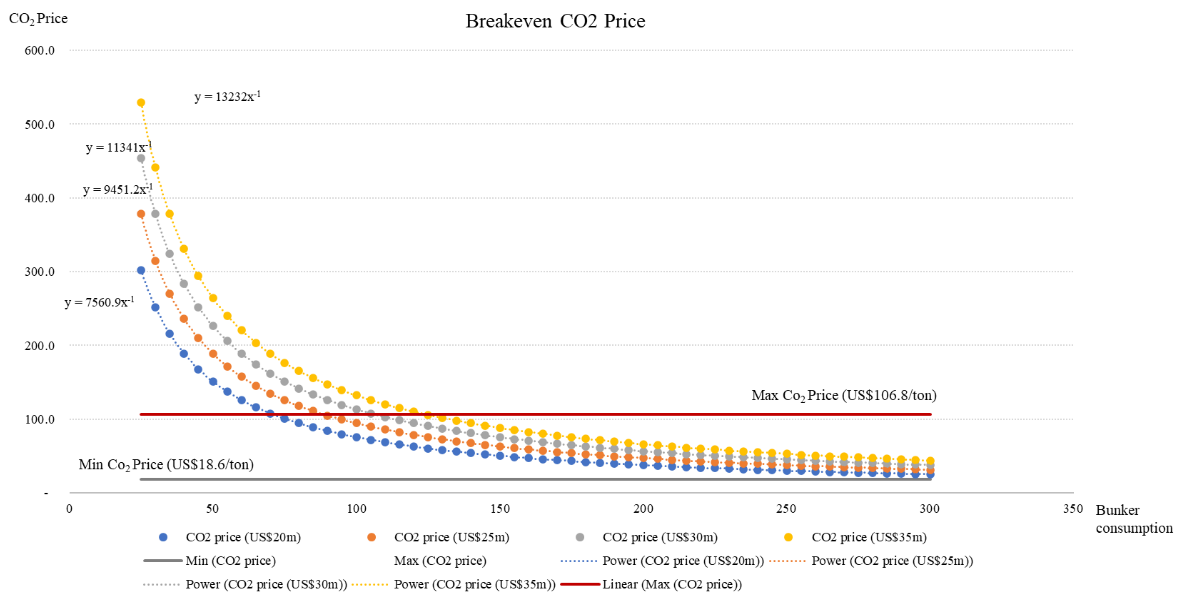


Figure 4.19: Breakeven CO_2 Price with 15-year economic life assumption

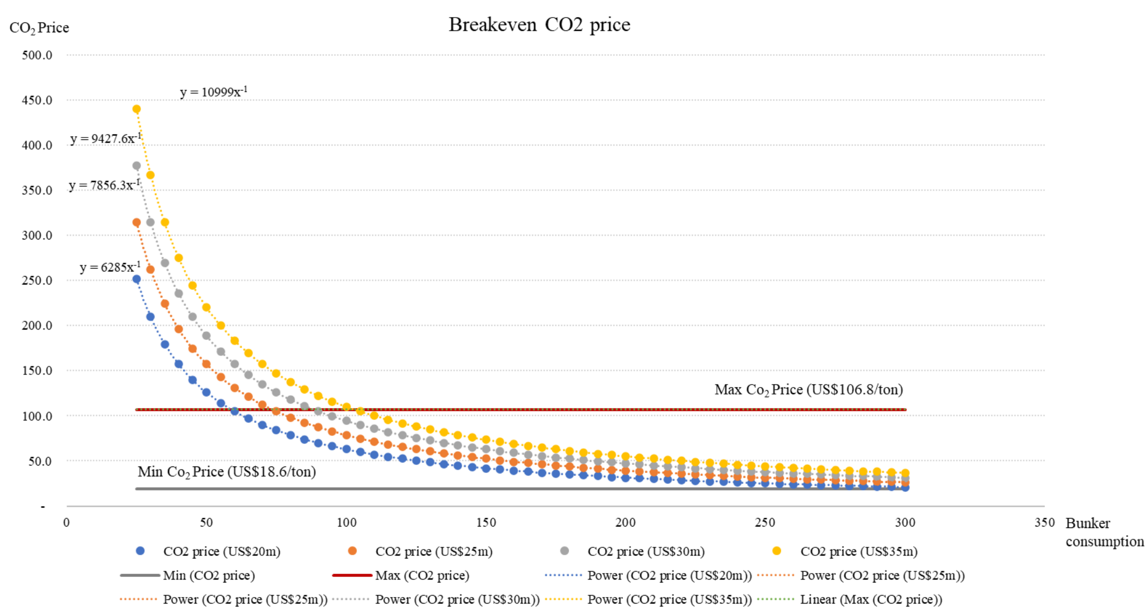
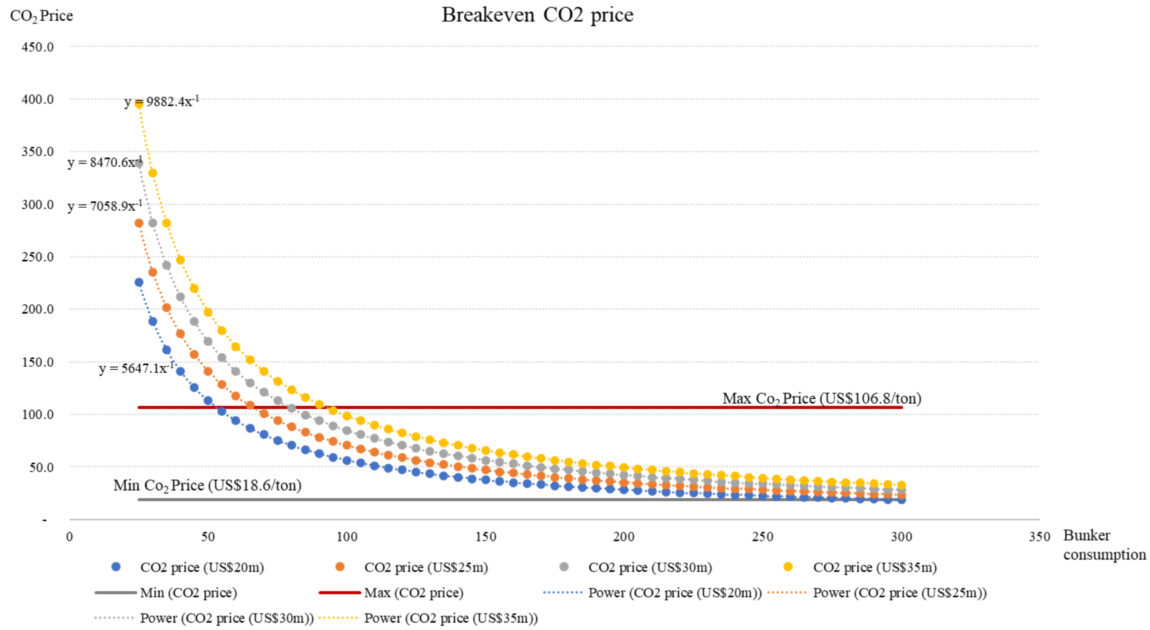


Figure 4.20: Breakeven CO_2 Price with 20-year economic life assumption



If the same scenario outlined in Case 1 is assumed, the breakeven CO_2 price for a Capesize bulk carrier, which utilizes between 50 to 70 tons of bunker fuel on a daily basis, is estimated to range from US$108.0 per ton to US$151.2 per ton, assuming the expected economic lifespan of the retrofit is 10 years and the projected investment in retrofit amounts to US$20 million. This breakeven price is anticipated to shift to a range of US$189.0 per ton to US$134.0 per ton should the projected investment in retrofit increase to US$35 million.

Given the prevailing CO_2 price (EUA price) of approximately US$70 per ton as of July 2024, it is advisable to evaluate the feasibility of retrofitting for vessels that have a fuel consumption exceeding 110 tons per day, particularly if the anticipated investment amounts to US$20 million. In the event that the projected investment increases to US$35 million, the vessel would be required to consume a minimum of 190 tons of bunker fuel to guarantee the financial viability of the retrofit investment (see Table 4.11). The baseline limit for daily bunker consumption is adjusted from 80 tons (US$20 million investment) to 140 tons (US$35 million investment) provided that the economic lifespan for retrofitting is lengthened to 20 years.

Table 4.11: Breakeven CO_2 Price with 10-year economic life assumption

Bunker consumption (ton/day)	CO_2 Price (US$20m)	CO_2 Price (US$25m)	CO_2 Price (US$25m)	CO_2 Price (US$30m)
80	94.5	118.1	141.8	165.4
85	89.0	111.2	133.4	155.7
90	84.0	105.0	126.0	147.0
95	79.6	99.5	119.4	139.3
100	75.6	94.5	113.4	132.3
105	72.0	90.0	108.0	126.0
110	**68.7**	85.9	103.1	120.3
115	65.7	82.2	98.6	115.1
120	63.0	78.8	94.5	110.3
125	60.5	75.6	90.7	105.9
130	58.2	72.7	87.2	101.8
135	56.0	**70.0**	84.0	98.0
140	54.0	67.5	81.0	94.5
145	52.1	65.2	78.2	91.3
150	50.4	63.0	75.6	88.2
155	48.8	61.0	73.2	85.4
160	47.3	59.1	70.9	82.7
165	45.8	57.3	**68.7**	80.2
170	44.5	55.6	66.7	77.8
175	43.2	54.0	64.8	75.6
180	42.0	52.5	63.0	73.5
185	40.9	51.1	61.3	71.5
190	39.8	49.7	59.7	**69.6**
195	38.8	48.5	58.2	67.9
200	37.8	47.3	56.7	66.2

The relationship between the price of CO_2 and the daily consumption of bunker fuel (HSFO) also can be articulated through the following equations (see Equation 4.8):

Equation 4.8: The function of bunker consumption and breakeven CO_2 price

Investment amount	Economic Life		
	10Y	15Y	20Y
US$20 million	$Y_{co2\ price} = 7{,}560.9x^{-1}$	$Y_{co2\ price} = 6{,}285x^{-1}$	$Y_{co2\ price} = 5{,}647.1x^{-1}$

US$25 million	$Y_{co2\ price} = 9{,}451.2x^{-1}$	$Y_{co2\ price} = 7{,}856.3x^{-1}$	$Y_{co2\ price} = 7{,}058.9x^{-1}$
US$30 million	$Y_{co2\ price} = 11{,}341x^{-1}$	$Y_{co2\ price} = 9{,}427.6x^{-1}$	$Y_{co2\ price} = 8{,}470.6x^{-1}$
US$35 million	$Y_{co2\ price} = 13{,}232x^{-1}$	$Y_{co2\ price} = 10{,}999x^{-1}$	$Y_{co2\ price} = 9{,}882.4x^{-1}$

Note. Variable X refers to the daily bunker consumption.

It is clearly observed that the coefficient of the X variable (daily bunker consumption) diminishes as the economic lifespan of the retrofit extends, provided that the investment amount remains constant and that the investment amount is lower when the economic lifespan of the retrofit is equivalent.

If a shipowner managing a fleet of Aframax tankers, each consuming 40 tons of HSFO daily, alongside VLCCs that utilize 100 tons of HSFO each day, contemplates a retrofit investment with an estimated financial outlay ranging from US$25 million to US$30 million, it is imperative that the CO_2 price exceeds at least US$ 211.77 per ton throughout the economic lifespan of the investment (see Table 4.12).

Table 4.12: Estimation of breakeven CO_2 price for Aframax and VLCC

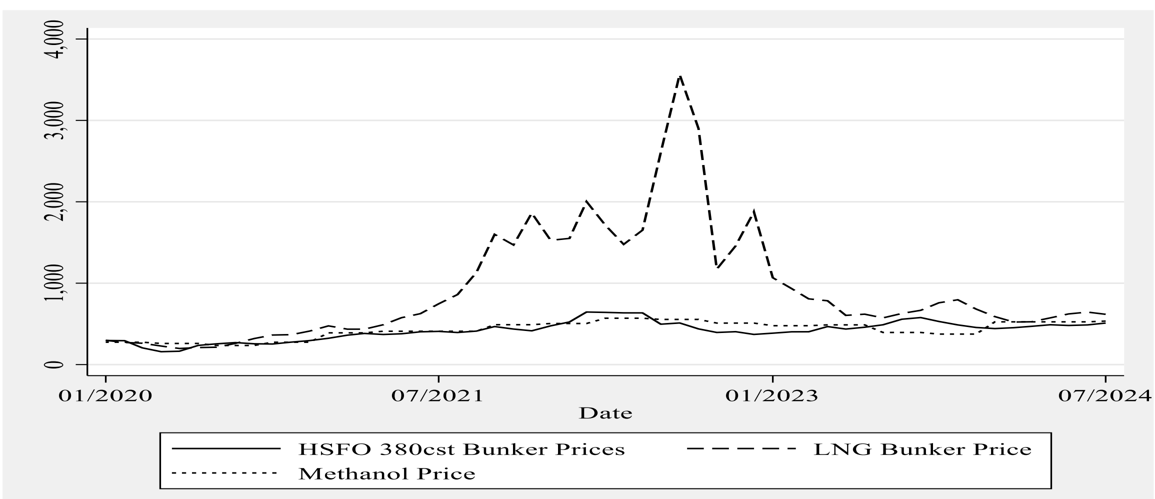
	Aframax tanker		
Investment amount	**Economic Life**		
	10Y	15Y	20Y
US$20 million	189.02	157.13	141.18
US$25 million	236.28	196.41	176.47
US$30 million	283.53	235.69	211.77
US$35 million	330.80	274.98	247.06
	VLCC		
Investment amount	**Economic Life**		
	10Y	15Y	20Y
US$20 million	75.61	62.85	56.47
US$25 million	94.51	78.56	70.59
US$30 million	113.41	94.28	84.71
US$35 million	132.32	109.99	98.82

Regarding the data provided by Clarksons concerning CO_2 pricing from January 2023 through July 2024, the price fluctuated between US$56 and US$103 per ton. This suggests that it may not be economically viable to contemplate retrofitting a vessel with a relatively small capacity that consumes less than 100 tons of HSFO daily.

4.5.4. Discussion

One factor that is overlooked in this analysis when determining the breakeven CO_2 price is the price differential between HSFO and LNG/methanol. In terms of historical price trends, the volatility of LNG prices has been markedly greater in comparison to that of HSFO and methanol (see Figure 4.21). However, it is noteworthy that the price of LNG consistently remains above that of HSFO. Consequently, the breakeven CO_2 price should be adjusted in accordance with the price disparity between HSFO and LNG/methanol. The analysis intentionally omits the price disparity, operating under the assumption that the price per ton for LNG, HSFO, and methanol is not significantly different, in order to isolate the intrinsic impact of CO_2 savings on the breakeven CO_2 price.

Figure 4.21: Historical price for HSFO, LNG and methanol per ton



Source: Clarksons Research

CO_2 pricing is profoundly affected by a multitude of factors. The establishment of regulatory frameworks and the implementation of government policies are pivotal in determining these prices. Moreover, the interplay of supply and demand, influenced by economic activity, energy market fluctuations, and advancements in technology, exerts a significant influence. Price volatility in the short term may arise from market dynamics, including speculative activities. In addition, global trends and environmental considerations add to the complicated nature of CO_2 pricing. In this context, the current pricing of CO_2 does not incentivize the investment in retrofitting alternative engines unless the capital expenditure required for such retrofitting is significantly decreased. Nonetheless, it could still represent a compelling choice for shipowners managing a fleet of large vessels that utilize over 100 tons of HSFO daily and anticipate a progressive rise in CO_2 pricing in the future.

4.6. Conclusion

According to Bloomberg NEF (Global Carbon Market Outlook 2024 | BloombergNEF), it is anticipated that the average carbon prices within the EU will reach €71 per ton (US$76 per ton) in 2024, a decrease from €85 per ton in 2023, with a forecasted rise to €149 per ton by 2030. The International Monetary Fund (IMF) further projects that in order to achieve the 1.5°C objective, carbon pricing should be established within a range of $100 to $200 per ton by the year 2030, with an anticipated increase continuing until 2050, depending on the array of policies implemented (A Path to Zero, n.d.). The projected range of CO_2 prices aligns with the calculated breakeven CO_2 price resulting from the retrofit investment analysis conducted in Chapter 4.5.

In the meantime, Basel IV, which is an extension of the Basel III regulatory framework, is scheduled to be implemented starting on January 1, 2025. This timeline reflects a delay from the original schedule, primarily due to the complexities involved in the global banking sector's adoption of these new regulations. Basel IV introduces stricter capital requirements and risk management standards, with significant changes to how banks calculate RWA and capital requirements. These changes aim to ensure that banks hold sufficient capital to cover potential risks, thereby enhancing the overall stability of the global financial system.

In this context, shipowners, especially those who operate their vessels within the EU, are progressively compelled to undertake investment decisions to adhere to decarbonization regulations primarily driven by the EU and IMO. Given the current CO_2 price, shipowners have minimal economic motivation to invest in retrofitting, irrespective of various alternative fuels such as LNG, methanol, and ammonia, when compared to acquiring EUAs in the market. If future GHG regulations encompass a broader environmental impact like NOx and methane, they will affect the prices of alternative fuels, resulting in a significant influence on the economics of wider decarbonization investments.

By calculating estimated CO_2 savings resulting from the retrofit investment across various scenarios, it has been determined that the retrofit investment attains economic viability relative to EUA acquisition when the CO_2 price is set at a significantly elevated level compared to the current market price.

Consequently, the procurement of EUAs is anticipated to be the option favored by a significant number of shipowners in the short term. Accordingly, financiers in the ship financing industry are expected to align with this trend, which will result in increased liquidity being available to shipowners, facilitating their acquisition of EUAs. Given the ambiguity surrounding the recognition of EUAs as physical collateral under Basel regulations, the lending approach to shipowners should be characterized as unsecured financing. Therefore, the credit rating of the borrower, which is reflected in the Probability of Default (PD) when determining RWA, will play a crucial role for financiers in their decision to extend financing. This may lead to a "flight to quality" phenomenon, indicating that shipowners with weaker credit profiles, who typically possess limited liquidity, may struggle to secure adequate support from financiers as banks are compelled to optimize their capital allocation in accordance with Basel IV. Furthermore, the strategy employed by financial institutions will vary based on the chosen rating model methodology as outlined by Basel IV. Banks should consistently prioritize retrofit investments over EUA acquisitions from an RWA perspective, irrespective of the borrower's credit rating under the Foundation Internal Ratings-Based (F-IRB) approach. Nevertheless, the inclination may shift toward EUA acquisitions for borrowers with favorable credit ratings whose PD falls below a specified threshold under the

Advanced Internal Ratings-Based (A-IRB) approach. It is unequivocal that financial institutions in the ship financing sector will persist in their significant contributions towards the decarbonization of the maritime industry, as envisioned by the EU and the IMO, evidenced by the fact that numerous international banks have committed to climate change initiatives that encompass the decarbonization of the shipping sector. Nevertheless, it is imperative that banking regulations, such as Basel IV, be meticulously examined in conjunction with decarbonization regulations within the maritime sector to synchronize the interests of financiers and stakeholders in the maritime industry, thereby facilitating the overarching objective of achieving decarbonization within this sector.

Chapter 5 Conclusion and recommendations

This comprehensive study has meticulously examined the multifaceted and intricate relationship that exists between the regulatory framework established by Basel IV and the domain of ship financing, particularly focusing on the burgeoning sector of green vessels as well as the ongoing decarbonization initiatives within the maritime industry, which are becoming increasingly critical in the context of global environmental sustainability. Through my rigorous analysis, I have unearthed a plethora of significant insights that warrant careful consideration by stakeholders in the field:

Firstly, the implementation of Basel IV regulations poses a myriad of considerable challenges for banking institutions that are actively engaged in the realm of ship financing, with particular emphasis on those financial entities that are utilizing the Advanced Internal Ratings-Based (A-IRB) methodology for assessing credit risk. Despite the empirical evidence provided by Global Credit Data indicating an average loss given default (LGD) of approximately 14% for loans issued within the shipping sector, my thorough analysis indicates that this specific statistic may not adequately reflect the true risk profile associated with low loan-to-value (LTV) portfolios, a discrepancy that could potentially lead to the imposition of excessively burdensome capital requirements on these financial institutions. In light of these findings, I have proposed the introduction of three innovative financing strategies, specifically designed to mitigate the impact of risk-weighted assets (RWA) as mandated under Basel IV: these strategies include Export Credit Agency (ECA) financing, the provision of insurance for collateral valuations, and the securitization of loan portfolios. Although these proposed approaches exhibit promising potential for alleviating the burdens associated with RWA, there remain pertinent concerns regarding their alignment with the overarching objectives of the Basel Committee, particularly with respect to the transfer of credit risk to less-regulated financial markets, which may undermine the stability intended by the regulatory framework.

Secondly, the investigation into the characteristics of green vessels did not yield substantial empirical evidence to suggest that these vessels possess a lower risk profile when compared to their traditional counterparts, thus implying that the loss given default (LGD) values should remain relatively uniform across both categories of vessels. Nevertheless, it is important to note that with the impending introduction of the European Union Emissions Trading System (ETS) scheduled for implementation in 2024, coupled with the anticipated trends in carbon pricing mechanisms, there exists the potential for the emergence of future green premiums that could alter the financial dynamics within the maritime sector.

Lastly, the empirical findings derived from the research suggest that shipowners, in the current economic climate characterized by uncertain market conditions, are confronted with a significantly constrained financial incentive to undertake investments aimed at retrofitting their vessels, particularly when compared to the more straightforward alternative of acquiring European Union Allowances (EUAs) as a means of compliance with regulatory requirements. This prevailing scenario not only complicates the operational landscape for financial institutions, particularly under the stringent parameters outlined in Basel IV regulations, but it may also lead to a pronounced "flight to quality" phenomenon in lending practices, where banks preferentially allocate their resources to borrowers deemed less risky.

While the findings presented herein undeniably contribute significantly to the ever-expanding corpus of scholarly knowledge within the field, it is imperative to acknowledge that they are not devoid of certain limitations, which notably include factors such as the relatively small sample size pertaining to the green vessels examined and the specific temporal horizons utilized for data collection that are essential for accurately calculating the green premium associated with these green vessels. In light of these limitations, future research endeavors could broaden the scope of this investigation by integrating a more extensive dataset concerning green vessels, particularly as advancements in alternative fuel engine technology continue to progress and evolve over time. Furthermore, it is of considerable importance to undertake a thorough examination of how the green premium might exhibit a correlation with the costs associated with decarbonization efforts in the shipping industry, as this relationship could yield significant insights into the economic implications of transitioning towards more sustainable maritime practices.

Looking to the future, I strongly advocate for a meticulously considered alignment between the regulatory frameworks governing banking practices and the ongoing decarbonization initiatives being implemented within the maritime sector, as this alignment is crucial to ensuring that the industry receives robust and adequate support in its transformative shift towards achieving greater sustainability and environmental responsibility. Furthermore, it is imperative that additional rigorous research be conducted to systematically track and analyze the effects of emerging regulatory measures and carbon pricing mechanisms on the valuations of vessels and the various financing strategies employed within this sector, as this understanding will be vital in guiding future investments and policy decisions.

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Appendix

A. 1: LNG DF containership

Name	TEU	DWT	Built	Builder
Post-Panamax				
CMA CGM Jacques Saade	23,112	221,250	2020	SCS Shipbuilding
CMA CGM Palais Royal	23,112	221,250	2020	SCS Shipbuilding
CMA CGM Champs Elysees	23,112	220,868	2020	Jiangnan SY Group
CMA CGM Louvre	23,112	220,868	2020	Jiangnan SY Group
CMA CGM Sorbonne	23,112	221,250	2021	SCS Shipbuilding
CMA CGM Concorde	23,112	221,250	2021	SCS Shipbuilding
CMA CGM Rivoli	23,112	221,250	2021	SCS Shipbuilding
CMA CGM Trocadero	23,112	220,868	2021	Jiangnan SY Group
CMA CGM Montmartre	23,112	220,868	2021	Jiangnan SY Group
Berlin Express	23,500	229,376	2023	Hanwha Ocean
Neo-Panamax				
Brussels Express	14,993	149,360	2014	Hyundai HI (Ulsan)
CMA CGM Tenere	15,294	158,999	2020	Hyundai Samho HI
CMA CGM Scandola	15,294	158,999	2020	Hyundai Samho HI
CMA CGM Iguacu	15,294	158,999	2021	Hyundai Samho HI
CMA CGM Bali	15,294	158,999	2021	Hyundai Samho HI
CMA CGM Kimberley	15,254	155,000	2021	Jiangnan SY Group
CMA CGM Hope	15,294	154,700	2021	Hyundai HI (Ulsan)
CMA CGM Unity	15,294	154,700	2021	Hyundai HI (Ulsan)
CMA CGM Patagonia	15,254	154,077	2021	Jiangnan SY Group
CMA CGM Symi	15,294	158,999	2022	Hyundai Samho HI
CMA CGM Arctic	15,294	158,999	2022	Hyundai Samho HI
CMA CGM Galapagos	15,254	155,000	2022	Jiangnan SY Group
CMA CGM Everglade	15,254	155,000	2022	Jiangnan SY Group
CMA CGM Greenland	15,254	155,000	2022	Jiangnan SY Group
CMA CGM Dignity	15,294	154,700	2022	Hyundai HI (Ulsan)
CMA CGM Liberty	15,294	154,700	2022	Hyundai HI (Ulsan)
MSC Fatma	15,294	154,700	2022	Hyundai HI (Ulsan)
CMA CGM Integrity	15,294	154,700	2022	Hyundai HI (Ulsan)
CMA CGM Pride	15,294	154,700	2022	Hyundai HI (Ulsan)
MSC Aaya	15,294	154,700	2022	Hyundai HI (Ulsan)
MSC Washington	14,428	153,319	2022	Yangzi Xinfu SB
MSC Virginia	14,428	153,319	2022	Yangzi Xinfu SB
ZIM Mount Everest	15,124	159,914	2023	Samsung HI
ZIM Mount Denali	15,124	159,914	2023	Samsung HI
ZIM Sammy Ofer	15,124	159,914	2023	Samsung HI
ZIM Mount Blanc	15,124	159,914	2023	Samsung HI
MSC Calypso	15,294	159,528	2023	Hyundai HI (Ulsan)
MSC Audrey	15,264	159,528	2023	Hyundai Samho HI
MSC Taylor	15,294	159,528	2023	Hyundai HI (Ulsan)
MSC Sofia	15,294	154,700	2023	Hyundai HI (Ulsan)

MSC Kayley	15,294	154,700	2023	Hyundai HI (Ulsan)
MSC Daria	15,294	154,700	2023	Hyundai HI (Ulsan)
Feedership				
Seaboard Blue	1,036	13,200	2011	CSC Jiangdong
Containerships Nord	1,400	20,272	2018	Huangpu Wenchong
Containerships Aurora	1,400	20,290	2019	Huangpu Wenchong
Containerships Polar	1,400	20,257	2019	Huangpu Wenchong
Containerships Arctic	1,400	20,200	2019	Huangpu Wenchong
Xiang Shui Yun 26	653	10,000	2020	Hunan Jinhang SB
Containerships Borealis	1,400	20,200	2021	Huangpu Wenchong
Containerships Stellar	1,400	20,200	2021	Huangpu Wenchong
Xiang Shui Yun 27	653	10,237	2021	Hunan Jinhang SB

Source: Clarksons Research

A. 2: LNG DF tanker

VLCC				
Name	**DWT**	**GT**	**Built**	**Builder**
Yuan Rui Yang	318,451	169,675	2022	Dalian Shipbuilding
Advantage Victory	299,468	156,186	2022	Daewoo (DSME)
Advantage Verdict	299,451	156,186	2022	Daewoo (DSME)
Eagle Valence	299,244	158,244	2022	Samsung HI
Eagle Vallery	298,700	158,244	2022	Samsung HI
Advantage Vital	299,590	156,186	2023	Daewoo (DSME)
Seaways Excelsior	299,468	156,186	2023	Hanwha Ocean
Advantage Vision	299,455	156,186	2023	Daewoo (DSME)
Hafeet	299,425	156,673	2023	Hanwha Ocean
Habshan	299,425	156,673	2023	Hanwha Ocean
Seaways Endeavour	299,365	156,186	2023	Daewoo (DSME)
Seaways Enterprise	299,365	156,186	2023	Daewoo (DSME)
Suezmax				
Current Spirit	129,801	85,329	2020	Samsung HI
Tide Spirit	129,632	85,329	2020	Samsung HI
Aurora Spirit	129,632	85,329	2020	Samsung HI
Rainbow Spirit	129,220	85,329	2020	Samsung HI
Eagle Balder	128,427	85,745	2020	Samsung HI
Eagle Blane	125,000	85,745	2020	Samsung HI
Starway	157,552	86,855	2022	GSI Nansha
Greenway	157,327	86,855	2022	GSI Nansha
Aframax				
Adam	113,226	64,909	2018	Hyundai Samho HI
Alfred	113,170	64,909	2018	Hyundai Samho HI
Alexander	113,170	64,909	2018	Hyundai Samho HI
Eagle Brasilia	113,416	62,150	2019	Samsung HI
Vernadsky Prospect	113,310	64,909	2019	Hyundai Samho HI
Korolev Prospect	113,232	64,909	2019	Hyundai Samho HI

Albert	113,095	64,909	2019	Hyundai Samho HI
Eagle Bintulu	113,049	62,150	2019	Samsung HI
Vladimir Monomakh	112,960	65,141	2020	Zvezda Shipbuilding
Pacific Emerald	113,306	63,555	2021	Samsung HI
Pacific Ruby	113,306	63,555	2021	Samsung HI
Pacific Diamond	113,306	63,555	2021	Samsung HI
Pacific Sapphire	113,306	63,555	2021	Samsung HI
Pacific Jade	113,306	63,555	2021	Samsung HI
Pacific Pearl	113,306	63,555	2021	Samsung HI
Pacific Garnet	113,306	63,555	2021	Samsung HI
Pacific Opal	113,306	63,555	2021	Samsung HI
Altera Wave	103,158	67,383	2021	Samsung HI
Altera Wind	103,118	67,383	2021	Samsung HI
Frida Knutsen	124,000	85,504	2022	Daewoo (DSME)
Sindre Knutsen	123,602	85,504	2022	Daewoo (DSME)
Pacific Topaz	113,306	63,555	2022	Samsung HI
Pacific Coral	113,306	63,555	2022	Samsung HI
Vladimir Vinogradov	112,960	65,141	2022	Zvezda Shipbuilding
Okeansky Prospect	112,651	65,141	2022	Zvezda Shipbuilding
Proteus Harvonne	109,999	66,982	2022	GSI Nansha
Proteus Sinead	109,999	66,982	2022	GSI Nansha
Proteus Philippa	109,999	66,982	2022	GSI Nansha
Proteus Bohemia	109,999	66,970	2022	GSI Nansha
Proteus Jessica	109,999	66,834	2022	Shanghai Waigaoqiao
Proteus Iwona	109,999	66,834	2022	Shanghai Waigaoqiao
Proteus Rebecca	109,999	66,834	2022	Shanghai Waigaoqiao
Proteus Stephanie	109,999	66,834	2022	Shanghai Waigaoqiao
Atlantic Emerald	109,201	64,933	2022	New Times SB
Atlantic Jade	109,201	64,933	2022	New Times SB
Proteus Tracy	109,999	66,982	2023	GSI Nansha
Proteus Elsie	109,999	66,970	2023	GSI Nansha
Proteus Ingrid	109,999	66,970	2023	GSI Nansha
Proteus Rong Na	109,999	66,982	2023	GSI Nansha
Hafnia Languedoc	109,999	65,145	2023	GSI Nansha
Hafnia Loire	109,999	65,145	2023	GSI Nansha
Handysize				
Fure West	17,557	11,548	2006	Shanghai Edward
Euro Viking	24,783	17,757	2007	Shanghai Edward
Tern Sea	14,878	11,463	2016	AVIC Dingheng SB
Ternfjord	14,848	11,463	2016	AVIC Dingheng SB
Ternsund	14,846	11,463	2016	AVIC Dingheng SB
Mia Desgagnes	14,986	12,061	2017	Besiktas Shipyard
Tern Ocean	14,827	11,463	2017	AVIC Dingheng SB
Damia Desgagnes	14,745	11,978	2017	Besiktas Shipyard
Gaia Desgagnes	17,999	12,770	2018	AVIC Dingheng SB
Thun Venern	17,999	12,770	2018	AVIC Dingheng SB
Ramanda	17,994	12,770	2018	AVIC Dingheng SB

Paul A. Desgagnes	14,980	12,061	2018	Besiktas Shipyard
Ramelia	17,999	12,770	2019	AVIC Dingheng SB
Fure Ven	17,991	12,770	2019	AVIC Dingheng SB
Rossi A. Desgagnes	14,919	12,061	2019	Besiktas Shipyard
Solar Roma	24,621	18,335	2021	Hyundai Mipo
Solar Alice	24,621	18,335	2021	Hyundai Mipo
Solar Naama	24,621	18,335	2021	Hyundai Mipo
Solar Catie	24,621	18,335	2021	Hyundai Mipo
Prospero	22,543	18,636	2021	Wuhu Shipyard
Fure Viten	17,999	12,763	2021	CMJL (Yangzhou)
Fure Vinga	17,999	12,763	2021	CMJL (Yangzhou)
Tern Island	15,024	11,432	2021	CMJL (Yangzhou)
Gold Trader	33,343	22,635	2022	Nantong Xiangyu
Gold Trader I	33,343	22,635	2022	Nantong Xiangyu
Gold Trader II	33,324	22,467	2022	Nantong Xiangyu
Pacifico	22,554	18,636	2022	Wuhu Shipyard
Eva Gold	19,900	13,644	2022	Nantong Xiangyu
Eva Diamond	19,880	13,644	2022	Nantong Xiangyu
Tern Fors	15,034	11,445	2022	CMJL (Yangzhou)
Bit Wind	13,823	9,896	2022	Jiangsu New YZJ
Bit Wave	13,822	9,896	2022	Jiangsu New YZJ
Gold Trader III	33,338	22,467	2023	Nantong Xiangyu
Atlantic Narval	23,500	19,913	2023	Wuhu Shipyard

Source: Clarksons Research

A. 3: Methanol DF tanker

VLCC				
Name	**DWT**	**GT**	**Built**	**Builder**
Manchac Sun	51,458	30,565	2016	Minaminippon (Ozai)
Cajun Sun	51,457	30,565	2016	Minaminippon (Ozai)
Lindanger	49,999	30,945	2016	Hyundai Mipo
Leikanger	49,999	30,945	2016	Hyundai Mipo
Mari Jone	49,999	30,945	2016	Hyundai Mipo
Mari Boyle	49,999	30,945	2016	Hyundai Mipo
Taranaki Sun	49,994	30,561	2016	Minaminippon (Ozai)
Takaroa Sun	49,849	29,987	2019	Hyundai Mipo
Mari Couva	49,765	29,987	2019	Hyundai Mipo
Mari Kokako	49,765	29,987	2019	Hyundai Mipo
Creole Sun	49,760	30,945	2019	Hyundai Mipo
Mari Innovator	49,999	30,873	2021	Hyundai Mipo
Capilano Sun	49,999	30,873	2021	Hyundai Mipo
Grouse Sun	49,999	30,873	2022	Hyundai Mipo
Savonetta Sun	49,999	30,873	2022	Hyundai Mipo
Andean Sun	49,999	30,873	2022	Hyundai Mipo
Bayou Sun	49,999	30,873	2022	Hyundai Mipo
Seymour Sun	49,999	30,873	2022	Hyundai Mipo

Stena Pro Marine	49,990	29,884	2022	GSI Nansha
Stena Promise	49,990	29,884	2022	GSI Nansha
Stena Prosperous	49,990	29,884	2022	GSI Nansha
Stena Pro Patria	49,900	29,884	2022	GSI Nansha
Cypress Sun	49,999	30,873	2023	Hyundai Mipo

Source: Clarksons Research

A. 4: LNG DF dry bulk vessel

Capesize				
Name	**DWT**	**GT**	**Built**	**Builder**
HL Green	179,649	97,545	2020	Hyundai Samho HI
HL Eco	179,070	97,545	2020	Hyundai Samho HI
HL Oceanic	179,070	97,574	2021	Hyundai Samho HI
Mount Tourmaline	209,936	112,164	2022	Shanghai Waigaoqiao
Mount Nova Terra	209,821	112,164	2022	Shanghai Waigaoqiao
Mount Jadeite	209,050	111,435	2022	New Times SB
Mount Gaea	208,970	112,435	2022	New Times SB
Mount Amelior	208,947	112,435	2022	New Times SB
Ubuntu Harmony	189,688	102,039	2022	Shanghai Waigaoqiao
HL Sunny	179,070	97,574	2022	Hyundai Samho HI
Mount Api	209,021	112,435	2023	New Times SB
Mount Aneto	209,013	112,435	2023	New Times SB
Mount Ararat	208,910	112,435	2023	New Times SB
Mount Tai	208,808	112,691	2023	New Times SB
Ubuntu Unity	189,784	102,039	2023	Shanghai Waigaoqiao
Ubuntu Empathy	189,774	102,039	2023	Shanghai Waigaoqiao
Ubuntu Community	189,741	102,039	2023	Shanghai Waigaoqiao
Ubuntu Humanity	189,721	102,039	2023	Shanghai Waigaoqiao
Ubuntu Equality	189,688	102,039	2023	Shanghai Waigaoqiao
Ubuntu Integrity	189,688	102,039	2023	Shanghai Waigaoqiao
Ubuntu Loyalty	189,688	102,039	2023	Shanghai Waigaoqiao
HL Nambu 1	178,952	97,574	2023	Hyundai Samho HI
Panamax				
Handymax				
Ilshin Green Iris	50,655	31,005	2018	Hyundai Mipo
Handysize				
Viikki	25,600	19,958	2018	CMJL (Nanjing)
Haaga	23,650	19,955	2018	CMJL (Nanjing)

Source: Clarksons Research