DECARBONIZING LNG SHIPPING: IMPACTS OF CARBON INTENSITY REGULATION ON FLEET DYNAMICS, CHARTER RATES, AND EMISSIONS TRAJECTORIES

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Overview

The global trade of liquefied natural gas (LNG) has experienced significant growth in recent years, particularly accelerated by the European gas crisis and the commissioning of new liquefaction capacities. Medium-term forecasts indicate continued growth in LNG demand and shipping capacity, with more than 300 vessels expected to enter the market, further expanding the global fleet. However, long-term projections diverge significantly beyond 2030. Concurrently, the International Maritime Organization (IMO) introduced the Carbon Intensity Index (CII) in 2023, mandating progressive decarbonization of shipping fleets by regulating CO_2 emissions per deadweight tonne-mile. Uncertainties remain, however, about enforcement - would non-compliant ships really be banned from loading and unloading in any port around the world - and the evolution of the increasingly stringent trajectory required to meet the 2050 GHG target. This regulatory shift therefore raises uncertainties about compliance strategies and the potential impact on shipping costs and LNG prices for end users, as well as the impact on fleet decarbonisation. The objective of this paper is twofold: first, to analyse the impact of CII regulation on the carbon emissions associated with the LNG fleet, and second, to assess its impact on charter rates. We developed an LNG shipping model to forecast annual LNG charter rates from 2024 to 2050, incorporating three regulatory scenarios to account for the potential evolution of the regulation.

Methods

(i) In essence, we first model the evolution of the LNG fleet and associated charter rates without the Carbon Intensity Indicator (CII) regulation, estimating for a given year (i) the LNG supply and demand across twenty major geographical zones, (ii) the annual LNG shipping demand, and (iii) the equilibrium shipping price, integrating endogenous investment and scrapping decisions. We then model a base scenario by (iv) incorporating the announced CII regulation into the computation of the equilibrium price, followed by the simulation of two additional scenarios: one simulating a decarbonation of the maritime sector by 2050 (High scenario), and one forcasting a slower transition of the sector with a total decarbonation by 2100 (Low scenario).**LNG Supply and Demand forecasting:** We first determine mid-term LNG supply and demand based on the expected utilization of existing and upcoming terminal capacities -regasification and liquefaction- and extend this to long-term forecasts using LNG supply scenarios provided by global energy forecasters.

(ii) **Shipping Demand Modelling**: We then model the annual shipping demand based on a route-optimal allocation of LNG exports and imports, taking into account routes prescribed by long-term contracts and current shipping patterns.

(iii) **Equilibrium Shipping Price**: Next, we model the equilibrium shipping price for each year, based on the short-run operating cost of the last available ship required to meet the demand. This calculation considers the portion of demand already fulfilled by period-chartered vessels. A scarcity premium is applied in case of low supply, modeled using regression analysis of historical charter rates under similar market conditions. This equilibrium price sets the achievable charter rates for all ships in the fleet. Additionally, the model simulates market actors' responses to shipping market developments, such as the retirement of ships due to age or lack of profitability, and the entry of new ships based on perceived future market needs and expected competitiveness. Investor decision-making is simulated by assessing whether new ships would provide satisfactory returns based on a myopic internal forecast of shipping prices.

(iv) **CII Regulation Integration**: The Carbon Intensity Indicator (CII) regulation establishes annual environmental bands (A to E, with A representing the lowest carbon intensity) based on CO_2-equivalent emissions per deadweight tonne-mile of ship activity. Ships categorized as band E or those in band D for three consecutive years are supposedly exited from the market. The required CII for each band progressively decreases according to a reduction factor, Z For a net-zero shipping industry, the Z-factor would eventually need to reach 100% . However, Z factors have only been set up to 2026. As such, while our base case

incorporates the IMO announced Z-factors and follows a linear trajectory after 2026, the High scenario set a Z-factor of 100% in 2050 when the Low scenario has a Z factor of 100% in 2100.
We model the possibility for every vessel to realize operational maintenance capping the stemming reduction CO2 to 18%, or complete -capex intensive- retrofit assuming no more CO2 emmissions emitted by the vessel afterward.

Results and conclusion

We performed a back-cast exercise over 2012–2023: the model successfully replicated the historical LNG shipping demand and charter rates over that period, highlighting its robustness. We also discussed our approach with market players, who broadly confirmed its relevance. The model generates annual forecasts for LNG shipping demand, the LNG carrier fleet, charter rates, and CO2 emissions.

In our base case, the model predicts that the XDF charter rate will be approximately $76,000/day in 2025, increasing to $105,000/day in 2030. As new capacity enters the market in the late 2020s, the model forecasts periods of oversupply where charter rates are driven by the marginal vessel's operating cost. With the introduction of more efficient ships, this cost decreases—for example, to $103,000/day in 2041. However, increasing regulatory constraints combined with limited additional capacity post-2030—due to shipowners anticipating reduced LNG shipping demand as LNG consumption diminishes—result in a gradual increase in average charter rates until 2050.

In our high scenario, assuming net-zero emissions by 2050, XDF charter rates are projected to be, on average, 20% lower than in the base scenario. This reduction is driven by regulatory exits, as more stringent Z factors increasingly penalize less-efficient vessels. This dynamic accelerates the adoption of more efficient ships, which set the benchmark for charter rates, resulting in overall lower prices.

Conversely, in a low scenario (net-zero by 2100), the trend becomes more volatile due to two opposing factors: an oversupply of ships, which reduces charter rates compared to the base scenario, and the presence of less efficient ships, which drives rates higher. For example, in 2030, charter rates in the low scenario are 37% higher than in the base scenario, while in 2040, they are 42% lower.

Regarding CO2 emissions, our model indicates that in the base scenario, annual emissions could gradually decrease from 50 Mt per year in 2030 to 19 Mt per year by 2050. In the high scenario, annual emissions are expected to approach near-zero levels by 2050, with a few tonnes of emissions remaining from vessels rated D that have not yet reached a third consecutive D-rating by 2050. In contrast, under the low scenario, annual emissions will remain at 31 Mt in 2050, which is 62% more than the base case scenario. Cumulatively, the high scenario is expected to avoid 197 Mt of CO2 emissions compared to the base scenario. In contrast, the low scenario is forecasted to result in an additional 172 Mt of emissions relative to the base scenario.

Conclusion

This study highlights the profound impact of the Carbon Intensity Indicator (CII) regulation on the LNG shipping sector, emphasizing its dual role in shaping charter rates and driving fleet decarbonization. By incorporating varying regulatory scenarios, our analysis provides insights into how regulatory stringency and fleet evolution could influence market dynamics and environmental outcomes. The results underscore the critical need for clear enforcement mechanisms and ambitious Z-factor trajectories to achieve meaningful reductions in CO_2 emissions. Future research should extend the scope of our analysis to other long distance carriers while exploring the interplay between regulatory policies, fleet investment behaviors, and market conditions. Such analyses will be crucial for policymakers and industry stakeholders navigating the transition toward a net-zero shipping industry.

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