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Analysing recent trends
and drivers of maritime
transport CO₂ emissions:
Insights from a
decomposition analysis for
the OECD and the world

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Abstract

International shipping is a cornerstone of global trade, but comes with a significant carbon footprint, at 2.5% of total energy-related CO₂ emissions in 2024. The decarbonisation of maritime transport has thus become a central focus in climate policy discussions. This paper uses the OECD's experimental maritime transport emissions database to assess recent trends and drivers of CO₂ emissions, contrasting dynamics for the OECD and the world. Global emissions rose by 9.3% between 2019 and 2024, with container ships and bulk carriers contributing the most.

A decomposition analysis is then applied to disentangle the relative contributions of six key factors: transport intensity, economic activity, capacity underutilisation, distance, emission factors, and fuel intensity. It shows that the increase in emissions was driven primarily by GDP growth, reinforced by rising transport intensity, with improvements in fuel intensity and a negative distance effect only partially offsetting these effects. Capacity underutilisation had a positive effect at global level, and mildly negative for the OECD. The emission factor effect played only a minor role. Analysis of decomposition results for top-emitting ship types shows significant dynamics which can be explained by exogenous shocks (Covid pandemic, disruptions to transport routes, wars) combined with structural changes in fleet dynamics and environmental regulation.

Résumé

Le transport maritime international est une pierre angulaire du commerce mondial, mais s'accompagne d'une empreinte carbone importante, à 2,5 % des émissions totales de CO₂ liées à l'énergie en 2024. La décarbonation du transport maritime est donc devenue un point central des discussions sur la politique climatique. Ce document de travail s'appuie sur la base de données expérimentale de l'OCDE sur les émissions du transport maritime pour évaluer les tendances récentes et les facteurs d'émissions de CO₂, en contrastant les dynamiques observées pour l'OCDE et le monde. Les émissions mondiales ont augmenté de 9,3 % entre 2019 et 2024, les porte-conteneurs et les vraquiers y ayant contribué le plus.

Une analyse de décomposition est ensuite appliquée pour isoler les contributions relatives de six facteurs clés : l'intensité en transport, le niveau d'activité économique, le degré de sous-utilisation des capacités, la distance, les facteurs d'émission et l'intensité en carburant. Elle montre que l'augmentation des émissions a dérivé principalement de la croissance du PIB, renforcée par l'augmentation de l'intensité en transport, l'amélioration

de l'intensité en carburant et un effet de distance négatif ne compensant que partiellement ces effets d'émissions croissantes. La sous-utilisation des capacités a eu un effet positif sur les émissions au niveau mondial, et légèrement négatif pour l'OCDE. L'effet du facteur d'émission n'a joué qu'un rôle mineur. L'analyse des résultats de décomposition pour les types de navires les plus émetteurs montre des dynamiques significatives pouvant s'expliquer par des chocs exogènes (pandémie de la Covid, perturbations des routes maritimes, guerres) combinés à des changements structurels dans la dynamique de la flotte maritime et la régulation environnementale.

Keywords: environmental economic accounting, SEEA, transport, maritime, shipping, greenhouse gas emissions, CO2 emissions, climate change, sustainable development, net zero, carbon mitigation, decomposition analysis.

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1 Introduction

International shipping is a cornerstone of global trade, transporting around 80% of the volume of goods and materials traded worldwide (UNCTAD, 2025^[1]). Its efficiency in moving large quantities of goods across long distances has made it an indispensable component of the global economy. However, this central role also comes with a significant environmental footprint. According to OECD and IEA estimates (IEA, 2025^[2]), maritime transport accounted for around 2.5% of total energy-related CO₂ emissions in 2024. This is a share comparable to that of major emitting economies, for example energy-related emissions from Japan and the European Union represented 2.6% and 6% respectively of the global total.

Recent trends show that between 2019 and 2024 CO₂ emissions from maritime transport increased by 7.8% in the OECD area and by 9.3% globally. Looking ahead, maritime transport emissions are projected to grow substantially in the coming decades if trade continues to expand and no further mitigation efforts are undertaken (IMO, 2020^[3]). In this regard, the decarbonisation of maritime transport has become a central focus in climate policy discussions. The International Maritime Organisation's revised greenhouse gas strategy commits to net-zero emissions from international shipping around mid-century, with interim reduction targets for 2030 and 2040 (IMO, 2023^[4]). Accordingly, governments and shipping companies are deploying measures to improve carbon efficiency, by adopting lower-carbon fuels and optimising maritime transport operations. Yet the sector's emissions trajectory remains uncertain because it reflects a complex interplay of different drivers pulling in different directions: economic activity, trade patterns, fleet composition and operational efficiency across regions and ship types.

Understanding the evolution and underlying drivers of maritime transport emissions is critical for monitoring progress and designing effective policies toward international climate goals. Against this policy backdrop, the decomposition analysis applied in this paper examines six key factors. *Transport intensity* captures the demand for maritime transport relative to economic activity. *Economic activity* itself captures a scale effect and is represented by real GDP. *Capacity underutilisation* measures how effectively the fleet's carrying capacity is used, with rising underutilisation increasing emissions relative to transport work. The *distance factor* reflects the capacity-weighted average distance, capturing the geographical structure of transport flows. The *emission factor* reflects the carbon content of fuels used, influenced by the fuel mix across the fleet. Finally, *fuel intensity* measures fuel consumption per unit of nominal transport work.

Building on this framework, this paper provides an empirical assessment of the trends and drivers of CO₂ emissions in maritime transport over the period 2019-2024. It applies a decomposition analysis to two country groups, the OECD area and the world, and provides a further breakdown of the fleet into the top-emitting ship types. This work makes use of the OECD's experimental maritime transport emissions database, which contains CO₂ emissions data from maritime transport (both domestic and international) by vessel type, covering nearly all countries. CO₂ emissions are estimated by the OECD using Automatic Identification System (AIS) data accessed via the United Nations Global Data Platform.

The results show that at the aggregate fleet level, the increase in emissions over the period was driven primarily by growth in economic activity, reinforced by rising transport intensity. These effects were only partly offset by improvements in fuel intensity and by a negative distance effect with the capacity underutilisation effect being positive for the world and negative for the OECD. The emission factor played only a minor role throughout the period. Across ship types, container ships contributed the most to the rise in emissions, followed by bulk carriers.

This study contributes to the existing research on monitoring and explaining maritime transport emissions in several ways. First, it is the first to present a side-by-side analysis of CO₂ emissions from maritime transport for the OECD and the world, allowing for a direct comparison of emission dynamics within a consistent analytical and methodological framework. Second, the analysis provides a detailed breakdown of trends and drivers by major vessel types, with a focus on the top-emitting ones, linking emission trends to underlying drivers such as changes in activities due to specific world events, fleet composition trends, and operational efficiency. Finally, this research makes use of the most recent data available, covering emissions up to the year 2024, thereby offering an up-to-date assessment of recent developments in the maritime sector.

This paper is organised as follows. Section 2 describes the methodology and data sources used for the decomposition analysis. Section 3 contains results, starting with an overview of recent trends in maritime transport CO₂ emissions, highlighting key developments across the OECD and the world, and across different vessel types. The decomposition results are then discussed, focusing on factor contributions by ship type. Section 4 discusses the results in light of other supporting data and policy developments and outlines potential directions for future research. Section 5 concludes.

2 Methodology and Data Sources

Methodology

Generally speaking, decomposition analysis provides a systematic method to disentangle the change in an aggregate such as CO₂ emissions into contributions from a set of factors or drivers. A decomposition approach is particularly well suited to the maritime transport sector where emissions are impacted by a combination of underlying factors: economic activity, trade dynamics, fuel use and technical efficiency. By expressing emissions as the product of these factors, it becomes possible to attribute changes in emissions over time to distinct effects.

In the field of decomposition analysis, one may distinguish between different traditions. In the area of environment, the literature often refers to structural decomposition analysis (SDA) reflecting that changes in the production structure of economies (as captured by Input-Output tables) are typically used as one of the explanatory factors. In the area of index number theory, where no Input-Output tables are applied, one often speaks about index decomposition analysis. In this paper we will use the generic term decomposition analysis, as we are not applying Input-Output tables, but are working in the environmental domain.

A challenge in applying decomposition analysis is that the decomposition forms, while being exact (i.e. not having any residuals), are not unique. Dietzenbacher and Los (1998^[5]) prove that when a decomposition into n factors is used, there are $n!$ possible decomposition forms. Practical applications such as De Haan (2001^[6]), who performed an SDA of pollution in the Netherlands, have therefore typically averaged across all possible decompositions to calculate their respective contributions. De Boer (2008^[7]) demonstrates that the use of a decomposition technique based on the logarithmic mean provides similar results as averaging across decomposition forms while being computationally much easier to apply. The Logarithmic Mean Divisia Index (LMDI) method, which applies the same approach, has been widely applied in energy and environmental studies because it ensures a complete decomposition without any residual differences. Furthermore, it produces results that are easily interpretable and is computationally efficient (Ang, 2015^[8]).

Earlier studies that have applied an LMDI approach in analysing maritime emissions include Yang and Ma (2019^[9]) who analyze CO₂ emissions from international shipping in China distinguishing between seven ship types covering the period 2000-2017, and Jeong and Yun (2024^[10]) who perform a decomposition analysis of CO₂ emissions from global shipping, distinguishing between five ship types covering the period 2007-2018 (**Table 2.1**)

Table 2.1. Comparison of maritime transport CO₂ emissions decomposition analyses

Study	Drivers	Scope	Ship types	Time period
Jeong and Yun	capacity, carbon intensity, distance , energy intensity, trade structure, transport scale	world	bulk carrier, chemical tankers, containers, gas tankers, oil tankers	2007-2018
Yang and Ma	economic development, emissions factor , energy intensity, population, trade structure, transport intensity	China-oriented international shipping	bulk carriers, chemical tankers, containers, gas tankers, crude oil carriers, oil product carriers, reefer cargos	2000-2017
OECD	capacity underuse, fuel intensity, distance, economic activity, emissions factor, transport intensity	OECD and world	all vessels, bulk carriers, chemical tankers, containers, cruise ships, oil tankers	2019-2024

Note: Drivers in bold denote drivers in common with this paper.

This paper applies an LMDI identity at the ship-type level to decompose CO₂ emissions into six factors: transport intensity, economic activity, capacity underutilisation, distance, emission factors, and fuel intensity. A key difference of this decomposition compared to the factors chosen in previous studies is that we have included a pure distance effect¹ to analyse the impacts of trade route disruptions such as in the Panama and Suez canals² as well as changes in trade routes as a result of geopolitical circumstances (e.g. sanctions, trade wars).

This formulation allows for insights into how these factors have jointly influenced maritime emissions. The results of the decomposition identify which drivers contribute the most to emissions growth, which provide mitigating effects, and where potential future reductions in emissions can come from.

LMDI Identity

Emissions for each ship type i can be expressed as a result of the terms expressed above:

$$E_i = \frac{TW_i}{GDP} \cdot GDP \cdot \frac{C_i}{TW_i} \cdot \overline{DIST}_i \cdot \frac{E_i}{FC_i} \cdot \frac{FC_i}{(\overline{DIST}_i \cdot C_i)} \quad (1)$$

Where E_i is the CO₂ emissions; TW_i is the transport work in tonne-miles; GDP is the real gross domestic product; C_i the total capacity supply in tonnes; \overline{DIST}_i the average capacity-weighted distance; and FC_i the fuel consumption (units).

And total emissions are the sum across ship types:

$$E = \sum_i E_i$$

Thus, emissions can be broken down into six separate factors:

Transport intensity [TI]

The transport intensity reflects the demand for maritime transport services relative to economic activity and is captured by the term $\frac{TW_i}{GDP}$. Transport work measures the volume of transport activity by multiplying the mass of cargo transported with the distance moved. Transport intensity indicates the extent to which maritime transport activity is coupled to economic growth; for example, an increase in transport intensity would indicate that maritime transport services are growing faster (or decreasing less) than economic activity.

Economic activity [GDP]

Economic activity is represented by real GDP which reflects the volume of economic activity in a given period. In the decomposition identity, GDP captures a scale effect, since larger economies generally require more maritime transport services to support production and consumption. Using GDP in constant prices ensures that only real changes in economic activity levels are captured, avoiding any distortions from price movements. This is particularly important given the period scrutinised (2019-2024), which has faced high levels of inflation related to COVID supply-chain disruptions, followed by Russia's full-scale invasion of Ukraine and its implications on prices of energy as well as agricultural and metal products largely sourced from Ukraine and Russia. Conceptually, maritime transport emissions correspond more closely to gross output, since transport demand is driven by the gross flow of goods rather than value added, but given data availability constraints, real GDP serves as a practical and widely used choice.

Capacity underutilisation [CAP]

The capacity underutilisation factor is measured as the ratio of available fleet capacity to transport work, $\frac{C_i}{TW_i}$. By construction, it is the inverse of fleet productivity (transport work per unit of capacity). An increase in the ratio means that the capacity supply has grown faster, or declined more slowly, than transport demand, implying a rising underutilisation of the fleet. Conversely, a decrease signals a more efficient and intensive use of existing capacity. Capacity (under)use is important for emissions because a fleet operating below optimal load factors will increase the emissions intensity relative to transport work.

For cargo vessels, the capacity is measured by deadweight whereas for passenger vessels and roll-on roll-off ships gross tonnage is used. A vessel's deadweight indicates how much mass a ship can carry, including cargo, fuel, ballast, passengers, and crew. The gross tonnage measures the internal volume of the ship and is a more suitable measure for vessels that transport passengers and cars since they occupy larger spaces than cargo but weigh much less (Olmer et al., 2017_[11]). For example, a cruise ship with 150,000 gross tonnage might only have a deadweight of 10,000 tonnes which is small compared to its actual operational scale. This is also in line with the IMO 2022 guidelines for calculating carbon intensity metrics which set out the use of gross tonnage for passenger vessels (IMO, 2022_[12]).

Distance [DIST]

The distance term shows the capacity-weighted average distance. This captures the geographical structure of transport flows, since carrying the same cargo load over longer distances requires more transport work and leads to higher emissions. Changes in the distance factor reflects shifts in trade routes such as rerouting caused by geopolitical or logistical disruptions.

A capacity-weighted average is used rather than total distance to maintain the consistency with use of distance in the denominator of the last term, $\frac{FC_i}{(DIST_i \cdot C_i)}$, which measures the nominal transport work capacity. This is because for ship type i , the nominal transport work capacity is calculated as $\sum_{j \in i} C_j * DIST_j$, across j vessels belonging to ship type i while this denominator is using total capacity, $C_i = \sum_{j \in i} C_j$. Therefore, in this case the nominal transport work capacity would need to be calculated as $C_i \cdot \frac{\sum_{j \in i} C_j * DIST_j}{C_i}$.

Emissions factor [EF]

The emissions factor term, $\frac{E_i}{FC_i}$, measures the carbon content of fuels, or the amount of CO₂ emitted per tonne of fuel consumed. It reflects the fuel mix used by the fleet; heavy fuel oil and marine diesel have relatively high carbon intensities whereas LNG and Methanol have lower emissions per unit of fuel (IMO,

2020^[3]). Historically, this factor has remained stable due to the dominance of oil-based fuels, but it is expected to play a larger role in decarbonisation efforts as lower-carbon fuels gain adoption.

Fuel intensity (Annual Efficiency Ratio) [AER]

The last term in the identity, $\frac{FC_i}{(DIST_i \cdot C_i)}$, represents the fuel intensity of the fleet. This measures the fuel consumption per unit of nominal transport work, defined as distance multiplied by capacity and can be considered a close proxy to the Annual Efficiency Ratio which uses carbon emissions in the numerator. An increase in the ratio means that the fleet is less fuel-efficient since fuel consumption is increasing faster or declining more slowly than nominal transport work; conversely a decrease indicates an improvement in fuel efficiency. Improvements in AER can arise from two sources: efficiency gains from operational improvements or cleaner technologies, and structural effects stemming from changes in fleet composition. For example, a vessel reducing its cruising speed significantly below its maximum speed, a practice known as slow steaming, will reduce fuel consumption and therefore emissions. Furthermore, if the fleet shifts towards larger ships, AER will decrease since larger ships are generally more efficient on a nominal capacity basis.

This intensity metric was first proposed by the IMO as a simplified alternative to the Energy Efficiency Operational Indicator (EEOI) which instead uses actual transport work in the denominator (TW_i) (IMO, 2020^[3]). The advantage of AER is that deadweight and gross tonnage capacity data is readily available whereas actual transport work must be estimated. This estimation issue is discussed in further detail in the data sources section below. From 2023, the AER indicator became a mandatory reporting item for all ships under the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 2023^[4]).

Therefore, with these six factors, equation 1 above can be re-expressed as:

$$E_i = TI_i \cdot GDP \cdot CAP_i \cdot DIST_i \cdot EF_i \cdot AER_i \quad (2)$$

Deriving factor contributions

Using an additive decomposition form, the changes in CO₂ emissions from one year to the next can be expressed as the sum of factor-specific changes (see Annex):

$$\Delta E_{i,t} = E_{i,t} - E_{i,t-1} = \Delta TI_{i,t} + \Delta GDP_t + \Delta CAP_{i,t} + \Delta DIST_{i,t} + \Delta EF_{i,t} + \Delta AER_{i,t} \quad (3)$$

Applying the LMDI formula for individual factor contributions yields:

$$\Delta TI_{i,t} = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{TI_{i,t}}{TI_{i,t-1}} \right) \quad (4)$$

$$\Delta GDP_t = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{GDP_t}{GDP_{t-1}} \right) \quad (5)$$

$$\Delta CAP_{i,t} = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{CAP_{i,t}}{CAP_{i,t-1}} \right) \quad (6)$$

$$\Delta DIST_{i,t} = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{DIST_{i,t}}{DIST_{i,t-1}} \right) \quad (7)$$

$$\Delta EF_{i,t} = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{EF_{i,t}}{EF_{i,t-1}} \right) \quad (8)$$

$$\Delta AER_{i,t} = L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{AER_{i,t}}{AER_{i,t-1}} \right) \quad (8)$$

Where $L(x, y)$ denotes the logarithmic mean defined as $L(x, y) = x$ if $x=y$, otherwise

$$L(x, y) = \frac{x-y}{\ln x - \ln y}$$

Each factor's contribution is determined by how much it changed from $t - 1$ to t , relative to the other factors, and by the difference in the amount of CO₂ emissions between the two years. The logarithmic mean acts as a weight that balances the influence of the previous and current year, so that the decomposition does not depend on which year is chosen as the reference. In this way, the LMDI method completely attributes the entire change in emissions to the six drivers without any residual difference.

Data description and sources

Fuel consumption and CO₂ emissions

The OECD maritime transport database estimates fuel consumption (in million tonnes of fuel) and CO₂ emissions (in million tonnes of CO₂) by applying the IMO 4th GHG Study methodology (IMO, 2020^[3]). While this analysis focuses exclusively on CO₂ emissions and does not include other greenhouse gases or air pollutants, the IMO GHG Study notes that non-CO₂ emissions represent only a small share of total climate-relevant emissions from international shipping.

This data is calculated at the vessel level using ship-tracking information collected via Automatic Identification System (AIS) data³ accessed via the UN Global Data Platform. While AIS provides near-global coverage, it does not capture all maritime activity, gaps may occur in regions with limited satellite reception or due to vessels intentionally operating without transmitting signals (so-called “dark fleet” activity). This is discussed in more detail in the Discussion section.

Country-level emissions (that are used in the OECD aggregate) are determined using the residence principle, whereby vessel-level emissions are attributed based on the economic residence of the vessel operator. In this way, the emissions are in line with the System of Environmental Economic Accounting (SEEA) central framework accounting principles. This attribution is done using vessel-level metadata available in the Information Handling Services (IHS) Markit ship registers which is also available on the UN platform. Emissions data for individual countries as well as the OECD and the world are made publicly available on the OECD data explorer. Further details on the [dataset](#) methodology are discussed in the OECD database methodology update note (OECD, 2025^[13]).

Distance

Distance data are calculated using geodesic measurements between consecutive coordinate points transmitted by AIS messages for individual vessels. This measurement, which considers the curvature of the Earth's surface, yields daily total distances for all vessels. Due to data quality issues, such as lost signals or invalid coordinate positions, the data is filtered to remove invalid positions that would lead to erroneous voyage segments using the methodology described in Clarke et al. (2023^[14]).

Vessel characteristics data

Ship types are identified by mapping the IHS ship type coding system (StatCode 5) (S&P Global Market Intelligence, 2023^[15]) to the IMO vessel classification, which distinguishes between 19 vessel categories.⁴ In the decomposition analysis, all ship types are separately calculated, but in the results we will separately analyse container ships, bulk carriers, chemical tankers, and oil tankers (the four vessel categories responsible for most of the emissions), as well as cruise ships (as an important contributor to changes in emissions over the period scrutinised), with all other ship types aggregated as a category “other”.

Similarly, deadweight and gross tonnage data are sourced from the ship registers. Additional vessel characteristics data from ship registers is used in the analysis of fleet evolution. These include the date of

build, which is used to calculate a vessel's age at the beginning of a given year. Design efficiency is a derived variable, measured as the ratio of engine power to deadweight tonnage or $\frac{kW}{DWT}$.

GDP

Real GDP for the OECD is sourced from the OECD national accounts database whereas world GDP is taken from the World Bank World Development Indicators database. The data is expressed in purchasing power parity (PPP)-adjusted 2020 US dollars using chain-linked volume measures.

Transport work

As noted above, transport work measures the volume of transport activity by multiplying the cargo tonnage carried by the distance travelled, including both laden and ballast voyages when the ship does not carry cargo (e.g. oil tankers or bulk carriers travelling back empty). Unlike cargo volume data which only considers the amount of cargo loaded or discharged, transport work accounts for how far the cargo is carried.

Since cargo carried is typically not reported by vessel operators, this must be estimated. The IMO describes an intensive estimation procedure in Annex D of their 4th GHG Study report (IMO, 2020_[3]). This entails quantifying voyage specific cargo levels based on lightweight, ballast/laden conditions and block coefficients. Alternatively, Olmer et al. (2017_[16]) note that AIS vessel draught data can be used to estimate cargo carriage along with simplifying assumptions on fuel and ballast loads. This study follows this latter approach by using the following proxy for cargo carried for each vessel j :

$$TW_{j,t} = \left(\frac{d_{j,t}}{rd_j}\right) \cdot C_j \cdot \rho_{i,s} \cdot DIST_{j,t}$$

Where $d_{j,t}$ is the recorded draught at time t , rd_j is the vessel's reference design draught, C_j the vessel capacity as either deadweight or gross tonnage depending on the ship type, $\rho_{i,s}$ a payload use correction factor based on the ship type i and ship type size bin s , and $DIST_{j,t}$, the distance travelled.

The payload use correction factor accounts for how much on average a vessel's weight is taken up by cargo or passengers. These correction factors are based on IMO reports (2015_[17]) as well as Olmer et al.'s (2017_[16]) discussion on draught correction factors. Comparing the results from this proxy method for the year 2019 with 2018 estimates from the IMO and UNCTAD, the most recent available data, show that they generally are near or within the range of these two sources (**Table 2.2**).

Table 2.2. Transport work estimations

Billion tonne-miles

	IMO (2018)	UNCTAD (2018)	OECD (2019)
Dry cargo	28,464	34,193	33,744
Chemical tanker	3,990	1,111	1,545
Container	15,153	9,535	9,568
Liquefied gas tanker	3,484	1,766	3,782
Oil tanker	14,343	13,809	15,507

Source: IMO 4th GHG Study (2020_[3]) option 1 methodology; UNCTAD Review of Maritime Transport (2018_[18]); OECD 2019 estimates

Note: Dry cargo comprises bulk carrier, general cargo, and refrigerated bulk vessels

3 Results

This section first describes the overall trends in maritime CO₂ emissions based on the OECD dataset. The second subsection presents the results of the decomposition analysis for the 2019-2024 period at the aggregate level. The third subsection analyses the changes for the main ship categories.

Overall trends

Annual trends for global and OECD CO₂ emissions

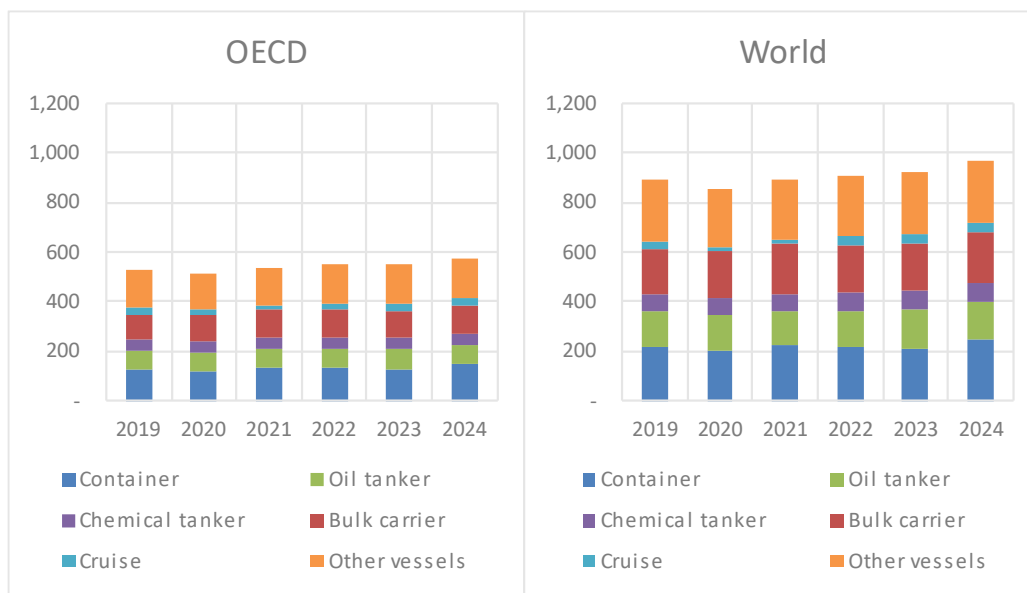
Between 2019 and 2024, global maritime transport emissions rose from 889.5 to 972.8 million tonnes of CO₂ (MtCO₂), representing an increase of 9.3% during this period. For OECD countries, emissions rose by 7.7%, from 529.9 to 571.1 MtCO₂ (**Figure 3.1**). Despite the slightly lower growth in emissions in the OECD area, their share has remained broadly stable over this period, accounting for around 60% of global emissions in both 2019 and 2024.

Container ships and bulk carriers contribute the most to global CO₂ emissions. Container ships transport a wide array of manufactured goods while bulk carriers carry essential raw materials such as grains, iron ore, and coal. On average over the period, container ships accounted for 24.2% of total global and OECD CO₂ emissions while bulk carriers made up around 21.3%. From 2019 to 2024 CO₂ emissions from container ships rose by 22.1% in the OECD and 14.7% in the world whereas emissions from bulk carriers rose by 5.0% in the OECD and 10.6% in the world (**Figure 3.2**).

The next largest contributors are oil and chemical tankers, which together account for around a quarter of total emissions in the world and slightly more than a fifth in the OECD. Oil tanker emissions rose by 7.9% in the world and 0.4% in the OECD, whereas chemical tanker emissions rose by 10.8% at the global level and 2.9% in the OECD. Emissions from all other vessel types, such as cruise ships, accounted for approximately a third of emissions across this period (in the world as well as the OECD).

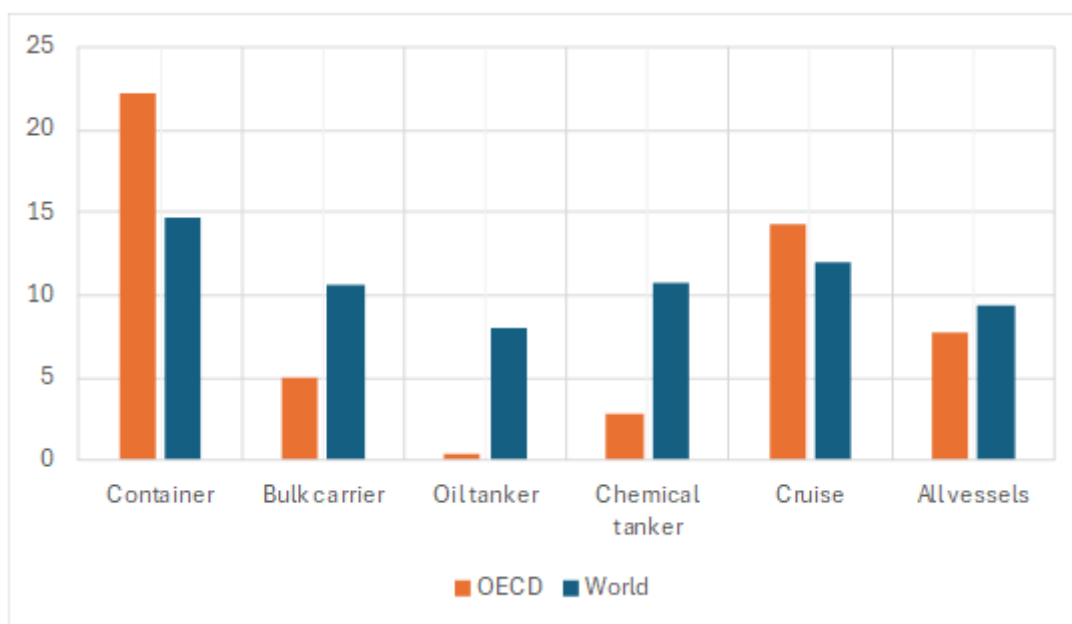
Figure 3.1. CO₂ emissions from maritime transport in OECD and the world, by ship type

Million tonnes CO₂ (MtCO₂)



Source: OECD Maritime Transport Emissions database

Figure 3.2. Percentage changes in CO₂ emissions from 2019 to 2024, by ship type



Source: Authors' calculations

Decomposition analysis at the aggregate level (all vessel types)

Applying the decomposition analysis described in Section 2, it is possible to disentangle the cumulative and year-to-year contribution of the six drivers of CO₂ emissions examined independently of each other:

transport intensity, economic activity, capacity underutilisation, distance, emission factors, and fuel intensity. This allows identifying which drivers contributed the most to emissions growth, which provided mitigating effects, and which levers are available to policymakers and ship operators in their efforts to achieve future reductions in emissions.

Table 3.1 contains the results for the decomposition analysis for the whole period 2019-2024, separately for the world and the OECD, broken down by the ship categories under scrutiny. The sum of the six decomposition effects for each of the ship categories adds up to the total change in CO₂ emissions.

Table 3.1. Decomposition analysis 2019-2024: effects by factor and ship type in MtCO₂

Ship type	Δ CO ₂	Transport intensity	Economic activity	Under-utilisation	Distance	Emission factor	Fuel intensity	Contributions
OECD								
Container	27.6	34.8	11.9	-4.6	-1.4	-0.1	-13.0	67%
Bulk carrier	5.2	7.3	9.2	-4.7	2.5	0.0	-9.1	13%
Oil tanker	0.3	-1.1	6.5	-2.2	1.8	0.0	-4.7	1%
Chemical tanker	1.3	-4.4	3.9	3.3	0.4	-0.4	-1.6	3%
Cruise	4.0	4.0	2.6	-0.1	0.1	-0.1	-2.5	10%
Other vessels	2.7	-4.4	13.3	5.8	-6.6	0.2	-5.4	7%
All vessels	41.1	36.2	47.4	-2.5	-3.2	-0.4	-36.3	100%
World								
Container	31.5	31.0	31.2	-5.1	-3.5	-0.1	-22.0	38%
Bulk carrier	19.6	11.2	26.5	-9.4	5.3	0.0	-13.9	24%
Oil tanker	11.5	-4.6	20.5	1.7	-1.8	0.0	-4.3	14%
Chemical tanker	7.5	-6.3	9.9	5.7	0.0	-0.3	-1.5	9%
Cruise	3.9	1.9	4.7	0.1	0.0	-0.1	-2.6	5%
Other vessels	9.3	-23.1	34.1	15.5	-16.1	0.3	-1.6	11%
All vessels	83.3	10.1	126.9	8.5	-16.1	-0.2	-44.8	100%

Note: The contributions column shows the cumulative percentage contribution of vessel-level changes in CO₂ emissions to the overall change in CO₂ emissions over the period 2019-2024.

Source: Authors' calculations

Between 2019 and 2024, maritime transport CO₂ emissions increased cumulatively by 41.1 million tonnes (+7.7%) in the OECD and by 83.3 million tonnes (+9.3%) globally. This is the result of mixed contributions over time (**Figure 3.3**), with some years recording a drop in emissions (notably 2020 but also 2023 for the OECD area), while others showing large increases. This mixed picture may be driven by the impact of specific global events, such as the Covid-19 pandemic and the emergence of geopolitical events.

The economic activity factor emerges as the dominant driver of emissions in both aggregates, with the effect for the world being more pronounced (126.9 MtCO₂ versus 47.4 MtCO₂ for the OECD area). This reflects the scale of the post-pandemic rebound in industrial output and trade. In 2020, the Covid-19 pandemic led to a drop in economic activity which reduced emissions, but the recovery and subsequent rise in economic activity in the following years had an important positive effect on emissions (**Figure 3.3**).

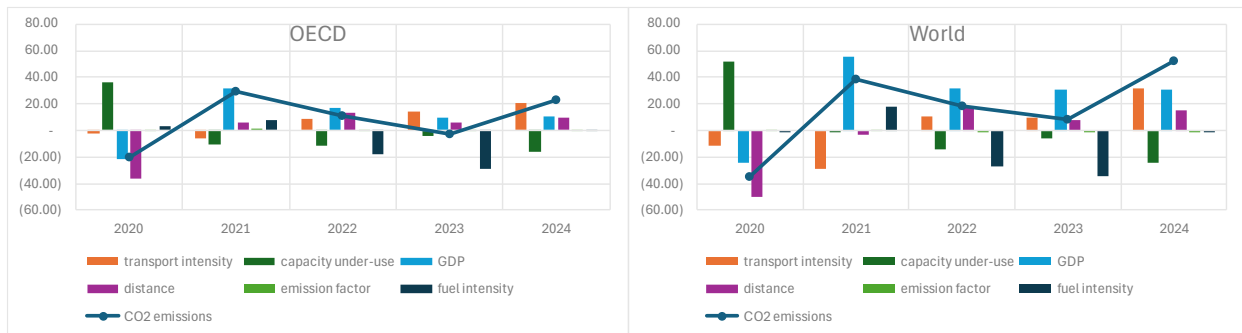
The transport intensity effect is the second largest positive effect, indicating that the growth in the demand for seaborne transport outpaced GDP growth. It still had a negative contribution in 2020 and 2021, but showed continuous increases from 2022 to 2024, leading to an overall positive contribution for the full time period.

The largest negative effect was fuel intensity, reflecting that less fuel was used per unit of nominal capacity (deadweight-nautical miles), with particularly large negative contributions in 2022 and 2023. This is followed by the distance effect at the global level, illustrating the decrease in average distance travelled per unit of capacity. In 2020, this had a negative impact (and to a certain extent still also in 2021 at the global level), related to the Covid-19 pandemic, but showed consistent positive contributions in the subsequent years.

The capacity underuse had different impacts in the OECD area and the world. It contributed substantially to an increase in CO₂ emissions in 2020, also related to the Covid-19 pandemic as transport work fell relative to available capacity which increased the underutilisation of the fleet. In subsequent years, capacity underuse contributed to a reduction in emissions, signalling fleet productivity gains. Over the full period, this led to an overall reduction in emissions in the OECD area, while remaining a slight driver of increased emissions at the global level by 2024. Finally, the impact of the emission factor is negligible, being close to zero for most of the years.

Figure 3.3. Year-on-year changes in CO₂ emissions in the OECD and world

Million tonnes CO₂



Source: Authors' calculations

Decomposition results at vessel type level

Examining the decomposition results by top-emitting ship types provides further insight into the drivers of CO₂ emissions. Variations in these drivers reflect the influence of three main forces: exogenous shocks, fleet dynamics, and environmental regulation. Since ship types differ in their operational patterns and cargo profiles, they are affected by these forces in distinct ways. In many cases, sharp year-over-year changes are closely associated with short-term exogenous shocks, such as the Covid-19 pandemic or geopolitical disruptions, whereas developments related to the fleet and regulation tend to manifest as more gradual, structural shifts. However, these forces can overlap in time and the decomposition results provide descriptive evidence on how the different drivers evolve rather than a strict causal attribution. The Discussion section examines the structural and regulatory dimensions in greater depth.

By looking at the last column of **Table 3.1** one can observe that container ships contributed the most to the increase in emissions (67% in OECD and 38% globally), followed by bulk carriers (respectively 13% and 24%). Notwithstanding that cruise ships are not a top-emitting vessel type, making up around 3-4% of total emissions in years with normal operations, they contributed 10% to increase in emissions for the OECD and 5% for the world.

Container ships

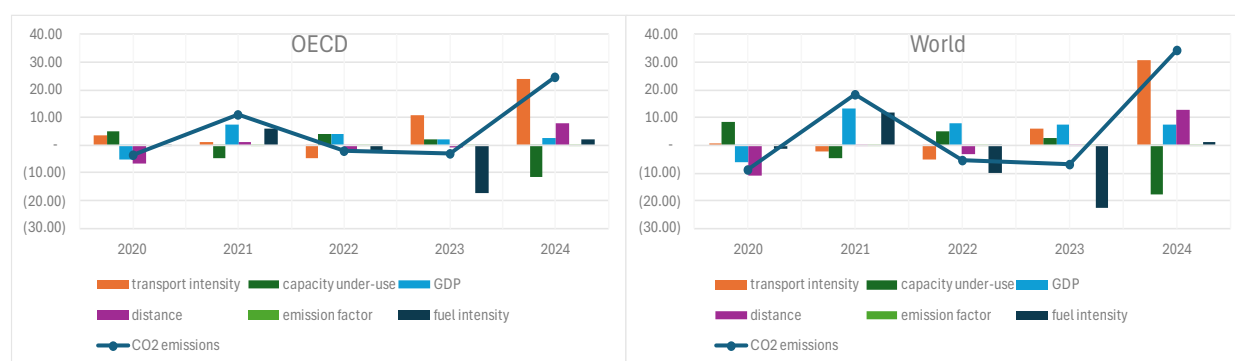
A container ship is a cargo vessel designed and equipped to carry standardised intermodal containers, typically measured in twenty-foot equivalent units (TEUs), on regular liner services between major ports.

Between 2019 and 2024, CO₂ emissions from container ships increased markedly, rising by about 27.6 MtCO₂ (+22.1%) in the OECD and 31.5 MtCO₂ (+14.7%) globally. The decomposition shows that transport intensity and economic activity were the main drivers of this growth. These upward pressures were only partly offset by improvements in fuel intensity and better capacity utilisation, while the overall impact of distance and fuel emissions factors was minor.

In 2020, emissions fell in both aggregates (**Figure 3.4**) as the pandemic disrupted global trade, mainly due to shorter voyage distances and decreased economic activity as demand on major trade routes, such as westbound Asia-Europe and eastbound trans-Pacific, decreased by approximately 10% in 2020 compared to 2019 (UNCTAD, 2020[7]). In 2021, emissions rebounded strongly with the recovery in GDP and trade volumes.

Figure 3.4. Year-to-year changes in container CO₂ emissions

Million tonnes CO₂



Source: Author's calculations

In 2023, container ships' emissions declined at both the global and OECD levels, driven by major improvements in fuel intensity, supported by a structural shift in the fleet composition towards larger ships, slower sailing speeds, and the implementation of new IMO carbon-intensity regulations. These factors substantially reduced emissions per tonne-mile (UNCTAD, 2024[11]).

In 2024, emissions strongly rose as transport intensity and voyage distances increased, the latter factor largely due to rerouting around the Cape of Good Hope following the Red Sea crisis, which severely curtailed Suez Canal transits for container ships. The Red Sea crisis affected container ships more severely than bulk carriers and tankers: between 2023Q3 and 2024Q3, container ship transits through the Suez Canal decreased by about 74% in number and by approximately 91% in volumetric cargo capacity (Suez Canal Authority, 2025_[19]). The impact was only partly offset by better capacity utilisation, as carriers absorbed some of the excess fleet capacity built up since 2022 (Notteboom et al., 2024_[20]).

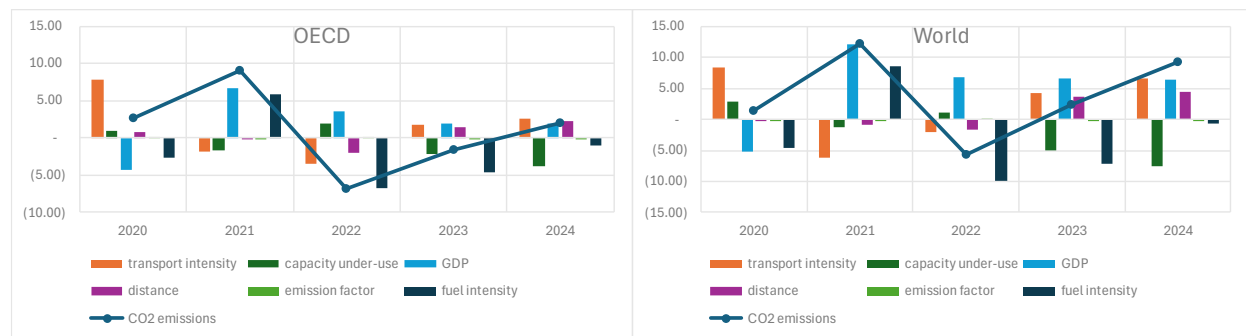
Bulk carriers

Bulk carriers form the backbone of dry cargo shipping, transporting coal, iron ore, and grain. Emissions are largely influenced by shifts in industrial activity and trade policy in China, as it dominates global coal and iron ore imports.

From 2019 to 2024, global emissions from bulk carriers rose by 19.6 MtCO₂ (+10.7%) (**Table 3.1**). The decomposition analysis shows that this was driven by strong positive effects from economic activity and transport intensity, which outweighed the cumulative negative effects from fuel intensity and capacity underutilisation. OECD trends broadly mirrored global patterns, with emissions increasing by 5.2 MtCO₂ (+6.3%). Smaller fluctuations observed in the OECD aggregate reflect the influence of major non-OECD shipping operators on global dynamics.

Figure 3.5. Year-to-year changes in bulk carrier CO₂ emissions

Million tonnes of CO₂



Source: Authors' calculations.

Looking at the year-to-year dynamics (**Figure 3.5**) shows that GDP growth was a constant driver of emissions, contributing positively in all years except 2020. After the pandemic-related contraction, economic recovery in 2021 generated a strong rebound in bulk trade (UNCTAD, 2022^[21]). Continued industrial demand from China, particularly for coal and iron ore, maintained upward pressure through 2024 (UNCTAD, 2025^[1]).

Transport intensity also played a major role, reflecting strong demand for bulk cargo. It remained positive for most years, except 2021 and 2022, when tonnage on the Australia-China route fell following China's import ban on Australian coal and iron ore, despite strong GDP growth (UNCTAD, 2021^[22]).

Fuel intensity was the most volatile component, negative in 2020 and over 2022-2024 but sharply positive in 2021. The 2021 rise stemmed from port congestion and rerouting disruptions (UNCTAD, 2022^[21]). Declines in 2022 and 2023 reflected slower sailing speeds linked to lower ballast speeds⁵ amid geopolitical uncertainty in the Black Sea (The Signal Group, 2022^[23]) and new IMO regulations (UNCTAD, 2024^[24]). By 2024, these effects weakened and limited fleet expansion further constrained these gains. The role of fleet expansion and IMO regulations are further investigated in the Discussion section.

The distance effect was modest early in the period but became increasingly positive after 2022. This reflected longer voyages as trade diversified toward more distant grain suppliers, such as the United States and Brazil, amid Russia's ongoing war of aggression against Ukraine. This was compounded by the Panama Canal transit restrictions caused by drought in 2023, which forced rerouting across the Pacific (UNCTAD, 2024^[24]).

Capacity under-use declined from 2021, briefly rising in 2022 following Russia's invasion of Ukraine, before declining again thereafter. The overall decline reflects a tightening market balance as demand continued to strengthen amid only limited fleet growth.

The effect of the emission factor remained negligible, as bulk carriers were slow to adopt alternative fuels and continued to rely on oil-based fuels (Det Norske Veritas, 2024^[25]), keeping emissions coefficients largely unchanged.

Oil tankers

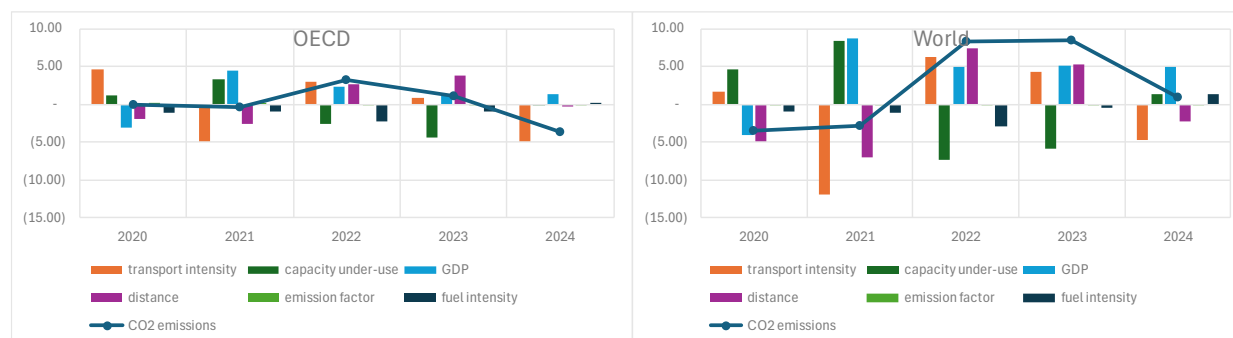
Oil tankers are vessels designed to transport crude oil and refined petroleum products. They range from smaller product tankers to Very Large Crude Carriers (VLCCs) and Ultra Large Crude Carriers (ULCCs) capable of carrying over two million barrels of oil (UNCTAD, 2025^[11]).

Between 2019 and 2024, CO₂ emissions from oil tankers remained broadly stable in the OECD, rising by only 0.3 MtCO₂ (+0.4%) (Table 3.1). This represented a 1% contribution to the change in total OECD maritime transport CO₂ emissions. At the global level, they increased by about 11.5 MtCO₂ (+7.9%), accounting for 14% of change in total world emissions. The decomposition shows that economic activity was the dominant driver of emissions growth in both aggregates, partly offset by improvements in fuel intensity and a more efficient use of capacity

At the global level, the yearly changes in emissions reveal sharp responses to volatile market conditions (Figure 3.6). The drop in emissions observed in 2020 was driven by shorter voyage distances and decreased economic activity. This was partially offset by higher capacity under-use and increased transport intensity. The contribution from the latter factor may be partly explained by the use of VLCCs for temporary offshore storage for surplus crude oil (Lloyd's Register, 2020^[26]). In 2021, emissions continued to decrease as the recovery in GDP and higher capacity under-use were offset by weaker transport demand and lower average distances.

Figure 3.6. Year-to-year changes in oil tanker CO₂ emissions

Million tonnes CO₂

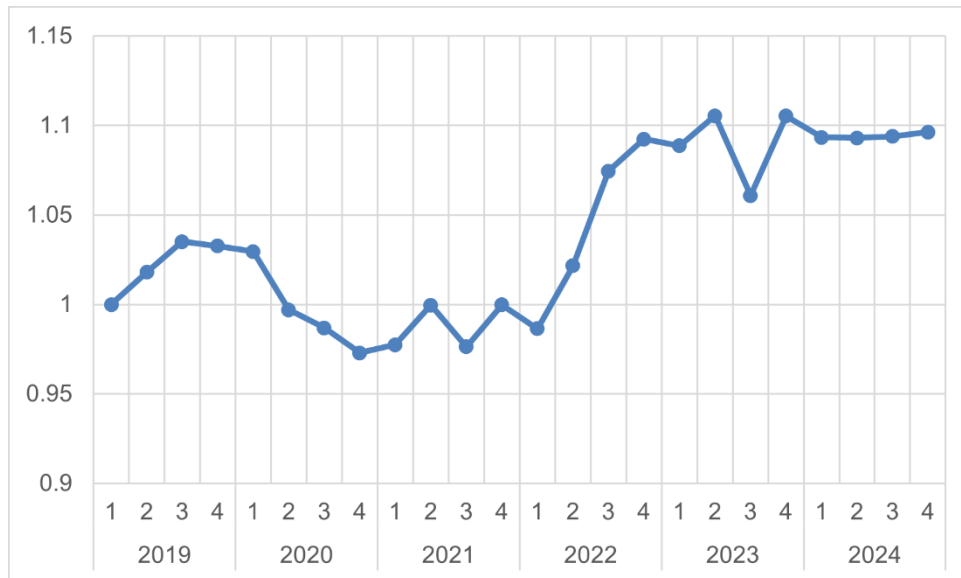


Source: Authors' calculations.

Emissions rose in 2022 and 2023 in both aggregates, driven by strong transport demand, longer voyage distances, and continued economic recovery. These increases were closely tied to geopolitical disruptions following Russia's invasion of Ukraine, which reshaped global oil trade flows. Russian crude oil, previously shipped over gas pipelines and short maritime routes to Europe, was redirected to more distant markets such as India and China, while European refiners substituted Russian oil with imports from North America, lengthening transatlantic routes and boosting transport work (UNCTAD, 2023^[27]). Figure 3.7 shows that total quarterly distances covered by oil tankers rose significantly starting in 2022-Q2, shortly after Russia's invasion of Ukraine.

Figure 3.7 Global oil tanker fleet distances

Index, 2019 Q1 = 1



Source: Authors' calculations

Chemical tankers

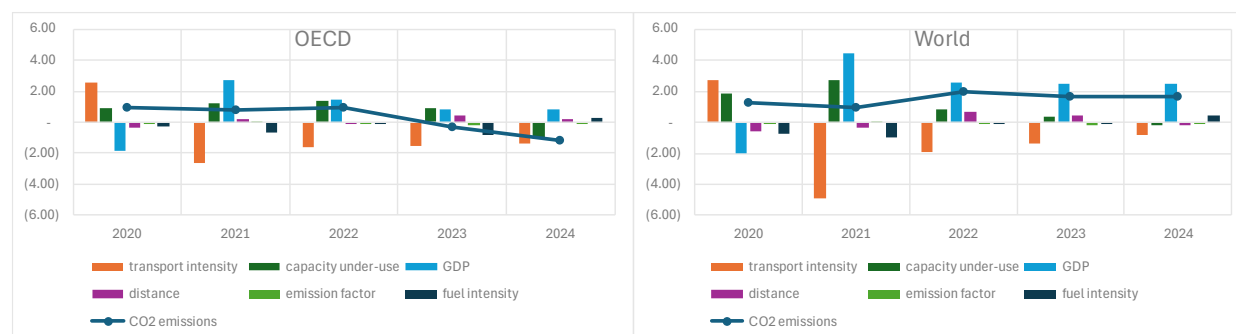
Chemical tankers are specialised vessels designed to transport liquid chemical products in bulk, including feedstocks for plastics and solvents, as well as other liquid cargoes such as vegetable oils and lubricants (Jetlund and Karimi, 2004^[28]).

Between 2019 and 2024, CO₂ emissions from chemical tankers increased by 1.3 MtCO₂ (+2.9%) in the OECD and 7.5 MtCO₂ (+10.8%) globally (**Table 3.1**). The decomposition results indicate that this growth was mainly driven by economic activity and capacity under-use, partly offset by lower transport intensity and fuel efficiency gains.

Emissions from chemical tankers rose in 2020 in both aggregates, reflecting the sector's resilience to the COVID-19 downturn (**Figure 3.8**). This increase was driven by continued transport demand and fleet expansion, as new vessels entered service with shorter average distances and lower load factors. **Figure 3.9** below shows the fleet size evolution relative to 2019. Fuel-intensity improvements were limited, leading to a net rise in emissions.

Figure 3.8. Year-to-year changes in chemical tanker CO₂ emissions

Million tonnes CO₂



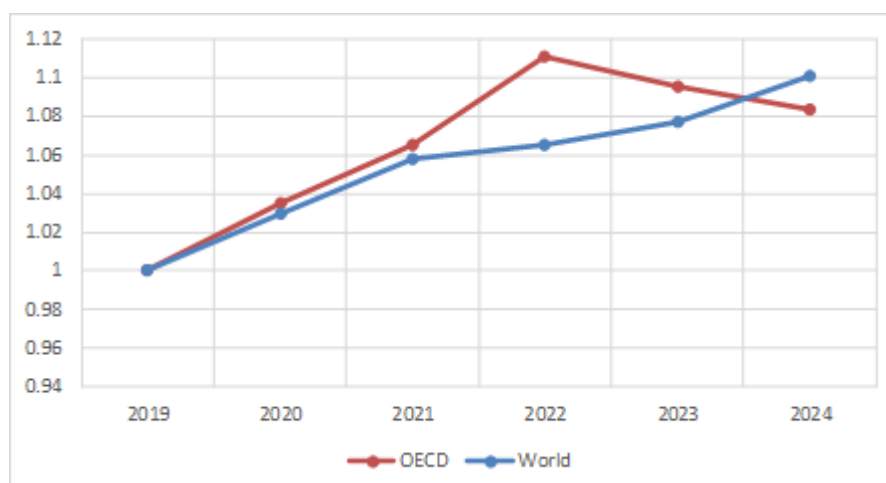
Source: Authors' calculations

In 2021 and 2022, emissions continued to increase in both the OECD and world, driven primarily by economic activity and capacity under-use. The rebound in GDP outpaced the relatively stable level of transport work, resulting in a negative contribution from transport intensity. At the same time, the addition of new vessels increased the capacity supply and therefore added to emissions through capacity under-use effects.

In the OECD, emissions began to decline in 2023, supported by improved carbon efficiency and lower transport demand, while still partly offset by economic growth and residual overcapacity. The decline continued in 2024, as fleet reductions lowered both transport work and capacity supply, reducing capacity under-use for the first time in the period. Globally, however, emissions continued to rise in 2023 and 2024, driven mainly by sustained economic activity with lower transport intensity providing the main offsetting effect.

Figure 3.9. Chemical tanker fleet size evolution

Index, 2019 = 1



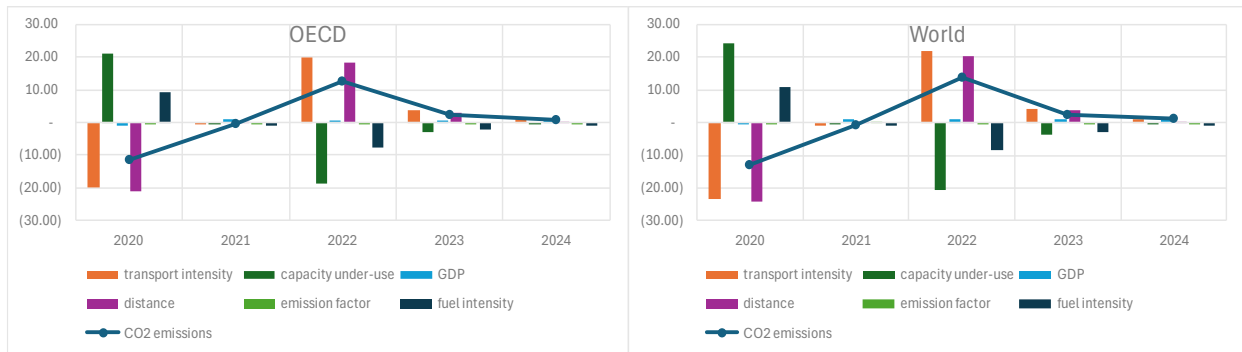
Source: Authors' elaboration based on ship registry data.

Cruise ships

Between 2019 and 2024, CO₂ emissions from cruise ships show an exceptional pattern of collapse and recovery, resulting in an overall increase of 4.0 MtCO₂ (+14.3%) in the OECD and 3.9 MtCO₂ (+11.9%) in the world⁶ (Table 3.1). Looking at the year-to-year dynamics reveals similar patterns in both aggregates since under the SNA residence principle, most cruise ship operators are resident units in OECD countries.

Figure 3.10. Year-to-year changes in cruise ship CO₂ emissions

Million tonnes CO₂



Source: Authors' calculations

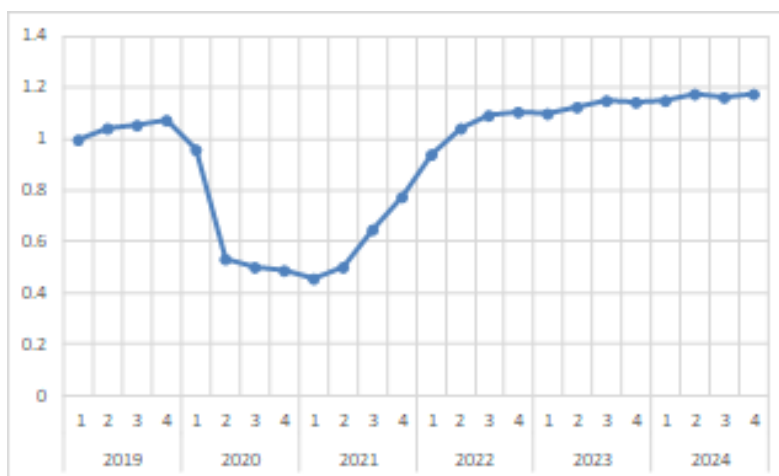
In 2020, emissions fell by 40.4% in both aggregates with a decrease of 11.5 MtCO₂ in the OECD and 13.1 MtCO₂ in the world as cruise operations were halted during the Covid-19 pandemic (Figure 3.10). The decomposition results attribute this drop to large decreases in transport demand and distances travelled, partly offset by increases in capacity under-use and fuel intensity.

Most of the decline occurred in 2020Q2 (Figure 3.11), coinciding with the U.S. Center for Disease Control's (CDC) "no sail" order (CDC, 2020^[29]) and the widespread suspension of cruise operations in Europe (European Maritime Safety Agency, 2021^[30]). Some emissions persisted due to repatriation voyages and hoteling emissions from docked vessels (Climate TRACE, 2023^[31]). Emissions remained low through early 2021 but began to rise from 2021Q1, marking the start of a steady recovery.

By 2022, emissions had returned to near pre-pandemic levels, increasing by 12.8 MtCO₂ in the OECD, driven by rising transport demand and longer sailing distances as cruise activity resumed. Gains in fleet productivity (lower capacity under-use) and fuel intensity improvements moderated the rebound in emissions, which continued to rise more gradually from 2022 to 2024 due to the same factors.

Figure 3.11. Evolution of quarterly cruise ship CO₂ emissions

Index, 2019 Q1 = 1



Source: Authors' calculations

4 Discussion

The results of the decomposition analysis indicate that factor contributions vary substantially across years and vessel type. Variations in these factors reflect the interaction of three broad determinants: exogenous shocks, fleet dynamics, and environmental regulation.

Exogenous shocks, such as disruptions to trade routes or fluctuations in global demand, primarily affect economic activity, transport intensity, capacity under-utilisation, and distance, manifesting through changes in routing patterns, congestion, and commodity flows.

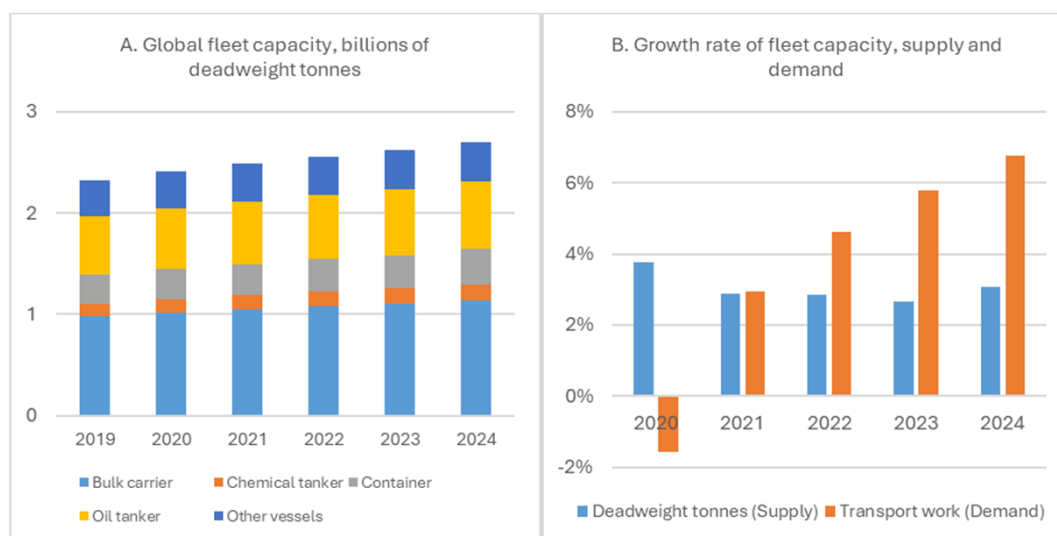
While such shocks explain short-term fluctuations, emission trends are shaped as well by fleet structure and regulatory frameworks, which together determine the sector's efficiency and fuel consumption. For instance, changes in fuel intensity arise from both structural effects and operational efficiency gains. The former reflects shifts in fleet composition, such as age, vessel size, and technology, while the latter increasingly results from environmental regulations promoting energy efficiency and cleaner fuels. The emissions factor depends on the fuel mix of the existing fleet and reflects the pace of alternative fuel adoption within the fleet.

As a result, the discussion now turns to the areas where policy can play a decisive role, namely, the evolution of the fleet and the implementation of environmental regulation. The following section is structured accordingly: it first examines these two developments, then concludes with the main limitations of the analysis and possible directions for future work.

Evolution of the fleet

The evolution of the global merchant fleet directly shapes several of the key factors driving maritime emissions through changes in both capacity supply and composition. Capacity utilisation reflects how much of the existing fleet can meet growing demand and is influenced by the rate of vessel renewal and scrapping. The fleet's age profile and vessel size affect fuel intensity: older vessels are generally less efficient in terms of emissions (UNCTAD, 2024^[24]), while a shift towards larger ships improves average efficiency as large vessels emit less CO₂ per tonne-mile. Moreover, the emissions factor is determined not only by the types of fuels used, but also by the deployment of emissions saving technologies (OECD, 2025^[32]). The following section examines these structural dynamics.

Figure 4.1. Evolution and dynamics of the global shipping capacity, 2019-2024



Source: Authors' elaboration based on ship registry data.

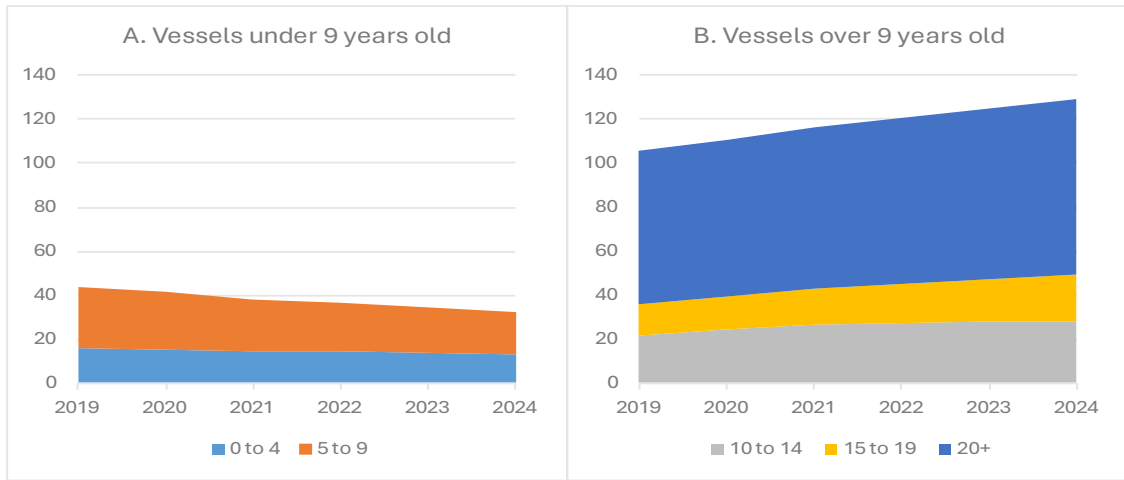
In 2024, the global merchant fleet capacity reached around 2.7 billion deadweight tonnes (**Figure 4.1**, Panel A). Bulk carriers accounted for the largest share, representing about 42.1% of total capacity, followed by oil tankers at 24.6% and container ships at 13.2%. Other vessel types, including general cargo and passenger ships, made up roughly 14.5% of total capacity, while chemical tankers represented about 5.5%. Although the composition of the global merchant fleet has remained largely stable since 2019, reflecting consistent demand across major cargo segments, the pace of supply growth has slowed significantly. Global fleet deadweight tonnage rose by about 3.0% per year over the 2019 to 2024 (**Figure 4.1**, Panel B), down from an annual average of 5.3% during 2009 to 2018

Fleet capacity reflects the total available carrying capacity of ships, in deadweight tonnes, and represents the supply side of maritime transport. In contrast, capacity demand refers to the use of that carrying capacity, represented by transport work. When demand for transport service grows faster than fleet capacity, this implies a higher utilisation of the existing fleet rather than an expansion of physical supply.

Over the period 2019-2024, the strong rebound in capacity demand markedly exceeded the pace of fleet growth. After contracting during the pandemic (-1.6%), demand growth accelerated sharply by 2024 (+6.8%). This expansion was reinforced by longer voyage distances stemming from rerouting and disruptions at key maritime chokepoints (UNCTAD, 2024^[24]). This resulting gap between demand and supply tightened market conditions and raised fleet utilisation (UNCTAD, 2025^[1]). This relationship between fleet capacity supply and demand aligns with the decomposition analysis, where 2020 showed a large positive contribution to CO₂ emissions from the underutilisation factor to emissions for both the global and OECD totals (+51.7 and +36.6 Mt CO₂), indicating an oversupply of vessel capacity. This was followed by a reduction in the same factor over the remainder of the period (**Figure 3.3**).

Figure 4.2. Age profile of global fleet

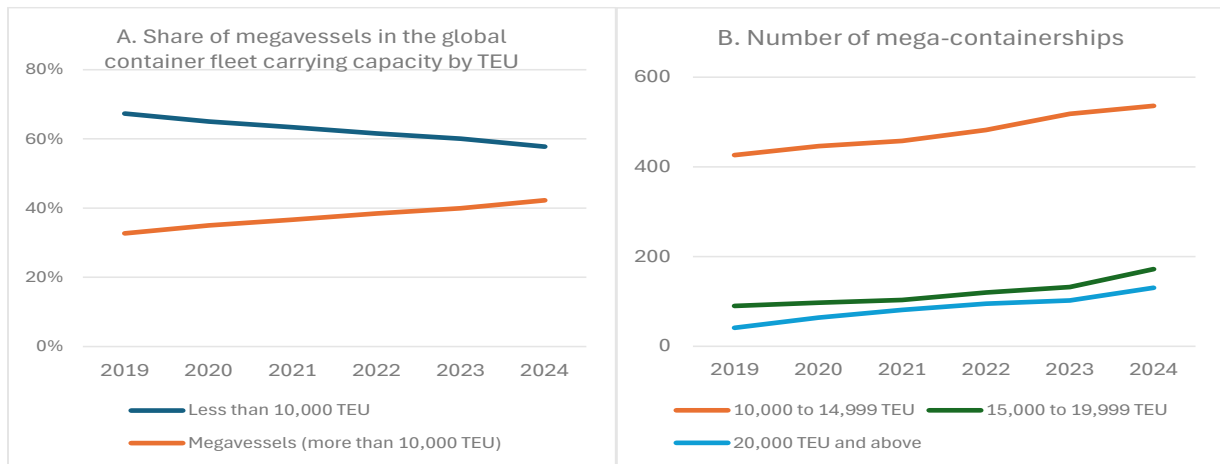
Number of vessels, in thousands



Source: Authors' elaboration based on ship registry data.

The slow turnover of vessels is evident in the age structure of the fleet. The composition of the fleet reveals a clear ageing trend (Figure 4.2, Panels A & B). From 2019 to 2024, the number of vessels aged 20 years or more increased from around 70,000 to nearly 80,000, while those in the 15 to 19-year age range grew from about 13,700 to 21,700. This shift reflects a steady movement of ships into older age brackets and highlights the slow pace of fleet renewal and the delayed scrapping in recent years. This keeps less efficient vessels in operation (UNCTAD, 2024^[24]), and thus, influences the fuel intensity of the fleet. This pattern is reflected in Table 3.1, which shows that improvements in fuel intensity were concentrated among containers and bulk carriers. For containers, efficiency gains partly reflect the influx of new vessel deliveries in 2023. In contrast, any improvements observed from bulk carriers and other vessel types likely stem from operational factors, such as slower sailing speeds, rather than from the introduction of newer, more efficient vessels.

Figure 4.3. Growth of mega-containerships in the global fleet

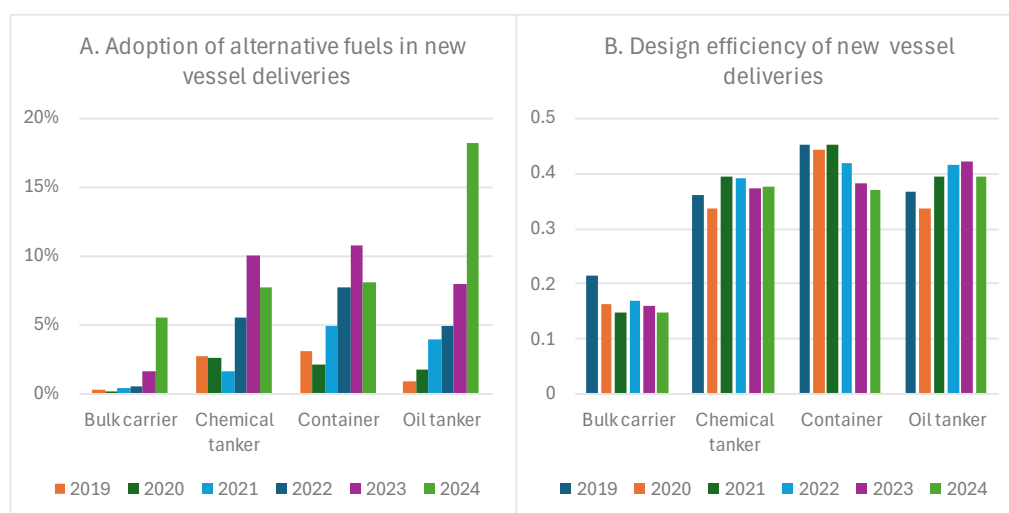


Source: Authors' elaboration based on ship registry data.

Another notable trend in the global fleet is the growth in vessel size (Figure 4.3). This is most evident in

container shipping where an increasing share of global cargo is carried by mega-containerships⁷. Their share of total capacity rose to 42.2% in 2024 (**Figure 4.3**, Panel A), and the number of ultra-large vessels (20,000 TEU or more) more than tripled in five years, from 41 in 2019 to 130 in 2024 (**Figure 4.3**, Panel B). While this shift is largely driven by economies of scale, it has implications on emissions. As larger ships are generally more efficient per unit of capacity, the fleet's average fuel intensity tends to decline. This can partly explain the pronounced drop in fuel intensity observed for container ships in 2023 (**Figure 3.4**).

Figure 4.4. Adoption of alternative fuels and improvements in design efficiency of new vessel deliveries, 2019-2024



Source: Authors' elaboration based on ship registry data.

Note: Alternative fuels in the dataset include LNG, LNG boil-off gas, LPG, methanol, hydrogen, ethane, and nuclear energy.

The use of alternative fuels, primarily LNG and methanol, has gained momentum in new vessel deliveries across major ship types, though uptake remains modest overall (**Figure 4.4**, Panel A). Between 2019 and 2024 the share of new deliveries using alternative fuels rose steadily, reaching around 8.2% and 7.7% for container and chemical tankers, respectively, and a more pronounced 18.2% for oil tankers. Bulk carriers have been slower to adopt alternative fuels, with only 5.6% of new deliveries equipped for them by 2024. This partly reflects their design: bulk carriers are optimised for heavy cargo transport at moderate speeds, giving them lower fuel intensity per tonne-mile and thus less immediate pressure to decarbonise (Det Norske Veritas, 2024^[25]).

Given the limited adoption of alternative fuels, complementary solutions remain important. Accordingly, shipowners are increasingly adopting energy-saving technologies, such as propeller and hull modifications, wind kites, and onboard carbon capture, to support emissions reductions and comply with tightening IMO requirements (OECD, 2025^[32]).

Although these developments mark progress, the green transition is still at an early stage and far from sufficient to offset growing emissions from a largely conventional, ageing fleet. Moreover, design efficiency has improved in several ship types, though not uniformly across (**Figure 4.4**, Panel B). Engine-power-to-deadweight ratios reduced notably for bulk carriers and container ships. In contrast, little or no efficiency gains are observed for oil and chemical tankers over the same period.

Ultimately, the 2019-2024 period reflects a fleet that is ageing but increasingly utilised, with incremental efficiency gains among new vessel deliveries insufficient to counterbalance rising activity and longer trade routes. The result is a shipping sector where emissions are still growing and are increasingly shaped by utilisation of older tonnage rather than by rapid technological renewal. Without accelerated replacement or

large-scale fuel switching, emissions reductions will depend primarily on operational measures such as slow steaming and continued improvements in energy efficiency within the existing fleet, making it difficult to reach IMO's revised GHG strategy intermediate targets for 2030 and 2040 of 20% and 70% reductions in GHG emissions relative to 2008 levels.

IMO and EU Regulations

Recent years have seen two major policy developments shaping maritime decarbonisation: the adoption of the IMO's Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII), and the inclusion of maritime transport in the EU Emissions Trading System (EU-ETS).

The IMO measures, introduced through amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI, address both technical and operational efficiency. The EEXI, effective since November 2022, establishes design efficiency standards for ships of 400 gross tonnes (GT) and above (UNCTAD, 2023^[27]), aiming to improve the structural performance of the existing fleet. Technical improvements, such as limiting engine power, have become the main means of regulatory compliance as vessels continue to rely on conventional fuels. This has kept the fleet's fuel mix largely unchanged, with contribution from the fuel emission factor remaining minimal over 2019-2024 (**Table 3.1**).

The CII, in force since January 2023, applies to ships over 5,000 GT and evaluates operational efficiency by linking annual CO₂ emissions to nominal transport work via the Annual Efficiency Ratio (AER). Vessels are rated from A to E, encouraging operators to optimize routes, speeds, and fuel use. Nonetheless, the metric has been criticised for favouring longer voyages and disadvantaging ships engaged in shorter or irregular operations, meaning that even highly efficiency vessels may receive lower ratings when trading patterns are less predictable (UNCTAD, 2023^[27]).

Although the EEXI has a relatively minor impact on operating speeds, CII can lead to a substantial reduction in both ship speeds and consequently carbon emissions (Zhang et al., 2024^[33]). Thus, slow steaming has emerged as a key operational strategy for compliance, offering a highly cost-effective means of reducing emissions (Tu, Liu and Zhang, 2024^[34]). The practice is particularly relevant for less energy-efficient vessels, and its adoption may partly explain the reduction in the contribution of the fuel intensity factor in 2023 (**Figure 3.3**). However, lower operating speeds reduce effective fleet capacity, meaning that more vessels may be required to meet the same transport demand (Degiuli, Martic and Grij, 2024^[35]). The reduction of the capacity under-utilisation factor in 2024 (**Figure 3.3**) may reflect this trade-off as available fleet capacity becomes more fully utilised.

In 2024, the EU-ETS expanded to include maritime transport, covering all ships over 5,000 GT carrying passengers or cargo for commercial purposes. The system covers all emissions from intra-EU voyages and half from routes between EU and non-EU ports. To comply, operators may use low-carbon fuels, join pooling arrangements with compliant vessels, or pay penalties (UNCTAD, 2025^[1]). The system is being phased in gradually, requiring companies to surrender allowances for 40% of verified emissions in 2024, 70% in 2025, and 100% from 2026 onward, effectively making CO₂ emissions into a priced component of maritime operations. Early studies suggest that the EU-ETS could lead to significant emissions reductions (Kotzampasakis, 2025^[36]; Nikolaidis et al, 2024^[37]), though its full impact remains to be seen as implementation of the EU-ETS in maritime transport progresses.

Given the multiple factors influencing fuel intensity, including exogenous shocks, it is difficult to isolate the specific contribution of recent regulations to reducing CO₂ emissions across individual ship types based solely on the presented data. A more targeted assessment over a longer time horizon, once these measures are fully implemented, would therefore be valuable. The AIS-based OECD dataset provides a strong foundation for such work, and decomposition analysis offers an effective approach for evaluating the impact of new policies across vessel types.

Looking ahead, additional regulations such as FuelEU Maritime, which introduces progressively tighter GHG-intensity limits in the EU/EEA from 2025, and the IMO's proposed Net-Zero Framework, which would establish a global lifecycle-based fuel standard and pricing mechanism, are expected to further influence operational behaviour and fuel choices. As these initiatives fall outside the 2019-2024 study period, they are not captured in the current results, but their implementation will create important opportunities to observe emerging impacts in future data.

Limitations and future work

Incomplete vessel coverage due to AIS coverage limitations and dark fleet activity

A key limitation of emissions derived from AIS-based datasets is the incomplete coverage of global vessel activity resulting from AIS coverage limitations and so-called dark fleet operations. Some areas of the globe have poor AIS satellite reception causing some signals to be lost. Dark fleet activity refers to vessels that either intentionally disable their AIS transponders or manipulate position signals to conceal movements, often to evade sanctions, avoid regulatory scrutiny, or to hide illicit activities. Since AIS data are the primary source for these emission estimates, the absence of these signals would lead to a systematic underestimation of global maritime transport emissions.

Paolo et al. (2024^[38]) combined satellite imagery, vessel GPS data, and machine-learning models to map industrial vessel activities and found that around three-quarters of global fishing activities are not publicly tracked and that between 21 to 30% of transport and energy vessel activity is missing from AIS data. However, fishing vessels make up a very small part of total vessel emissions and therefore are not a focus of this study. It also means that the exclusion of fishing activity would not significantly impact the total emissions results presented in this study. Furthermore, Clarke et al. (2023^[14]) found that maritime transport emissions are highly concentrated among large operators for which there is good AIS data coverage. Therefore, it is likely that the missing transport vessel activity would not represent a major part of total transport vessel emissions. However, when looking at country-specific or regional emissions, it may become more important to account for this missing activity. Therefore, further work may look to enhance the existing coverage by incorporating earth observation data to estimate emissions for vessels lacking AIS data.

Temporal coverage

Another limitation of this analysis concerns its temporal coverage. The findings presented in this report are based on annual data from 2019 to 2024 which means that developments occurring in 2025, such as the introduction of new tariff measures, are not included. As maritime transport activity and therefore emissions can respond rapidly to changes in global trade or geopolitical conditions, the inclusion of more recent data would improve the timeliness of some findings. Moreover, the absence of data prior to 2019 limits the ability to examine longer-term structural trends or to contextualize recent developments within broader historical patterns.

Country level decomposition results

The decomposition framework presented in this study could also be applied at the country level, whereby emissions from vessels are attributed based on the economic residence of operators. Extending this analysis to countries would allow for further policy-relevant insights such as the assessment of progress towards decarbonisation commitments. It would also allow for comparison of emissions across national fleets.

Inclusion of other greenhouse gases (GHG)

This study focuses only on CO₂ emissions, which constitute the dominant greenhouse gas emitted by maritime transport. However, shipping also produces a range of other air pollutants, such as nitrogen oxides, sulfur oxides, particulate matter, and black carbon. Including these pollutants would provide a more comprehensive picture of the sector's overall climate impact. A multi-pollutant approach would also facilitate better alignment with comprehensive frameworks such as the SEEA Air Emissions Accounts. Therefore, future work could look to expand the pollutant scope to arrive at total GHG estimates.

5 Conclusion

The International Maritime Organisation has adopted a revised greenhouse gas strategy targeting net-zero GHG emissions from international shipping by or around 2050, with intermediate targets for 2030 and 2040 of 20% and 70% reductions in GHG emissions compared to 2008 levels (IMO, 2023^[41]).

The OECD dataset on maritime CO₂ emissions can serve as a key resource for monitoring the development of global maritime emissions. Indeed, this AIS-based dataset indicates that between 2019 and 2024, global maritime transport emissions rose from 889.5 to 972.8 MtCO₂, an increase of 9.3%, while emissions from OECD countries rose by 7.8%, from 529.9 to 571.1 MtCO₂.

To better understand these trends, this paper applied a decomposition analysis, offering a structured framework for disentangling the drivers of rising maritime transport emissions and highlighting potential policy levers. The paper decomposed changes in emissions into the contributions of six drivers for two groups of countries: the world and the OECD. At the aggregate fleet level, the increase in emissions was driven primarily by growth in economic activity, followed by rising transport intensity, indicating that the demand for seaborne transport expanded faster than economic output. These effects were only partly offset by improvements in fuel intensity and a negative distance effect. Capacity underutilisation exerted opposite effects for the two regions: an increase in emissions globally but a reduction in the OECD. The emission factor effect played only a minor role throughout the period. Across vessel types, container ships contributed most to the increase in emissions, followed by bulk carriers.

The 2019-2024 period was shaped by significant exogenous shocks that impacted different vessel categories in distinct ways, thereby resulting in significant dynamics of resulting CO₂ emissions as well as the various decomposition effects. These included the Covid-19 pandemic, which significantly disrupted trade patterns; geopolitical events such as Russia's invasion of Ukraine from 2022; increasing maritime security risks in the Red Sea from 2023; and severe droughts affecting transits through the Panama Canal in 2023-2024.

These shocks interacted with several structural developments. In particular, the maritime sector faced new global and regional regulations during the period aimed at improving ship energy efficiency and reducing emissions. While the analysis found improvements in fuel intensity for container ships and bulk carriers, the multiple factors influencing this factor makes it challenging to isolate the specific contribution of these regulations to CO₂ emissions for individual ship types. Moreover, the analysis of the evolution of the fleet illustrated that the use of alternative fuels has gained momentum across vessel types. However, without accelerated replacement or large-scale fuel switching or additional regulations such as the introduction of carbon pricing mechanisms currently being discussed by the IMO, emissions reductions will depend primarily on operational measures such as slow steaming as well as adoption of energy-saving technologies.

Future work could extend the analysis to a higher temporal resolution, incorporate earth observation data, include other greenhouse gases and pollutants, and extend the decomposition to the country or regional level. Nonetheless, this paper already provides useful insights on current trends and their drivers, as well as policy-relevant insights to support countries and ship operators in their efforts towards carbon-mitigation in maritime transport.

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Annex A. LMDI decomposition: From multiplicative identity to additive form

1. Identity at time t and $t - 1$

For a given ship type i :

$$E_{i,t} = TI_{i,t} \cdot GDP_t \cdot CAP_{i,t} \cdot DIST_{i,t} \cdot EF_{i,t} \cdot AER_{i,t} \quad (A1)$$

$$E_{i,t-1} = TI_{i,t-1} \cdot GDP_{t-1} \cdot CAP_{i,t-1} \cdot DIST_{i,t-1} \cdot EF_{i,t-1} \cdot AER_{i,t-1} \quad (A2)$$

2. Multiplicative LMDI

Divide (A1) by (A2):

$$\frac{E_{i,t}}{E_{i,t-1}} = \frac{TI_{i,t}}{TI_{i,t-1}} \cdot \frac{GDP_t}{GDP_{t-1}} \cdot \frac{CAP_{i,t}}{CAP_{i,t-1}} \cdot \frac{DIST_{i,t}}{DIST_{i,t-1}} \cdot \frac{EF_{i,t}}{EF_{i,t-1}} \cdot \frac{AER_{i,t}}{AER_{i,t-1}} \quad (A3)$$

This is the **multiplicative** decomposition: the total change is expressed as a product of factor ratios.

3. Apply Natural Logarithms

Taking the natural logarithms and exploring the property of logarithms that $\log a \cdot b = \log a + \log b$ (and $\log \frac{a}{b} = \log a - \log b$) brings the pure multiplicative decomposition to the **additive** form in **log-space**:

$$\begin{aligned} \ln\left(\frac{E_{i,t}}{E_{i,t-1}}\right) &= \ln E_{i,t} - \ln E_{i,t-1} = \ln\left(\frac{TI_{i,t}}{TI_{i,t-1}}\right) + \ln\left(\frac{GDP_t}{GDP_{t-1}}\right) + \ln\left(\frac{CAP_{i,t}}{CAP_{i,t-1}}\right) + \\ &\quad \ln\left(\frac{DIST_{i,t}}{DIST_{i,t-1}}\right) + \ln\left(\frac{EF_{i,t}}{EF_{i,t-1}}\right) + \ln\left(\frac{AER_{i,t}}{AER_{i,t-1}}\right) \end{aligned} \quad (A4)$$

4. Introduce the log-mean (LMDI)

LMDI moves from log-space back to level-space using the **logarithmic mean** defined as:

$$L(x, y) = \begin{cases} \frac{x - y}{\ln x - \ln y} & , \quad x \neq y, x > 0, y > 0, \\ x & , \quad x = y \end{cases}$$

Therefore :

$$L(E_{i,t}, E_{i,t-1})(\ln E_{i,t} - \ln E_{i,t-1}) = E_{i,t} - E_{i,t-1} = \Delta E_{i,t} \quad (A5)$$

By substituting (A4) into (A5) we therefore obtain:

$$\begin{aligned} \Delta E_{i,t} &= L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{TI_{i,t}}{TI_{i,t-1}}\right) + L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{GDP_t}{GDP_{t-1}}\right) \\ &\quad + L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{CAP_{i,t}}{CAP_{i,t-1}}\right) + L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{DIST_{i,t}}{DIST_{i,t-1}}\right) \\ &\quad + L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{EF_{i,t}}{EF_{i,t-1}}\right) + L(E_{i,t}, E_{i,t-1}) \ln\left(\frac{AER_{i,t}}{AER_{i,t-1}}\right) \end{aligned} \quad (A6)$$

This is now **additive in level-space**: the change in E_i is written as the sum of contributions.

5. Identify the factor contributions

We now *define* each factor's contribution as the corresponding term in the right-hand side of (A6). This is in line with equations (4) to (9) in the text.

$$\begin{aligned}\Delta TI_{i,t} &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{TI_{i,t}}{TI_{i,t-1}} \right) \\ \Delta GDP_t &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{GDP_t}{GDP_{t-1}} \right) \\ \Delta CAP_{i,t} &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{CAP_{i,t}}{CAP_{i,t-1}} \right) \\ \Delta DIST_{i,t} &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{DIST_{i,t}}{DIST_{i,t-1}} \right) \\ \Delta EF_{i,t} &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{EF_{i,t}}{EF_{i,t-1}} \right) \\ \Delta AER_{i,t} &\equiv L(E_{i,t}, E_{i,t-1}) \ln \left(\frac{AER_{i,t}}{AER_{i,t-1}} \right)\end{aligned}$$

6. Full additive decomposition (Equation (3))

Then (A6) becomes the **additive decomposition**:

$$\Delta E_{i,t} = E_{i,t} - E_{i,t-1} = \Delta TI_{i,t} + \Delta GDP_t + \Delta CAP_{i,t} + \Delta DIST_{i,t} + \Delta EF_{i,t} + \Delta AER_{i,t}$$

Notes

¹ Yang and Ma do not include a distance effect. Jeong and Yun include a distance effect that is defined as total distance travelled by ship type divided by fuel consumption.

² In recent years, the Panama Canal has faced recurring disruptions due to prolonged droughts, which reduced water levels and limited vessel transits. These restrictions have led to congestion, delays, and rerouting of ships. The Suez Canal has faced major disruptions from both operational and geopolitical causes. The most notable was the Ever Given grounding in March 2021, which blocked the canal for six days and halted global trade flows. More recently, Red Sea security threats in 2023-2024 – referred to as the Red Sea crisis in the remainder of this paper – prompted widespread vessel rerouting around the Cape of Good Hope, resulting in a sharp reduction of Suez canal transits (UNCTAD, 2024^[24]).

³ AIS is a shipborne transponder system that is mandated for most commercial vessels. Vessels continuously broadcast standardised messages that provide the vessel's identity, position, speed, course, among other navigational information (IMO, 2024^[39]).

⁴ They are: Bulk carrier, Chemical tanker, Container, Cruise, Ferry-RoPax, Ferry-pax only, General cargo, Liquefied gas tanker, Miscellaneous – fishing, Miscellaneous – other, Offshore, Oil tanker, Other liquids tankers, Refrigerated bulk, Ro-Ro, Service – other, Service – tug, Vehicle, Yacht.

⁵ *Ballast speed* denotes the average sailing speed of a vessel when traveling without cargo. In contrast, *laden speed* refers to the vessel's average speed when carrying cargo, generally lower due to increased draft and hydrodynamic resistance.

⁶ The world increase is smaller because cruise emissions in non-OECD countries declined over this period.

⁷ *Mega-containerships* are those with a container capacity greater than 10,000 twenty-foot equivalent units (TEU). (UNCTAD, 2021^[22])