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Assessing the Early Impact of the EU ETS on Turkish-Flagged Vessels: Operational and Legal Insights

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ABSTRACT

This study explores the early effects of the EU Emissions Trading System (EU ETS) on the Turkish shipping industry. Combining empirical evidence and legal analysis, it fills a gap in the literature that has mostly focused on EU-based fleets by examining the indirect legal and operational impacts of the EU ETS on Turkish maritime actors operating under the European regulatory regime. It uses publicly available EU MRV data for 93 Turkish-flagged vessels with complete records for both 2023 and 2024.Three indicators were considered: total CO_2 emissions, emission intensity per nautical mile, and annual time at sea. Overall emissions stayed relatively stable while emission intensity decreased and operational activity increased. The results demonstrate that Turkish shipping companies have begun to adapt their operational practices in the light of emerging carbon-efficiency requirements, while full compliance adaptation is still developing. The study further elaborates the legal implications of the EU ETS and its potential influence on maritime governance in Türkiye. Overall, the findings contribute to better understanding of Türkiye's preparedness for closer alignment with EU climate policies and provide new insights into the country's role in the wider maritime decarbonisation process.

1. Introduction.

Maritime transport is a vital part of the world economy, representing some 80% of the volume of global merchandise trade. The constant rise in seaborne trade is generally taken to imply an increase in shipping activity, which often worsens the environmental impact of the sector [1].As a response, the European Commission launched the European Green Deal in 2019 with the target to reach climate neutrality by 2050 and a reduction of greenhouse gas (GHG) emissions by 55% by 2030 [2]. In 2024, the European Union has extended its Emissions Trading System (EU ETS) to the maritime sector, representing a historic regulatory shift to carbon pricing in global shipping [3], [4]. This evolution must be seen within the framework of the broader evolution of Maritime Decarbonisation from an environmental technical problem to a legal problem of the distribution of responsibility among shipowners, charterers, flag States, port States and regulatory bodies [5]. Legally, this extension of the EU ETS is not just a sectoral environmental policy reform, but rather a real transformation of the regulatory architecture governing maritime activities, by which shipping operations are subject to binding carbon market obligations in the context of EU environmental and energy law [6].

Specifically, as of 1 January 2024, the maritime EU ETS will apply to cargo and passenger ships of 5 000 gross tonnage (GT) and above that dock at ports within the European Economic Area (EEA), irrespective of the flag state. The scheme covers all emissions from voyages between ports within the European Economic Area (EEA) and emissions from ships at berth in EEA ports. For voyages between an EEA port and a non-EEA port 50% of emissions are covered by the system. The compliance obligation will also be phased in: from 2024,

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shipping companies will be required to surrender allowances for 40% of verified emissions reported, rising to 70% in 2025 and 100% from 2026 [3], [4].It moves away from voluntary or piecemeal initiatives by now including shipping in the EU's cap-and-trade architecture where emissions are offset with allowances. Financial penalties are imposed on vessels that fail to procure sufficient allowances. Theoretically, this mechanism is a market-based incentive for cost-effective reduction of emissions [7]. It alters the legal risk profile of maritime activities. This is particularly relevant in maritime transport, since shipping is inherently transnational [5]. A vessel may be registered in one State, operated from a different state and engaged in voyages involving several legal orders. As a consequence, the EU ETS affects the classical principles of maritime law, such as flag State jurisdiction, port State control, freedom of navigation, contractual risk allocation and the need for uniformity in international maritime regulation [5]. Economic inefficiencies and direct regulatory sanctions result from non-compliance in accordance with EU public law and market governance principles [8].

This has led to a surge in scholarly interest and a body of literature [9]. Recent research focuses on the legal and economic implications of maritime ETS systems. Recent studies on maritime emissions trading have increasingly addressed the issue from a legal and economic perspective in the context of the EU's climate policy framework. For example, Dominioni [3] uses a doctrinal approach to analyse the compatibility of maritime carbon pricing with World Trade Organization law while Flodén et al. [10] employ scenario modelling to assess the costs, emissions and risk of modal shift. Building upon this, Wang et al. [11] focus on international investment law, and the possible threat of investor-state disputes and regulatory chill. Collectively these studies indicate that the impacts of maritime emissions trading are likely to be unevenly distributed between EU and non-EU actors.

Another research path focuses on regulatory compliance and the Monitoring, Reporting, and Verification (MRV) systems that enforce the Emissions Trading Scheme (ETS). The Monitoring, Reporting and Verification (MRV) system was originally developed as a data transparency instrument [12], but has been extended to include enforcement and compliance. Such transformation puts pressure on the verification institutions because their assessment is directly connected to the carbon liability [13]. Hence, verifier institutions act as regulatory intermediaries and their assessments are prominent in the EU's Emissions Governance framework. This raises issues of fairness, accountability and certainty. The financial consequences of even small reporting errors can be large given the size of allowance prices. [14]. Deane et al. [13] suggest that integrity issues in carbon liability assessments may arise from differences among accredited verifiers. This is also recognised by Psaraftis et al. [15], who stressed the importance of harmonised MRV standards to secure data integrity. However, other scholars have indicated initial signs of institutional learning and data quality improvement [16], which demonstrate the evolution of practices. This transition is addressed by integrating macroeconomic modelling with stakeholder-based approaches. For example, Soner [17] uses empirical financial analysis and Wang and Wenbo [11] uses scenario-based forecasting to predict long-term behavioural change under various policy regimes. However, the actual effect of this integration on the operational and legal dynamics of shipping has been insufficiently studied, particularly in the case of non-EU flagged vessels under EU jurisdiction.

Despite the depth and diversity of this literature, notable gaps remain. In particular, empirical evidence on the behavioural and compliance responses of non-EU flagged vessels, such as those registered in Türkiye, is insufficient. This is a notable omission given the fact that the EU ETS imposes obligations on vessels calling at EU ports irrespective of flag. In this sense, the EU ETS is regional in legal origin but transnational in commercial consequence. Turkish-flagged vessels are therefore a particularly relevant case, because their exposure to the system is triggered not by nationality, but by their operational connection with EU ports.

In addition, the impact of verifier-caused reporting discrepancies on operational decision-making and assessments of carbon liability is still not quantified. The present study seeks to address those deficiencies by providing a targeted analysis of Turkish-flagged ships based on publicly available EU MRV data (THETIS-MRV) and a review of verification methodologies to investigate the impact of institutional heterogeneity on emissions accounting and compliance behaviour.

This study is the very initial empirical examination of the changing dynamics in question, using a unique dataset of 93 Turkish-flagged vessels operating under the EU MRV framework in 2023 and 2024. Türkiye is a particularly instructive case: as a non-EU country with active maritime trade with the EU, its vessels are covered by the ETS despite having no formal representation in EU policymaking. This case also reflects a broader problem of regulatory fragmentation, since EU climate instruments may affect ships registered in third States through the logic of port and market access [10]. Although such measures are justified by climate objectives, they may complicate the uniformity [18] traditionally sought in international maritime regulation. In the study changes are analysed in emission intensity, operational efficiency and verifier-linked reporting discrepancies pre- and post-ETS introduction using publicly available MRV data. Paired-sample t-tests and two-way repeated-measures ANOVA were employed to identify behavioural patterns and systemic vulnerabilities with broader relevance to the decarbonisation agenda. In this regard the case of Turkish flagged vessels suggests the tension between the EU's climate regulations and international maritime law, especially regarding jurisdiction, regulatory power and the role of non-EU states in environmental governance.

2. Methodology.

The study examines whether the early implementation of the maritime EU ETS leads to measurable changes among Turkish - flagged vessels. The EU MRV data is used and the 93 Turkish flagged ships that submitted operational data for the years 2023 and 2024 are analysed. The data set was built on publicly available submissions to the MRV, which were submitted by shipping companies and verified by accredited organisations. The final sample was restricted to vessels with complete and consistent data in both years.

The variables used in the analysis were as follows: total fuel consumption (tonnes), total CO_2 (tonnes), time at sea (hours), mean fuel consumption (kg / nm) and mean CO_2 emissions (kg/nm). To explore institutional variation in reported data, an additional grouping factor of verifier institution identity was added.

Descriptive statistics such as mean, standard deviation, skewness and kurtosis were used to assess the distribution of the data. Normality was assessed using skewness and kurtosis, with acceptable values for parametric analysis being between ±1.96. In this study, it was particularly important to ensure the reliability and robustness of the statistical results, as the empirical findings provide a basis for the assessment of compliance trends and discussions on the broader regulatory implications of the EU ETS for the maritime sector.

To investigate changes in vessel performance indicators over time, paired samples t-tests were performed. The reported emission values were subjected to a two-way ANOVA to evaluate the effect of the verifier institution. Mauchly's Test of Sphericity was used to check the assumptions of the repeated measures analysis. Established tests are important for ensuring the analysis is correct, which is vital if emission data is to be legally or administratively reviewed.

Post hoc comparisons were conducted using the Tukey HSD test where appropriate. Statistical analysis All statistical analyses were performed using SPSS (version 20; IBM, Armonk, NY, USA) and significance was set at the 95% confidence level ($p < 0.05$). As a result, the methodological approach used in this study provides not only empirical validity but also a legally sound basis on which regulatory interpretations and compliance-related determinations can be reliably based.

3. Findings.

This section presents the empirical results of the analysis of 93 vessels sailing under Turkish flag reported under the EU MRV (Monitoring, Reporting and Verification) framework for the years 2023 and 2024.

We used descriptive analysis, paired-sample t-tests and repeated measures ANOVA to assess the early effect of the EU Emissions Trading System (ETS) on operational behaviour.

The findings below, from a legal perspective, provide information on the effectiveness of the EU ETS as a compliance mechanism and the range of potential legal exposure faced by shipowners and operators.

A. *Descriptive Trends and Efficiency Indicators.*
Descriptive statistics show that total CO_2 emissions remained virtually unchanged between 2023 and 2024 (mean ≈ 10,489 tons), while emission intensity metrics improved.

Table 1: Summary of key operational and emission indicators (N = 93).

Variable	Mean (2023)	SD (2023)	Mean (2024)	SD (2024)	Skew (2023)	Skew (2024)	Kurtosis (2023)	Kurtosis (2024)
Total Fuel Consumption (tons)	3356.37	4539.41	3356.71	4469.93	1.725	1.678	1.532	1.305
Total CO_2 Emissions (tons)	10489.21	14132.54	10489.53	13916.85	1.724	1.677	1.531	1.304
Time at Sea (hours)	2570.60	2064.40	2715.37	2025.87	0.894	0.904	-0.366	-0.175
Fuel Consumption / Distance	87.21	32.67	84.55	31.07	0.486	0.348	-0.548	-0.714
CO_2 Emissions / Distance	274.09	101.75	265.55	96.47	0.505	0.350	-0.497	-0.686

Source: Authors.

Skewness values fall within ±2, indicating acceptable normality for parametric testing.

B. *Paired Sample Analysis of Year-on-Year Change.*
To test for significant differences between 2023 and 2024, paired-sample t-tests were conducted on all main indicators.

Table 2: Paired-Sample t-Test results.

Variable	t	p-value	Significant at 0.05?
Total Fuel Consumption	-0.003	0.997	No
Total CO_2 Emissions	-0.001	0.999	No
Time at Sea	-1.250	0.214	No
Fuel Consumption per Distance	1.998	0.049	**Yes** (*)
CO_2 Emissions per Distance	2.003	0.048	**Yes** (*)

Source: Authors.

Significant reductions in the emission intensity metrics were observed statistically, namely fuel and CO? emissions per distance ($p < 0.05$). However the total amount of fuel used and the absolute amount of emissions stayed the same. This implies improvements in operational efficiency, possibly as a result of anticipatory behavioural adjustments to ETS pricing signals or monitoring pressure. These behavioural adjustments have legal implications, as they show how the EU ETS regulatory expectation and compliance incentives modify operational behaviour long before the enforcement mechanisms have fully developed.

C. *Institutional Effects on Reported Emissions.*
A two-way repeated measures ANOVA was used to test for a significant effect of verifier institution on reported emission metrics.

Table 3: Two-Way repeated measures ANOVA summary.

Factor	F	p-value	Significant?
CO_2 Emissions per Distance × Verifier	2.359	0.030	**Yes** (*)

Source: Authors.

This indicates there are differences in how much reported emissions vary depending on the organisation reporting them. This causes concerns about the harmonisation and consistency of the MRV framework.

D. *Post Hoc Analysis of Verifier Discrepancies.*
Tukey HSD post hoc tests revealed the following significant differences:

Table 4: Turkey HSD post hoc comparison of verifier institutions.

Verifier (I)	Verifier (J)	Mean Diff	p-value	Significant?
DNV	Hellenic Lloyd's	28.42	0.002	**Yes**
DNV	Normec	59.67	0.000	**Yes**
DNV	Bureau Veritas	53.61	0.000	**Yes**
DNV	Nippon Kaiji	46.93	0.000	**Yes**
DNV	Polish Register	45.96	0.032	**Yes**
DNV	RINA	27.13	0.158	No
DNV	American Bureau	22.30	0.488	No

Source: Authors.

Ships verified by DNV reported lower CO_2 emissions per distance per distance than other institutions, suggesting institutional differences in verification. This highlights the importance of harmonising methodologies, notably in non-EU contexts, such as Türkiye. The existence of gaps in harmonised verification standards could escalate cross-border compliance disputes and the risk of litigation and make the legal position of non-EU flag states operating within the EU's regulatory perimeter more complicated.

4. Discussion and Conclusions.

The empirical results of the present study indicate that the early implementation phase of the EU ETS in maritime transport already has legally significant effects. While absolute emissions remain unchanged, statistically significant reductions in emission intensity suggest behavioural response to regulatory anticipation and emerging compliance obligations [5], [10]. Legally, this indicates that market-based instruments can influence behaviour even before the enforcement mechanisms are fully in place [18]. These findings show that the EU ETS is not only an economic tool, but also a method of managing the legal environment of maritime operations [5], [19].

Shipowners and operators need to internalise carbon costs in order to manage legal risks and comply with climate regulations. However, the party legally responsible for EU ETS compliance may not always be the party commercially responsible for the operational decisions that generate emissions [20]. For instance, in a time charter arrangement, the charterer may determine voyage instructions, speed, route selection and waiting periods, while the regulatory obligation to surrender allowances remains with the shipping company [21], [6]. This shows that carbon compliance is not only a matter of public regulation, but also a question of private law risk allocation.

The economic burden of EU ETS compliance may also be reflected in private contractual relations through freight rates, emission surcharges or price adjustment mechanisms [10]. Accordingly, the legal impact of the EU ETS is not confined to the regulated shipping company; it may extend along the wider transport and trade chain [22]. EU ETS-related costs may therefore be understood as regulatory transport-related costs: they arise from public climate regulation, but become economically relevant through the performance and pricing of maritime carriage.

In addition to these contractual uncertainties, the MRV system also presents challenges related to differences among verifier institutions [19]. Institutional variability in the process of emission verification may undermine legal certainty, distort competitive equality and generate significant compliance risks [5]. This is particularly important because reported and verified emissions form the basis of carbon liability under the EU ETS.

The experience of Turkish-flagged vessels points to the growing friction between regional climate regulation and the inherently global nature of maritime transport. As non-EU operators are subject to growing EU climate obligations, but have little power in the rule-making process, questions of regulatory fairness and the design of transnational environmental governance. The findings show that the inclusion of maritime transport in the EU ETS is resulting in a transformation of the legal and operational environment of global shipping. There are early indications that the initiative is resulting in changes in operational behaviour, but its effectiveness over time will depend on the stability of the regulatory frameworks, the existence of transparent verification mechanisms and an improvement in engagement with non-EU maritime stakeholders. Addressing these issues is necessary to ensure the environmental effectiveness, legal validity, and equitable enforcement of maritime climate regulation.

In the context of overall tendencies, this observation indicates a slow change of the EU ETS. It is moving from an economic market-based instrument to a regulatory tool for maritime transport. It is evident that the system seems to have the potential to influence operational decision-making processes in the early stages of implementation. This influence, however, is not exerted through the mechanism of direct enforcement, but through the expectation of legal and financial liabilities. This demonstrates that market-based climate policies can have an impact on behaviour if embedded in a wider legal framework, even in the absence of fully developed enforcement mechanisms.

The findings show major weaknesses that undermine the regime's credibility. The diverging practices of verifier institutions seem to reveal some tension between the regulatory purpose and the operational capacity. The inherent variability of the verification process may impact the established legal principles. Failure to do so will likely result in a compliance situation that is strategic and uneven, instead of one that is firmly based on legal principles. A pertinent example of the disconnect between EU climate regulation and international maritime law is the case of Turkish-flagged vessels. There is a need for more dialogue and coordination to ensure that the EU's regulatory approach is seen as a stable element of global maritime governance.

The results indicate a gradual evolution in the regulatory framework of the shipping industry due to the inclusion of maritime transport in the EU ETS. Taken together, these findings suggest that the maritime EU ETS is not merely a regional carbon pricing mechanism, but also an emerging regulatory framework capable of shaping the operational behaviour of non-EU flagged vessels engaged in EEA-related trade. The scheme has been shown to create incentives for more environmentally friendly practice. The effectiveness of the system is said to depend on the uniform enforcement of the same rules, the trustworthiness of verification mechanisms and the close collaboration between stakeholders. Regulatory uncertainties on compliance and verification procedures need to be resolved to ensure the environmental effectiveness, legal certainty and long-term credibility of the EU ETS. In the first phase of the EU ETS the study uses publicly available MRV data and focuses on vessels flying the Turkish flag.

There are some limitations to this study. First, the analysis relies on only two reporting years, which limits the ability to make strong causal claims. Second, the study does not consider vessel type, age, gross tonnage, route structure, cargo condition or company level operational strategies. Third, verifier-related differences may be a reflection of fleet composition rather than verification inconsistency. Fourth, the results are based on public MRV data, thus they are to be interpreted as early evidence, not proof, of ETS caused behavioural change. It is encouraged that future research is to extend the analysis to other flag states, longer time frames, and the use of qualitative data from industry stakeholders to enable a more comprehensive understanding of compliance challenges and regulatory adaptation in the maritime sector.

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