NAVIGATING GREEN: THE IMPACT OF IMO'S ENVIRONMENTAL POLICIES ON GLOBAL SHIPPING AND THE SUEZ CANAL

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ABSTRACT:

The maritime transport sector is crucial for the world economy, responsible for 85% of global trade volume, but only contributes 2.89% of global carbon emissions. The International Maritime Organization (IMO) has set an ambitious goal of near-zero emissions by 2050 and set short-, medium-, and long-term policies for promoting green shipping. However, these policies also pose challenges and economic burdens for the shipping sector. Medium-term policies will lead to an increase in shipping costs due to the carbon tax. The study examined the impact of IMO's green policies on the global fleet, international trade, and the Suez Canal, which contributes to a strong reduction in emissions. The autoregressive distributed lag (ARDL) model showed a positive and significant short- and long-term effect of world seaborne trade on the Suez Canal trade. However, IMO's policies showed no immediate significant impact in the short-term but negative long-term effects; however, the positive long-term effects of world seaborne trade were found to be greater than the negative long-term effects of IMO's policies on Suez Canal trade.

Keywords: IMO, GHG, So_x, Green Shipping, Carbon Tax, Suez Canal, ARDL.

1. INTRODUCTION

During the 21st session of the Conference of Parties (COP 21) under the United Nations Framework Convention on Climate Change, the Paris Agreement was embraced in December 2015 (Bullock et al. 2020). The purpose of this agreement is to enhance international efforts in mitigating the effects of climate change, with the goal of limiting the increase in global temperatures to below 2°C compared to pre-industrial levels. Furthermore, it strives to minimize this rise to 1.5°C if feasible (Roelfsema et al. 2022). In response to this, the IMO initiated its preliminary strategy for reducing greenhouse gas emissions (GHG) from shipping in April 2018, setting a target to reduce emissions by 50% by 2050, compared to 2008 levels (Joung et al. 2020). The goal was changed to zero GHG emissions by 2050 in July 2023 (MEPC, 2023). The emissions from ships exhaust consist of nitrogen, oxygen, carbon dioxide, and water vapour, along with lesser amounts of carbon monoxide, sulphur, and nitrogen oxides. Additionally, partially reacted and non-combusted hydrocarbons, as well as particulate matter, are present in smaller quantities (Topic et al. 2023). The main concerns are greenhouse gases and poisonous, noxious, and sulfuric gases, which harm health and the environment (V. P. Singh et al. 2022). Shipping accounts for 70% of global trade by value (Pratson, 2023), and 85% of goods are transported by volume, or 12 billion tonnes in 2022 (Clarkson's research, 2023). IMO's 2020 Fourth emission study estimated maritime transport's 2018 global carbon emissions at 1,056 million tonnes, including local activities and fishing. This accounted for 2.89% of global carbon emissions, up 9.7% since 2012 (see Table 1). This assessment used vessel- and voyage-based methods, unlike the third GHG study. Reevaluation showed 2008 emissions of 794 million tonnes, not 940 million tonnes.

Table 1: International Maritime Shipping Carbon Emissions and Fossil Fuel Consumption (2012-2018)

Year	*Total*		*International Shipping Co_2*				*HFO $_{eq}$ fuel consumption*		
	(1) Shipping Co_2		*(2) Voyage-based*		*(3) Vessel-based*		*(1)*	*(2)*	*(3)*
	**Mt*	*% ***	*Mt*	*% ***	*Mt*	*% ***	*Mt*	*% share*	*%share*
2012	*962*	*2.76*	*701*	*2.01*	*848*	*2.44*	*309*	*72.8*	*88.0*
2013	*957*	*2.74*	*684*	*1.96*	*837*	*2.39*	*307*	*71.7*	*87.6*
2014	*964*	*2.7*	*681*	*1.93*	*846*	*2.37*	*310*	*70.6*	*86.5*
2015	*991*	*2.81*	*700*	*1.99*	*859*	*2.44*	*318*	*70.8*	*86.8*
2016	*1,026*	*2.90*	*727*	*2.05*	*894*	*2.53*	*330*	*70.6*	*87.0*
2017	*1,064*	*2.97*	*746*	*2.08*	*929*	*2.59*	*342*	*69.9*	*87.1*
2018	*1,056*	*2.89*	*740*	*2.02*	*919*	*2.51*	*339*	*70.2*	*87.0*

Source: (*IMO*, 2020), **MT (million tonne) ** share from global Co_2*

Heavy fuel oil-equivalent (HFO_{eq}) usage in the shipping sector (fishing, domestic, international) increased 9.7% from 309 million tonnes in 2012 to 339 million tonnes in 2018, and international shipping share in fuel usage declined to 70.2% from 72.8% by voyage-based estimation and 88% to 87% by vessel-based estimation (see Table 1), highlighting the need for effective emission reduction measures. the Imo's emission reduction goals and policies, and particularly the Suez Canal, will be examined in this paper. the following section of this paper focus on Imo's emission reduction targets and policies. section 3 shipping adaptation with Imo's regulations. section 4 displays green shipping and fuel costs. section 5 explains impact of green shipping on the Suez Canal, while section 6 draws the conclusion and recommendations.

2. IMO'S EMISSION REDUCTION TARGETS AND POLICIES

The IMO set a strategy for the shipping industry in 2018, aiming for a 50% reduction in GHG by 2050 compared to 2008 levels, a 40% reduction by 2030, and a 70% reduction by 2050 for carbon intensity Index (CII), despite not being included in the 2015 Paris Agreement on Climate Change (Serra and Fancello 2020).

The IMO has revised its 2023 GHG Strategy, aiming to reduce ships' carbon intensity, achieve a 40% reduction in CO_2 emissions per unit of transported goods by 2030, and increase the proportion of zero-carbon fuels in the maritime shipping sector's energy mix from 5% up to 10%. The long-term goal is to achieve net-zero GHG emissions by 2050, aligning with the Paris Agreement's temperature objectives (see Table 2).

Table 2: IMO's Greenhouse Gas Reduction Targets

Items	*Year*	*Initial Strategy 2018*	*Modified Strategy 2023*
Baseline	*2008*	*100%*	*100%*
CII	*2030*	*- 40%*	*- 40%*
	2050	*- 70%*	*- 100%*
GHG	*2030*	*-*	*- 20% / - 30%*
	2040	*-*	*- 70% /- 80%*
	2050	*- 50%*	*- 100%*

Source: (MEPC, 2023)

The IMO targets a 40% reduction in (CII) within the shipping trade by 2030, with the ultimate goal of reaching a nearly 100% reduction by 2050.

Table 3: IMO GHG Strategy 2023 Candidate Measures

Timelines	*Policy*
Short-term (2013–2023)	- *EEDI, SEEMP, DCS, EEXI, and CII*
Medium -Term (2023–2030)	- *a technical element "alternative fuel"* - *an economic element, "carbon tax"*
Long-term (beyond 2030)	- *Development is planned during the 2028 IMO GHG Strategy Review.*

Source: (MEPC, 2023)

The strategy is scheduled for review during the 88th session of the Marine Environment Protection Committee (MEPC) in autumn 2028. The IMO has formulated emission reduction policies since 2011, and the 2023 strategy divides these into short-, medium-, and long-term categories. Short-term policies are set to be completed by January 2026, while medium-term policies are slated for adoption by 2025 until 2030 (see Table 3).

2.1 Short-Term (2013–2023)

The IMO implemented the Energy Efficiency Design Index (EEDI) in 2013 to reduce shipping carbon emissions (MEPC, 2011). The EEDI measures ship energy efficiency is a technical requirement for new ships. Ships must meet EEDI standards based on their type and size, with a five-year carbon reduction level (MEPC, 2018). The EEDI required ships to reduce carbon intensity by 10% to 20% from Phase 1 in 2015 to Phase 2 in 2020. Phase 3 was set to start in 2025. However, the IMO moved Phase 3 enforcement to April 2022 and strengthened regulations, affecting container ships, general cargo ships, refrigerated cargo carriers, combination carriers, gas carriers, and cruise ships. A 50% energy reduction was also set for container ships over 200,000 deadweight tonnes (see Table 4).

Table 4: EEDI Reduction Percentage

Phase	*Time line*	*Reduction rate (%)*
Initial	*2013 - 2015*	*0*
One	*2015 - 2020*	*10*
Two	*2020 -March 2022* *2020 - 2025*	*20* *20*
Three	*April 2022 onwards* *2025 onwards*	*30: 50* *30*
Four	*Under study*	*-*

Source:(MEPC, 2021)

The shipping industry is implementing technical measures to promote energy-efficient technologies, reduce emissions, and encourage innovation. These measures include reducing hull resistance, improving propeller efficiency, slow steaming, using low-carbon fuels, and optimizing routes and operations. However, the accelerated implementation of Phase 3 and commitment to decarbonize the shipping industry require additional solutions. Additionally, the MEPC approved guidelines for a working group to investigate the implementation of a fourth EEDI phase (MEPC, 2019). The Ship Energy Efficiency Management Plan (SEEMP) encourages ship owners and operators to use best practices to improve vessel performance (Hansen, Rasmussen, and Lützen ,2020). The SEEMP process includes planning, implementation, monitoring, and self-evaluation. The 2022 SEEMP guidelines include cutting-edge strategies for optimizing a ship's fuel efficiency and well-structured templates with three key components: Part I outlines a ship management plan to improve energy efficiency, Part II includes a strategy for collecting fuel oil consumption data, and Part III manages operational carbon intensity.

The IMO Data Collection System (DCS), implemented in October 2016, required ships to meticulously record and report fuel consumption. This data is essential for maritime transport GHG reduction (MEPC, 2016). Since January 2019, ships exceeding 5,000 gross tons must record fuel use to their flag states and transmit data to the IMO DCS by May 31. MEPC aggregates flag status data for yearly reports, needed to calculate ship operating CII by 2023 (MEPC, 2021).Ships with 400+ gross tonnes must calculate their Energy Efficiency Existing Ship Index (EEXI) to achieve fleet parity, similar to the 2022 EEDI levels, assessing technical or design efficiency. The CII is a requirement for ships over 5,000 tonnes, calculated as the ratio of Co_2 emissions to transport work in a year. The ship's administration determines its operational CII, with A indicating major superiority, B minor superiority, C moderate inferiority, D minor inferiority, and E significant inferiority. Ships rated D or E must develop a corrective action plan.

2.2 Medium-Term (2023 - 2030)

The IMO introduces two policies aimed at fostering a greener shift within maritime transportation. The first policy focuses on the adoption of carbon-neutral fuels. This strategy outlines a substantial goal of achieving a minimum adoption rate of 5%, aspiring for 10%, of zero or near-zero greenhouse gas emission technologies, fuels, or energy sources by 2030. The second policy, involves the implementation of a carbon tax on the shipping Co_2 emission. This tax aims to narrow the price difference between fossil fuels and alternative green fuels. both policies aim to ensure equal opportunities and a fair transition in maritime transport. These strategic measures underscore a broader commitment to exploring sustainable and environmentally friendly solutions within the maritime industry, aiming to align economic incentives with eco-conscious practices for a more balanced and environmentally considerate maritime sector. The European Union took the lead over the IMO by implementing a carbon tax. Starting in January 2024, the EU's Emissions Trading System (EU ETS) included Co_2 emissions from all large ships (5,000 gross tonnage or more) entering EU ports, regardless of flag. This system accounts for 50% of emissions from voyages that begin or end outside of the EU, allowing the third country to address the remaining emissions. It covers all emissions between two EU ports and while ships are in EU ports. To ensure a smooth transition, shipping companies are required to surrender allowances for a portion of their emissions during an initial phase-in period: 40% of their reported emissions in 2024 by 2025, 70% of their reported emissions in 2025 by 2026, and from 2027, they must account for 100% of their reported emissions. (European commission, 2023).

2.3 Long-Term Beyond 2030

long-term policies, they encompass measures that may extend beyond 2030. The plan is to finalize and secure the agreement on these measures through the Committee as part of the 2028 review of the IMO's GHG Strategy. These steps underscore a commitment to sustainable endeavors aimed at reducing GHG within the maritime shipping industry.

3. SHIPPING ADAPTATION WITH IMO'S REGULATIONS

3.1 Shipping Transition Indicators

The shipping industry has been implementing various measures to comply with the IMO regulations and reduce No_x and So_x emissions. These measures include the use of very low sulphur fuel oil (VLSFO) and liquefied natural gas (LNG) (A. Singh and Shanthakumar ,2022). Some ship owners and operators preferred to install exhaust scrubbers and continue using HFO, leading to an increased share of the fleet equipped with scrubbers in the global fleet (see Figure 1).

The industry is also building eco-fleet that incorporate new technologies, optimize ship designs, and improve operational practices to achieve the EEDI. The trend of constructing eco-fleet has steadily risen since the IMO enforced EEDI on all newly built vessels, by September 2023, the global maritime fleet counted 107,503 vessels, and 2.3 billion deadweight tonnes (DWT).

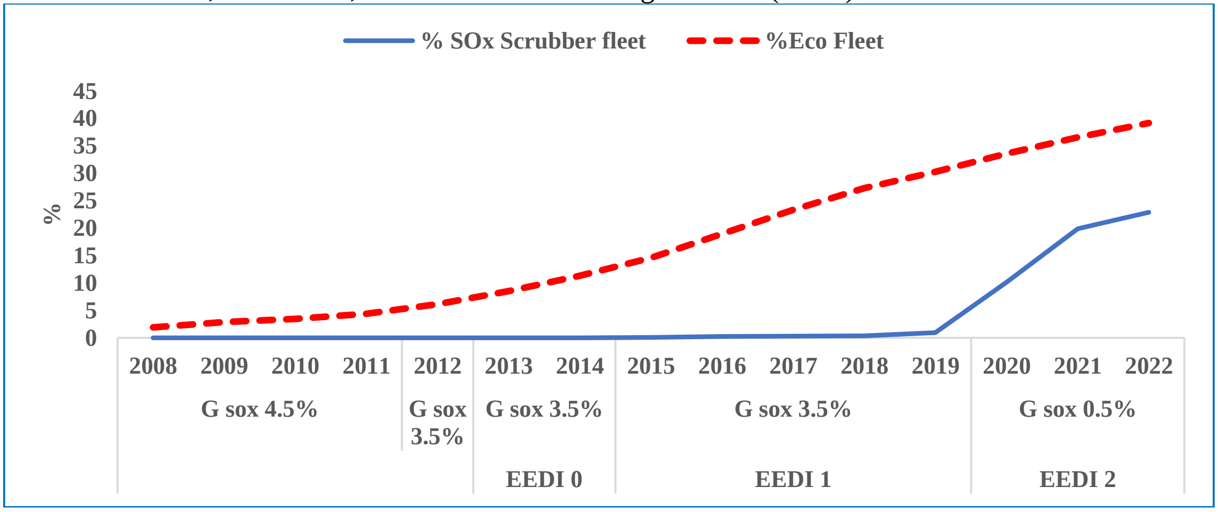

Figure 1: Share of Scrubber and eco fleet from the world DWT fleet (Clarkson's Research, 2023b).

In adherence to the IMO's environmental directives, shipping firms have embarked on constructing vessels driven by eco-ships. Specifically, over 22% of the fleet's capacity has been fitted with scrubbers, and approximately 39.2% have incorporated eco engines. Furthermore (see Figure 1), around 1644 vessels, constituting 5.8% of the world fleet gross tonnage, utilize alternative fuels, while nearly 1483 vessels in the order book represent 49.2% of the total fleet order book by gross tonnage (see Table 5).

Table 5: Alternative Fuel Capable Vessels by Fuel/Propulsion Type (September 2023)

Alternative fuel	*Fleet (number)*		*order book (number)*	
LNG	964	59%	896	60%
LPG	89	5%	83	6%
Methanol	25	2%	165	11%
Hydrogen	7	0%	15	1%
Ethane	22	1%	24	2%
Biofuel	88	5%	15	1%
Nuclear	10	1%	7	0%
Battery/ hybrid	439	27%	278	19%
Total	*1644*	*100%*	*1483*	*100%*
% world fleet Gt	5.8%		49.2%	

Source:(Clarksons Research ,2023a)

The Table indicates a shift in the marine transportation sector toward adopting alternative fuel as a greener energy, comprising 49.2% of the fleet's order book. This transition showcases the industry's dedication to cleaner energy sources, aiming to curtail emissions and contribute to global climate change initiatives, showcasing its potential for long-term sustainability.

3.2 Shipping And Speed

The relationship between a ship's speed and fuel consumption is straightforward, as a ship's drag and water resistance increase as it accelerates. Slow steaming, a practice reducing cruising speed, is an efficient approach to decreasing conventional fuel consumption in maritime transport (Panayides 2019). Previously, shipping companies used slow steaming for cost reduction when fuel prices rose to reduce the cost of shipping (Ronen,1982) (Psaraftis,2019).

However, with the emergence of emission reduction policies established by the IMO, shipping companies have started using speed reduction as a means to reduce emissions (Pelić, Bukovac, Radonja, & Degiuli, 2023) and adapt to environmental policies (Zincir, 2023).

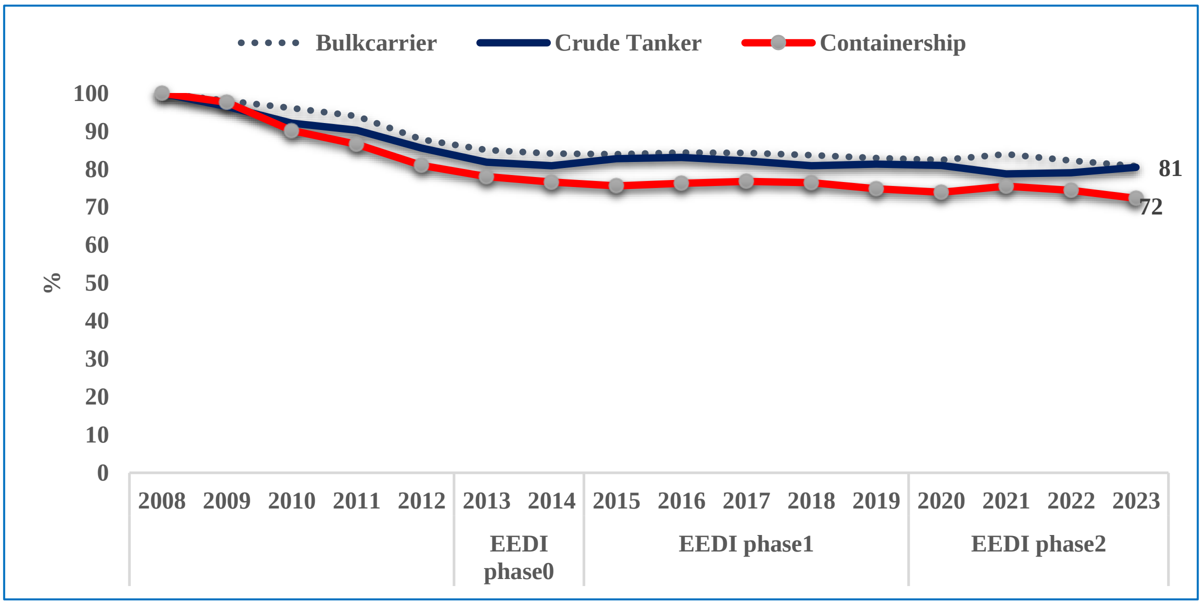

Figure 2: World Fleet speed indices (Clarkson's Research ,2023a)

An investigation into reducing container ship speeds by 10%, 20%, and 30% revealed corresponding reductions in Co_2, No_X, So_X, and PM emissions by 21%, 34%, and 45%, respectively (Pelić et al., 2023). The Clarkson Index (see Figure 2) for global fleet speed indicated that the average speed of container ships dropped by 28% in 2023 compared to 2008 levels. Likewise, bulk carriers and petroleum tankers experienced a 19% decline in speed (Clarksons Research, 2023b).

4. GREEN SHIPPING AND FUEL COSTS

4.1 Alternative Fuel And Future Gap Price

Prior to 2020, ship fuel regulations were globally unrestricted, allowing 3.5% sulfur content in ship fuel and 0.1% in emission control areas (ECAs). Ships predominantly used heavy fuel, shifting to marine gas oil (MGO) solely within ECAs (Vedachalam, Baquerizo, and Dalai, 2022). However, the global sulfur limit has now decreased to 0.5%. To comply, ships have adapted by employing MGO or HFO with scrubbers, whereas LNG-powered vessels were already compliant without further adjustments. This change by the IMO resulted in increased shipping fuel costs due to higher MGO prices compared to HFO (as depicted in Figure 3). The So_X limit has prompted a transition in marine fuels, elevating the use of MGO, VLSFO, and LNG fuels at the expense of HFO to mitigate sulfur emissions. (See Figure 3).

The proposed levy of a carbon tax as a medium-term policy aims to narrow the price gap between traditional and higher-cost green fuels. With a levy tax of $1 per tonne of carbon Co_2, the expenses for conventional fuels like LNG might increase by $2.75 per tonne, and for HFO and MGO, by $3.11 and $3.2 per tonne, respectively (see emissions factor in Table 1 in the appendix). Our analysis focused on the impact of this tax on fuel prices, considering the average prices at the Port of Rotterdam from 2020 to October 2023 across various tax levels on bunker fuel prices (see Figure 4).

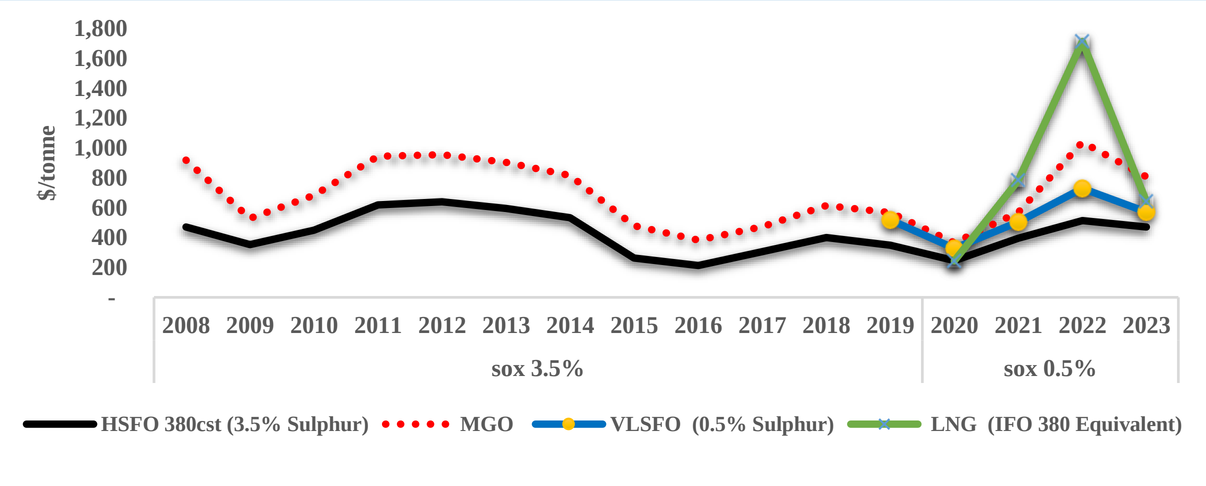

Figure 3: average yearly bunker price at port of Rotterdam (Clarkson's Research ,2023a)

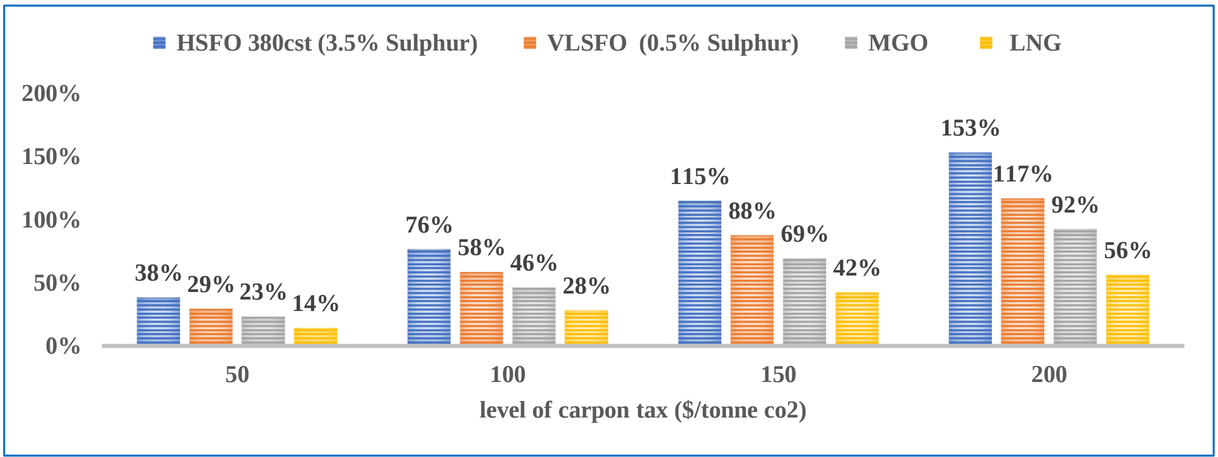

Figure 4: Estimate the effect of carbon tax at different levels on the traditional bunker price (by authors)

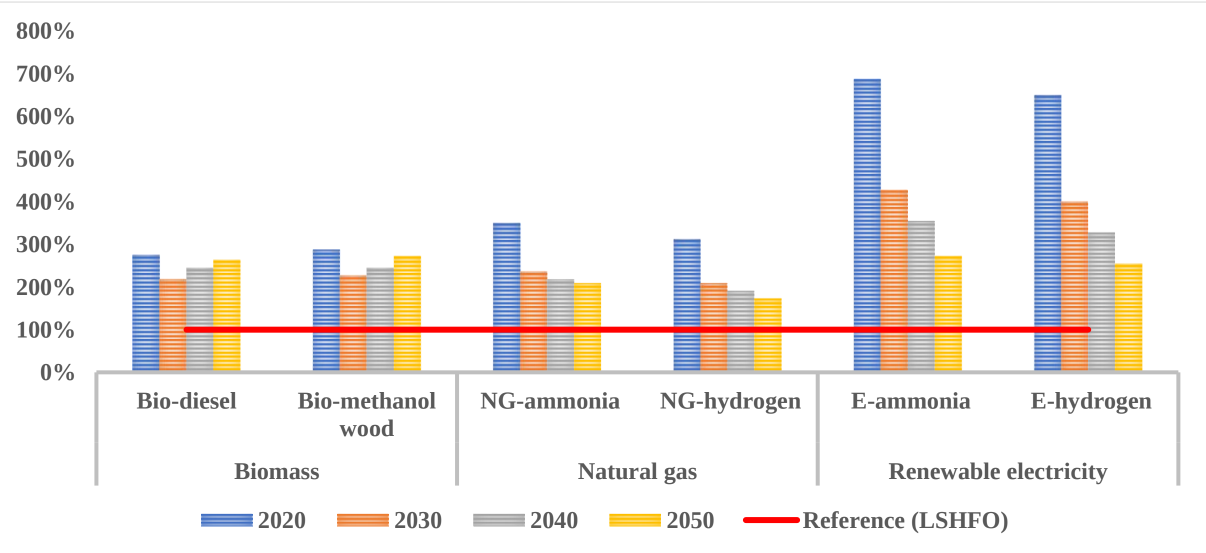

Figure 5: Future price gap between alternative fuels and HFO (Cullinane and Yang 2022)

A $100 carbon tax per Co_2 tonne is estimated to increase fuel costs by 28% to 76%, depending on fuel type and current prices. This move aims to encourage the adoption of alternative fuels, starting with biofuel or methanol in the near term and transitioning to hydrogen and green ammonia in the medium to long term.This transition to low-carbon or carbon-neutral fuels is crucial to comply with the IMO's regulations. According to current expectations, the price gap between alternative fuels and fossil fuels without a carbon tax is very high in the short and medium term, depending on the source of fuel production. The long-term price gap is expected to decrease as more ships transition to alternative fuels, but it will likely remain higher than fossil fuels (see Figure 5).

4.2 World Seaborne Trade And Emissions Pathway

The IMO's emission reduction policies reduced emissions by 18.3% in 2022 compared to 2008. the share of each seaborne trade tonne from Co_2 decreasing by 40.1%. However, world seaborne trade increased by 36.1% from 2008. (see Figure 6) The third phase of the EEDI, CII, and EXII indicators is expected to contribute to continued emissions reduction. Green sailing will lead to further carbon reduction in the maritime shipping sector. It has become certain that medium- and long-term policies will lead to an increase in international shipping costs, and their impact on world seaborne trade will depend on the level of carbon tax, investments in alternative fuels, and technological advancements in shipbuilding.

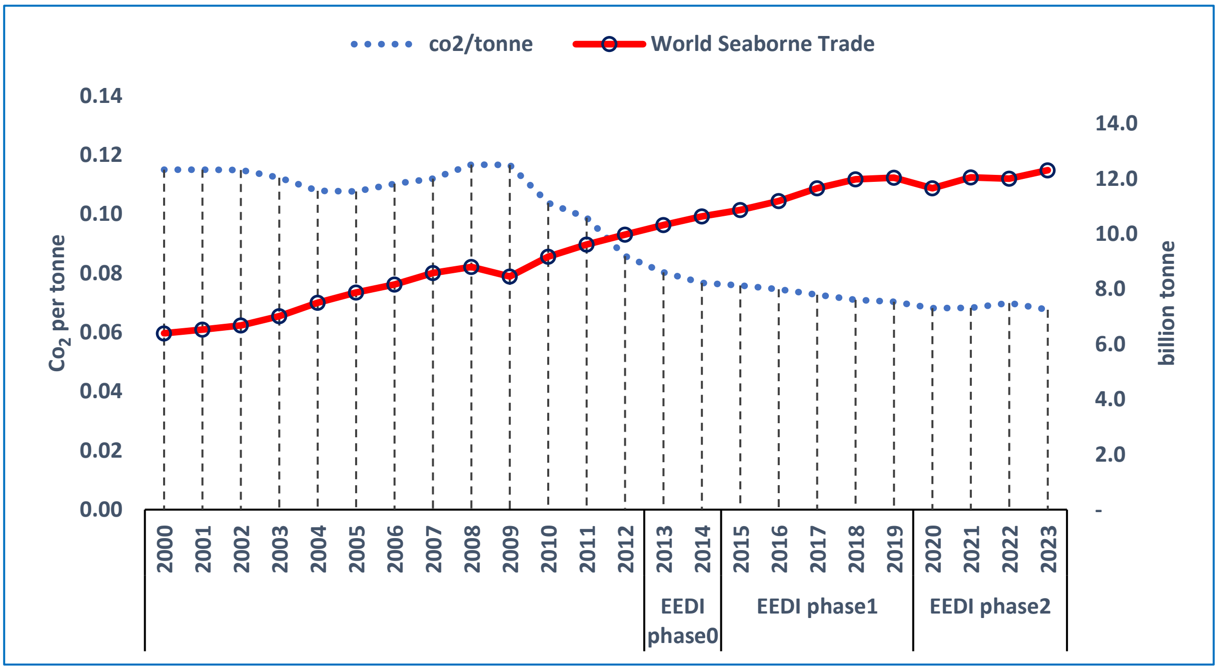

Figure 6: World Seaborn Trade and Co_2 per tonne (Clarkson's Research, 2023)

5. IMPACT OF GREEN SHIPPING ON THE SUEZ CANAL

The Suez Canal, located in Egypt, is the longest canal without locks and the shortest route between the North Atlantic and Indian Ocean. It connects the Mediterranean Sea and the Red Sea, offering savings in distance, time, fuel consumption, emissions, and ship operating costs compared to the Cape of Good Hope route (Khaled El Sakty, 2020). The Suez Canal, a significant global maritime route, handles 12% of international seaborne trade annually (Wan et al., 2023).

The Suez Canal is of particular importance in tackling the issue of climate change due to its enormous contribution to lowering fuel usage, leading to a substantial drop in carbon emissions. Since the ultimate goal of green sailing is to reduce carbon. we will focus on the contribution of the Suez Canal to this reduction and the impact of the carbon tax on the Suez Canal. The subsequent discussion expounds upon significant aspects of this noteworthy achievement for the first time.

5.1 Estimating the effect of Imo's Policies on Suez Canal saving (case study)

The emissions reduction achieve by the Suez Canal is influenced by various factors such as ship type, size, fuel used, origin and destination region, etc. For a concise comparison, we have conducted an in-depth examination of these variables through a case study involving a 158,000 DWT tanker. The vessel, operating at a 90% load factor and traveling at a speed of 12 knots per hour, embarks on voyages from the Basrah Oil Terminal in the Arabian Gulf (AG) to two distinct destinations: Augusta Port in Italy in the Mediterranean Sea (MED) and Rotterdam in the Netherlands in Northwest Europe (NWE). Our comparison between the Suez Canal route (SC) and the Cape of Good Hope (CGH) route reveals significant emission savings with the SC route. These savings amount to 3,425 tonnes of Co_2 for the AG-MED route and 2,300 tonnes for the AG-NEW route (see Table 6).

Table 6: Case Study for calculating Emission Savings via the Suez Canal for Crude Oil Trade

Assumptions	*AG-MED SC*	*AG-MED CGH*	*AG-NEW SC*	*AG-NEW CGH*
Ship Size (DWT)	158,000	158,000	158,000	158,000
Load factor (%)	90	90	90	90
Cargo (barrel)*	1,042,326	1,042,326	1,042,326	1,042,326
Distance (miles)**	4,281	11,329	6,630	11,363
Laden voyage -Fuel consumption (tonnes)	669	1,770	1,036	1,775
Co_2 Emissions (tonnes)	2,080	5,505	3,222	5,522
SC Emission Saving (tonnes)	3,425		2,300	

Source: by authors *tonne =7.33 Barrel *https://sea-distances.org

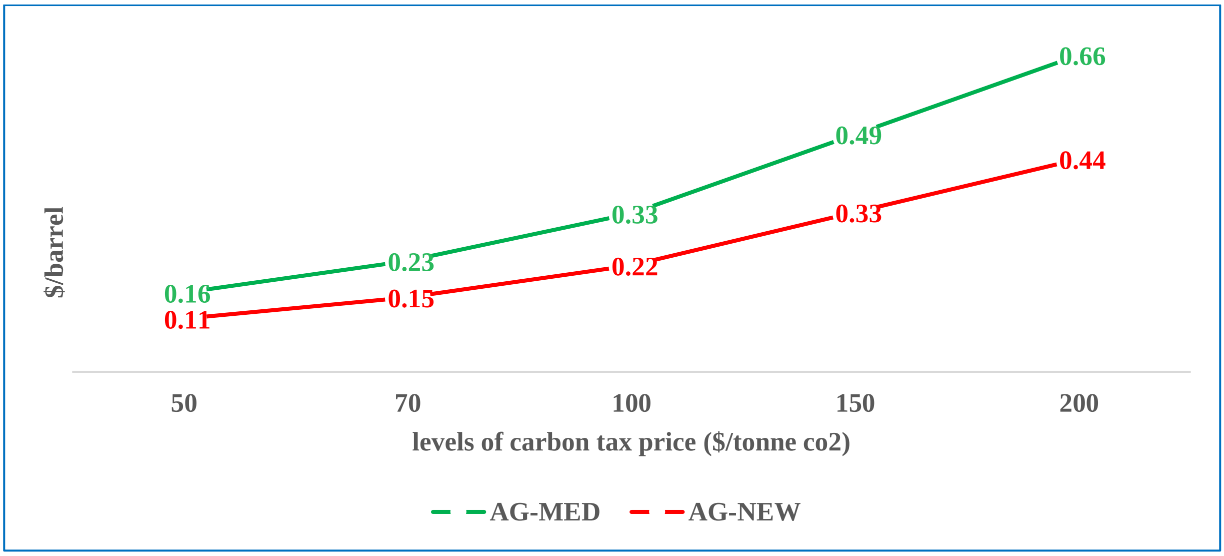

Figure 7: Suez Canal emission saving values for crude oil trade per barrel at different levels of Co_2 tax (by authors)

Suez Canal offers environmental benefits due to reduced distance, lower fuel consumption, and decreased Co_2 emissions, reducing the maritime industry's carbon footprint. With a carbon tax of $100 per tonne, the Suez Canal route offers significant savings for crude oil trade per barrel. Customers could save \$0.35 per barrel on the AG-MED route and \$0.23 per barrel on the AG-NEW route (see Figure 7) compared to the CGH route. However, the emission savings values are variable and would adjust based on the actual carbon tax price. By using the same method as in the previous case study, for all vessels transited the Suez Canal, which counted 23,851 vessels in 2022 and about 1.2 billion tonnes. The Suez Canal reduced Co_2 emissions by approximately 49.9 million tonnes compared to the CGH route. Notably, 33% of these emission reductions came from container vessels, 30% from tanker fleets, 21% from dry bulk fleets, 5% from gas carriers, 4% from general cargo ships, 1% from car carriers, and 6% from the remaining fleet (see Figure 8).

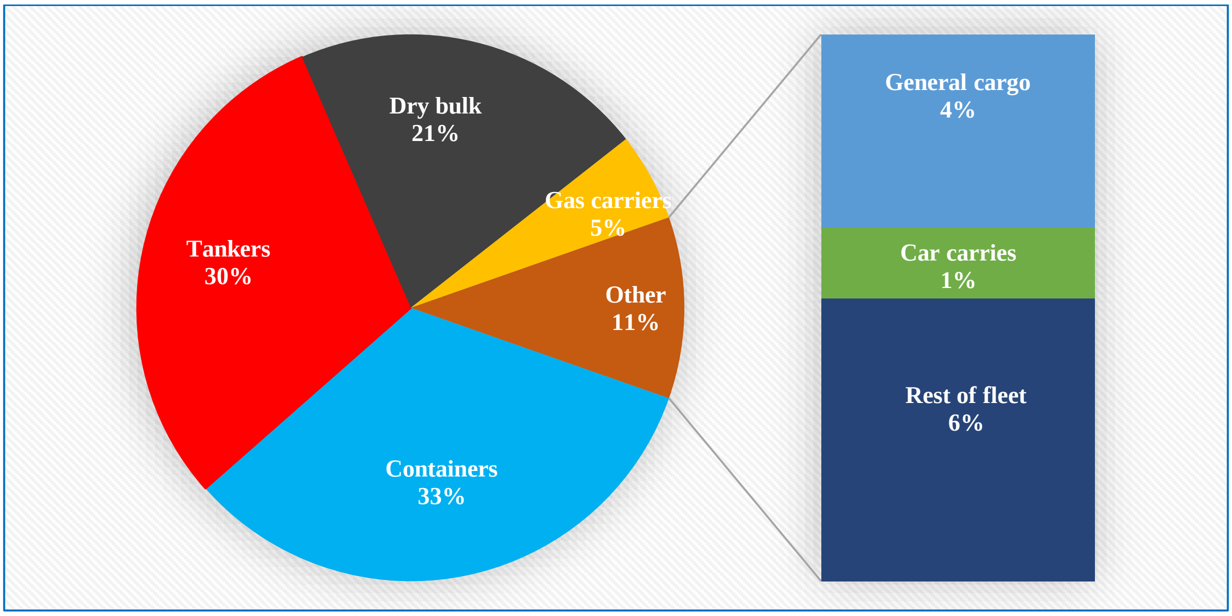

Figure 8: Distribution of ships' contributions to emission reductions in the Suez canal in 2022 (selim, 2023)

Based on the 2022 Co_2 savings attributed to the Suez Canal, it is estimated to generate an average annual savings of 49.9 million dollars for each 1-dollar levy carbon tax. These estimations underscore the substantial economic and environmental advantages offered by the Suez Canal on a global scale. From another perspective, if the IMO imposes a carbon tax on the shipping industry, it would incentivize shipping companies and operators to reduce emissions. This could be achieved either through enhanced fuel efficiency or the adoption of low-carbon alternative fuels such as green methanol or green hydrogen, albeit at higher costs (see Figure 5). Therefore, green navigation will ultimately contribute to an increase in the cost savings provided by the Suez Canal.

5.2 Estimating the effect of Imo's Policies on Suez Canal Trade

In this section, we examine the impact of shipping Co_2 emissions, representing IMO's policies, and world seaborne trade used as independent variables on Suez Canal trade, the dependent variable. by using annual time series data from 1990 to 2022, sourced from the Suez Canal Authority and Clarkson's database, The equation representing this relationship is expressed as:

$$\ln SCT_t = \beta_0 + \beta_1 WST_t + \beta_2 SCo2_t + \varepsilon_t \quad (eq1)$$

The variables in the equation are denoted as follows: 'Ln' refers to the logarithm, 'T' represents the time period, (β_0, β_1, β_2) signify the assessed coefficients, 'SCT' stands for Suez Canal trade, 'WST' represents world seaborne trade, 'SCo_2' denotes shipping Co_2, and 'ε' signifies the random error term. The ARDL, a cointegration test in econometrics, facilitates the analysis of relationships among nonstationary variables. The ARDL limit test comprises three stages. Initially, it assesses the existence of long-term relationships between the variables. Subsequently, it computes the short, and long-term coefficients of the series identified as cointegrated .in the first stage, a joint integration test is carried out within the UECM framework, which takes the following formula:

$$\Delta\,(\ln SCT_t) = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\,\Delta(\ln SCT_{t=i}) + \sum_{i=1}^{q} \beta_{2i}\,\Delta(\ln WST_{t=i}) + \sum_{i=1}^{n} \beta_{3i}\,\Delta(\ln SCo2_{t=i}) + \alpha_{\,1} ln\, SCT_{t=1} + \alpha_{\,2} lnWST_{t=1} + \alpha_{\,3}\, ln\, SCo2_{t=1} + \mu_t \;\; (eq2)$$

The symbols (α₁ ، α₂ ، α₃) signify coefficients that represent long-term relationships, whereas (β_{1i} ، β_{2i} ، β_{3i}) indicate information about short-term relationships. The symbol Δ denotes the first differences of the variables, while (P,q,n) represents the lags of the variables. The symbol μ represents the random error. The boundary-by-procedure test, proposed by Pesaran et al (Pesaran, Shin, and Smith 2001), assesses whether variables have a long-term relationship through cointegration. It uses the F test to compare computed values with critical values (UCB and LCB) based on integration degrees (I (0) and I (1)). The null hypothesis (H_0: $\alpha_1 = \alpha_2 = \alpha_3 = 0$) suggests no cointegration, while the alternative (H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$) indicates cointegration. If the calculated F-value exceeds the UCB, it rejects the null hypothesis, supporting cointegration. below the LCB, it accepts the null hypothesis. Values in between yield an inconclusive result. Upon confirming cointegration, the next step involves establishing the long-term equation to understand the enduring relationship between variables with the following equation.

$$(\ln SCT_t) = \beta_0 + \sum_{i=1}^{p} \Phi_{1i}\,(\ln SCT_{t-i}) + \sum_{i=1}^{p} \Phi_{2i}\,(\ln WST_{t-1}) + \sum_{i=1}^{p} \Phi_{3i}\,(\ln SCo2_{t-1}) \; + v_t \;\; (eq3)$$

In the equation 3, (Φ_1 ، Φ_2 ، Φ_3) stand for the coefficients of the variables, while p represents the lag periods. The term ν denotes the boundary for random errors. The order of lag selection in the ARDL model is determined based on either the Akaike Information Criterion (AIC) or the Schwarz Bayesian Criterion (SBC). Subsequently, the specified model is assessed for potential serial or autocorrelation in the random errors using Ordinary Least Squares (OLS) method. In the third phase, the short-term dynamics within the ARDL framework can be captured through the development of the Error Correction Model (ECM) using the following equation:

$$\Delta\,(\ln SCT_t) = \beta_0 + \sum_{i=1}^{p} \theta_{1i}\,\Delta(\ln SCT_{t=i}) + \sum_{i=0}^{q} \theta_{2i}\,\Delta(\ln WST_{t=i}) + \sum_{i=0}^{n} \theta_{3i}\,\Delta(\ln SCo2_{t=i}) + \lambda\, ECT_{t-1} + U_t \;\; (eq4)$$

The term "ECT" signifies the error correction term. All coefficients within the short-run equation pertain to the transient dynamics responsible for the model's convergence towards its equilibrium state. The symbol λ denotes the error correction factor, quantifying the rate at which any short-term imbalance adjusts towards the long-term equilibrium position.

Finally, we assess the stability of both short-run and long-run coefficients using cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests. These statistics, continuously updated and plotted against specific breakpoints, offer insights into coefficient stability. If the plotted CUSUM and CUSUMSQ statistics remain within the 5% significance level's critical bounds, it indicates the inability to reject the null hypothesis indicating stable coefficients in the regression analysis. To conduct these tests, we will employ EViews 12 statistical software, Comprehensive outcomes of each step will be available in the appendix.

In our empirical analysis, we initially conducted unit root tests for each series, and the outcomes are presented in Table 2 in the appendix. These tests were carried out using both the Augmented Dickey-Fuller (ADF) and Phillip Parren methodologies. The results indicate that the variables are integrated at order one, suggesting the potential applicability of the ARDL methodology to explore long-term relationships among these variables. Subsequently, we estimated the ARDL model, and the findings are displayed in Table 3 in the appendix. The adjusted-R value of 0.98 signifies a strong correlation among the variables, and the tests indicate the absence of heteroskedasticity (see Table 4 in the appendix) and serial correlation (see Table 5 in the appendix). Furthermore, the bound test results suggest the presence of cointegration among the variables, implying a long-term relationship.

The results in Table 7 from the appendix show a significant positive long-term relationship between the world seaborne trade and the Suez Canal trade. Meanwhile, shipping Co_2, reflective of IMO's policies, exhibits a significant negative effect on the Suez Canal trade. The short-run dynamics of this relationship were investigated using the ARDL error correction model, detailed in Table 8 in the appendix. The results indicate that world seaborne trade exhibits the most substantial influence on the Suez Canal trade in the short run. Specifically, a 1% rise in world seaborne trade corresponds to a 2.92% increase in the Suez Canal trade volume. Conversely, the impact of SCo_2 on the Suez Canal trade appears insignificant in the short run for the period (t, t-1, t-2), gaining significance from the period (t-3, t-4) onwards. This means that the effectiveness of IMO's policies aimed at reducing SCo_2 emissions will take time to affect the Suez Canal trade.The ECM term's coefficient is appropriately signed and statistically significant, confirming the existence of a relationship between the variables. Moreover, the ECM coefficient implies a rapid adjustment process, with around 15% of the prior year's discrepancy in Suez Canal trade from its equilibrium rectified in the current year. The CUSUM and CUSUMSQ plots to check the stability of short-run and long-run coefficients in the ARDL error correction model are given below in Figure 9 showing that both statistics, CUSUM and CUSUMSQ, are within the critical bounds of 5%, indicating that the model is structurally stable.

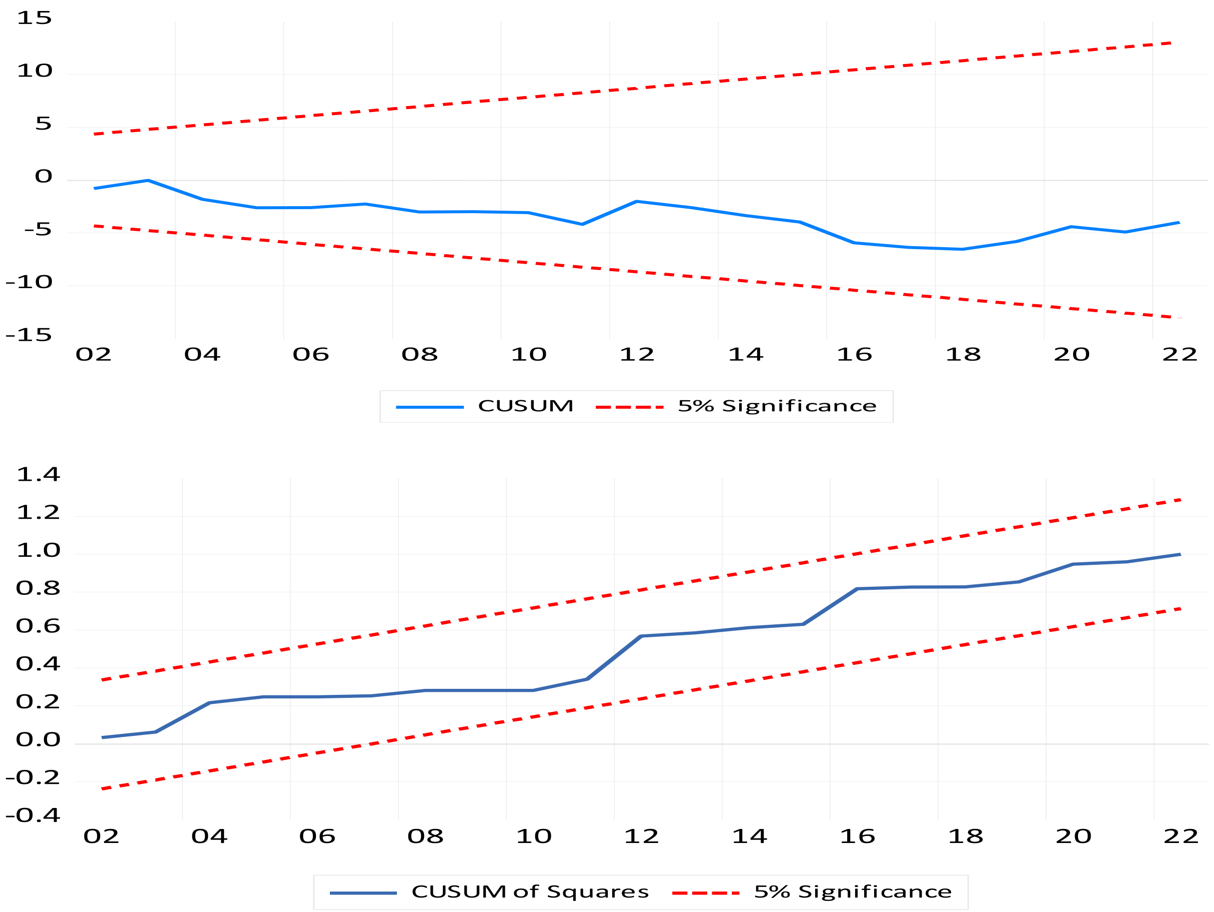

Figure 9: CUSUM And CUSUM Of Squares Test. (EViews 12 Results)

Overall, the evidence presented in this section indicates that fluctuations in the world seaborne trade primarily drive the Suez Canal trade, both in the short run and the long run, while SCo_2 emerges as a less influential determinant in the short run but becomes more significant in the long run.

6. CONCLUSION AND RECOMMENDATIONS

The study examines the Maritime Organization's efforts towards green transformation in the short, medium, and long term. It found that the IMO's short-term policies have pushed maritime transport towards building eco-ships, exhaust scrubbers, and modern ships with alternative fuels. The trend is expected to continue with tighter policies. However, medium-term policies will lead to increased shipping costs due to the Co_2 per tonne levy tax, which will increase the cost of conventional fuel by 2.75 to 3.2 dollars per tonne. The study also examined the role of the Suez Canal in reducing global emissions, estimated at 49.9 million tonnes in 2022. The study found that medium-term policies will increase the value of savings achieved by the Suez Canal for maritime shipping. The ARDL model was used to estimate the short- and long-term effects of world seaborne trade and IMO policies on the Suez Canal trade. The results showed a positive and significant short, and long-term effect of world seaborne trade on the Suez Canal. However, IMO policies showed no immediate significant impact in the short-term but negative long-term effects, and overall, the positive long-term effects of world seaborne trade will be greater than the negative long-term effects of the IMO's policies on the Suez Canal trade.

Based on the final results of the study, the following recommendations can be made: (1) It is imperative to channel concerted efforts towards the proactive establishment of global port infrastructure featuring green technologies. This entails the provision of facilities for green fueling, aimed at supporting green navigation and decreasing GHG from shipping. (2) The Egyptian maritime shipping industry's most influential players should work together to draft a detailed schedule that meets the exacting standards set by the IMO. To achieve a thorough and efficient green transformation. (3) The Suez Canal Authority must highlight its critical role in the global effort to reduce emissions. This can be accomplished by implementing a meticulously designed emission calculator record system for vessels that pass through its waters. Such measures will not only help to meet carbon reduction targets but will also promote transparency and accountability. The adoption of these recommendations will significantly fortify the ongoing efforts aimed at promoting sustainable practices within the maritime shipping sector, consequently contributing to the attainment of carbon emission reduction objectives on both a global and local scale and supporting green navigation.

7. APPENDIX

Table 1: Average Emissions factor by fuel type (2012 -2018) (kg pollutant/tonne fuel)

Fuel / Pollutants	*HFO*	*MGO*	*LNG*
Co_2	*3,114.00*	*3,206.00*	*2,750.90*
No_x	*76.9*	*55.3*	*7.9*
So_x	*48.1*	*2*	*-*
PM	*7.3*	*0.9*	*0.1*
$PM_{2.5}$	*6.7*	*0.9*	*0.1*
NMVOC	*3.2*	*2.3*	*1.2*
Co	*2.9*	*2.5*	*2.8*
BC	*0.3*	*0.4*	*-*
N_2O	*0.2*	*0.2*	*0.1*
CH_4	*0.1*	*0.1*	*8.6*

Source:(IMO, 2020).

Table 2: Results of unit root test

Time series	*Prob*	*levels*			*1St differences*		
		ADF	PP	unit root*	ADF	PP	unit root*
Ln SCT	p-value	0.9990	0.9996	YES/YES	0.0001	0.0001	No/No
Ln WST	p-value	0.4104	0.9928	YES/ YES	0.0002	0.0002	No/No
Ln SCo_2	p-value	0.4805	0.8499	YES/ YES	0.0010	0.0008	No/No

* Null Hypothesis decision for the two tests respectively.

Table 3: ARDL (1, 1, 4) selected based on Akaike info criterion (AIC)

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
Ln $SCT_{(t-1)}$	0.852301	0.077225	11.03655	0.0000
Ln $WST_{(t)}$	2.929444	0.493453	5.936622	0.0000
Ln $WST_{(t-1)}$	-2.491214	0.503545	-4.947346	0.0001
Ln $C_{O2(t)}$	0.117780	0.315352	0.373489	0.7125
Ln $C_{O2(t-1)}$	-0.005697	0.553607	-0.010291	0.9919
Ln $C_{O2\,(t-2)}$	-0.804150	0.504903	-1.592682	0.1262
Ln $C_{O2\,(t-3)}$	1.162099	0.512244	2.268645	0.0340
Ln $C_{O2\,(t-4)}$	-0.815042	0.322750	-2.525304	0.0197
R-squared		0.991646		
Adjusted R-squared		0.988861		
S.E. of regression		0.049600		
S.D. dependent var		0.469951		
Durbin-Watson stat		1.848092		

Table 4: Heteroskedasticity Test: Breusch-Pagan-Godfrey results

Null hypothesis: Homoskedasticity			
F-statistic	0.346472	Prob. F (8,20)	0.9364
Obs*R-squared	3.529877	Prob. Chi-Square (8)	0.8969
Scaled explained SS	1.536020	Prob. Chi-Square (8)	0.9921

Table 5: Breusch-Godfrey Serial Correlation LM Test results

Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	0.060198	Prob. F(2,19)	0.9418
Obs*R-squared	0.182604	Prob. Chi-Square (2)	0.9127

Table 6: Bounds Test results

F-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	Value	Signif.	I (0)	I (1)
F-statistic	6.286861	10%	2.17	3.19
k	2	5%	2.72	3.83
		2.5%	3.22	4.5
		1%	3.88	5.3
t-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	Value	Signif.	I (0)	I (1)
t-statistic	-4.544979	10%	-1.62	-2.68
		5%	-1.95	-3.02
		2.5%	-2.24	-3.31
		1%	-2.58	-3.66

Table 7: ARDL (1, 1, 4) Model Long Run results dependent variable ln (SCT)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNWST	2.967045	0.758730	3.910540	0.0008
LNCo_2	-2.335895	0.853291	-2.737515	0.0123

Table 8: ARDL (1, 1, 4) Error Correction model ECM "short run"

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (Ln WST)	2.929444	0.364885	8.028402	0.0000
D (LN Co_2)	0.117780	0.296171	0.397677	0.6949
D (LN Co_2 (-1))	0.457093	0.325402	1.404705	0.1747
D (LN Co_2 (-2))	-0.347057	0.295393	-1.174897	0.2532
D (LN Co_2 (-3))	0.815042	0.304269	2.678686	0.0141
ECM (-1)	-0.147699	0.032497	-4.544979	0.0002

The ECM equation is given as ECM = LN SCT - (2.9670*LN WST -2.3359*LN Co_2)

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