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ESI Score: An Insight to Incentives for UK Ports

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1. Abstract

This study focuses on the "Environment" and "Maritime Infrastructure" themes of Maritime 2050, a long-term strategy developed by the UK Department for Transport. The Environmental Ship Index has been chosen to examine its applicability in the UK ports as a "green incentive measure" with the aim of mitigating climate change, and therefore contributing to achieve Maritime 2050 goals. To this end, the paper analyses the UK Port Infrastructure as well as the relationship between ports and climate change. Following this, the research focuses on finding out the economic incentives of Environmental Ship Index for ports. Although shipping companies see clear incentives due to discounts on port dues, it is arguable the economic benefits for ports apart from a cleaner environment. This research aims to motivate ports to include this measure as a means of building on a competitive advantage based on social responsibility in a green era for maritime transport.

2. Introduction

The UK is one of the world's leading maritime nations. Maintaining and further improving this position though requires adapting and planning for the future. The maritime sector has played a critical role for the UK as a primary facilitator of global trade, as the UK is a service-oriented economy and benefits heavily from the maritime sector, which plays a vital role in facilitating international trade. Dependence on shipping for domestic and international trade arise relevance for ports as key instruments of this economic activity.

Addressing climate change impacts in the port sector is challenging, but an issue that needs to be taken into account. Climate Variability and Change (CV & C) impacts on seaports refer to sea level rise, storm surges, heat waves, extreme winds, and waves. In order to approach this problem, there are two main policy responses to climate change: mitigation and adaptation. While mitigation tries to address the causes by e.g. reducing greenhouse gases (GHG) emissions, adaptation aims to lower the risks caused by the climate change. The UK has been at the forefront of policies aiming to reduce GHGs sending a clear message that a switch to zero (or at least, close-to-zero) emission technologies is imminent and will deliver benefits for air quality. Following air quality issues, the "Clean Air Strategy 2019" is a UK government strategy that aims to address air pollution through the analysis of its sources. This programme focuses among others in NO_x and SO_x[1] as some of the main air pollutants. Due to the great importance of this topic, a specific mitigation strategy has been selected in this study: "green port fees", and more specifically the ESI (Environmental Ship Index).

[1] Nitrogen oxide (**NOx**): It is a chemical compound of oxygen and nitrogen formed by reacting with each other during Sulphur oxides (**SOx**) are made up of sulphur and oxygen molecules. The most common sulphur oxide is sulphur dioxide (SO2), which is a colourless gas with a burnt match type smell.

The International Association of Ports and Harbours (IAPH) has taken part into mitigation strategies through a program initially aimed to study many alternatives to confront climate change. One of these alternatives is the ESI, which is an index that measures the environmental performance of ships calling at ports in order to reward the cleanest vessels with rebates of port charges. Advantages and disadvantages of this index are studied and compared to other sources of "green incentives" that ports can provide to reduce the carbon footprint related to the maritime industry.

3. Ports and Climate Change: UK Perspective and Strategies to Address the Issue

3.1. Profile of the UK Port Infrastructure and Trade

A major implication of the UK's geography is the country's dependence on shipping for domestic and international business. Ports are a great facilitator of trade and economic activity and numerous of the most important metropolitan areas in the world have grown up next to waterways and coastal sites due to commercial opportunities linked to seaborne trade. UK's maritime industry is expected to keep playing a key role in enabling international trade in goods, and therefore contributing significantly to the UK's economy.

Around 95% of British trade-in-goods were moved by sea in 2016 (The UK Department for Transport, 2019). The UK economy is mainly service-sector oriented, resulting on the UK importing more goods than exporting. According to the UK Department for Transport (2018), a total of 300.9 million tonnes imports entered UK ports in 2017, while exports reached 180.7 million tonnes. Figure 1 presents the inwards and outwards UK's maritime trade during the period 2008-2017. Evidently, the UK is a net importer while realising an increase in both imports and exports. Therefore, the importance of trade and in turn, of the maritime industry is becoming even more significant. Consequently, a potential disruption in shipping and port operations can have major consequences for the UK.

The UK's maritime sector generated £14.5 billion in 2016 and directly supported an estimated 186,000 jobs. The substantial direct economic contribution of the UK's maritime sector exceeds those of other comparable industries. For instance, the direct turnover contribution of just over £40 billion compares to £31.1 billion from the entire aerospace industry in 2015. Concerning the indirect economic impacts (i.e. supply chain), it is expected that the maritime sector helped to support a total of £37.4 billion of GVA in 2015 (CEBR, 2017).

Furthermore, apart from the trade in goods, maritime plays a key role in the tourist and leisure industry with approximately 2 million cruise passengers passing through UK ports in 2016 (UK Department for Transport, 2019).

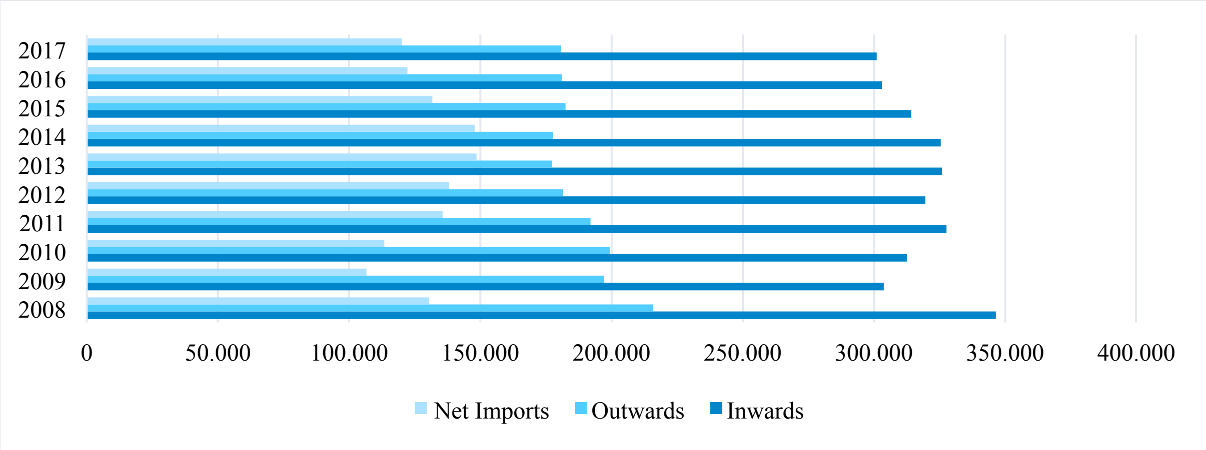

Figure 1. UK's inwards and outwards maritime trade in thousand tonnes. 2008-2017 (Department for Transport, 2018)

Since the major UK ports (53 ports) handled 98% of the UK port tonnage in 2017, the following analysis focuses on those. A list of the major UK ports and their geographical distribution is provided in Table C1 and Figure C1 in Appendix C. Furthermore, Figure 2 shows all UK major ports traffic by cargo type in the period 2008-2017. Although liquid bulk has experienced a negative growth trend, it remains the primary source of trade for UK's ports, accounting for 40% of all tonnage of the UK ports.

However, in the long term, the decarbonisation of the energy sector and the associated increase in the use of renewable energy is expected to significantly reduce the amount of oil and gas transported by sea. The most important international route for crude oil trade is Norway, where nearly all crude oil traded is imported to the UK, while the second largest route is the Netherlands, reversing the trade direction as the vast majority is exported. Ro-Ro (Roll-on Roll-off) is the second largest cargo type (in terms of volume) overtaking the dry bulk sector in the last recent years. This cargo type is relevant for the UK's maritime sector as among general cargoes, the import-export of vehicles plays a key role. This is of relevance because the automotive industry is one of the leading industries for the UK accounting for 14.4% of the UK's total export goods (SMMT, 2019). Domestic Ro-Ro refers to the trade entirely between the UK ports and makes up nearly 20% of all units passing through the UK ports. The vast majority of international Ro-Ro trade routes are with European countries, especially France, which accounts for half of the freight units in both directions (inwards and outwards).

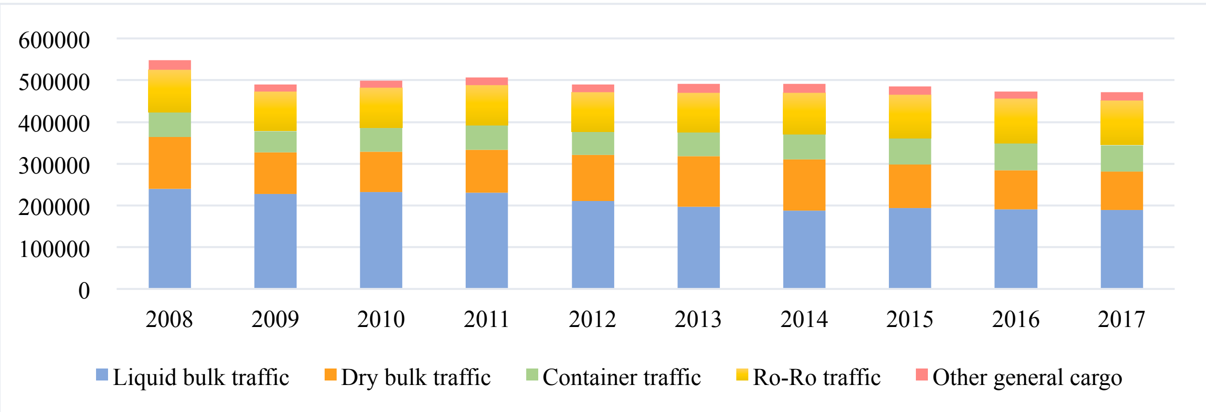

Figure 2. The UK major ports freight traffic in thousand tonnes. 2008-2017. (Department for Transport, 2019)

Furthermore, a brief analysis of these main two cargo trades among the major UK ports is provided. Figure 3 represents the top 15 UK major ports in liquid bulk traffic in 2017. Crude oil and oil products dominate this type of cargo and the five largest ports in this category account for approximately 60% of the total liquid bulk traffic in 2017. Milford Haven is the leading port in liquid bulk cargo as nearly 97% of its total freight is related to this cargo type, making of this port a specialised port. Forth follows a similar trend, while the case of Southampton is relevant. Port of Southampton is the largest port for crude oil passing in the inwards direction, with 11.9 million tonnes passing through in 2017.

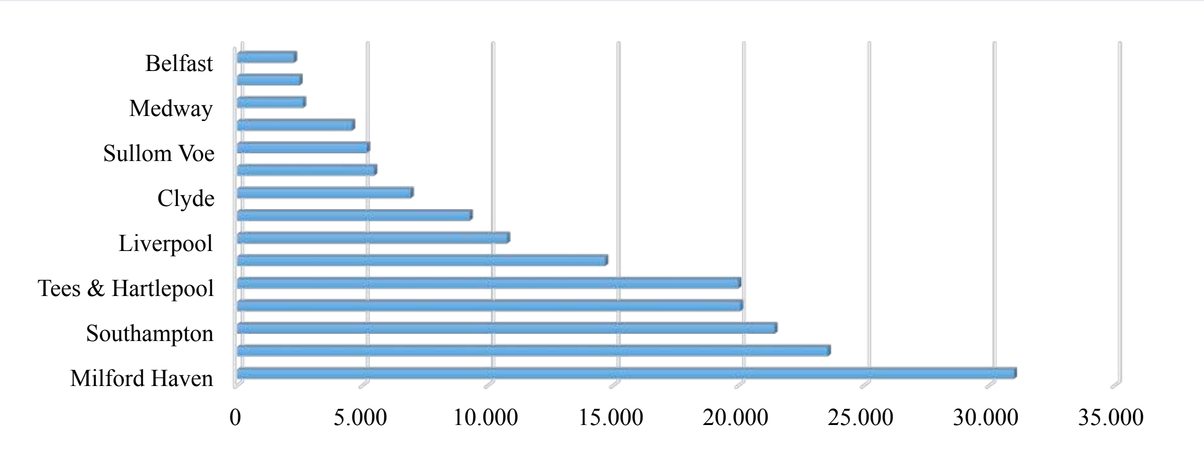

Figure 3. Top 15 UK major ports in liquid bulk traffic in thousand tonnes. 2017. (The UK Department for Transport, 2018)

With respect to Ro-Ro traffic, Figure 4 shows a huge difference between the leading port (Dover), and the rest of the ports. Approximately 98% of Dover's total freight is related to Ro-Ro traffic, fact that makes this port standing out for its specialisation in this cargo category. Ro-Ro traffic has been rising during the most recent years, overtaking dry bulk traffic as the second largest cargo trade for the UK's maritime sector.

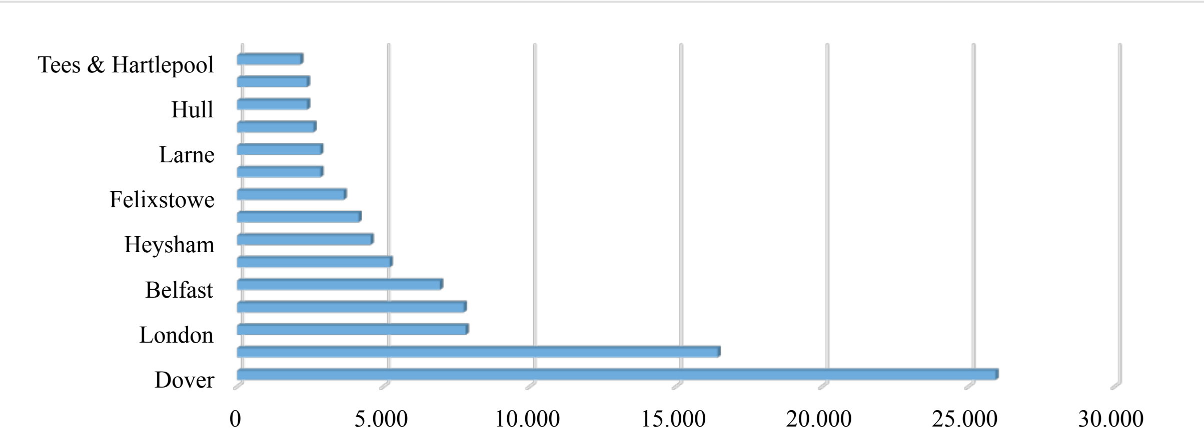

Figure 4. Top 15 UK major ports in Ro-Ro traffic in thousand tonnes. 2017. (UK Department for Transport, 2019)

Regarding the dry bulk and container cargoes, a list and a map with the top UK ports by cargo is provided in Table C2 and Figure C2 of Appendix C, respectively. Moreover, it is relevant to remark that the UK ports sector is one of the largest in Europe handling 470.7 million tonnes (The UK major ports) in 2017. A graph of the largest European countries in terms of cargo handling is provided in

Figure C3 in Appendix C. With respect to port's ownership, the majority of the UK's biggest ports (15 of the largest 20 UK ports by tonnage) are in the private sector, which is considered to be an efficient market due to strong competition between ports. Much of the tonnage is handled in a small number of ports, with the top 15 ports accounting approximately 80% of the UK's total traffic. Concerning safety and security, British companies play a key role in security by protecting ports through high technology tracking or access to control systems. Besides, safety is another area of relevance in which the UK stands out for its know-how and compliance with industry and governmental guidelines.

3.2. Climate change and port infrastructure

Addressing climate change impacts in the port sector is challenging and definitely an issue that needs to be taken into account as according to the IAPH seaports are vulnerable to changes such as mean sea level, storm water levels, wind, waves and swell, tidal regime, acidity, etc. Consequently, policy makers might need to take important decisions that are related to sustainability of port infrastructure through assessment methods.

On a global scale, "human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, and is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate" (IPCC, 2019). Moreover, warming greater than the global annual average has been experienced in many regions around the world, including two to three times higher in the Arctic. Consequently, the Arctic ice sheets are losing mass, and together the ocean thermal expansion and glacier mass loss explain around 75% of the global mean sea level rise (O'Keeffe et al., 2016). According to the UNCTAD (2017), the main reasons why ports are likely to be at risk from climate change are: (i) by virtue of their locations on coasts, they are highly exposed to a range of climate hazards such as the ones mentioned before; (ii) shipping industry can be affected by adverse climatic conditions causing delays to port operations; (iii) they are vulnerable to impacts of climate change through global trade; and (iv) ports are vulnerable to utilities like water or power disruptions.

CV & C impacts on seaports refer to sea level rise, storm surges, heat waves, extreme winds and waves. The main consequences of the increase of sea levels are coastal inundation, erosion, wind hazards and inland flooding, which do not only disrupt the shipping movements but also transport networks in and out of the port on roads, rail and air (Abia Mojafi, 2019). Moreover, changes in extreme precipitation may result in coastal riverine floods that can cause direct damages, which eventually requires emergency responses. According to UNCTAD (2017), flooding from intensifying extreme rainfalls will increase disruptions/delays in rail and road transportation, affecting also connections/access to seaports. On the other side, storms/hurricanes could lead to infrastructure damage and therefore transportation interruptions. Besides, extreme winds, projected to be more catastrophic in the future, could also cause infrastructure failure and service interruptions. Eventually, Heat waves may limit operations and staff safety issues damages. Climatic factors and the potential impact on seaports can be seen in Table C3 in Appendix C.

3.3. Adaptation and Mitigation Strategies: The role of WPSP

According to BMT (2019), there are two main policy responses to climate change: mitigation and adaptation. While mitigation tries to address the causes of climate change (e.g. by reducing GHG emissions), adaptation aims to lower the risks caused by climate change. Although there are a number of alternatives that ports can implement in order to reduce carbon emissions, adaptation is still a new issue. As a result, several nations have taken part in policy-making with the main purpose to regulate the consideration of climate change when it comes to ports infrastructure planning. The most notable case is the United Kingdom, where ports are required to undertake a risk assessment and adaptation plan under the UK Climate Change Act 2008.

Adaptation implies carrying out a vulnerability assessment to demonstrate to internal and external stakeholders that ports will face considerable implications due to climate change. This risk assessment involves three mains steps: (i) identify critical information like global forecasts and assets in the port that are vulnerable to future climate change impacts; (ii) develop response measures that are appropriate for implementation like feasibility studies; and (iii) implement measures that can be incorporated into long term planning.

With regards to mitigation strategies, IAPH has taken part through the creation of World Ports Sustainability Program (WPSP), which aims to demonstrate global leadership of ports in contributing to the Sustainable Development Goals of the United Nations. The program initially aimed to address five themes: resilient infrastructure (related to adaptation of ports to climate change); climate and energy (related to mitigation strategies to reduce CO_2 emissions from shipping, port and land operations); community outreach and port-city dialogue; safety and security; and ethics and governance.

The UK has been at the forefront of policies aiming to reduce GHGs stemming from shipping operations, especially after the recent commitment of the International Maritime Organisation (IMO) to phasing out GHG emissions from shipping as soon as possible by at least 50% by 2050. This sends a very clear message that a switch to zero (or at least, close-to-zero) emission technologies is now imminent and will deliver benefits for air quality. Due to this fact, this study focuses on mitigation strategies supported by WPSP to reduce GHG emissions; specifically, we examine the applicability of the Environmental Ship Index (ESI) using four representative ports of the UK: Port of London, Port of Southampton, Port of Felixstowe and Port of Dover. Although the Port of London is currently using the ESI, this will be used to make comparisons to other three ports not using this environmental index yet. The analysis related to the ports mentioned can be found in Appendix B.

3.4. Clean Air Strategy 2019

Analysing the impact of pollution involves studying how much is emitted and how harmful it is and eventually where it ends up and how sensitive the exposed population or environment is. "Clean Air Quality Strategy" is a UK government strategy that builds on an extensive consultation process analysing sources of air pollution in order to protect nature and making air healthier to breathe. Exposure to pollution is one the UK's biggest public health challenges, as it damages quality of life for many people and also the natural environment. Therefore, clean air is essential for life, health, the environment and the economy and government must act to tackle air pollution. "Clean Air Strategy 2019" focuses on five of the most harmful air pollutants: fine particulate matter, ammonia, nitrogen oxides, sulphur dioxide, and non-methane volatile organic compounds (The UK Government, 2019).

The role of transport is directly related to reducing emissions and meeting the government's objectives on the environment and public health. The UK has played a leading role in negotiating international limits to pollutant emissions from shipping such as through the North Sea Emissions Control Area (ECA). Moreover, the IMO has also agreed to the introduction of a NO_x emissions control area for the North Sea from 2021 which will reduce the limit on NO_x emissions from new ships operating in this area by around three-quarters (The UK Department for Environment, Food and Rural Affairs, 2019). Furthermore, as it has been explained before, in order to address the issue related to shipping emissions, The UK Department for Transport has developed a long-term maritime strategy called "Maritime 2050". This plan focuses on domestic policies to reduce GHGs and pollutant emissions from shipping, while maximising the potential economic benefit for the UK from global transition to zero emission shipping. In addition, a new government-led Clean Maritime Council has been created to bring together different parts of the maritime sector. The Clean Maritime Council set three main objectives: (i) improving air quality on and around our waterways, ports and shipping lanes; (ii) reducing GHG emissions from the maritime sector and: (iii) delivering clean growth opportunities from green shipping for the UK.

Consequently, due to the current relevance of this topic for the UK, this study will focus on air pollution related to shipping emissions. As a result, the ESI Score focuses mainly in two of the major pollutants: NO_x and SO_x. A graph with the main sources and effects of these two components can be found in Figure C4 in Appendix C.

4. Environmental Ship Index (ESI)

One of the most relevant and recent projects in climate change mitigation that the WPSP has developed is the Environmental Ship Index (ESI). The index "identifies seagoing ships that perform better in reducing air emissions than required by the current emission standards of the IMO" (ESI, 2019). Ships need to comply with MARPOL 73/78 Annex VI, which sets limits on sulphur content limits and sets engine standards. This index, established in 2011, evaluates the amount of nitrogen oxide (NO_x) and sulphur oxide (SO_x) emitted by a ship, indicating the environmental performance of the vessel and identifying the cleanest ships.

The ESI aims to be used by ports in order to reward ships that participate in the ESI with the main objective to promote clean ships. Although the ESI database will provide a total score per vessel, the rewards given by the port can be either based on that total or on each of its constituent parts separately. Despite the fact that ESI is voluntary, WPSP aims for the global port community to adopt this rewarding role in order to improve port environment. Moreover, increasing number of companies are keen on calculating ESI score to provide with information to ships so these can take advantage of port dues discounts. Appendix A discusses the calculation of the index.

4.1. Port-based practices as financial incentives to promote environmentally-friendly port infrastructure

According to the OECD (2018), port incentives can be categorised based on either the sort of incentive or the sort of behaviour that they aim to influence. The first one is related to the functions and responsibilities of ports. Within this criterion, the following sorts of incentives are distinguished: green port fees, green port procurement and green berth allocation. Furthermore, some treat carbon pricing schemes are considered. The second way to categorise these incentives is based on the sort of behaviour that they aim to stimulate, such as low emissions, energy efficiency of ships, use of low-carbon fuels or alternative energy and low speed. For the purposes of this research, the analysis will focus on green port fees, as the Environmental Ship Index is included in this category.

Green port fees take into account environmental performance of ships, with the main purpose of charging lower fees to ships that are less polluting. Normally, the cleanest ships get a deduction of the regular port fee, either a fixed amount or a proportional deduction (e.g. a 10% rebate on the port fee). There are 28 of the major world ports that apply green port fees. A list of these ports, which belong to the largest hundred world ports, either measured by their volume in tonnage or by their volume in containers, is included in Table C4 in Appendix C. The introduction of green port fees forms part of a broader interest of the port authority in improving its environmental footprint, and are generally linked to green ship indexes, use of alternative fuels and energy and vessel speed.

4.2. Comparison of main green ship indexes: The multiple scheme and carbon-pricing scheme

The majority of the green port fees are based on one or more indexes that evaluate the environmental performance of an individual ship. These are used as justification for the amount of the reduction of the regular port fees. Table C5 in Appendix C shows a comparison between the four most widely used indexes: The ESI, the Green Award, the Clean Shipping Index (CSI) and the GHG Emissions Rating of RightShip.

According to OECD (2018), "all indexes have a different focus, different intended users and different methods for collecting the information on which the score is based". The main conclusions are:

- The widest focus is covered by Green Award Certificate, which takes into account fifty different criteria, ranging from safety and service quality to environmental performance. On the opposite side, the narrowest focus is applied in GHG Emissions Rating, which just focuses on the energy efficiency of ships. In between these two, the Environmental Ship Index focuses on air pollution and the Clean Shipping Index assesses air emissions, chemicals, waste and water.

- The main target groups of these indexes differ as it can be seen in the table provided in the Appendix mentioned above. Some indexes are more port-oriented, while others focus more on carriers and shippers. This might be also explained by the main angle of the indexes. For example, "local air pollution is a strong concern for ports, whereas energy efficiency of ships is more of interest to charterers and shippers" (OECD, 2018).

However, various ports have implemented incentive schemes that include multiple indicators. A clear example of this port financial incentive scheme is the EcoAction programme, operated by the port of Vancouver (Canada). It uses all the four indexes described above and an additional one the Green Marine Index, (only used in North America). Port of Vancouver's EcoAction program provides vessels with 3 different levels of discounts on port dues. Ships may qualify for gold, silver or bronze levels, which is translated into a 23%, 35% or a maximum 47% discount. "It offers perhaps the most flexible incentive program of any major port, with discounts being provided also for the use of cleaner fuels and a wide range of technologies, and for holding an environmental designation from a classification society" (NRDC, 2018). On the other side, apart from green port fees, carbon pricing is generally considered an effective tool to mitigate shipping emissions. The idea behind carbon pricing is that shipping companies have a financial incentive to decrease GHG emissions by pricing carbon. A very successful model for carbon-pricing that could be applied in ports is based on the Norwegian NO_x Fund. In this scheme, companies operating in Norway pay a fee that is included in the Fund. Affiliated shipping companies are allowed to apply for funding from this fund (up to 80%) to invest in innovative projects that aim to reduce NO_x emissions from the ships.

4.3. An insight into measures' effectiveness

With regards to the uptake of green port fees, currently there is a marginal share of the ships calling ports with green port fees benefitting from these deductions. Although for large ports like Rotterdam and Vancouver the uptake in terms of ship calls reaches 18%, this is not the reality for the majority of the rest. On the other side, the most popular index is the ESI, which counts 57 ports using it in 2019. Figure 5 shows the number of ports using ESI by country in 2019. ESI is widely used by northern European countries and the leading country is Norway with 12 ports. The category "others" include countries with just one port using the index such as Spain (Port of Barcelona); Sweden (Port of Gothenburg); and United Kingdom (Port of London). Moreover, by June 2019, 8,358 ships had an ESI score that could be used as basis for a green port fee (ESI, 2019). Another issue related to the calculation of the ESI scores is the accuracy of the information. This is particularly important when it comes to indexes that depend on self-reporting by shipping companies. According to OECD (2018), 12.5% of the vessels have been found to be non-compliant with ESI audits.

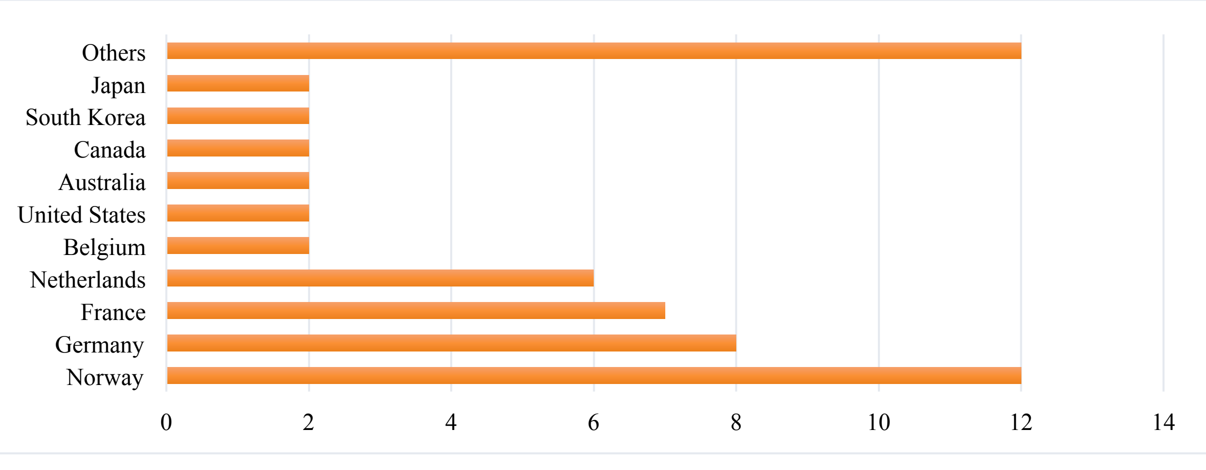

Figure 5. Number of ports using ESI by country. 2019. (ESI, 2019)

Regarding existing criticisms about the ESI, as well as the other indexes, while they implement a positive incentive, none considers a higher tariff for the more polluting ships. In accordance with this, it is relevant to remark that port dues represent a small share of the operating expenses of a vessel, but a relatively large share of port revenues. Port costs represent less than 10% of the running costs, indicating that port fees (included in port costs) only represent 5-10% of these. As a consequence, in practice, port fee reductions might not represent a great cost-saving option for shipping companies. This might be the result of: (i) most ports do not have green fees; (ii) the difference in port fees between best and worst performers is very small; and (iii) it is not that clear if the shipping company gets the benefit of the port fee reduction. Nevertheless, green port fees could be considered as a way of port authorities to attract shipping companies. Leakage effects because of port competition are the main reason why there is no effective environmental differentiation of port fees, as ports know that if they penalise the worst performing ships with a higher fee than competing ports, these ships might be diverted to alternative ports.

Eventually, a possibility that could be implemented to incentivise ports to use the ESI Index is obtaining subsidies from government and other international organisations. These subsidies would cover the correspondent port dues (income) that ports would stop receiving. As a result, both sides would benefit from this green incentive, as shipping companies would be rewarded through lower port dues and ports would not forego any source of income, as this would be provided by the agents mentioned above. Governments and international organisations need to take the lead on motivating ports through incentives for them as well.

4.4. Environmental awareness as a competitive advantage for ports: The role of ESI

Addressing climate change has become one of the main issues affecting the maritime industry. Consequently, environmental sustainability has turned out to be an essential part of the long-term strategy of the majority of the shipping companies as well as logistics companies and ports.

The raise of importance in environmental awareness can be related to compliance with regulations but also to the risk associated to the loss of client support. As a result, the majority of shipping companies have focused on environmental accreditation as a proof of conformity with legislation. Indeed, these certificates aim to show not only their customers but also the society their environmentally friendly objectives. However, although this environmental awareness has risen heavily among shipping companies as a means of marketing image, this has not yet been the case with ports.

As a result, “green port incentives”, and particularly the ESI Index seems to provide an incentive for ports in order to build on a competitive advantage based on environmental sustainability. Therefore, by implementing this kind of mitigation strategy, ports protect their ports from climate change as well as moves from a low-cost competitive strategy to a differentiation strategy. This also aims to create better brand loyalty from clients. This loyalty comes from a considerable investment in research and development, in this case sustainable and environmental practices, and results in customers recognising the effort of ports in addressing climate change and becoming greener ports.

Hence, the fact that a UK port may incorporate the ESI Index into their green port incentives might become increasingly attractive. Consequently, this sends a sign to the potential customers that those ports take into account their responsibility in addressing climate change. Moreover, ports could take advantage of companies that have already started offering services regarding ESI Score calculation. Therefore, ports would save time on ESI calculations, although would be recommended to elaborate their own numbers to compare among the different companies and choose the more accurate one.

Indeed, the fact that companies are giving importance to this index also reflects an interest and awareness about environmentally friendly practices that contribute to mitigate climate change.

Finally, addressing climate change has become a delicate issue that has been proved to remain in the maritime industry for years to come. This is evidenced through upcoming regulation such as IMO 2020 and 2050, which focus out of the several topics on environmental issues. Consequently, a port that is aware of this potential challenge can work on converting it into an opportunity and a competitive advantage for the port.

5. Conclusions and Policy Recommendations

The maritime sector plays a critical role for the UK as a primary facilitator of global trade, but also affects climate change. Addressing climate change impacts in the port sector is challenging, but an issue that needs to be taken into account. The UK has been at the forefront of policies aiming to focus on air quality issues through "Clean Air Strategy 2019". As a result, this study has focused on a specific mitigation strategy: "green port fees", and more specifically ESI (Environmental Ship Index).

In conclusion, despite the fact that ESI Score has been heavily criticised due to its "arguable accuracy of information", it is proved to have been a successful project since it started in 2011. It is intended to be a win-win opportunity for both ports and shipping companies. While shipping operators benefit from a reduction of port dues as well as an evidence of environmental awareness to the public, ports take advantage of receiving cleaner vessels reducing the environmental impact of shipping in ports and improving their marketing image of corporate social responsibility, which can seriously contribute to differentiate them from the competitors. Therefore, ESI is meant to be an effective measure to mitigate climate change although this measure should be combined with other mitigation strategies. Moreover, the future regulations will imply more severe rules aiming to protect the environment, therefore, the more ports are adapted to shipping innovation regarding emissions, the greater profit these will gain.

As a recommendation on policy making for the UK ports in the future, this research study has led to suggest the combination of multiple instruments to address climate change mitigation. Although ESI Index is proved to contribute to reduce effects of climate change, it is recommendable that it is combined with other indexes and implement a programme similar to EcoAction. Moreover, another proposal is to work on a fund in which shipping companies contribute that can be used for innovation in shipping related to emissions such as the Norwegian NO_x Fund. Finally, whether the UK decides to introduce ESI Index, this research concludes that it is necessary both a positive reward for the cleanest vessels (port dues reduction) and a penalty to the most pollutant ships. In the first case, ports could be subsidised by the government or any other organisation and in the second scenario, penalties charged to those shipping companies could be used by ports to invest in implementation of other kinds of mitigation instruments or adaption of the ports to climate change.

Eventually, it is recommended that ports study their port freight characteristics as this will lead to prioritise on what kind of vessels are most likely to visit the ports and therefore need to be more taken into account. As a consequence, policy making for specific types of vessel (such as Ro-Ro vessels in Port of Dover) could be made in order to promote this financial incentive to them.

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Appendix

Appendix A: ESI Score

With regards to the calculation of the ESI, it can be break down into four elements: (i) NO_x (mainly dependent on the engine properties); (ii) SO_x (mainly dependent on the fuel's sulphur content); (iii) CO_2 (mainly dependent on the amount of fuel used); and (iv) OPS (related to the possibility of a vessel to be fitted with an on-shore power supply installation).

The ESI Score is the sum of points for each of the four groups. The maximum sub points that can be reached for the calculation of ESI NO_x and ESI SO_x is 100, while ESI CO_2 contributes to the index with between 5 and 15 points to the ESI Score, and the presence of OPS adds another 10 points. As a result, the ESI Score is constituted as:

$$\text{ESI Score} = \text{ESI } NO_x + \text{ESI } SO_x + \text{ESI } CO_2 + \text{OPS (max 100)}$$

The final calculations according to ESI for the four elements are:

ESI NO_x: 2 x NO_x sub points / 3

ESI SO_x: SO_x sub points / 3

CO_2: Reporting during the 3-year period adds 5 points to the ESI score and any efficiency increase in % in the reporting period is added to the ESI Score as points. The ESI CO_2 is capped at 15 points

OPS: 10 points if On-shore Power Supply installation is fitted

- **ESI Calculation**

ESI NO_x

According to ESI (2019), calculating the ESI NO_x score is related to MARPOL Annex VI requirement for ships to be installed with engines that meet certain NOx emission standards (ESI). Depending on the date of the ship's construction, these standards are divided into tiers: Tier I (ships constructed on or after 1 January 2000 through 31 December 2010); Tier II (ships constructed on 1 January 2011 or beyond. Once ships are distinguished by tier, then crankshaft speed of the engines in revolutions/minute (rpm) will set the limit values (LV) expressed in g/kWh. In addition, from 1 January 2016, Tier III is applicable for ships sailing in an ECA.

The information needed for ESI NO_x calculation can be found in an International Air Pollution Prevention (IAPP) that ships are issued and an Engine International Air Pollution (EIAPP) that each engine installed is issued. Furthermore, ships that are constructed before 1 January 2000 and have not been issued an IAPP and EIAPP Certificate cam obtain an ESI NOx score if its proved that engines meet Tier I requirements. The ESI Working Group has developed the following formula (1) for the ESI NO_x sub-points calculation:

$$ESI\ NOx = \frac{100}{\sum_{i=1}^{n} RPi} \times \sum_{i=1}^{n} \left\{ \frac{(LVi - RVi) \times RPi}{LVi} \right\} \quad (1)$$

ESI SO_x

In accordance with ESI formulas, ESI SO_x sub points are calculated based on the amount and type of sulphur of fuel bunkered based on stipulated margins depending on high, mid or low sulphur. The ESI Working Group has developed the following formula for ESI SO_x sub points calculation:

$$ESI\ SOx = x * 30 + y * 35 + z * 35 \quad (2)$$

The baselines for the various fuels are 3.50% S for high (IMO regulation), 0.50% S for medium (ESI Working Group Decision) and 0.10% S for low (IMO regulation). In addition, ESI SO_x calculations provide with fuel bonus for those ships that do not bunker fuels higher than 0.50% sulphur or that only bunker fuels wit sulphur content less than or equal to 0.10% S. While *x* is the relative reduction of the average sulphur content of HIGH, *y* is the relative reduction of the average sulphur content of MEDIUM, and *z* is the relative reduction of the average sulphur content of LOW.

ESI CO_2

With regards to the third component of the ESI Formula, the ESI Working Group's recommended method implies the recording of fuel amount consumed and distance sailed in a certain period. Reporting during a 3-year period adds 5 points to the ESI Score and any efficiency increase (%) over a base line is added to the score. The ESI CO_2 is capped at 15 points. For the purposes of this research study, as it would be the first year of calculation of the ESI Index for the ships, it will be assumed a score of 0 regarding this parameter.

- **Limitations**

The ESI Score is the sum of points for each of the emission groups NO_x, SO_x and CO_2. Although initially this study aimed to provide a calculation of the ESI Score for four major UK ports (discussed below), significant data limitations have arisen. Most importantly, there is no access to the list of the vessels that arrived to those ports and consequently to the EIAPP (Engines International Air Pollution) Certificate of the corresponding vessels. Note that while the DfT provides aggregate data regarding ship arrivals by ports (namelys number of ships of a specific type and size) there does not exist a publicly available dataset for the specifications of each vessel that arrived (e.g. year built, engine specification, fuel consumption, etc.). Having the list of vessels and their respective EIAPP Certificates though and following the calculation procedure described above, it is straightforward for ports to estimate the ESI.

Appendix B: Case Study

This appendix discusses four major UK ports that could benefit from the adoption of the ESI: Port of Southampton (largest port in the cruise sector and third largest port of the UK); Port of London (largest port in dry cargo and second largest port of the UK); Port of Felixstowe (largest port in containers cargo) and Port of Dover (largest port in Ro-Ro cargo).

- **Port of Southampton**

The Port of Southampton is a major international deep-sea port of significant global importance recognised as a dynamic international transport hub. As the third largest port by traffic in the UK (2017), it handles different types of trades, from which the most significant include containers, cars, cruise, and petrochemicals. It is the busiest cruise port in the UK and a critical stopping point on the world's busiest trade route from the Far East. It handles around 40-45% of the UK's deep-sea trade with the fast-growing economies such as China (Atkins, 2011). It is also an international gateway for the automotive industry. Moreover, Port of Southampton is of particular importance to the UK economy because it is the UK's busiest cruise port welcoming nearly 86% of the total number of cruise passengers in 2017 (The UK Department for Transport, 2018). Furthermore, Figure B1 shows cruise passengers in the period 2008-2017, representing a significant growth over this period.

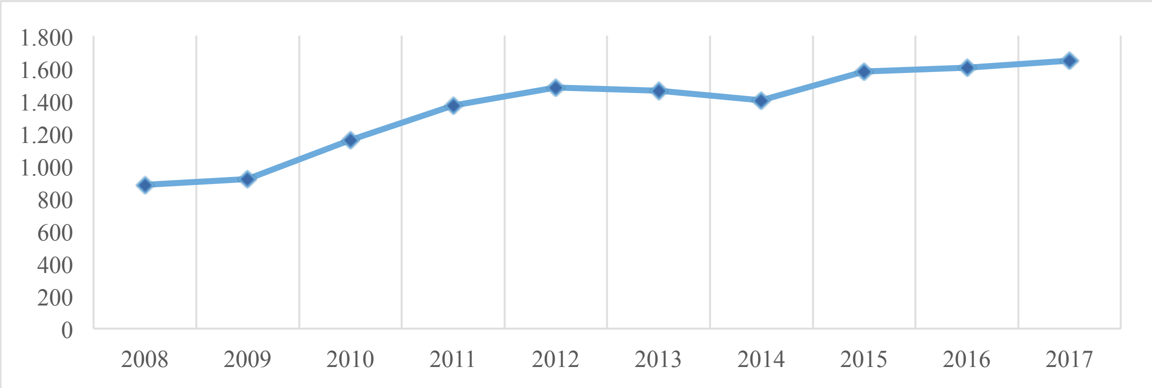

Figure B1. Sea passengers traffic in Port of Southampton. 2008-2017. (The UK Department for Transport, 2019)

Regarding freight traffic, liquid bulk is the largest trade of Port of Southampton accounting for 62% of the total freight tonnage in 2017. It is relevant to remark the special importance of this trade, as Port of Southampton is the largest port for crude oil passing in the inwards direction in the UK. Furthermore, the second largest cargo type is related to container traffic, accounting with 28% of the total freight traffic. This fact is of importance as Port of Southampton is recognised as the most efficient container terminal in Europe, position that is necessary to maintain, as container traffic is a significant proportion of the total port freight. Eventually, Ro-Ro trade accounts for a smaller fraction of Port of Southampton's freight traffic (4%). However, this does not imply that Ro-Ro trade is not meaningful, as Port of Southampton stands for the UK's leading port for car handling.

- **Port of London**

The Port of London Authority (PLA) manages 95 miles of the tidal river Thames playing three main key roles: protect (targeting zero harm and improved sustainability); improve (running efficient operations) and promote (leading its vision to unlock the potential of the Thames). Port of London is the second largest port in the UK by tonnage, handling 49.9 million tonnes in 2017. The vast majority of the port freight traffic (79% in 2017) trades in international routes (both deep sea countries and short sea countries including European Union). Port of London is characterised for the inwards direction of its tonnage (85% in 2017) and handles all kinds of cargoes. Finally, Port of London is not the only port using ESI Score among the selection of ports in this study, but also is the only British port committed to green ship indexes.

As mentioned before, Port of London is considered an inwards-direction port. Also, even though the largest cargo in terms of imports is liquid bulk, dry cargo is the most important cargo for Port of

London overall. Actually, Port of London is the largest port handling this latter type of cargo (15,620 thousand tonnes in 2017). With regards to this cargo, it is noticeable the fact that the world's largest sugar cane refinery is located within the Port of London (Tate & Lyle in Silvertown). Moreover, the third largest trade is related to container traffic. London Gateway, the new container terminal is capable of handling the world's largest container ships (Port of London Authority, 2019).

- **Port of Felixstowe**

Felixstowe is the UK's top port for container traffic, handling 40% of the UK's container throughput in 2017. Felixstowe was the 8th largest container port in Europe in 2017 (Port Economics, 2018). The port handles more than 4 million TEUs each year, welcoming around 3,000 ships (per year). "Felixstowe plays a pivotal role in keeping the UK's trade moving, and delivers real benefits to customers, the community and the industry" (Port of Felixstowe, 2019). With regards to port freight of Port of Felixstowe, it is noticeable the fact that approximately 87% of the total cargo handled in 2017 is related to container traffic. The other relatively important cargo for this port is Ro-Ro traffic. Nevertheless, it could be stated that Port of Felixstowe is a considerably specialised container port. According to The UK Department for Transport (2019), it continues to handle the largest amount of containerised traffic in the UK (41% of all UK containers in both directions in 2017). Moreover, containerised traffic was the only cargo group in 2017 where the EU is not the number one trading partner. Particularly, nearly 82% of Felixstowe containerised cargo was non-EU traffic.

- **Port of Dover**

"The Port of Dover is not only Europe's busiest Roll-on Roll-off ferry terminal, but it also has established cruise and cargo businesses" (Port of Dover, 2018). Moreover, the port manages other activities such as logistics enterprise and a portfolio of property in the docks and on the waterfront. Port of Dover plays a key role in the UK's economy as it provides the gateway to Europe handling around £122 billion of the UK's trade in goods, 11.5 million passengers, 2.6 million freight vehicles and 2.3 million tourist vehicles every year (Port of Dover, 2018). Port of Dover stands out to be a considerably specialised port in Ro-Ro traffic as 99% of its total port freight is related to Ro-Ro traffic. It is the largest port regarding this type of cargo (25,931 thousand tonnes in 2017) and it accounts for approximately one quarter of the total Ro-Ro traffic in 2017. Moreover, the relationship between inwards and outwards trade is quite balanced (41% vs. 59% respectively). Finally, it is noticeable the fact that this port handled no liquid bulk cargoes. Evidently, Ro-Ro traffic remains the dominant business for Port of Dover, however, ferry business continues to grow and is the second largest port in sea passengers, after the leading port in this sector: Port of Southampton.

- **Conclusions on Freight Characteristics: Port of Southampton, Port of London, Port of Felixstowe and Port of London**

Figure B2 represents an overall view of each port's freight characteristics. As detailed above, Port of Southampton is recognised as leading port in the liquid bulk cargoes sector. Moreover, it is a well-balance port as it handles all kinds of cargoes. Furthermore, it is the busiest port in the UK related to the cruise sector. Secondly, Port of London (second largest port of the UK) follows a similar trend, although there is no cargo that stands out. However, it is the largest port in dry bulk cargo and it is characterised for its inwards direction of the cargo handled. Furthermore, Port of Felixstowe is well known as the largest port in containerised cargo (87% of the total cargo handled in 2017). Interestingly, apart from containers, the other kind of cargo handled is Ro-Ro. Finally, another extreme case is Port of Dover, which essentially manages Ro-Ro traffic (99% of the total freight handled).

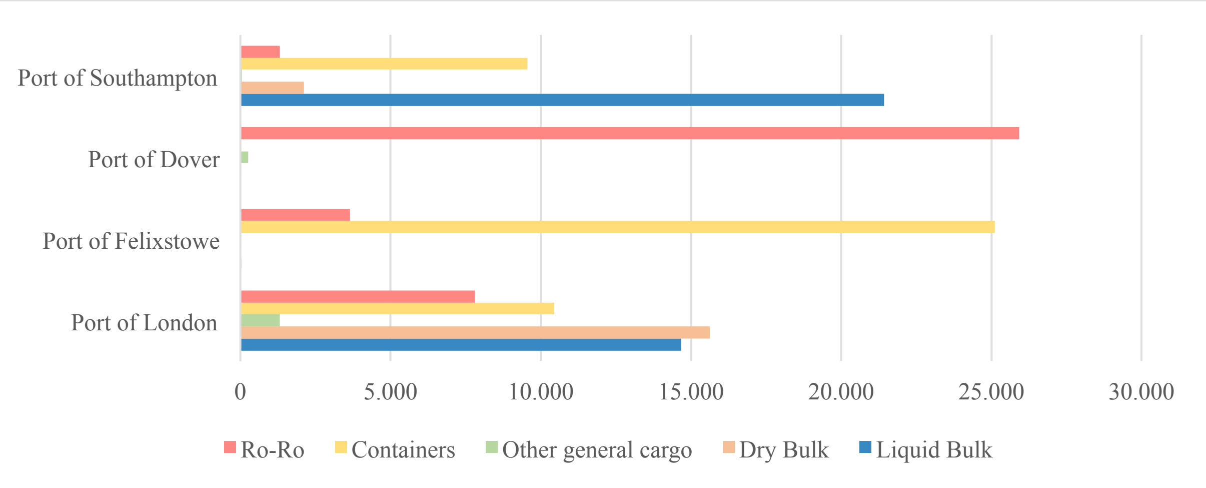

Figure B2. Freight by port and type of cargo handled. 2017. (The UK Department for Transport, 2018)

Appendix C

Ports	Port Group	Ports	Port Group
Aberdeen	Scotland East Coast	Liverpool	Lancs and Cumbria
Belfast	Northern Ireland	Loch Ryan [3]	Scotland West Coast
Boston	Wash & Northern E Anglia	London	Thames and Kent
Bristol	Bristol Channel	Londonderry	Northern Ireland
Cairnryan	Scotland West Coast	Manchester	Lancs and Cumbria
Cardiff	Bristol Channel	Medway	Thames and Kent
Clyde	Scotland West Coast	Milford Haven	West and North Wales
Cromarty Firth	Scotland East Coast	Newhaven	Sussex and Hampshire
Dover	Thames and Kent	Newport	Bristol Channel
Dundee	Scotland East Coast	Orkney	Scotland East Coast
Felixstowe	Haven	Peterhead	Scotland East Coast
Fishguard	West and North Wales	Plymouth	West Country
Fleetwood	Lancs and Cumbria	Poole	West Country
Forth	Scotland East Coast	Port Talbot	Bristol Channel
Fowey	West Country	Portsmouth	Sussex and Hampshire
Glensanda	Scotland West Coast	Ramsgate	Thames and Kent
Goole	Humber	River Trent	Humber
Great Yarmouth	Wash & Northern E Anglia	Rivers Hull and Humber	Humber
Grimsby & Immingham	Humber	Shoreham	Sussex and Hampshire
Harwich	Haven	Southampton	Sussex and Hampshire
Heysham	Lancs and Cumbria	Stranraer	Scotland West Coast
Holyhead	West and North Wales	Sullom Voe	Scotland East Coast
Hull	Humber	Sunderland	North East
Ipswich	Haven	Swansea	Bristol Channel
Kilroot Power Station Jetty	Northern Ireland	Tees and Hartlepool	North East
Larne	Northern Ireland	Tyne	North East
		Warrenpoint	Northern Ireland

Table C1. The UK Major Ports by port group (Department for Transport, 2019)

Top 15 UK major ports in dry bulk	
Port	**Dry bulk & other general cargo**
London	16,931
Grimsby & Immingham	15,252
Liverpool	8,598
Port Talbot	7,589
Belfast	7,331
Glensanda	6,138
Medway	5,063
Bristol	4,294
Tees & Hartlepool	4,141
Hull	3,822
Newport	3,450
Southampton	2,164
Ipswich	2,052
Shoreham	1,995
Tyne	1,842

Top 15 UK major ports in containers	
Port	**Containers**
Felixstowe	25,346
London	10,448
Southampton	9,560
Liverpool	5,424
Grimsby & Immingham	2,281
Forth	2,208
Tees & Hartlepool	2,160
Hull	1,773
Belfast	1,694
Bristol	807
Medway	661
Clyde	599
Tyne	399
Portsmouth	305
Warrenpoint	221

Table C2. Top 15 UK Major ports by cargo: Dry bulk and containers. 2017. (The UK Department for Transport, 2019)

Climatic Factor	Impacts on seaports
Sea Level	✓ High waves that can damage port's facilities ✓ Transport infrastructures in the port get flooded ✓ Coastal erosion to the port ✓ Sedimentation along the port's channel ✓ Relocation of people/business ✓ Increased risks for coastal road/railway links
Temperature	✓ Damage to infrastructure and asset lifetime reduction ✓ Increases in staff health and safety risk ✓ Higher energy consumption for cooling terminal and cargo (higher energy costs) ✓ Extension of the construction season ✓ Restriction for inland navigation affecting port competitiveness
Precipitation and Fog	✓ Land infrastructure inundation ✓ Damage to cargo/equipment ✓ Network inundation and vital node damage ✓ Impact on ship and terminal operations (reduced visibility)
Wind Speed	✓ Inability to safely berth ✓ Coastal defence overtopping ✓ Operational disruptions due to inability to load/unload

Table C3. Climatic factors and impacts on seaports (UNCTAD, 2017)

Europe	Asia	America	Africa
Rotterdam (Netherlands) Antwerp (Belgium) Amsterdam (Netherlands) Hamburg (Germany) Bremerhaven (Germany) Le Havre (France) Zeebrugge (Belgium) Sines (Portugal) Valencia (Spain) London (UK) Bergen (Norway)	Singapore Shenzhen (China) Hong Kong (China) Busan (South Korea) Ulsan (South Korea) Tokyo (Japan) Yokohama (Japan) Nagoya (Japan) Kitakyushu (Japan) Ashdod (Israel)	Los Angeles (US) Long Beach (US) New York/New Jersey (US) Vancouver (Canada) Montreal (Canada) Buenos Aires (Argentina)	Durban (South Africa) Richard's Bay (South Africa)

Table C4. Global top 100 ports with environmental port fees (OECD, 2017)

	ESI	CSI	GHG EMISSIONS RATING	GREEN AWARD
Purpose	Reducing port dues for registered vessels with good NO_x, SO_x and/or CO_2 performance	Rating and benchmarking of environmental performance on ship-to-ship + aggregated carrier basis – can be used by shippers for shipping service procurement, vetting or risk mitigation as well as by ports to attract green ships by offering port due discounts	Rating and benchmarking of CO_2 performance on the vessel basis – can be used by shippers for shipping service procurement, vetting or risk mitigation as well as by ports to attract green ships by offering port due discounts	Certifying vessels to incentivize improvements in safety of shipping and environmental protection – can be used by incentive providers, including ports, to provide financial or non-financial benefits
Primary users	Ports, carriers	Carriers, shippers, and to a lesser extent, ports including the Swedish Maritime Administration	Carriers (mainly bulk carriers and tankers), shippers, and to a lesser extent, banks and ports	Carriers, shippers, ports, and to a lesser extent, maritime service providers and banks
Ease of entry for owners of OGVs	Easy – self-registration with small chance of being audited	Moderate – more effort needed and verification required for highest score	None – nearly all OGVs in the world are already captured and scored in database; companies can submit edits if they do not agree with score	Difficult – scheme aims to attract frontrunners. All registered OGVs go through rigorous audits and verification.
Popularity of the scheme	Late 2017: • ~7,130 ships with valid ESI score • 47 participating ports • 6 non-port incentive providers	Late 2017: • >2,250 ships with CSI score • 30 members (cargo owners, forwarders, ports, shipowners, clean tech providers) • 74 affiliated shipping companies (reporting shipowners) • 6 ports • 1 national authority (Sweden)	Late 2017: • 54 affiliated charterers • 24 shipowners/managers (although 76,000 vessels listed) • 3 private terminals • 2 participating ports • 4 participating finance or insurance providers	Late 2017: • 45 ship companies • 257 ships (sea) • 630 ships (inland) • 60 participating ports, of which 33 are seaports
Modal scope	All types of OGVs	All types of OGVs	All OGVs, but key focus on bulk carriers and tankers	Several types of OGVs + inland vessels
Use of actual data or approximations & verification	Actual; self-registration by shipowners – some ports are allowed to conduct audits	Actual; self-registration + requirement to have at least 2 vessels of the fleet verified by audit	N.A. - design efficiency (approximation based on a global database)	Actual; office audit and ship survey; for OGVs, annual checks once certified, for inland vessels, survey conducted once every three years; certification is renewed every 3 years
How is the scheme paid for?	ESI incentive providers contribute to the costs for maintaining the ESI website, with contributions based on the port's "tonnage handled". Shipowners pay no fee.	CSI network members (shipping companies, cargo owners and forwarders) are charged €2,800 a year for administration and further development.	Carbon War Room pays for creating and maintaining the Shipping Efficiency website, through which companies can have free access to design efficiency information of listed ships. Companies can pay a fee to RightShip if they want to obtain full access to data.	Incentive providers pay no fee. Shipowners pay a fee for application, audits and surveys; once certified, shipowners pay an annual fee.

Table C5. Comparison of the four industry-led Green Shipping Incentive Initiatives (NRDC, 2018)

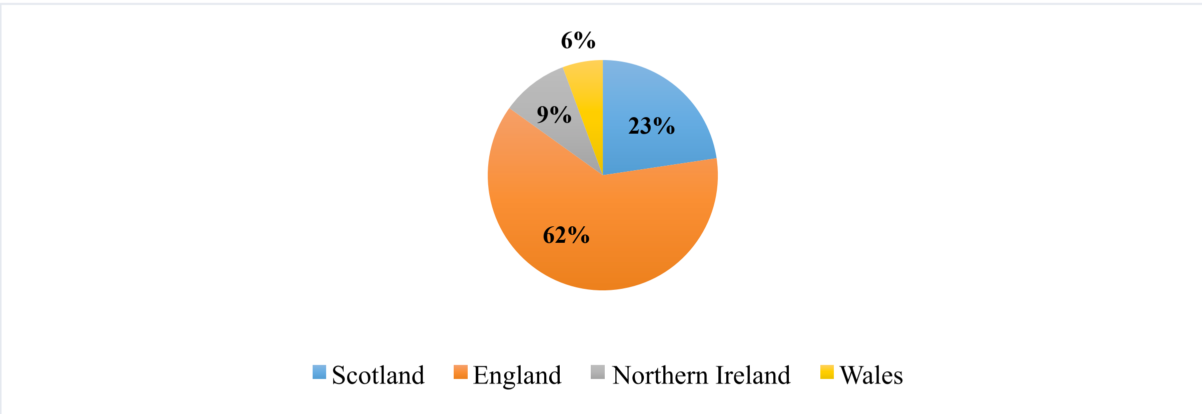

Figure C1. Geographical distribution of UK major ports (The UK Department for Transport, 2019)

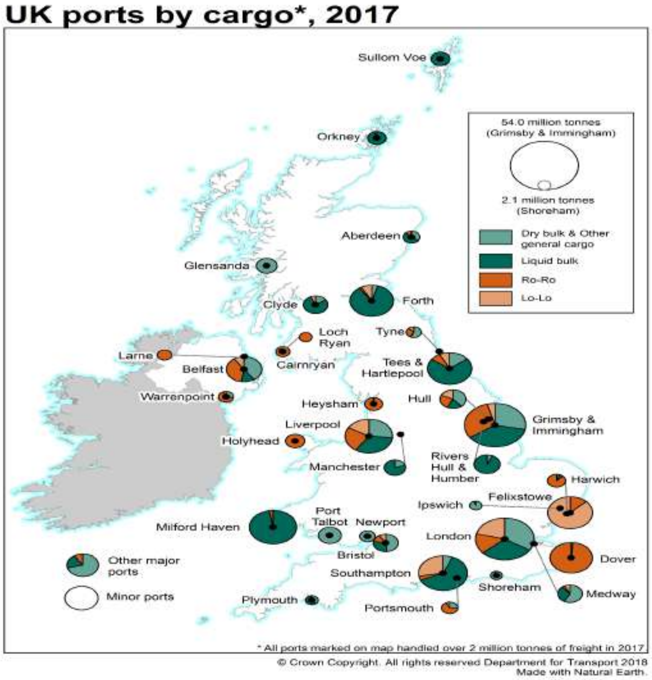

Figure C2. Map of UK major ports by cargo. 2017. (The UK Department for Transport, 2019)

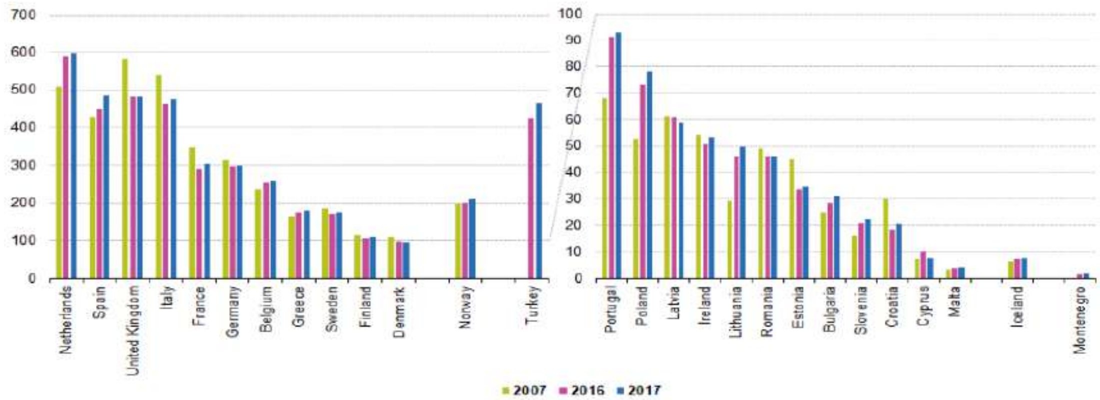

Figure C3. Seaborne trade handled by European countries (Eurostat, 2019)

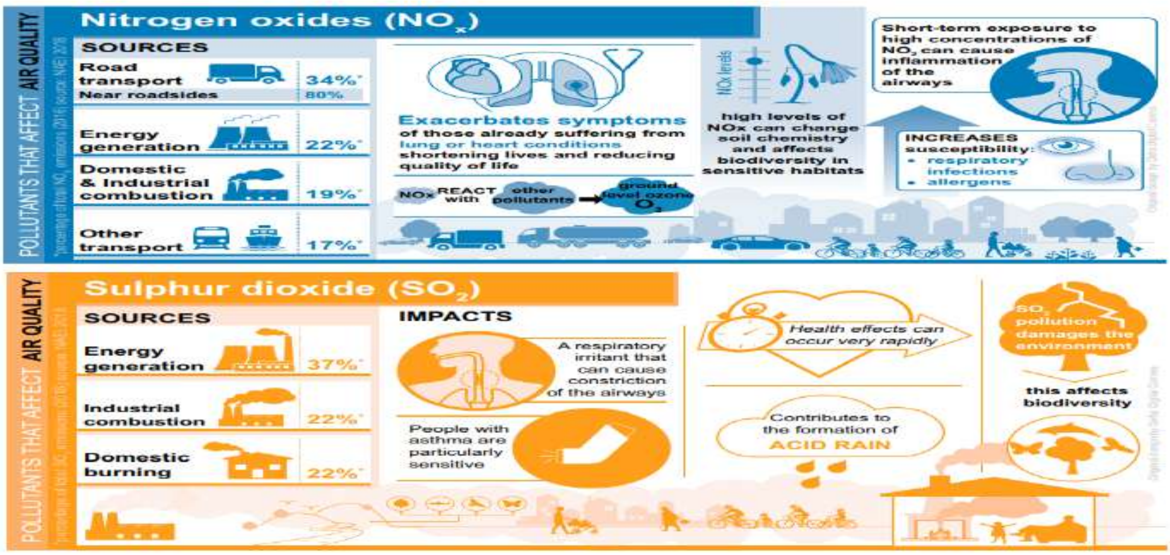

Figure C4. Sources and effects of NOx and SOx (The UK Department for Environment, Food & Rural Affairs, 2019)