



 **All aboard!**

Too expensive for ships to evade EU carbon market

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Author: Sofie Defour (main report) and Filipe Afonso (appendixes)

Modelling: Filipe Afonso

For more information, contact:

Sofie Defour

Shipping policy officer

Transport & Environment

sofie.defour@transportenvironment.org

Mobile: +32(0)479 57 28 93

Square de Meeûs, 18 – 2nd floor | B-1050 | Brussels | Belgium

www.transportenvironment.org | [@transenv](https://twitter.com/transenv) | fb: Transport & Environment

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Executive Summary

Maritime shipping is the only transport sector not yet subject to GHG reduction targets or measures in the EU. This is despite EU related CO₂ emissions from maritime transport being comparable to the emissions of Belgium and representing 13% of total EU transport emissions.¹ In 2019, the European Commission committed in its European Green Deal to extend the European emissions trading system (ETS) to the maritime sector.² Several actors have since raised concerns that the inclusion of maritime transport in the EU ETS would lead to policy evasion, i.e. ships making an evasive port call outside the EU/EEA before sailing to European ports. This would reduce the scope of emissions covered by the EU ETS, hence diminishing its practical effectiveness.

To evaluate the risk of policy evasion under a future maritime ETS, this report performs a cost-benefit analysis for an evasive port call and assesses the drivers in the cost structure that determine the cost-effectiveness of evasion from the shipowner's perspective. It does so for both a full and a semi-full scope ETS design. Under a full scope ETS design, the ETS would cover the full extent of the voyages reported under the MRV regulation, meaning 100% of inbound, outbound and intra-EEA voyages, as well as 100% of emissions at berth. A semi-full scope ETS design would still cover 100% of emissions from intra-EEA shipping and 100% of emissions at berth, but for both inbound and outbound voyages to/from the EEA, only 50% of the emissions would be covered by the prospective EU ETS. The assumption is that the remaining 50% of emissions of these voyages would be covered by third-countries in case they decide to implement similar regional/national regulations. A variation of the semi-full scope could include all inbound extra-EEA emissions and exempt all outbound extra-EEA emissions.

Analysis concludes that an evasive port call comes with a lot of new additional costs, including extra fuel, operational, port-call, and opportunity costs. In order for it to be in a ship's financial interest to avoid the ETS, the compliance cost (determined by the CO₂ price) would need to be higher than the sum of all these extra costs. By simulating the impact of different ETS price levels on individual voyage costs to be covered by the future ETS, this report aims to identify 'turning points', i.e. the ETS CO₂ price levels at which evasion becomes more profitable than compliance.

¹ European Commission. (2020) 2019 Annual Report on CO₂ Emissions from Maritime Transport. Retrieved from https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/c_2020_3184_en.pdf

² European Commission. (2019) The European Green Deal. Retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

An evasive port call comes with a lot of extra costs

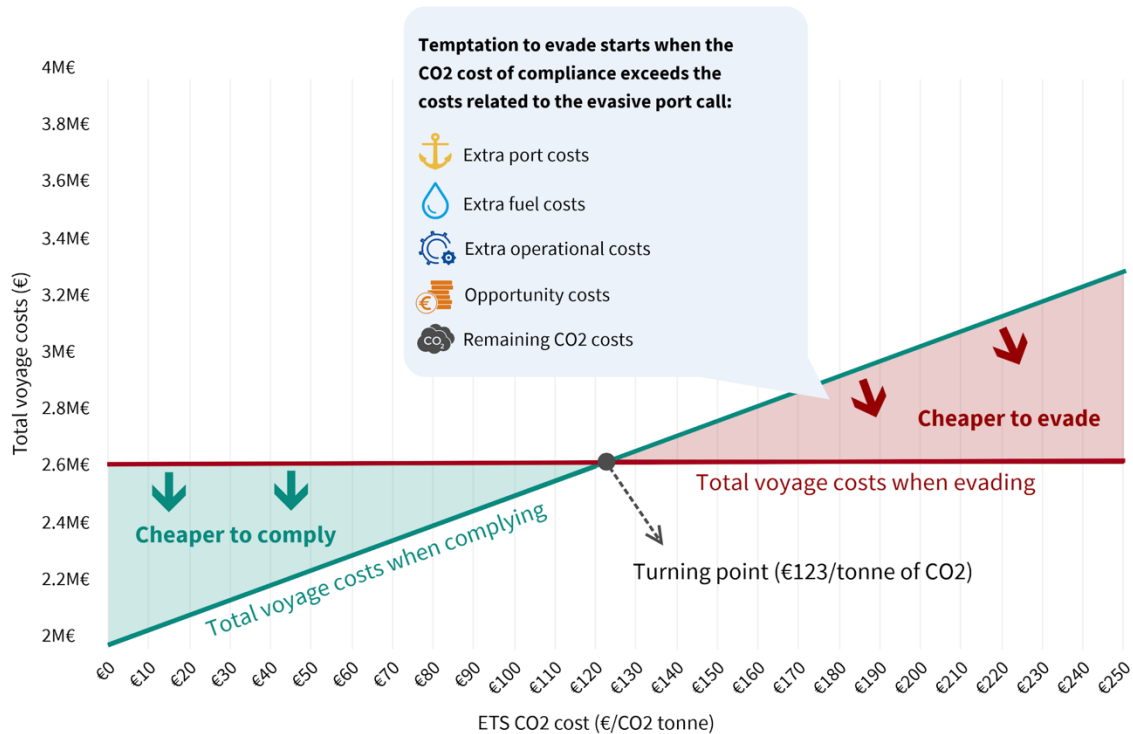


Figure 1: Extra costs related to an evasive port call

The analysis is based on the case studies of three countries with major seaports in close proximity to a non-EEA port: Greece, Spain and the Netherlands. Ships sailing to and from these countries are assumed to be the most susceptible to policy evasion. Only containerships, bulk carriers and oil tankers were analysed, given that these ship types are most active in extra-EU shipping.

The overall results across the three case study countries point out that the potential risk of policy evasion is very limited at the current carbon price levels. Under a semi-full scope ETS design, it would not be in the financial interest of any ship to make a stopover in a non-EEA port in order to avoid paying the €30/tonne of CO₂ compliance cost. Under a full scope ETS design, 6.7% of all voyages, representing 2.7Mt of emissions, would be tempted to evade at that CO₂ price. Given that not all countries are subject to the same degree of exposure to nearby non-EU ports, the actual evasion risk will likely be even smaller if the whole of EEA emissions were considered. A full scope ETS covering international voyages to/from Greece, Spain and the Netherlands would entail 23.9Mt of CO₂ or 16.6%

of total EU shipping emissions under the full scope. A semi-full scope ETS in those three countries would cover 11.9Mt. Note that the simulations in this report do not include voyages calling at any other EEA countries, nor the emissions of intra-EEA voyages, domestic shipping and emissions at berth in the three countries analysed.

Five sensitivity analyses were also performed in order to better understand the influence of cost difference parameters on the financial attractiveness of evasion. These parameters are fluctuations in freight and charter rates, fuel prices and the possibility of congestion in the non-EEA ports that are frequented for evasive port calls. The most important cost parameter affecting the evasion decision is the opportunity cost of time. The latter is affected by the time lost during the evasive port calls, especially if all ships use the same nearby EEA ports for their stopover. Therefore, the more ships are prone to make an evasive port call, the less financially interesting it becomes for everyone.

6.7% of all voyages would be tempted to evade at a carbon price of €30/tonne under a full scope ETS, but none would be tempted under a semi-full scope design

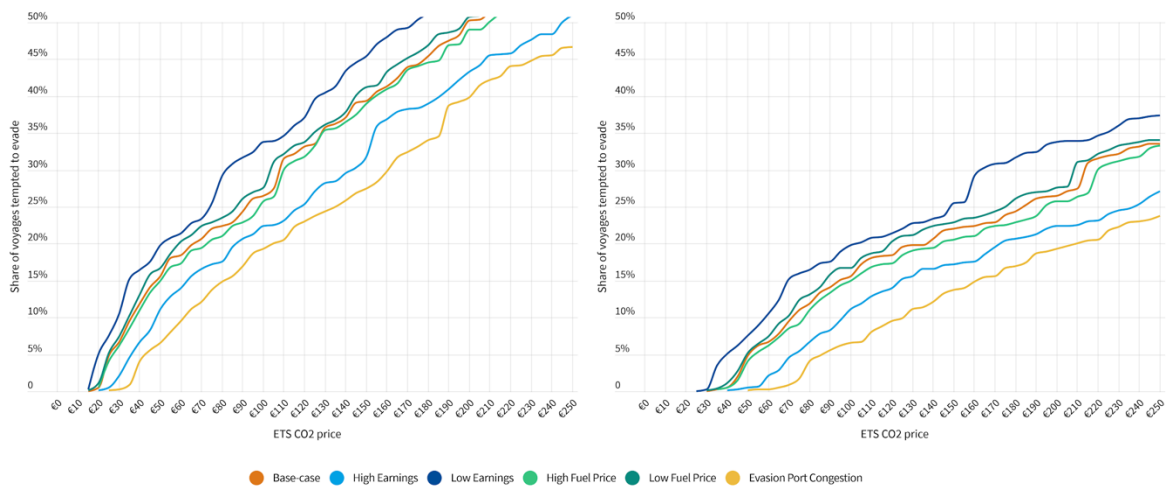
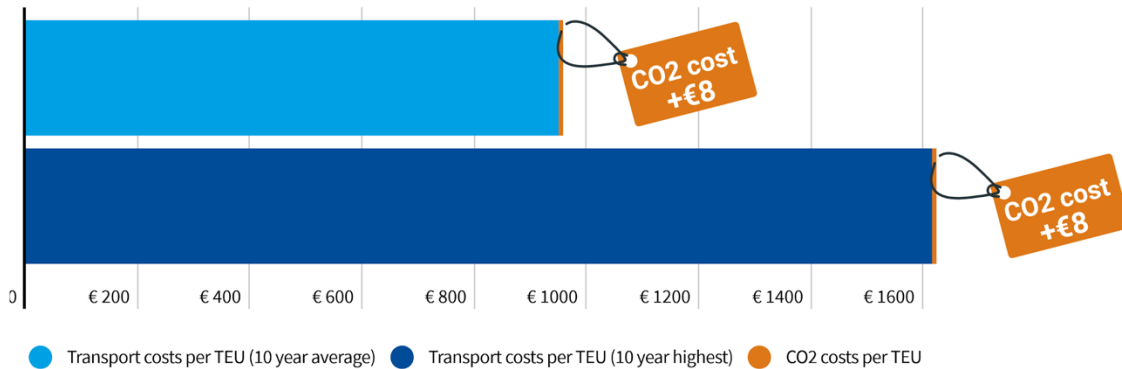


Figure II: Risk of policy evasion under a semi-full scope maritime ETS covering Greece, Spain and the Netherlands

Analysis also shows that in the case of ETS compliance, CO₂ costs would add only a very small amount to the overall transport costs. For transporting a standard container (TEU) from Spain to Singapore under a semi-full scope ETS design, the CO₂ costs would represent less than 1% of the overall transport costs. This drops to 0.5% if one assumes the highest transport costs (in this case, freight rates) observed in the past 10 years. This gives ground to assume that ETS costs would be easy to

pass on to the final consumers as the impact on transport costs would be much smaller than the natural multi-annual variations in the freight rates.

CO2 costs negligible compared to overall transport costs



Note: An ETS allowance price of €30 euro/tonne is assumed under a semi-full scope ETS design. The port-to-port transport costs are based on the 10 year average freight rates (which include fuel, operational, capital, port and cargo-related costs) for sailing an 18,000 TEU container ship from Spain to Singapore.

Figure III: CO₂ costs compared to overall transport costs per standard container (semi-full scope)

Perhaps counter-intuitively, the results also show that a higher degree of policy evasion at higher CO₂ prices still delivers higher overall ETS revenues. At carbon price levels that are deemed politically feasible, ETS revenues from international voyages to and from the three countries examined in this report are considerably higher under a full scope than under a semi-full scope ETS design. Therefore, purely from a revenue generation perspective, a full scope ETS is a more interesting policy option. Note that this study assumes that ships do not take emission reduction measures to lower their ETS compliance costs.

High CO2 prices lead to more policy evasion, but also to higher total ETS revenues (under a full scope ETS, total revenues stabilize after €105/tonne)

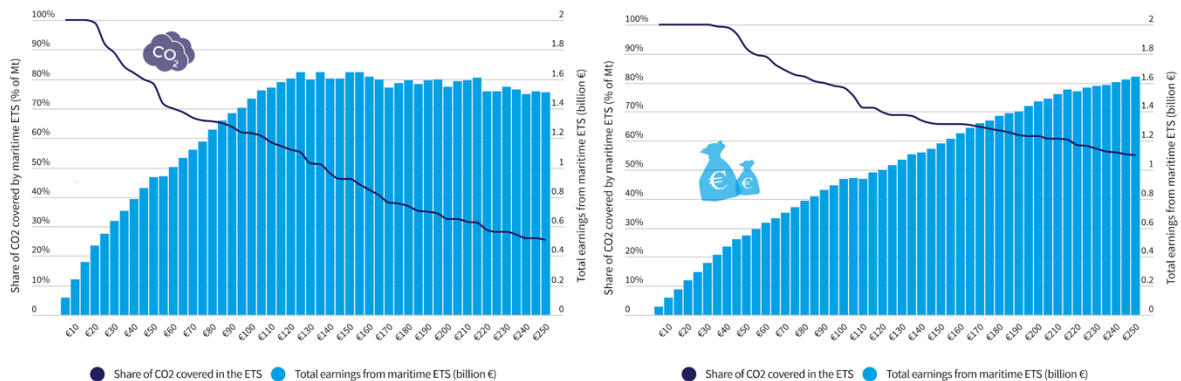


Figure III: Total ETS revenues under a full scope (left) and a semi-full scope (right) maritime ETS covering ships calling at Greek, Spanish and Dutch ports

If the EU does opt for a semi-full scope ETS design, it would do so under the assumption that other regions/countries would cover the remaining 50% of emissions of these voyages with similar national/regional regulatory measures. To ensure that this materialises, the EU should actively encourage other countries to put in place national MRV systems, include shipping in their national NDCs under the Paris Agreement and mandate reduction measures, including carbon pricing mechanisms similar to the EU ETS. The Union should review the progress made in other regions, but also other fora, like the IMO, and in the absence of satisfactory progress extend the maritime ETS to the full scope of the MRV emissions.

Whether the EU opts for a full scope or a semi-full scope ETS design, a maritime ETS would always benefit from regulatory safeguards to discourage even the smallest risks of carbon leakage. One way to tackle evasive behaviour would be to adjust the definition of ‘port of call’ under the EU MRV regulation. To ensure a stopover is not misused to evade the ETS, the definition of port of call should require a demonstration of genuine business activity taking place in these and other potential evasion ports. The regulation could ensure this by including a certain percentage of cargo/passengers that needs to be (un)loaded/(dis)embarked during a port of call. In order to reduce the complexity of regulation and enforcement, such a stringent definition could apply to only a limited number of ‘blacklisted evasion ports’ in the EU neighbourhood.

The report also considers earmarking the revenues of the maritime ETS for a maritime decarbonisation fund. This could serve as a support mechanism aimed at helping the shipping industry and ports meet the innovation and investment challenges of the transition to a low-carbon economy.

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1. Introduction: policy and regulatory context

Maritime shipping plays a major role in European freight trade and passenger transport. It accounts for 75% of the EU's external trade, 36% of intra-EU trade flows and more than 400 million passengers per year.³ Waterborne transport is in most cases the most energy-efficient mode of transport. However, European shipping is still a very large source of greenhouse gas emissions and air pollution. EU related CO₂ emissions from maritime transport reached 144 Mt in 2019.⁴ In 2018, maritime emissions represented 3.7% of total EU CO₂ emissions, making its climate impact comparable to that of Belgium, and 13% of the EU's transport emissions.⁵ In pace with expected growth in global trade, shipping's global emissions are projected to increase by up to 50% between now and 2050.⁶

By signing the Paris Agreement, the European Union has committed to 'economy wide' greenhouse gas (GHG) emission reduction efforts. While ships have been required since 2018 to monitor and report, among other metrics, their CO₂ emissions and operational efficiency, to this day shipping is the only transport sector not subject to GHG emission reduction targets or measures in the EU. When adopted in 2015, the idea was that this Monitoring, Reporting and Verification Regulation (MRV) would be the first step of a staged approach for the inclusion of maritime CO₂ emissions in the EU's climate policy. With the adoption of the European Green Deal in December 2019, the European Commission committed to taking some of the next steps.⁷ One of those will be the extension of the European emissions trading system (ETS) to cover the maritime sector.⁸

Several actors have since raised concerns that the inclusion of maritime transport in the EU ETS would lead to policy evasion, i.e. ships making an evasive port call outside the EU jurisdiction to drop off part of their cargo or passengers before sailing to European ports. This would reduce the scope of emissions

³ European Commission. (2020) 2019 Annual Report on CO₂ Emissions from Maritime Transport. Retrieved from https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/c_2020_3184_en.pdf

⁴ This number is based on the EU MRV scope (see chapter 1.1.) and reflects the 95th version of the 2019 THETIS-MRV database. This database is permanently updated, meaning there might be more recent versions available. Outliers have been filtered out in order to take into account that some ships report their emissions inconsistently. Note that the MRV scope includes less emissions than the UNFCCC scope, with the former based on real life monitoring of emissions and the latter based on fuel sales in Europe.

⁵ European Commission. (2020) 2019 Annual Report on CO₂ Emissions from Maritime Transport. Retrieved from https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/c_2020_3184_en.pdf

⁶ International Maritime Organization. (2020) Fourth GHG study.

⁷ The European Green Deal is a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral by 2050.

⁸ European Commission. (2019) The European Green Deal. Retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

covered by the EU ETS and thus diminish its practical effectiveness. To evaluate the risk of policy evasion under a future maritime ETS, this report performs a cost-benefit analysis for an evasive port call. The goal is to assess the drivers in the cost structure that determine the cost-effectiveness of evasion from the shipowner's perspective.

1.1. The EU Monitoring, Reporting and Verification regulation (MRV)

The main objectives of the MRV are to collect robust and verified CO₂ emissions data, to stimulate the uptake of energy solutions with more transparency and to support the development and implementation of future climate mitigation policies.⁹ The Regulation requires all ships over 5,000 gross tonnage to report inter alia their annual fuel consumption and associated CO₂ emissions when (un)loading cargo or passengers for commercial reasons. Covered are the emissions:

- from voyages between ports within the European Economic Area (EEA)¹⁰,
- from voyages between the last non-EEA port and the next port located within the EEA,
- from voyages between the last EEA port and the next non-EEA port and
- occurring when the ship is at berth.

CO₂ emissions are determined based on the amount of fuel consumed in combination with the fuel-specific CO₂ emissions factor. This policy scope allows the MRV to cover around 90% of all EU maritime CO₂ emissions, whilst only including around 55% of all ships calling at EEA ports.¹¹

Once a year, shipping companies operating on EU shipping routes have to aggregate their data and have it verified by independent verifiers before submitting it to the European Commission. The Commission then publishes most of this verified data and prepares an annual report to inform the public and other European institutions. The first year of compliance was set for 2018 with the annual emissions reports released on June 30th.

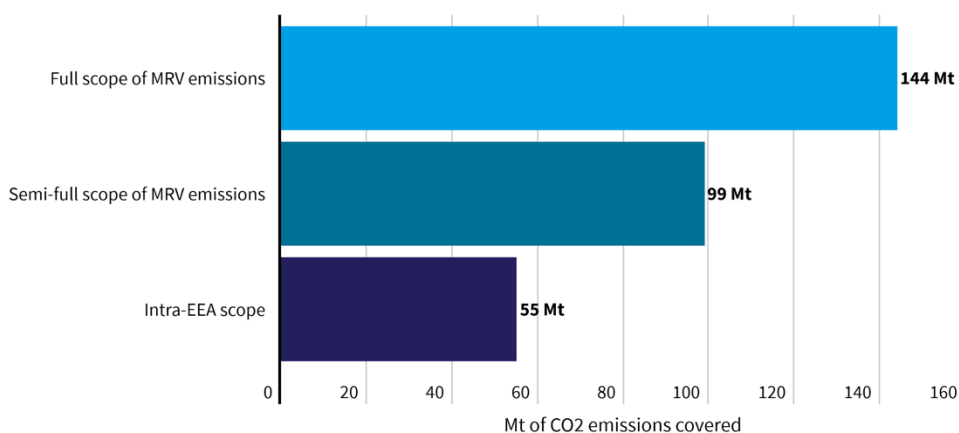
⁹ European Commission. (2020) 2019 Annual Report on CO₂ Emissions from Maritime Transport. Retrieved from https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/c_2020_3184_en.pdf

¹⁰ The European Economic Area (EEA) combines the countries of the European Union (EU) and member countries of the European Free Trade Association (EFTA) to facilitate participation in the EU's single market. The EFTA Member States subject to the regulation are Iceland, Liechtenstein and Norway.

¹¹ European Commission. (2020) 2019 Annual Report on CO₂ Emissions from Maritime Transport. Retrieved from https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/c_2020_3184_en.pdf

1.2. The introduction of a maritime Emissions Trading System (ETS)

In its European Green Deal communication, the European Commission announced its intention to extend the ETS to the maritime sector. Such an extension means that, for the first time ever in EU history, the ‘polluter pays’ principle will also apply to shipping. Ships would need to pay a carbon price for each tonne of CO₂ they emit, based on the fuel consumption they reported under the MRV regulation. Looking at the scope of a maritime ETS, figure 1 illustrates the three potential options that could be considered and the amount of emissions that each of those scopes would cover.



Source: EU THETIS MRV, extract: 2019-v95-05112020-EU MRV Publication of information.xlsx. Outliers have been filtered out in order to take into account that some ships report their emissions inconsistently.

Figure 1: Breakdown of CO₂ emissions from EU shipping in 2019 by potential maritime ETS scope

- **Full scope**, the ETS would cover exactly the same voyages as the MRV regulation, meaning 100% of inbound, outbound and intra-EEA voyages, as well as 100% of emissions at berth. Note that with a total of 144Mt of CO₂ emissions in 2019, the MRV scope includes less emissions than the UNFCCC scope, which is based on marine fuel sales in Europe but cannot be attributed to individual ship(owner)s.
- **Semi-full scope**, the ETS would still cover 100% of emissions from intra-EEA shipping and 100% of emissions at berth. But for both inbound and outbound voyages to and from the EEA, only 50% of their emissions would be covered by the prospective EU ETS. The rationale is that the remaining 50% of emissions of these voyages would be covered by third-countries in case they decide to implement similar regional/national regulations. A semi-full scope would cover 99Mt of CO₂, representing 69% of EU shipping emissions (i.e. the emissions covered under the MRV

regulation). A variation of the semi-full scope would be to include all emissions from incoming voyages but exempt all emissions from outgoing voyages, or the other way around.¹²

- **Intra-EEA scope**, the ETS would only cover emissions from intra-EEA voyages and emissions at berth. Including merely 55Mt of CO₂ (38% of the EU shipping emissions), such a scope would undermine the effectiveness and the very environmental rationale of the ETS and MRV. Therefore, the intra-EEA option is not considered in this study.

1.2.1. The potential risk of carbon leakage

Ships could attempt to reduce their ETS obligations by shortening the length, and thereby the emissions, of their journeys covered under the proposed regulatory scheme. Both under a full and a semi-full scope ETS design, the scheme would only cover - in addition to intra-EEA voyages - the first and last legs of the journey to/from non-EEA countries. Specifically, voyages from the last non-EEA port to the first EEA port and from the last EEA port to the first non-EEA port. By adding a stopover in a nearby non-EEA port, ships could shorten this first and/or last leg of their journey, thereby limiting their exposure to the policy and the ensuing compliance costs. For example, a ship sailing from the USA to Spain could make a stopover - a so-called 'evasive port call' - in Morocco (see figure 2). This ship would then not pay any CO₂ costs for the emissions of its voyage from the USA to Morocco, but only for the emissions of its voyage from Morocco to Spain. A form of carbon leakage, such behaviour could affect the coverage of the emissions regulated by the policy scheme. There is one catch though. To qualify as a port of call under the MRV regulation, a stopover needs to meet the following condition: *'the port where a ship stops to load or unload cargo or to embark or disembark passengers'*. A ship would thus need to drop off at least one container or one passenger during its evasive port call.

¹² When opting for such a variation of the semi-full scope, it would probably be more logical to include all emissions from incoming voyages in the maritime ETS as opposed to all emissions from outgoing voyages. This could simplify the enforcement of maritime ETS. Note that the inbound emissions are slightly higher than the outbound emissions and such a scope would thus cover slightly more emissions than an even 50-50% split.

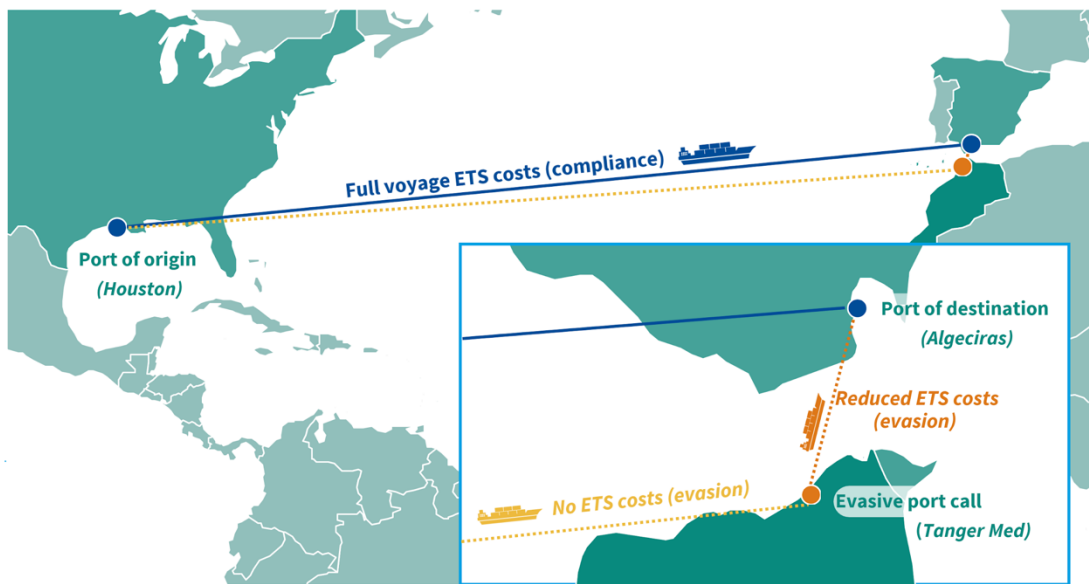


Figure 2: Illustrative representation of an evasive port call

While an evasive port call reduces the ETS compliance cost, there are additional costs attached to a stopover as well. Needless to say that an extra port call comes with extra port costs. Furthermore, by increasing the length of their overall journey (between the country of origin and destination of the cargo/passengers), ships would also burn more fuel, leading to extra fuel costs. In addition, they would increase the duration of their journey, leading to extra operational costs (the cost to pay their crew, insurance, etc.) and to opportunity costs. Imagine a hypothetical ship, normally operating 360 days a year, usually performs 15 direct journeys a year to EEA ports, each taking 24 days. By trying to evade the ETS, this ship would now make a stopover on each of these journeys, adding at least one additional day per journey. Because of that extra day, each journey now takes 25 days to finish, which means the same ship can now only make about 14 journeys to EEA ports per year. The revenues that our ship could have otherwise earned from the 15th journey is called foregone revenue, or ‘opportunity cost’ of the increased journey time due to evasive stopover.

The cost of policy compliance, i.e. the price per tonne of CO₂ emitted, will determine whether a ship would be inclined to make the additional expenses related to an evasive port call or not. To be in a ship’s financial interest to avoid the ETS, the compliance costs would need to be more expensive than the sum of all the extra costs ensued from the evasive port call. After the introduction of a maritime ETS, ships might make such a cost-benefit analysis. This report performs a similar analysis, by modelling the price level needed on each individual voyage to incentivise ships to evade the ETS. This price level is called the ‘turning point’. Figure 3 indicates the turning point for a large container ship sailing from Spain to

Singapore. To incentivise this specific ship to evade the ETS, a CO₂ price of at least €123/tonne would be required (see chapter 4.2.1.). This does not mean that this ship would definitely evade at carbon price levels above €123/tonne. While it would be in its financial interest, there might be additional, non-financial barriers to changing its route, such as tight delivery schedule, congestion in the evasion port, etc.

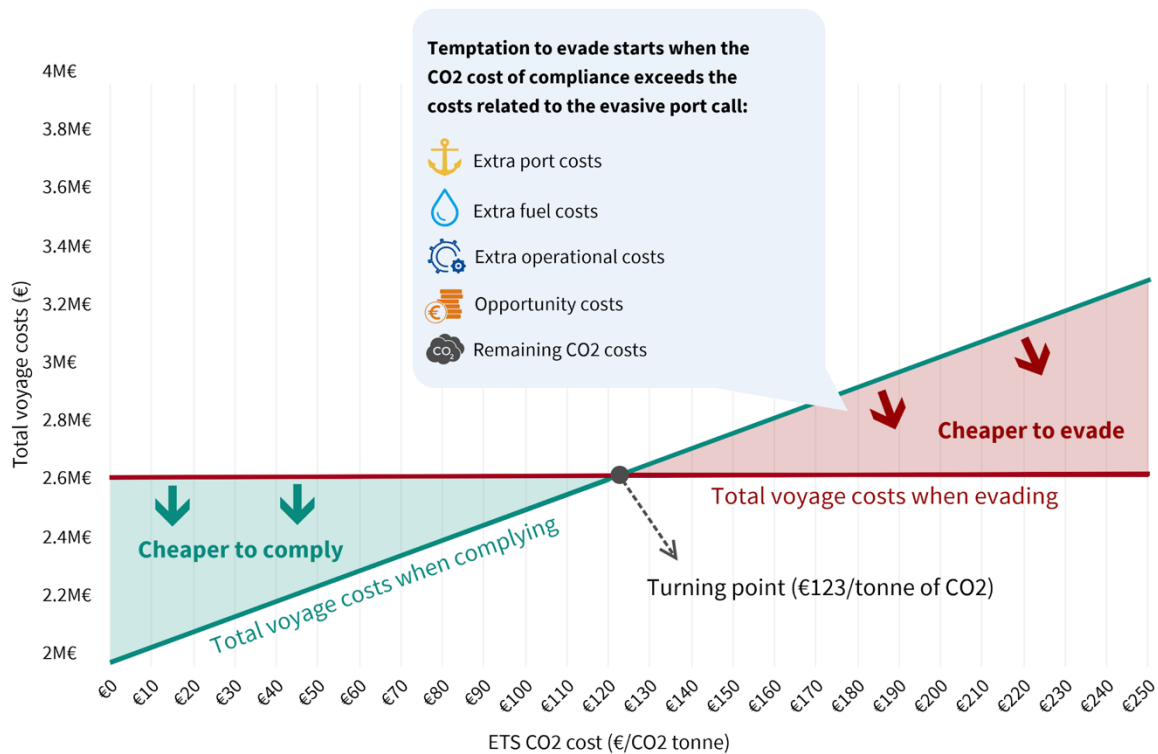


Figure 3: Extra costs related to an evasive port call made by a large container ship sailing from Singapore to Spain (semi-full scope)

2. Scope of the report: scenarios and sensitivity analyses

To evaluate the risk of policy evasion under a maritime ETS, this report compares the costs versus the benefits of an evasive port call and assesses the drivers in the cost structure that determine whether a ship would be tempted to evade or not.

The analysis is based on the case studies of three countries:

- Greece, where we analyse the probability of ships calling at the port of Piraeus using the port of Haydarpasa in Turkey for an evasive port call,
- Spain, where we analyse the probability of ships calling at the port of Algeciras using the port of Tanger Med in Morocco for an evasive port call,
- and the Netherlands, where we analyse the probability of ships calling at the port of Rotterdam using the port of Southampton in the UK for an evasive port call.

Ships sailing to and from these countries are assumed to be the most susceptible to policy evasion as they have major seaports in close proximity to a non-EEA port. 2016 satellite (AIS) data was used to identify the international voyages sailing to and from Greece, Spain and the Netherlands. Every voyage considered in this study is thus based on real-world operational activity of ships calling at EEA ports. Overall, over 15,000 individual voyages are included. Only containerships, bulk carriers and oil tankers are analysed, given that these ship types are most active in extra-EU shipping and would arguably be more prone to evasion than vessel types engaged in coastal shipping. This is a conservative approach, as it would be very complicated for bulk carriers and oil tankers to unload part of their cargo during an evasive port call. These vessel types usually operate in the charter market and implement door-to-door cargo transportation for a single cargo owner at a time.

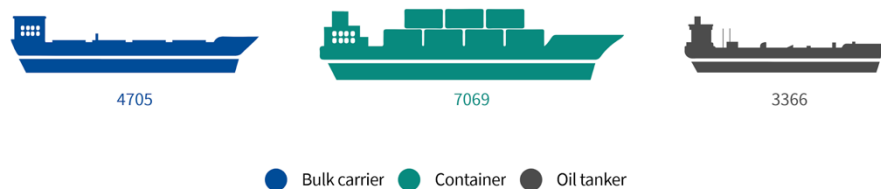


Figure 4: Number of individual voyages to and from Greece, Spain and the Netherlands analysed in this study

The study contains a base-case scenario and 5 sensitivity analyses as described in Figure 5. For our base-case scenario, we used historical average prices and port waiting times as input assumptions. The five sensitivity analyses were performed in order to better understand which parameters have the strongest influence on the financial attractiveness of evasion and account for variations in freight and charter rates, fuel prices and the possibility of congestion in the non-EEA ports that could be used for evasive port calls.





 Base-case scenario	Historical average prices and port waiting times derived from a literature review.
 High/low earnings	A ship's earnings are determined by the price that is charged to transport one standard container (TEU) to the destination port (a.k.a. freight rate) or by the price paid per day to charter a bulk carrier or oil tanker (a.k.a. daily charter rate). These sensitivities study the impact of an increase/decrease in a ship's earnings on its evasive behaviour by modelling the highest and lowest historical average earnings of the past 10 years (respectively +70% and -40% compared to the base-case).
 High/low fuel prices	A ship's costs are highly dependent on the fuel price. In these two sensitivities, an increase/decrease of fuel prices by 50% is modelled.
 Port congestion	In order to limit their policy compliance costs as much as possible, all ships would be inclined to use the same few nearby non-EEA ports for their evasive port call. This would lead to increased traffic in these ports and thus to the occurrence of congestion. This sensitivity considers a doubling of the time spent in the stopover port. Extra time spent in a port would translate into extra operational costs and opportunity costs.

Figure 5: Base-case scenario and sensitivity analyses

Our base-case scenario and these 5 sensitivities have been run separately for the full and semi-full scope ETS design options as presented in section 3 below. A full scope ETS covering international voyages to/from Greece, Spain and the Netherlands would entail 23.9Mt of CO₂ or 16.6% of total EU shipping emissions under the full scope. A semi-full scope in those three countries would cover 11.9Mt. Note that these amounts of CO₂ emissions do not include voyages calling at any other EEA countries, nor the emissions of intra-EEA voyages, domestic shipping and emissions at berth in the three countries analysed.

3. Overall results: a maritime ETS is relatively carbon leakage proof

The overall results across the three case study countries indicate that the potential risk of policy evasion is very limited for the levels of carbon pricing that are deemed politically feasible. Assuming a €30/tonne carbon price under a semi-full scope ETS design, no ship would find it financially attractive to make a stopover at a nearby non-EEA port. Under a full scope ETS design, policy evasion at the current CO₂ price level would be limited to 6.7% of all the analysed voyages. Given that not all countries are subject to

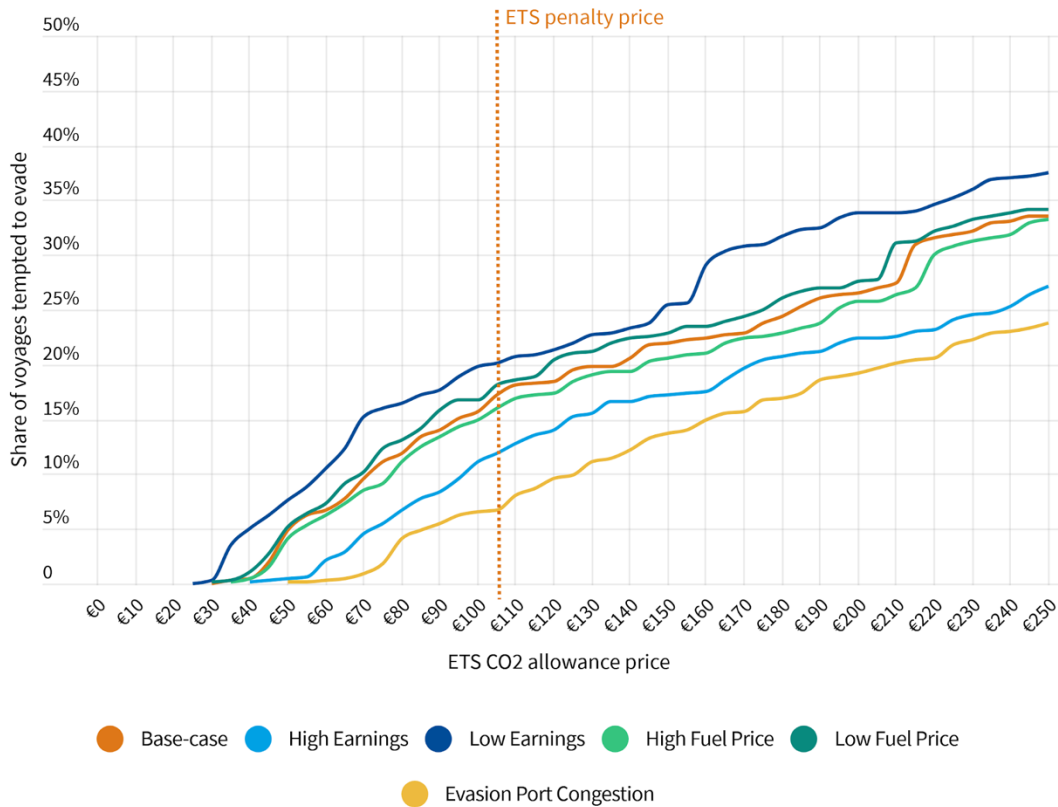
the same degree of exposure to nearby non-EU ports as Greece, Spain and the Netherlands, the actual risk of policy evasion will likely be even smaller if the whole of EEA emissions are considered.

Perhaps counter-intuitively, the results also show that a higher degree of policy evasion at very high CO₂ prices would still generate high ETS revenues. This is because higher ETS earnings from a limited amount of remaining voyages more than compensate the lost earnings due to policy evasion. However, as the purpose of an ETS is first and foremost to lead to emission reductions, the scheme should be designed in such a way as to minimize the risk of carbon leakage as much as possible (see chapter 5.2. for our policy recommendations). It is important to note that ships can also limit their exposure to the scheme by implementing technical measures to reduce their emissions in order to also lower their ETS compliance costs. Such adaptive behaviour and its impacts on the potential ETS revenues is beyond the scope of this study.

3.1. The risk of potential policy evasion is very limited

As illustrated in Figure 6, analysis shows that there is no risk of policy evasion under a semi-full scope ETS at CO₂ prices below €30/tonne (*orange line*). The risk is extremely limited across all sensitivities analysed. Even if earnings drop to their lowest point observed in the past ten years (*dark blue line*), only 0.3% of all voyages would be tempted to evade. This is of course assuming no other country, nor the IMO, implements a carbon pricing mechanism. If the CO₂ price increases to €50/tonne, policy evasion in the three countries analysed becomes profitable to 4.8% of all voyages. However, these 4.8% of voyages do represent 8.2% of the total emissions covered under the semi-full scope. Chapter 3.3. will explain in more detail why the biggest emitters, i.e. the vessels performing the longest routes, are the first to evade. As a result, the share of CO₂ evading the ETS scheme increases at a faster rate than the share of individual voyages vulnerable to policy evasion. Note that the graph in Figure 6 was capped at 50% in order to increase readability. It illustrates the risk of policy evasion at any given CO₂ price up to €250/tonne. As in practice the ETS has a price cap of €106/tonne, the legislation would need to be changed before we could ever reach such high levels of carbon pricing.¹³

¹³ As the ETS penalty is defined at €100/tCO₂, non-compliance would be more profitable than compliance if the CO₂ price were to ever exceed €100/tCO₂. In practice, the ETS penalty is slightly higher than that (€106/tCO₂) because it is adjusted for annual inflation since 2013.

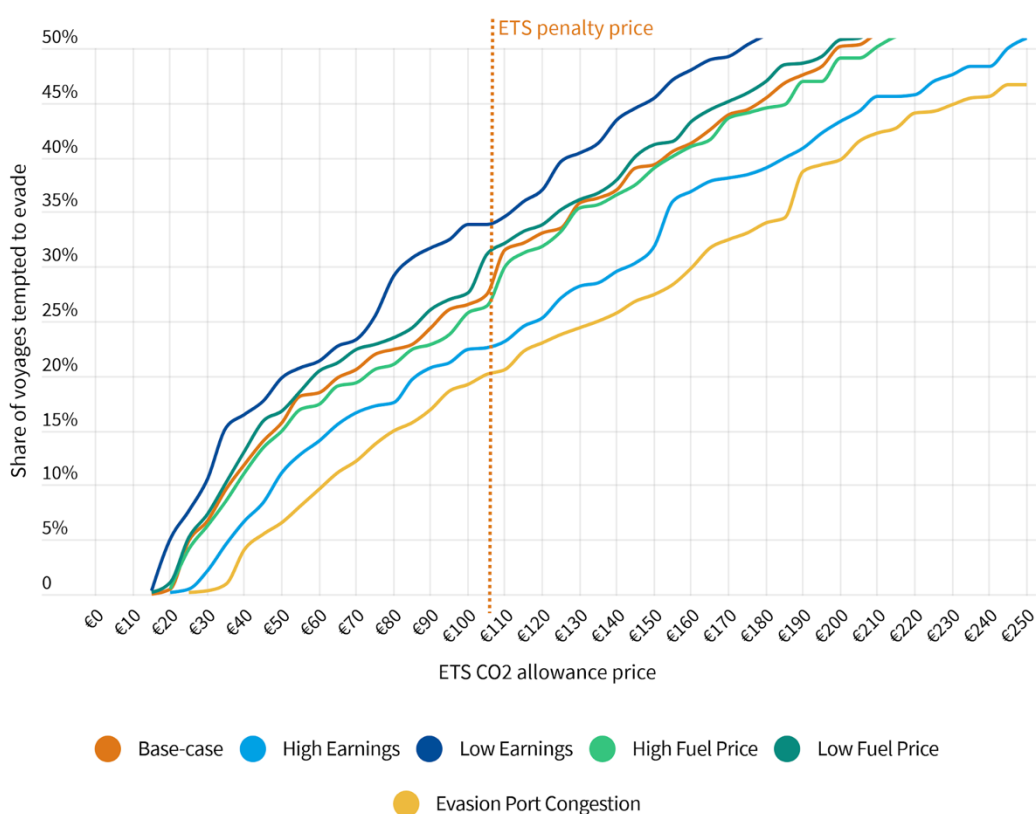


Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 6: Risk of policy evasion under a semi-full scope maritime ETS covering Greece, Spain and the Netherlands

The results from our sensitivity analyses indicate that a potential increase in port waiting times (*yellow line*) constitutes the most impactful parameter analysed. This is based on an assumption that more ships willing to evade would lead to increased waiting times in the evasion port, all other things being equal. This would incur more operation and opportunity costs, resulting in less financial incentive for evasion. The blue lines indicate the impact of fluctuations in a ship's earnings (freight or charter rates) on their potential decision to evade. A drop in earnings would reduce the opportunity costs and increase a ship's interest to evade, and vice versa. The risk of policy evasion turns out to be relatively less sensitive to our last sensitivity analysis: an increase/decrease in fuel prices. That being said the results indicate that ships would be less inclined to evade at higher fuel prices (*light green line*) than at lower fuel prices (*dark green line*). As we have seen in chapter 1.2.1., making an additional port call comes with extra fuel consumption, thereby increasing total fuel costs of the entire journey even further.

Under a full scope ETS design, the risk of policy evasion is slightly more elevated (see Figure 7). At a CO₂ price of €30/tonne, 6.7% of all voyages in the base-case would be tempted to evade, representing 11.1% of the total emissions covered under the full scope. The risk of policy evasion increases further to 15.6% at €50/tonne, which corresponds to 21.7% of all emissions under the full scope. As the ETS compliance cost needs to outweigh the sum of extra costs related to an evasive port call, logically this occurs faster when ships are required to pay for 100% of the emissions from their voyage instead of for half of the emissions under a semi-full scope ETS. However, in the likely occurrence of congestion in the ports used to evade the ETS, the risk of policy evasion drops back to 6.5% (*yellow line*) at a CO₂ price of €50/tonne. Again, Figure 7 assumes that third countries, or the IMO, do not implement a similar regional/global carbon pricing scheme.



Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

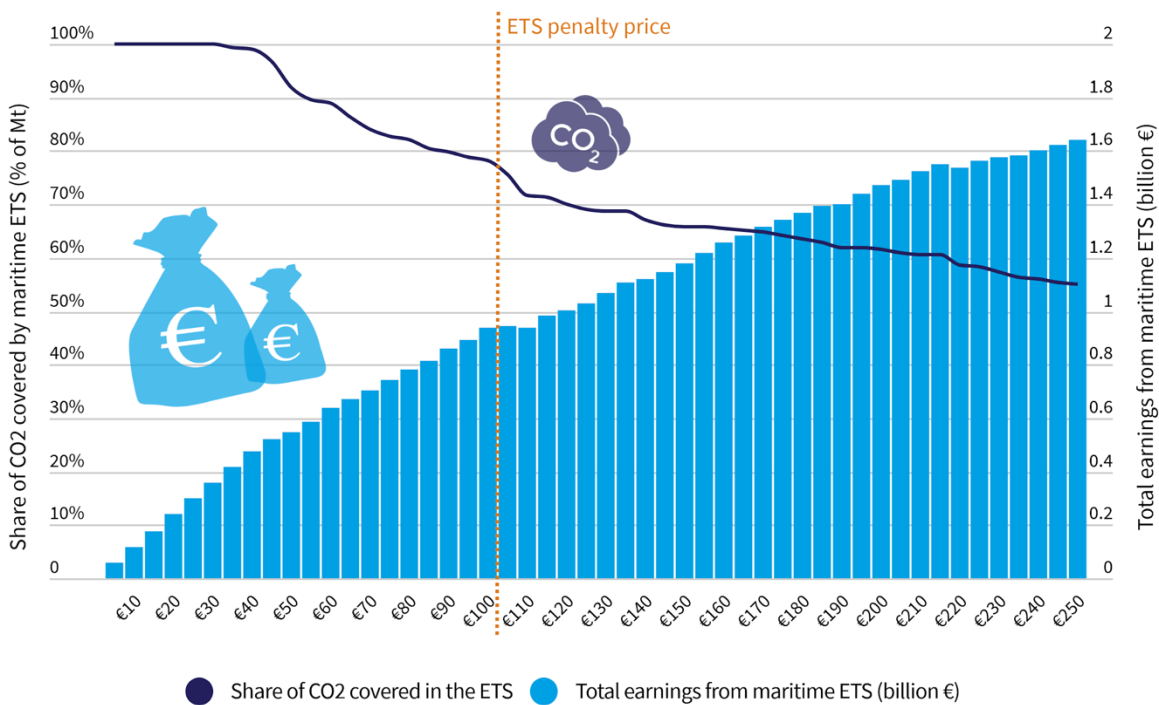
Figure 7: Risk of policy evasion under a full scope maritime ETS covering Greece, Spain and the Netherlands

3.2. Revenues increase as the CO₂ price increases, even with evasion

Emissions under the EU MRV reached 144Mt in 2019.¹⁴ If all of these emissions were covered under a carbon pricing scheme and the current ETS price of €30/tonne applied, revenues from a maritime ETS would reach €4.3 billion a year. In our analysis, we only look at the revenues from international voyages to and from Greece, Spain and the Netherlands. That means revenues do not include earnings from voyages calling at any other EEA countries, nor earnings from the emissions of intra-EEA voyages, domestic shipping and emissions at berth in the three countries analysed.

A semi-full scope carbon pricing scheme covering 11.9Mt of EU maritime CO₂, or 50% of the emissions of international voyages to/from Greece, Spain and the Netherlands, would generate €358 million a year at the current ETS price of €30/tonne (see figure 8). The revenues increase as the CO₂ price rises, but so does the risk of policy evasion. At a CO₂ price of €55/tonne, 10% of the emissions covered by the semi-full scope ETS are not paid for due to evasion. However, as the remaining share of ships that do still comply with the ETS pay ever higher compliance dues, total revenues remain higher at higher carbon price levels compared to lower price levels with larger emissions coverage. Therefore, purely from a revenue generation perspective, policy evasion is not much of a concern. Even with evasive behaviour, high CO₂ prices still lead to the greater revenues. This is of course assuming that ships do not take emission reduction measures to lower their ETS compliance costs.

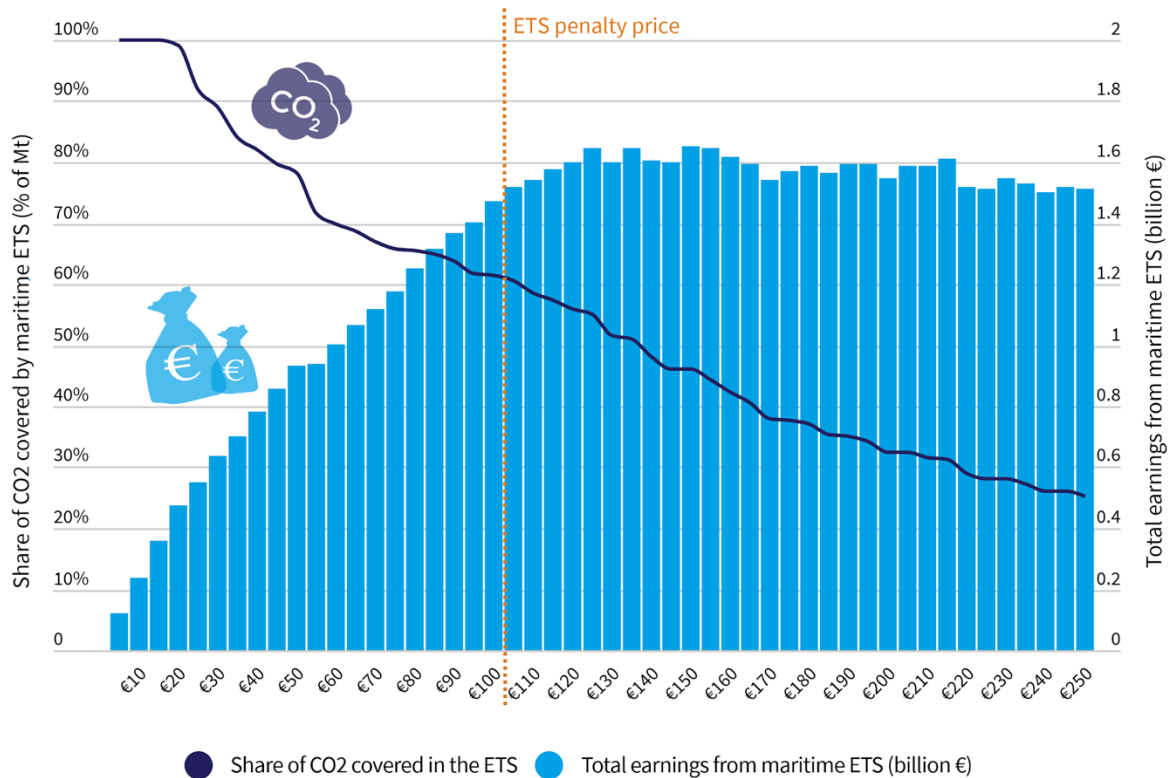
¹⁴ This number is based on the EU MRV scope (see chapter 1.1.) and reflects the 95th version of the 2019 THETIS-MRV database. This database is permanently updated, meaning there might be more recent versions available. Outliers have been filtered out in order to take into account that some ships report their emissions inconsistently.



Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 8: Total ETS revenues under a semi-full scope maritime ETS covering international voyages to and from Greece, Spain and the Netherlands

Under a full scope design covering 23.9Mt of CO₂ emissions, a maritime ETS in Greece, Spain and the Netherlands would generate €637 million a year from international voyages at a CO₂ price of €30/tonne (see figure 9). However, at this point already 10% of emissions are not paid for due to evasion. Note that the revenues as shown in figure 9 again only reflect ETS revenues from international voyages.



Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 9: Total ETS revenues under a full scope maritime ETS covering international voyages to and from Greece, Spain and the Netherlands

The revenues also increase as the CO₂ price increases, but only up to the point where the CO₂ price hits €105/tonne, which is roughly the inflation adjusted maximum CO₂ allowance fine for non-compliance.¹⁵ After that, the revenues fluctuate between €1.49 billion and €1.64 billion. From the moment when the CO₂ price exceeds €220/tonne, a semi-full scope ETS generates more revenues than a full scope ETS in this simulation, as too many voyages have an interest to evade the full scope ETS.

3.3. Distance is a key driver for policy evasion

For all destinations and ship types, the length of the voyage plays a decisive role in determining a ship's turning point. Chapter 1.2.1. explained how the turning point is determined by the balance between the

¹⁵ As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

CO₂ cost of policy compliance and the additional costs associated with an evasive port call. As fuel and operational costs are already more elevated on longer voyages, the additional costs from an evasive port call would be a much smaller part of the total costs of these voyages. Thus, ships would be more and more inclined to evade the ETS as they are performing longer voyages. And because it is the vessels on the longest routes that are the first to evade, the share of CO₂ covered by the ETS scheme decreases at a faster rate than the risk of evasion for individual voyages increases (see chapter 3.2.). Figure 10 below illustrates the correlation between voyage length and CO₂ price turning points.

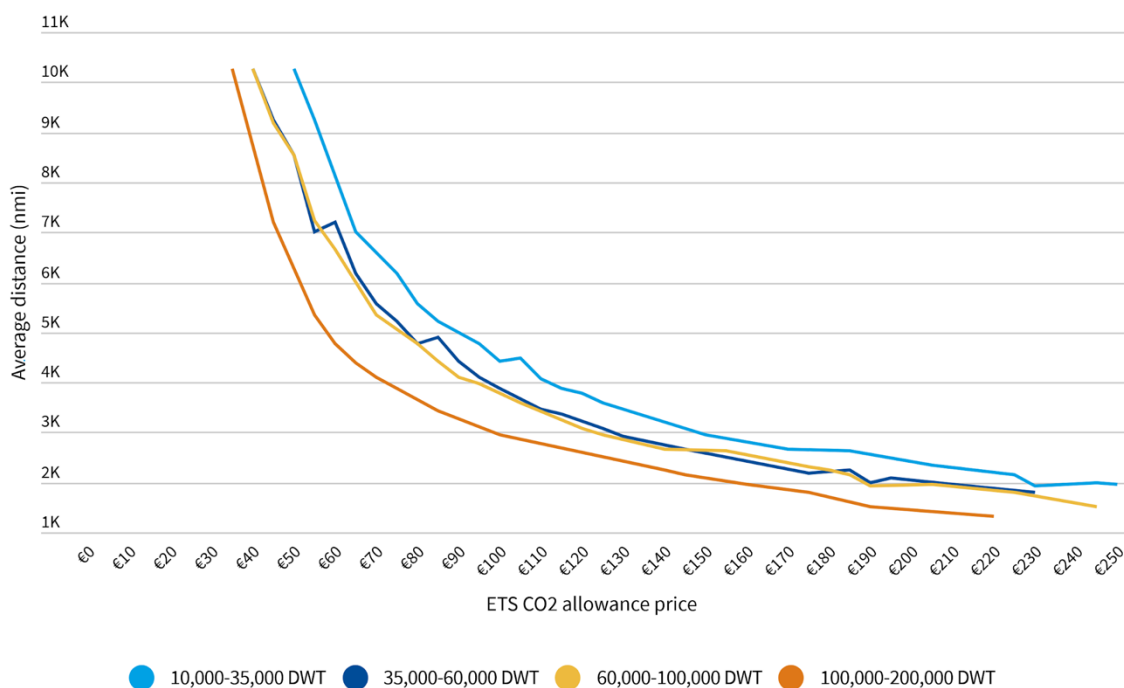


Figure 10: The turning points for bulk carriers sailing to and from Spain, for different CO₂ prices and different voyage lengths

4. Case studies: digging into the main drivers of policy evasion

To gain insight into the main drivers of policy evasion, this study relies on the case studies of three countries: Greece, Spain and the Netherlands. The analysis looks into the overall risk of policy evasion for each country, as well as into the cost structure of one specific vessel on a representative route. For Greece a bulk carrier is considered, for Spain a container ship and for the Netherlands an oil tanker. For brevity and simplicity, the report text only focuses on our base-case scenario under a semi-full scope ETS design and thus considers historic average prices and port waiting times.

4. 1. Case study of Greece, with an evasive port call in Turkey

Our first case study looks into the international voyages calling at Greek ports under the MRV regulation and models the probability of these ships using Turkey for an evasive port call. Analysis assumes all ships sailing to and from Greece use the port of Piraeus, as well as all evasive port calls taking place in the port of Haydarpasa in Turkey.¹⁶ Figure 11 presents the number of individual voyages, for each ship type and for each voyage type, considered in this case study. Note that one ship may have performed multiple voyages to and from Greece and that all of these voyages then would have been counted and analysed separately in this report.

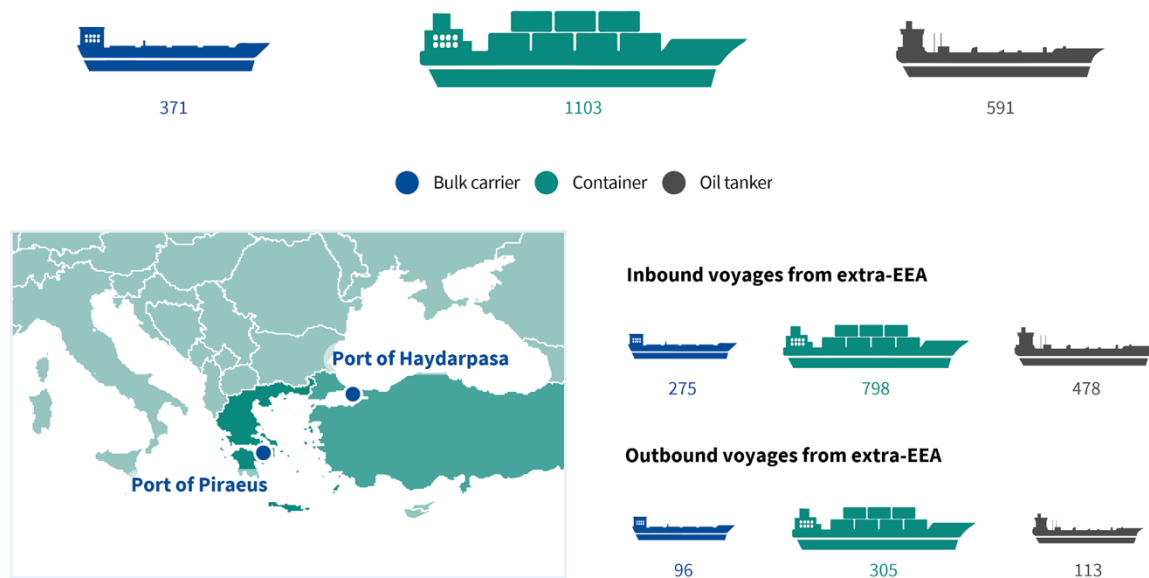
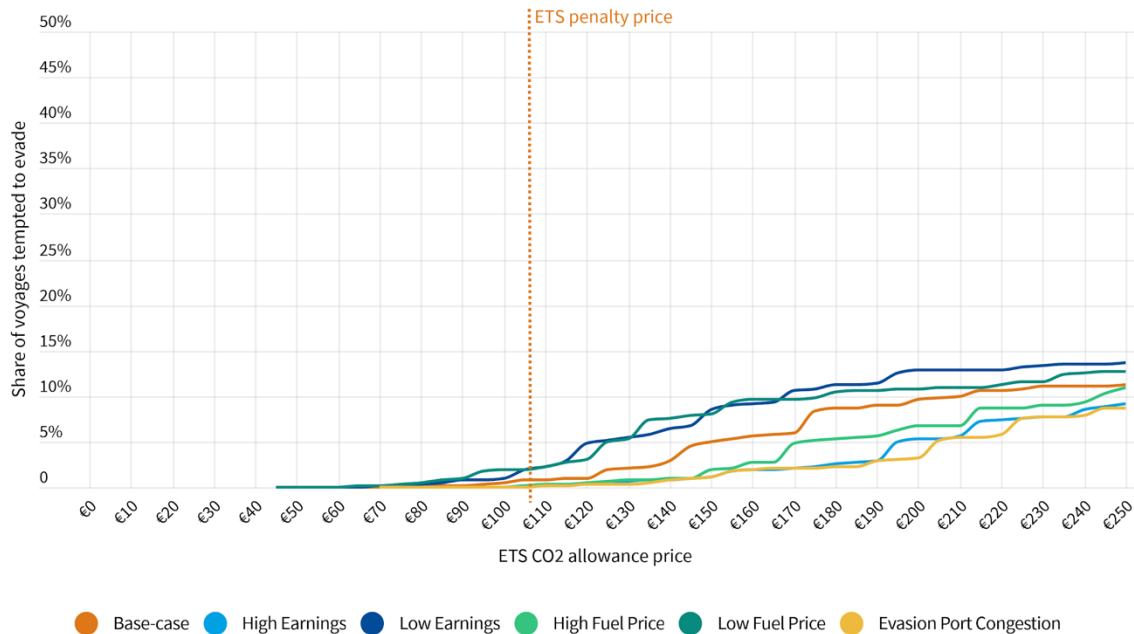


Figure 11: Case study of Greece - 2065 voyages

Figure 12 models, at any given CO₂ price, the percentage of these voyages that could be inclined to use the port of Haydarpasa for an evasive port call. Analysis shows that it would not be financially interesting for any ship to evade the ETS below a CO₂ price of €30/tonne. Even if the CO₂ price rises to €100/tonne, the risk of policy evasion would still be limited to a mere 0.5% of all voyages. This is because the extra port costs, the extra fuel costs, the extra operational costs, the opportunity costs and the remaining CO₂ costs far outweigh the costs of policy compliance. Note that the y-axis in figure 12 was capped at 50% in order to increase readability.

¹⁶ A sensitivity analysis of ships using another Greek port or using another port for their evasive port call can be found in Appendix II.



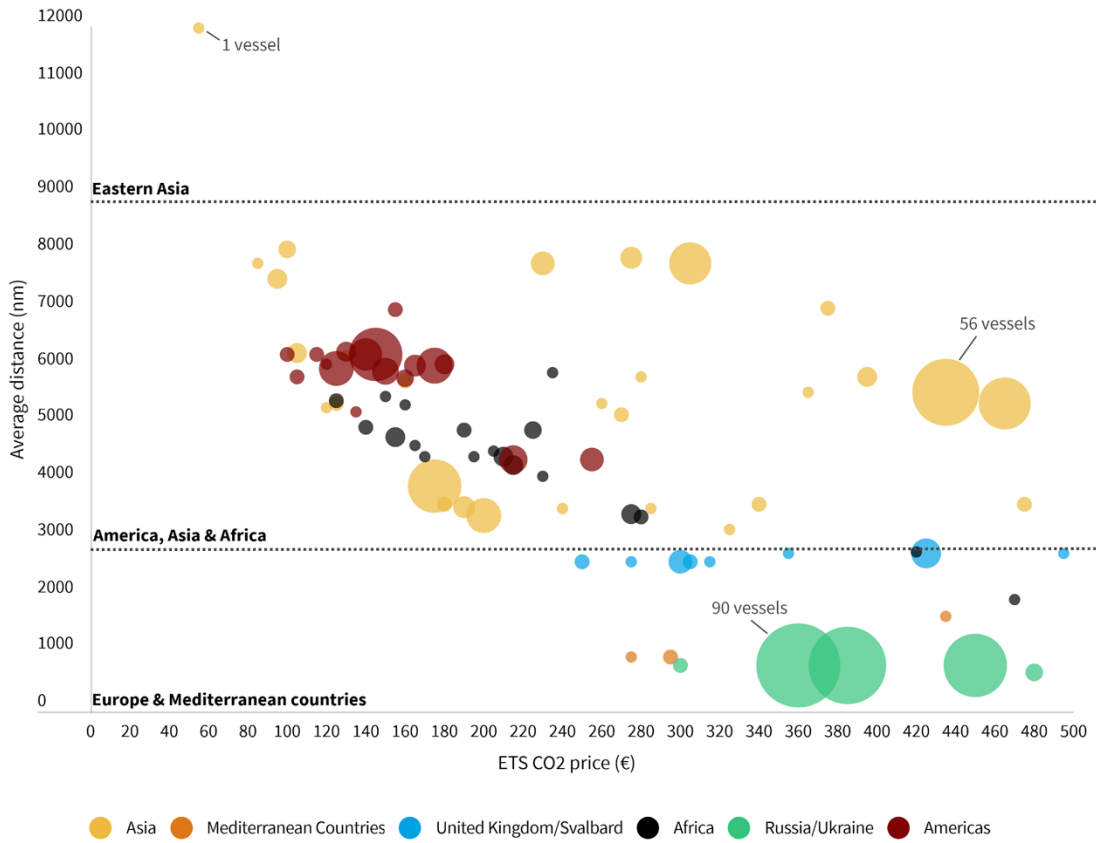
Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 12: risk of policy evasion for Greece (semi-full scope)

Figure 13 illustrates the main Greek trading partners for maritime transport in 2016. The colours represent the destination/origin of the vessels calling at Greek ports and the size of the bubbles indicates the number of voyages on those routes that might find it financially attractive to evade at any given CO₂ price. For example, all 125 voyages going to or coming from the Americas would be inclined to evade at CO₂ prices between €100 and €255/tonne, but none of the 381 voyages going to or coming from Russia and Ukraine would be inclined to evade at CO₂ prices under €300/tonne.¹⁷ Below €100/tonne, the ETS “price cap”¹⁸, only six voyages would be tempted to evade. All of these six ships sail to/from Asia. This illustrates yet again the relationship between the distance sailed and the incentive to evade: the shorter the route, the lower the risk of evasion.

¹⁷ Note that most of these voyages going to/coming from Russia and Ukraine have turning points above €500/tonne and are therefore not visible on figure 13.

¹⁸ As the penalty and enforcement structure of the EU ETS imposes a fine of €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable than compliance if the CO₂ price exceeds €106/tCO₂.



Note: The colors represent the destination/origin of the vessels calling at Greek ports. The dotted lines indicate the span in sailing distance between these regions and Greece. The size of the bubbles indicates the number of vessels sailing to/from Greece that might find it financially attractive to evade at any given CO2 price.

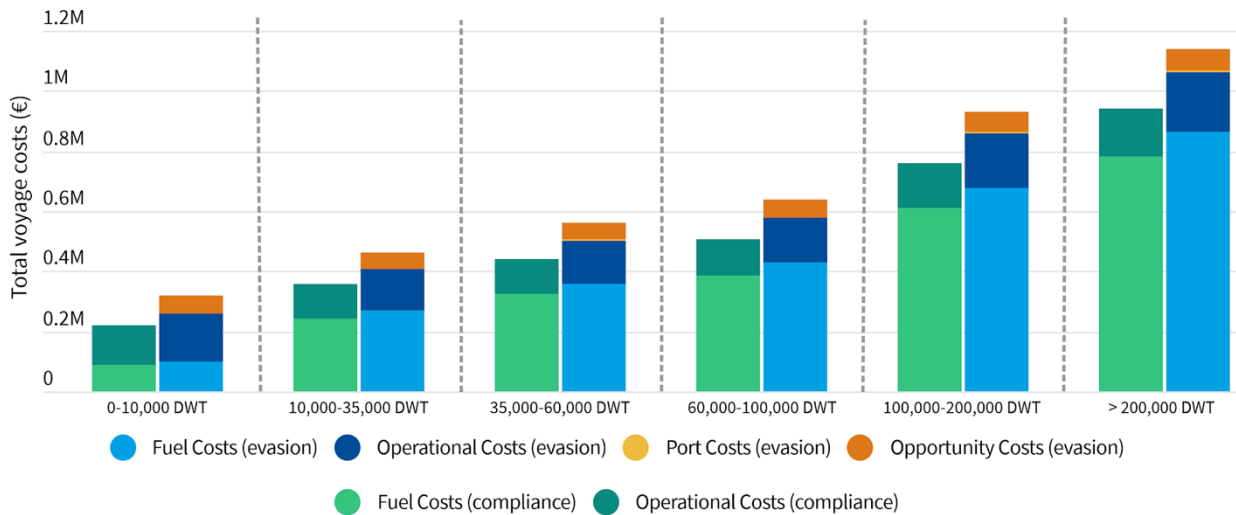
Figure 13: Origin/destination of voyages calling at Greek ports and their turning points (semi-full scope base-case)

4.1.1. Cost breakdown: a bulk carrier sailing from Uruguay to Greece

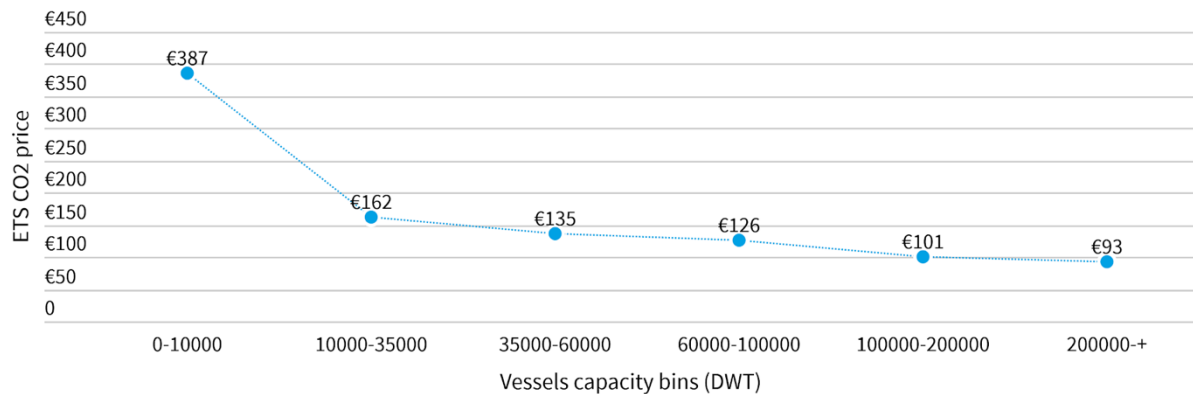
The figures below dig a bit deeper into the voyage costs of bulk carriers sailing from Uruguay to Greece. As illustrated in chapter 1.1.2., an evasive port call comes with additional fuel costs, operational costs and port costs, as well as with opportunity costs and the remaining CO₂ costs. Figure 14 illustrates how this cost structure would play out for different size categories of a bulk carrier.¹⁹

¹⁹ 'Deadweight tonnage' (DWT), the measure of how much weight a ship can carry, is used as a proxy for the size of the vessel.

As opportunity costs don't increase much by size...



... the smallest bulk carriers will be the last ones to evade



Note: The top graph illustrates the cost structure of a bulk carrier before any CO2 price is imposed. For each size category, the column on the left shows the cost breakdown without an evasive port call and the column on the right shows the increase in each of those costs when an evasive port call is made. The second graph depicts the turning points for each of those bulk carriers. All of these vessels are sailing on the same route from Uruguay to Greece. The bulk carrier of 0-10,000 DWT, 100,000-200,000 DWT and >200,000 DWT are simulations. All the other bulk carriers represent real-world operational activity (2016) of ships calling at Greek ports. These journeys are comparable to the scope of the EU MRV regulation.

Figure 14: Cost structure and turning points of bulk carriers sailing from Uruguay to Greece (semi-full scope base-case)

While all costs increase as the size of the vessel increases, the opportunity costs of bulk carriers increase much slower than the other costs elements. This is because bulk carriers are not paid per unit of cargo they transport, but per day they spend transporting that cargo from point A to point B. These daily earnings (or charter rates) vary by size, but not enormously. Thus, opportunity costs also don't vary enormously by size (see more detail in chapter 4.2.1.). As a result, for the smallest bulk carriers, the opportunity costs represent a proportionately larger share of total costs (19%) than for the largest ones (6%). This makes evasive port calls relatively more expensive for these smaller vessels. They would require a higher ETS price to find evasion economically attractive.

Zooming in on the 3 bulk carriers of 60,000-100,000 DWT sailing on this route, figure 15 compares, for different CO₂ prices, the cost difference between policy compliance and policy evasion. €0/tonne of CO₂ represents a situation where there is no maritime ETS in place. €15 and €30/tonne of CO₂ are respectively the lowest and the highest ETS prices observed in the past year.²⁰ €126/tonne of CO₂ is the ETS price required to make an evasive port call financially attractive for these 3 specific bulk carriers with a carrying capacity of 60,000-100,000 DWT sailing from Uruguay to Greece. In other words, at €126/tonne of CO₂, the cost of policy compliance outweighs all its extra costs associated with an evasive port call in Turkey. This assumes no port congestion in Turkey, as well as no similar carbon pricing schemes in place in any other country or at the IMO level.

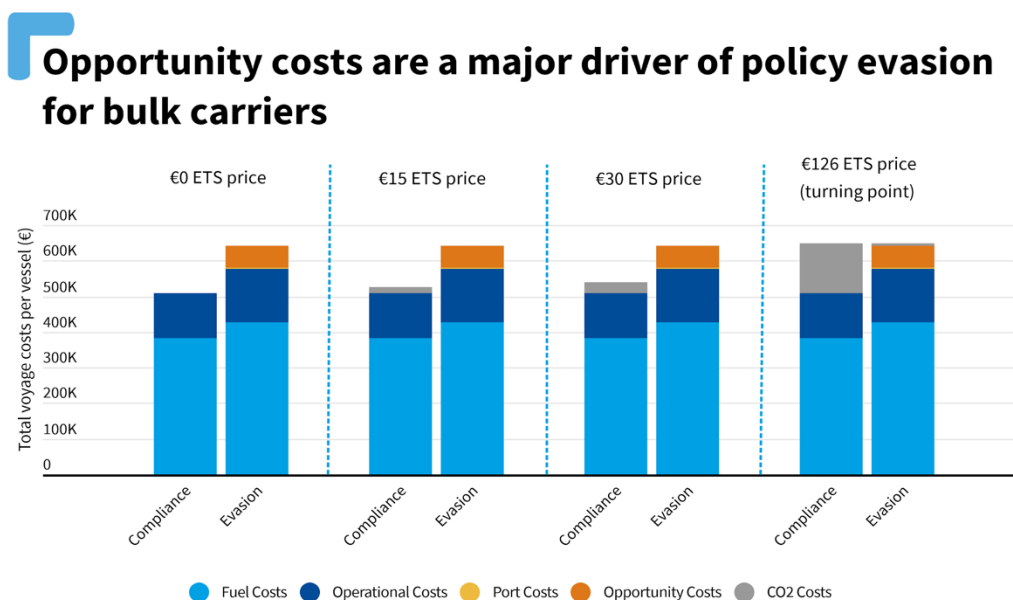


Figure 15: Compliance vs. evasion costs for the 3 bulk carriers of 60,000-100,000 DWT sailing from Uruguay to Greece (semi-full scope base-case)

²⁰ Between November 2019 and November 2020, including the period of the outbreak of COVID-19.

4.2. Case study of Spain, with an evasive port call in Morocco

Our second case study looks into the international voyages calling at Spanish ports under the MRV regulation and models the probability of these ships using Morocco for an evasive port call. Analysis assumes all ships sailing to and from Spain use the port of Algeciras, as well as all evasive port calls taking place in the port of Tanger Med in Morocco.²¹ Figure 16 presents the number of individual voyages, for each ship type and for each route type, considered in this case study.

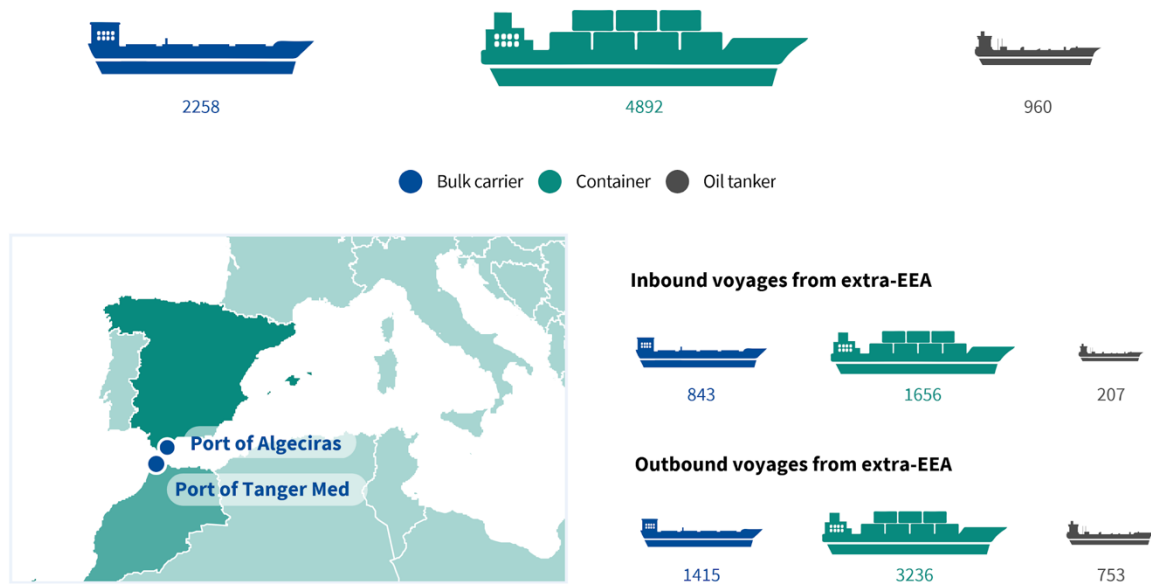
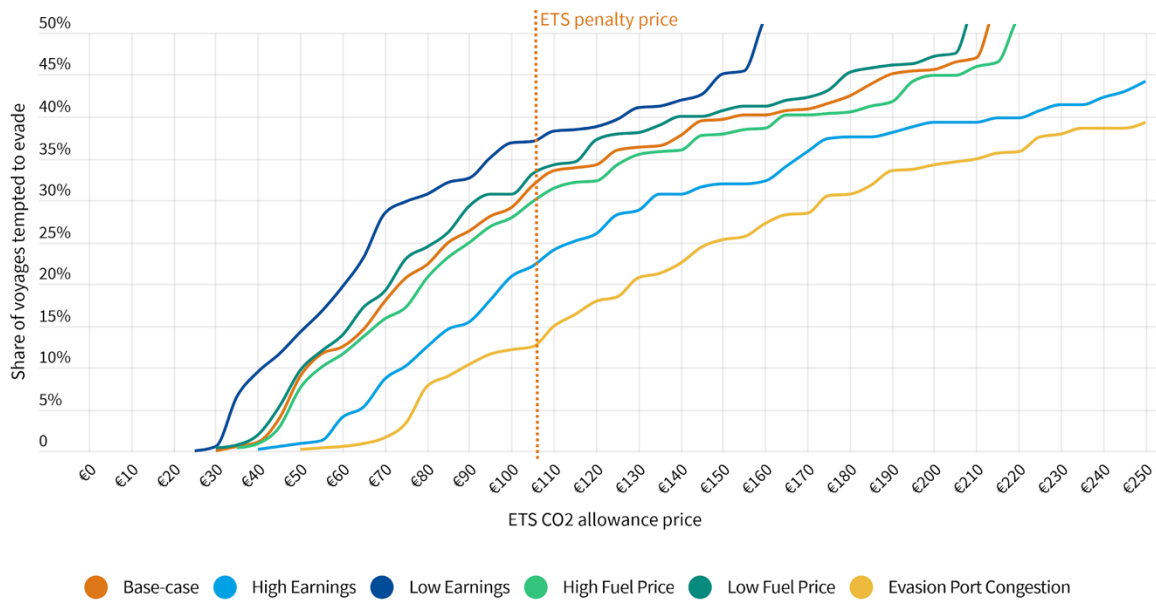


Figure 16: Case study of Spain - 8810 voyages

Figure 17 models the percentage of these voyages that could be inclined to use the port of Tanger Med for an evasive port call, at any given CO₂ price. In our base case scenario (*orange line*), there is no risk of policy evasion at a CO₂ price of €30/tonne, but a 9% risk at a CO₂ price of €50/tonne. Under extreme circumstances, where a ship's earnings would diminish by 40% due to harsh economic circumstances (*dark blue line*), the risk of policy evasion would increase further to 14.1% at a CO₂ price of €50/tonne. However, it is more likely that a maritime ETS will lead to congestion in the port of Tanger Med, in which case the risk of policy evasion at a CO₂ price of €100/tonne would drop to 0.2% (*yellow line*). Note that the graph in figure 17 was capped at 50% in order to increase readability.

²¹ A robustness check of ships using another Spanish port or using another port for their evasive port call can be found in Appendix II.



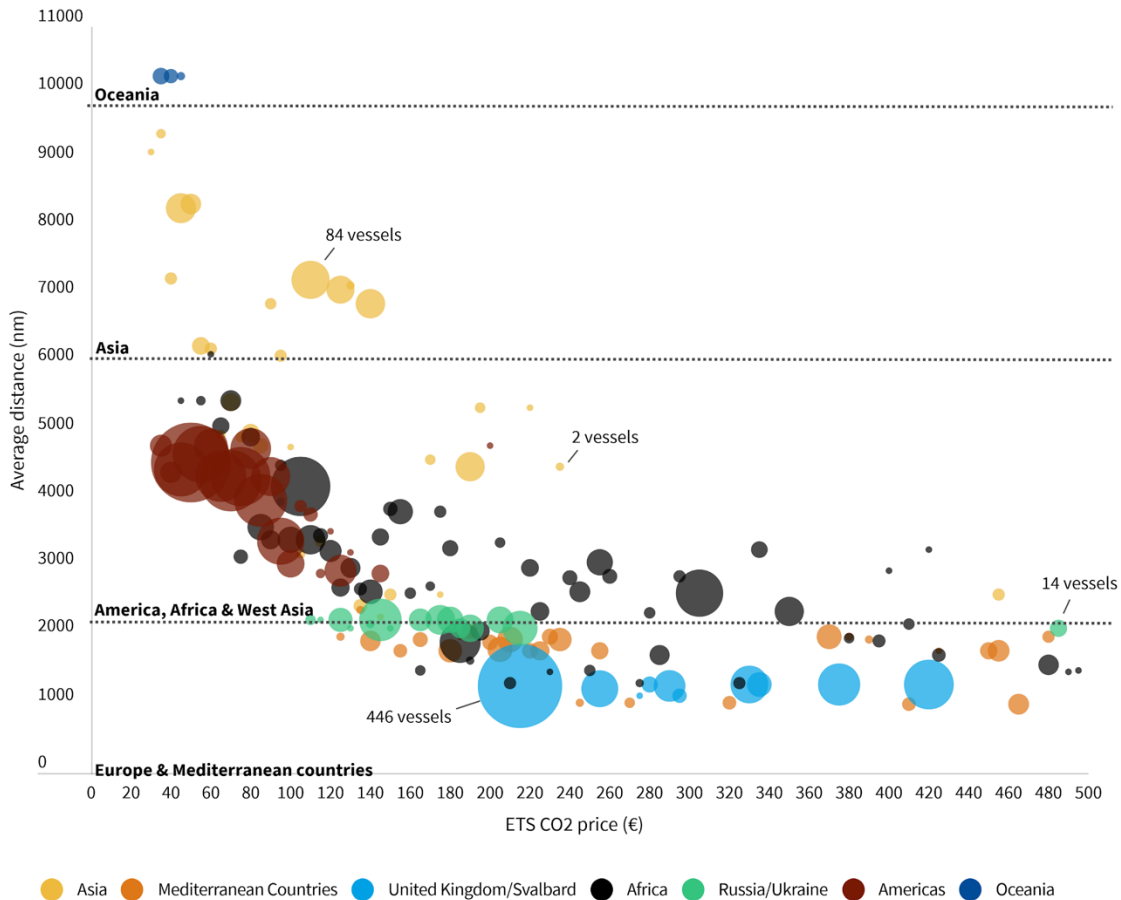
Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 17: Risk of policy evasion for Spain (semi-full scope)

Figure 18 illustrates the main Spanish trading partners for maritime transport in 2016. The colours represent the destination/origin of the vessels calling at Spanish ports and the size of the bubbles indicates the number of voyages on this route that would find it economically attractive to evade as of the CO₂ price indicated on the x-axis. For example, all 24 voyages sailing to or from Oceania would be inclined to evade at a CO₂ price of €45/tonne, but none of the 1194 voyages sailing to or from the UK and Svalbard²² would be inclined to evade at CO₂ prices under €215/tonne.²³ This demonstrates yet again the correlation between the distance sailed and the incentive to evade: the shorter the route, the lower the risk of evasion.

²² Although Norway is part of the EEA, the port of Svalbard in Norway is not.

²³ Note that most of these voyages going to/coming from the UK and Svalbard have turning points above €500/tonne and are therefore not visible on figure 18.



Note: The colors represent the destination/origin of the vessels calling at Spanish ports. The dotted lines indicate the span in sailing distance between these regions and Spain. The size of the bubbles indicates the number of vessels sailing to/from Spain that might find it financially attractive to evade at any given CO₂ price.

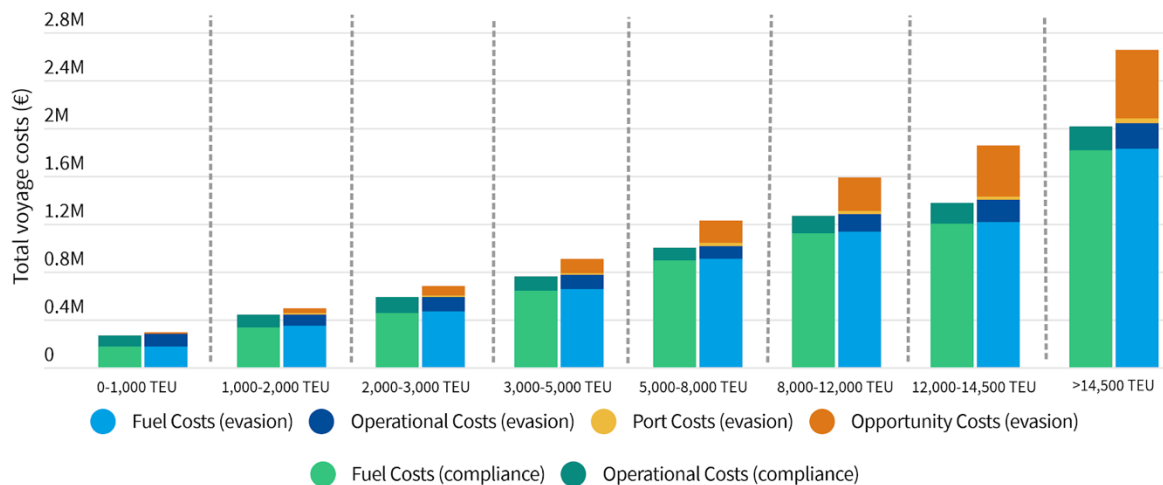
Figure 18: Origin/destination of ships calling at Spanish ports and their turning points (semi-full scope base-case)

4.2.1. Cost breakdown: a container ship sailing from Spain to Singapore

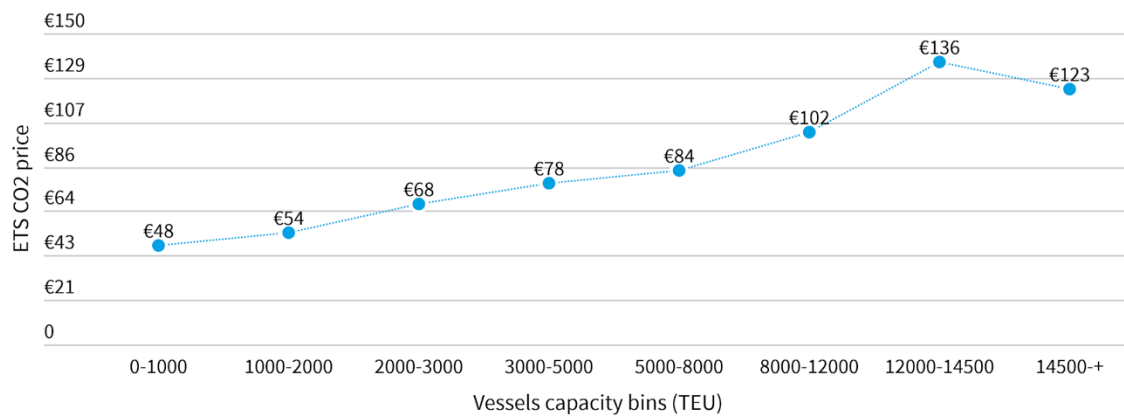
The figures below dig a bit deeper into the voyage of container ships sailing from Spain to Singapore. As explained in chapter 1.2.1., an evasive port call comes with additional fuel costs, operational costs and port costs, as well as with opportunity costs and the remaining CO₂ costs. Figure 19 illustrates how these additional costs would play out for different size categories of a container ship.²⁴

²⁴ Carrying capacity or ‘twenty-foot equivalent units’ (TEU) is used as a proxy for the size of the vessel.

As opportunity costs increase sharply by size...



... the smallest container ships will be the first ones to evade



Note: The top two graphs illustrate the cost structure for different size categories of a container ship before any CO2 price is imposed. The first one shows the cost breakdown without an evasive port call and the second one shows the increase in each of those costs when an evasive port call is made. The third graph depicts the turning points for each of those container ships. All of these vessels are sailing on the same route from Spain to Singapore. The container ships of 0-1000 TEU and 2000-3000 TEU are simulations. All the other container ships represent real-world operational activity (2016) of ships calling at Spanish ports. These journeys are comparable to the scope of the EU MRV regulation.

Figure 19: Cost structure and turning points of container ships sailing from Spain to Singapore (semi-full scope base-case)

Unlike for bulk carriers, opportunity costs do increase significantly as the size of the container ship increases. This is because container ships receive a fee per container carried (freight rate), whereas bulk carriers and oil tankers receive a daily fee (charter rate). As a result, the earnings of a container ship increase more sharply as their carrying capacity increases (see table 1 below).²⁵ As a result of this big increase in opportunity costs by size category, evasive port calls are relatively more expensive for larger container ships. Hence, the larger the container ship, the higher the ETS price it will require to become tempted to evade.

Ship type	Earnings on a representative voyage from the USA to Europe (at a freight rate of €231/TEU)	Increase in earnings between smallest and largest size segment
Smallest container ship	€ 125 666	
Largest container ship	€ 3 817 673	x 30 times
Ship type	Daily earnings (charter rates)	Increase in earnings between smallest and largest size segment
Smallest bulk carrier	€ 10 400	
Largest bulk carrier	€ 13 803	x 1.3 times
Smallest oil tanker	€ 8 365	
Largest oil tanker	€ 29 325	x 3.5 times

Table 1: Increase in earnings between smallest and largest segments of different ship types²⁶

Zooming in on the container ships that have the largest carrying capacity, figure 20 below compares, for different CO₂ prices, the cost difference between policy compliance and policy evasion. €123/tonne is the CO₂ price required to make an evasive port call financially attractive for these 23 specific container ships of >14,500 TEU sailing from Spain to Singapore. At €123/tonne, the policy compliance costs outweigh all the extra costs associated with its evasive port call.

²⁵ To calculate a ship's revenue, we used the average price per container over the past 10 years (source: UNCTAD) and multiplied this with the carrying capacity of the vessel.

²⁶ The charter rates for oil tankers and bulk carriers are based on the Clarkson Reports, retrieved from https://www.crsi.com/acatalog/Shipping_Publications.html. The freight rates for container ships are based on UNCTAD's 2019 Review of maritime transport. Retrieved from https://unctad.org/system/files/official-document/rmt2019_en.pdf

Opportunity costs are a major driver of policy evasion for container ships

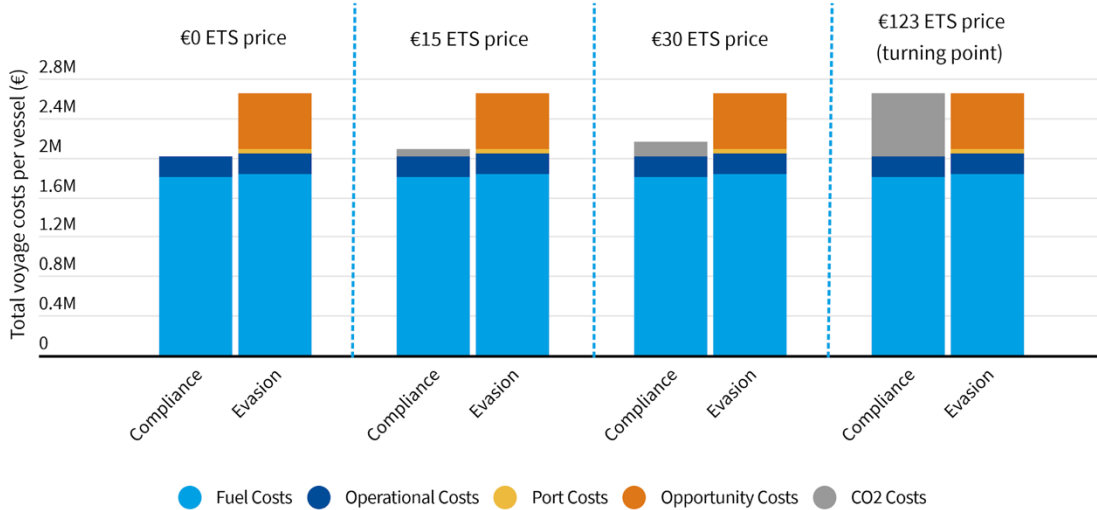


Figure 20: Compliance vs. evasion costs for the 23 container ships of >14,500 TEU sailing from Spain to Singapore (semi-full scope base-case)

4.3. Case study of the Netherlands, with an evasive port call in the UK

Our third case study looks into the international voyages calling at Dutch ports under the MRV regulation and models the probability of these ships using the UK for an evasive port call. Analysis assumes all ships sailing to and from the Netherlands use the port of Rotterdam, as well as all evasive port calls taking place in the port of Southampton in the UK.²⁷ Figure 21 presents the number of individual voyages, for each ship type and for each route type, considered in this case study.

²⁷ A robustness check of ships using another Dutch port or using another port for their evasive port call can be found in Appendix II.

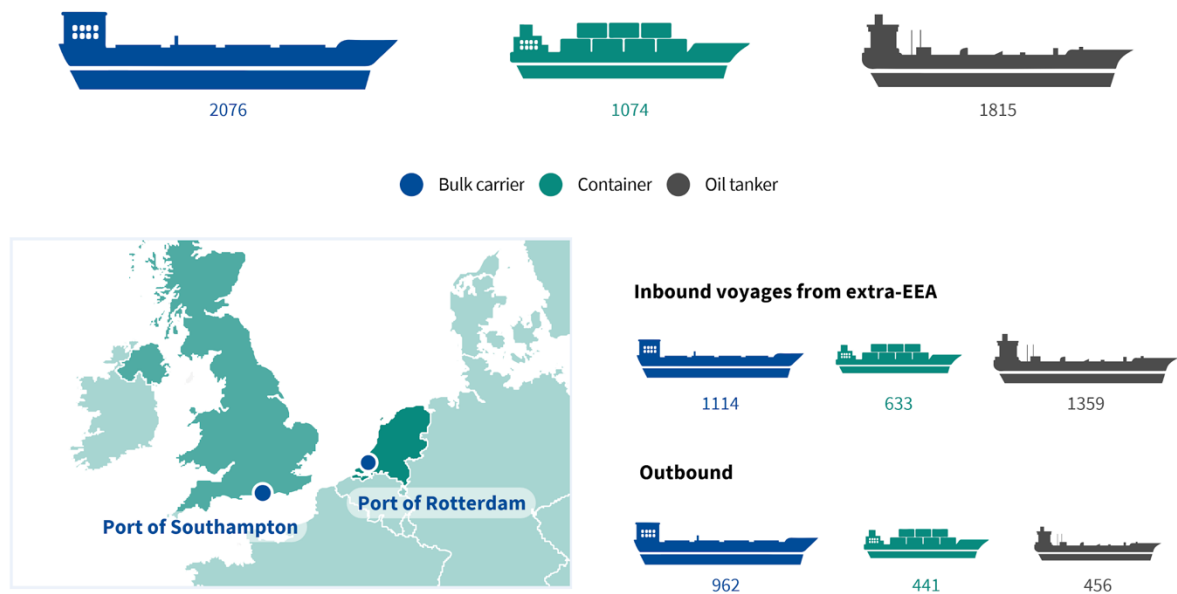
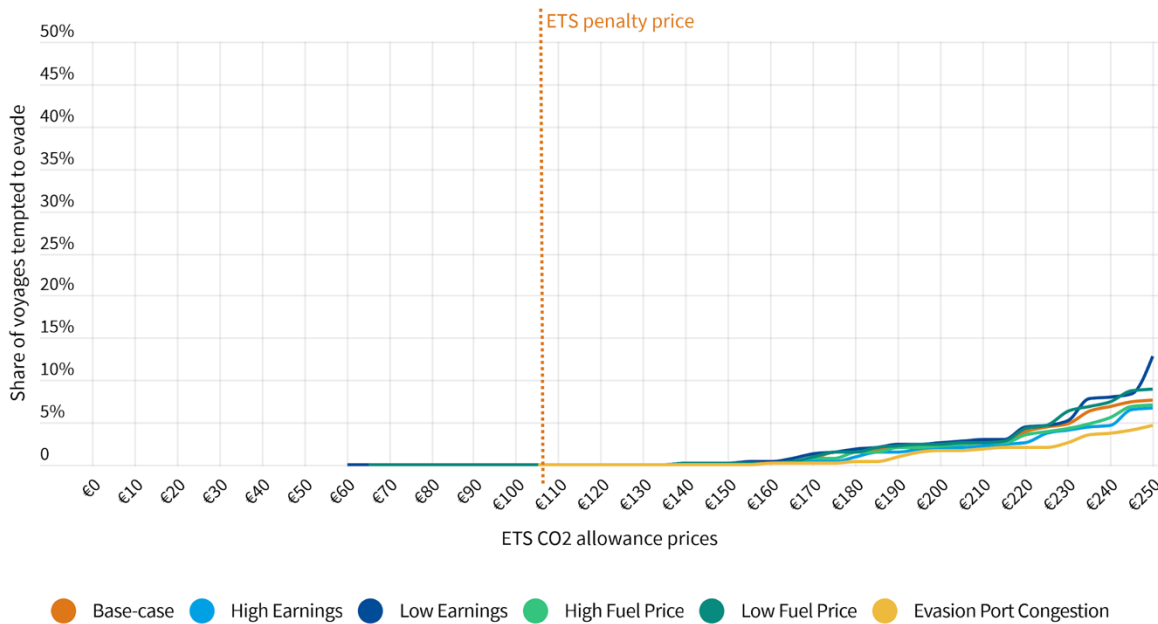


Figure 21: Case study of the Netherlands - 4965 voyages

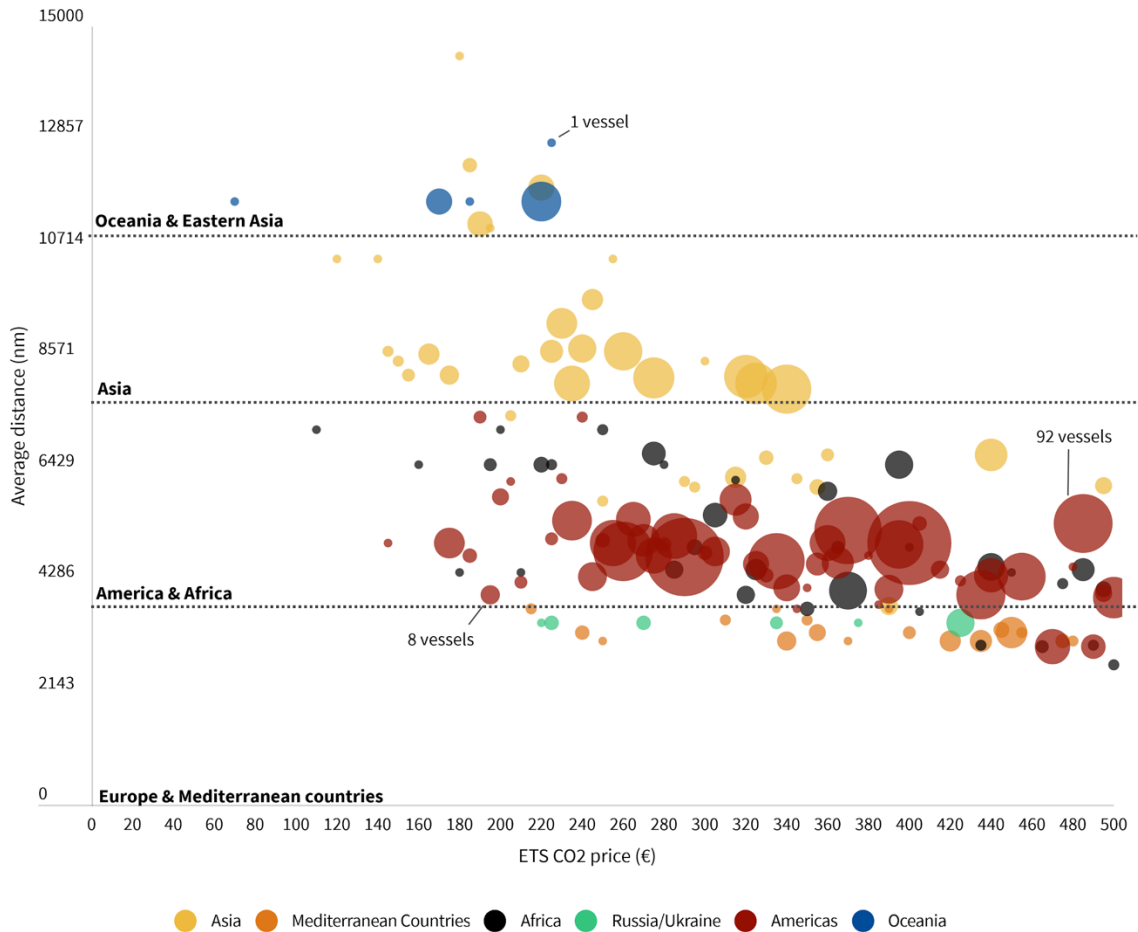
Figure 22 models the percentage of these voyages that could be inclined to use the port of Southampton for an evasive port call, at any given CO₂ price. Under all modelled circumstances, there is no risk of policy evasion for CO₂ prices under €100/tonne. Note that the graph in Figure 22 was capped at 50% in order to increase readability.



Note: The dotted line represents the ETS 'price cap'. As the ETS penalty is defined at €100/tCO₂ (€106 adjusted for annual inflation since 2013), non-compliance would be more profitable if the CO₂ price were to ever exceed €106/tCO₂.

Figure 22: Risk of policy evasion for the Netherlands (semi-full scope base-case)

Figure 23 illustrates the main Dutch trading partners for maritime transport in 2016. The colours represent the destination/origin of the vessels calling at Dutch ports and the size of the bubbles indicates the number of vessels on this route that would be tempted to evade as of the CO₂ price indicated on the x-axis. This illustrates yet again the relationship between the distance sailed and the incentive to evade: the shorter the route, the lower the risk of evasion.



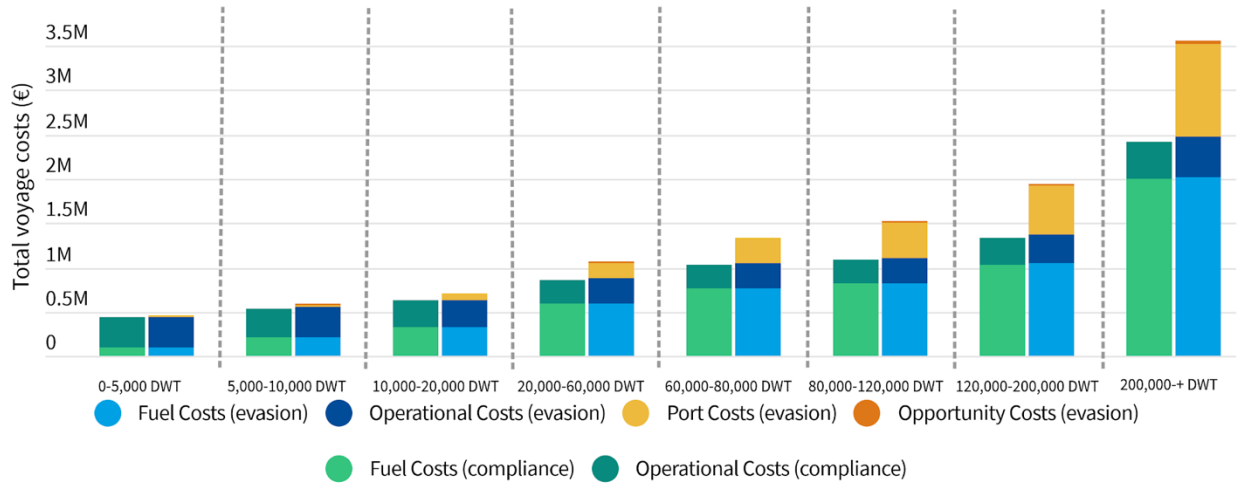
Note: The colors represent the destination/origin of the vessels calling at Dutch ports. The dotted lines indicate the span in sailing distance between these regions and the Netherlands. The size of the bubbles indicates the number of vessels sailing to/from the Netherlands that might find it financially attractive to evade at any given CO₂ price.

Figure 23: Origin/destination of ships calling at Dutch ports and their turning points (semi-full scope base-case)

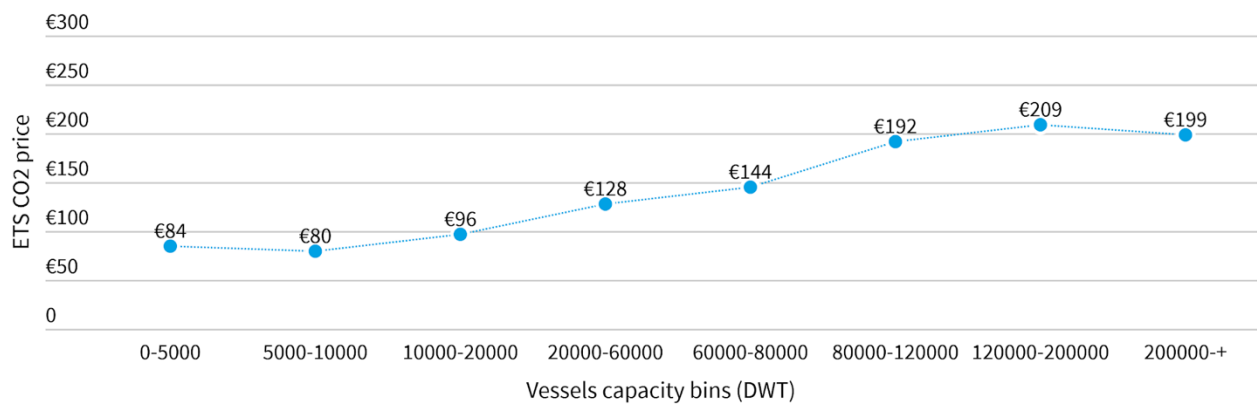
4.3.1. Cost breakdown: an oil tanker sailing from the Netherlands to China

The tables below dig a bit deeper into the voyage of oil tankers sailing from the Netherlands to China. As illustrated in chapter 2.1.1., an evasive port call comes with additional fuel costs, operational costs and port costs, as well as with opportunity costs and the remaining CO₂ costs. Figure 24 illustrates how this would play out for different size categories of an oil tanker.

When port tariffs are high and increase sharply by size...



... the smallest vessels will be the first to evade



Note: The top two graphs illustrate the cost structure for different size categories of an oil tanker before any CO2 price is imposed. The first one shows the cost breakdown without an evasive port call and the second one shows the increase in each of those costs when an evasive port call is made. The third graph depicts the turning points for each of those oil tankers. All of these vessels are sailing on the same route from the Netherlands to Australia. As there are only oil tankers of 2000-6000 DWT and of 6000-8000 DWT sailing from the Netherlands to China in the 2016 satellite (AIS) dataset, all the other oil tankers are simulations.

Figure 24: Cost structure and turning points of oil tankers sailing from the Netherlands to China (semi-full scope base-case)

As with the bulk carriers, the opportunity costs of oil tankers increase much slower than all the other costs as the size of the vessel increases. As a result, they represent a proportionately larger share of the total costs of the smallest oil tankers (2%) than of the largest oil tankers (1%). However, it is not the opportunity costs that determine the turning point in this case study. The port of Southampton charges very high port costs, especially for large vessels.²⁸ If they would try to evade the ETS, port costs would represent 30% of total costs of the largest oil tankers. Therefore, even though a smaller vessel has higher opportunity costs, the largest oil tanker will require the highest ETS price when calling at the port of Southampton for their evasive port call.

Zooming in on the one oil tanker that has an average turning point, figure 25 below compares, for different CO₂ prices, the cost difference between policy compliance and policy evasion. €144/tonne is the CO₂ price required to make an evasive port call financially attractive for this one specific oil tanker of 6000-8000 DWT, sailing from the Netherlands to China. At €144/tonne CO₂, the policy compliance costs outweigh all the extra costs associated with its evasive port call.

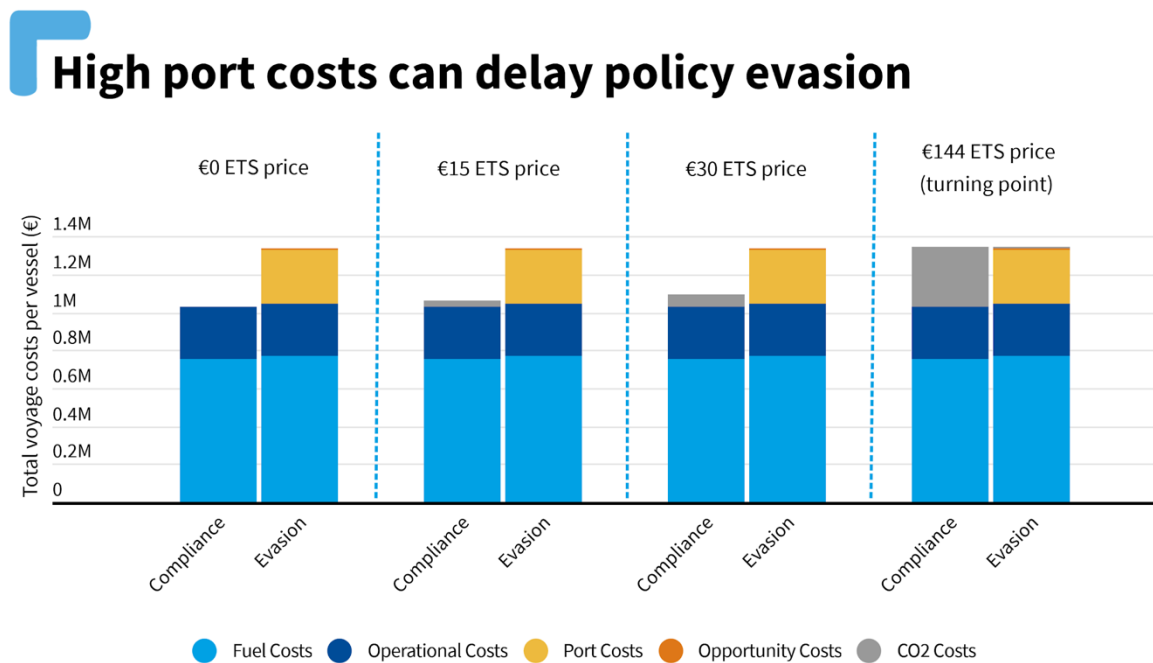


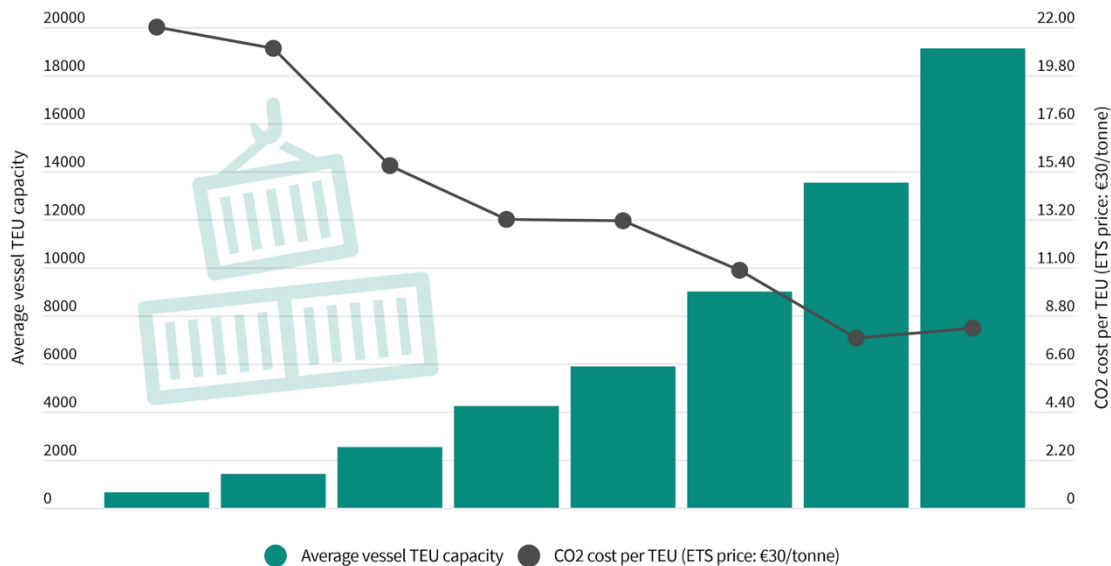
Figure 25: Compliance vs. evasion costs for one oil tanker of 60,000-80,000 DWT, sailing from the Netherlands to China (semi-full scope base-case)

²⁸ See table A5-A13 in Appendix I. A robustness check of these port costs can be found in Appendix III, as the port costs in Southampton seem unusually high. The robustness check evaluates the risk of policy evasion if the port costs had been lower.

4.4. Case study conclusions: main drivers of policy evasion

Besides the length of the voyage, the case studies identified two other main drivers of policy evasion: the opportunity costs and the port costs.

As demonstrated in chapter 4.2.1., the opportunity costs depend on the ship type. For container ships, opportunity costs increase more significantly in relation to their capacity than for bulk carriers and oil tankers. This is because of the substantial difference in earnings between small and large container ships. As a consequence, large container ships have higher turning points - i.e. the CO₂ price at which evasion becomes attractive. For the other two ship types, the large vessels will be the first to evade. Container ships also have relatively higher opportunity costs than bulk carriers and oil tankers due to the way the container market is structured. Therefore, container ships appear to be less susceptible to evasion. This is all under the assumption that shipowners absorb the extra costs related to ETS compliance or to the evasive port call. In reality, extra costs related to ETS compliance could be passed through to the final consumers reducing the need for policy evasion. Figure 26 below illustrates the CO₂ cost per standard container (TEU) that could potentially be passed onto the cargo owners at a CO₂ price of €30/tonne. The CO₂ costs per TEU decrease as the capacity of the vessel increases.

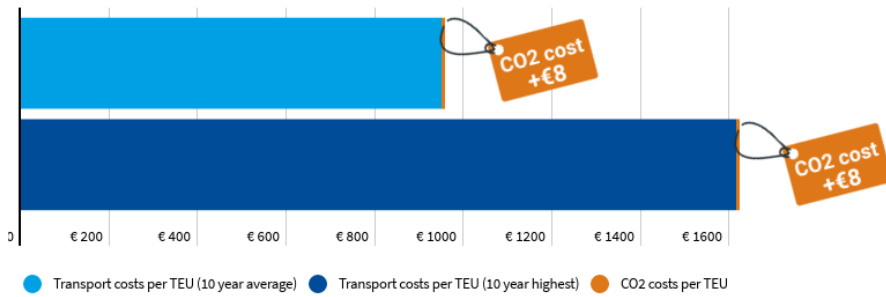


Note: This graph represents the evolution in CO₂ cost per TEU for container ships sailing from Spain to Singapore at an ETS price of €30/tonne. It assumes policy compliance under a semi-full scope ETS design and thus represents the CO₂ cost/TEU for the entire journey between Spain and Singapore. The container ships of 0-1000 TEU and 2000-3000 TEU are simulations. All the other container ships represent real-world operational activity (2016) of ships calling at Spanish ports. These journeys are comparable to the scope of the EU MRV regulation.

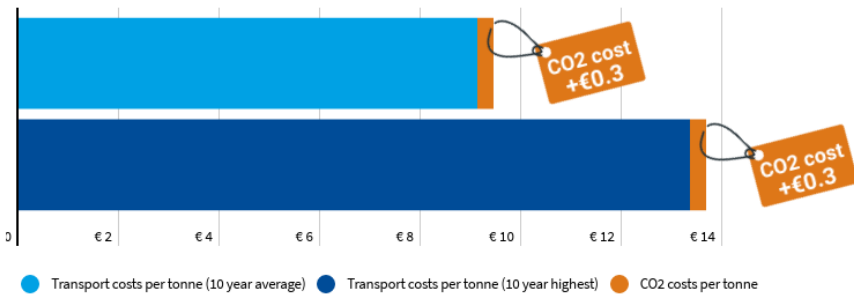
Figure 26: Evolution in CO₂ cost per TEU for container ships sailing from Spain to Singapore (semi-full scope base-case)

Comparing these CO₂ costs per TEU to the port-to-port transportation costs, figure 27 shows that a semi-full scope ETS would add less than 1% to the port-to-port costs to transport a standard container from Spain to Singapore. If the freight rates increase by 70% as in our 'high earnings' sensitivity, this drops to 0.5%. For bulk carriers the CO₂ costs would add only about €0.3 to the overall transport costs per tonne and €0.6 for oil tankers.

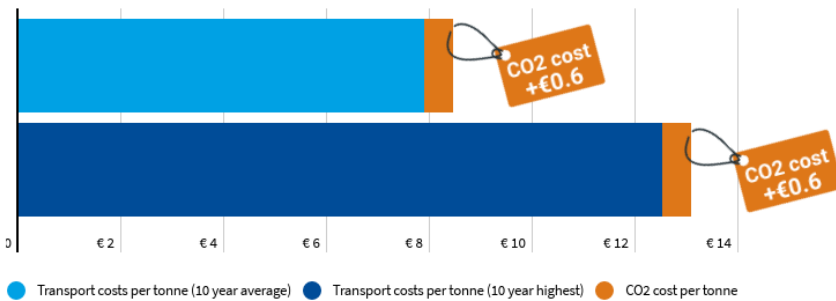
Port-to-port transport costs for a large container ship (Spain to Singapore)



Port-to-port transport costs for a large bulk carrier (Uruguay to Greece)



Port-to-port transport costs for a large oil tanker (Netherlands to China)



Note: An ETS allowance price of €30 euro/tonne is assumed under a semi-full scope ETS design. The port-to-port transport costs for sailing a 18,293 TEU container ship from Spain to Singapore are based on the freight rates (which include fuel, operational, capital, port and cargo-related costs) of the past 10 years. The port-to-port transport costs for a 252,689 DWT bulk carrier sailing from Uruguay to Greece and a 308,477 DWT oil tanker sailing from the Netherlands to China are based on the sum of the fuel costs and the charter rates (which include operational and capital costs, but exclude port and cargo-related costs) of the past 10 years.

Figure 27: CO₂ costs per TEU/tonne compared to the port-to-port transport costs per TEU/tonne (semi-full scope base-case)

The other determining driver in the costs structure is the port costs. If nearby non-EEA ports lower their port tariffs, this again would impact the turning point and thus the percentage of ships inclined to evade at any given CO₂ price.

5. Policy and design recommendations

5.1. Scope of a maritime ETS

At carbon price levels that are deemed politically feasible in the coming decade, ETS revenues from international voyages to and from the three countries examined in this report are considerably higher under a full scope than under a semi-full scope ETS design (see table 2).²⁹ Note that the earnings presented in Table 2 only reflect the emissions from international voyages to/from the three case study countries. In practice, the total earnings for these three countries would also include ETS revenues from the emissions of intra-EEA voyages, domestic shipping and emissions at berth. Note that the revenues from these types of voyages would be the same under a full and a semi-full scope, meaning the difference in total earnings would be smaller if you include all voyages. Table 2 takes the foregone revenue due to policy evasion into account, but does not account for the possibility that ships lower their ETS compliance costs by implementing technical measures to reduce their emissions.

CO ₂ price	Annual revenues under a full scope ETS	Annual revenues under a semi-full scope ETS	Difference in annual revenues
€30/tonne	€637 million	€358 million	+78%
€50/tonne	€935 million	€548 million	+71%
€75/tonne	€1,180 million	€741 million	+59%
€100/tonne	€1,470 million	€935 million	+57%

Table 2: Revenues comparison between a full and a semi-full scope maritime ETS covering Greece, Spain and the Netherlands

Therefore, purely from a revenue generation perspective, a full scope ETS would be a more interesting policy option. But as Table 3 illustrates, the full scope design does also imply a relatively higher risk of carbon leakage. Because the vessels on the longest routes are the first to evade, the share of CO₂ covered by the ETS scheme decreases at a slightly faster rate than the risk of evasion by individual ships increases. However, as we explain in more detail in chapter 5.2., there are regulatory safeguards

²⁹ Table 2 is based on the figures 8 and 9 in chapter 3.2. For reference, the 2030 carbon price for the ETS sectors in the policy scenarios of the European Commission's 2030 climate target plan impact assessment is 32 euros for the REG scenario, 44 euros for the MIX scenario, 60 euros for the CPRICE scenario and 65 euros for the ALLBNK scenario.

available to limit this risk of policy evasion. It is also important to caveat that table 3 represents results for the three case study countries only. As the length of a voyage is a major driver of policy evasion (see chapter 3.3.) and these three countries have major seaports in close proximity to a non-EEA port, ships sailing to and from Greece, Spain and the Netherlands would be the most susceptible to policy evasion. Given that other countries don't have non-EEA ports so close to their own ports, the actual risk of evasion for the whole of MRV emissions would likely be smaller.

CO ₂ price	Full-scope			Semi-full scope		
	Risk of evasion	Share of CO ₂ evading	Amount of CO ₂ covered (total = 23.9Mt)	Risk of evasion	Share of CO ₂ evading	Amount of CO ₂ covered (total = 11.9Mt)
€30/tonne	6.7%	11.1%	21.2Mt	0%	0.1%	11.9Mt
€50/tonne	15.6%	21.7%	18.7Mt	4.8%	8.2%	11Mt
€75/tonne	22%	34.2%	15.7Mt	11.1%	17.3%	9.9Mt
€100/tonne	26.5%	38.5%	14.7Mt	15.6%	21.7%	9.4Mt

Table 3: Risk of policy evasion comparison between a full and a semi-full scope ETS covering international voyages to and from the three case study countries

From a climate impact perspective, a full scope ETS would be the desirable option. Even with a higher risk of policy evasion at higher ETS CO₂ prices, the full scope still covers a larger scope of emissions and raises higher revenues that can be reinvested to decarbonise the sector (see chapter 5.3). However, if the EU opts for such a full scope ETS design, it would be essential to develop additional policy safeguards to limit the risk of possible policy evasion and ensure the effectiveness and level playing field of the regulation (see suggestions in chapter 5.2.).

If the EU opts for a semi-full scope ETS design, it would do so under the assumption that other regions/countries would cover the remaining 50% of emissions of these voyages with similar national/regional regulatory measures. To ensure that this materialises, the EU should actively encourage other countries to put in place national MRV systems, include shipping in their national NDCs under the Paris Agreement and mandate reduction measures, including carbon pricing mechanisms similar to the EU ETS. The Union should review the progress made in other regions, but also other fora, like the IMO, and in the absence of satisfactory progress extend the maritime ETS to the full scope of

the MRV emissions. For example, the EU could set itself an objective for climate diplomacy to ensure the remaining of the maritime emissions are covered by 2025 with equivalent carbon pricing via regional/global schemes. In case of failure, a full-scope maritime EU ETS should be considered as a fall-back option.

5.2. Safeguards to further reduce limited risk of carbon leakage

This analysis demonstrates that the risk of carbon leakage is very limited under politically realistic carbon pricing levels and a semi-full scope design. Under a full scope ETS design, there would not be a lot of evasive behaviour at the current carbon price level, but there might be if the CO₂ price comes closer to (or goes above) €50/tonne. Therefore, a maritime ETS could benefit from regulatory safeguards to discourage even the smallest risks of carbon leakage.

One way to tackle evasive behaviour would be to adjust the definition of a ‘port of call’ under the EU MRV regulation. Currently the following definition applies: *‘the port where a ship stops to load or unload cargo or to embark or disembark passengers’*.³⁰ This means that a ship only needs to drop off only one container or one passenger in the port of Haydarpara, Tanger Med or Southampton, to make this stopover qualify as a port of call and to thereby reduce the part of their journey covered under the EU MRV and maritime ETS. If we want to ensure that a stopover is not misused to evade the ETS, the definition of port of call should require a demonstration of genuine business activity taking place in these and other potential evasion ports. The regulation could ensure this by including a certain percentage of cargo/passengers that needs to be (un)loaded/(dis)embarked during a port of call. If appropriate, this percentage can vary according to ship type and size to better reflect market conditions. In order to reduce the complexity of regulation and enforcement, such a stringent definition could apply to only a limited number of ports. Policy evasion is financially attractive only if the non-EEA evasion port is in very close proximity to the EEA port of destination/origin. Therefore, all ships would be interested in the same few nearby non-EEA ports, including the port of Haydarpara, Tanger Med and Southampton examined in this report. The EU could develop a ‘blacklist of evasion ports’, for which this stringent definition would apply. For all other ports, the current definition would be sufficient.

To enforce this new definition, ships would need to be required to keep a copy of the bills of lading³¹ or passenger tickets associated with commercial (cargo or passenger) activities in the ‘carbon leakage

³⁰ This means that evasive port calls for refueling, crew changing, emergencies, etc. do not qualify under the existing EU MRV definition and cannot be used for ETS evasion.

³¹ The bill of lading is a document issued by a carrier to a shipper that details the type, quantity, and destination of the goods being carried. It serves both as proof of receipt of the goods on board and as a shipment receipt when the carrier delivers the goods at a predetermined destination. Therefore, it would

ports' outside the EEA. These documents can be used by the verifiers, as well as national competent authorities, to ensure stringent compliance. Member States could do this by making sure that any inspection of a ship in a port under its jurisdiction carried out in accordance with Directive 2009/16/EC includes checking the bill of lading and passenger tickets.

5.3. A maritime decarbonisation fund

As part of its revision of the EU MRV regulation, the European Parliament has proposed to earmark a substantial part of the maritime ETS revenues, raised by the sale of emissions allowances, for a new 'Ocean Fund'. This flow-back mechanism resembles how the NER 300 Programme, as well the Innovation and the Modernisation Funds, will be resourced and operated in Phase 4 (2021-2030) of the ETS. The Fund would serve as a support mechanism aimed at helping the shipping industry and ports to meet the innovation and investment challenges of the transition to a low-carbon economy. Specifically, the Fund could finance energy efficiency improvements, deployment of innovative technologies and zero-carbon fuels (e.g. green hydrogen and ammonia) in vessels and relevant infrastructure in European ports. According to the European Parliament, the remaining revenues should flow to the Member States to be used to tackle climate change in the Union and third countries, to protect and restore marine ecosystems impacted by global warming or to support a just transition.

If such an Ocean Fund were to be set up, one way of supporting the deployment of sustainable hydrogen-based fuels is to provide financial support to the first zero-emissions vessels via the Fund's revenues. Green hydrogen(-based fuel) is considerably more expensive than the current fossil alternatives. Therefore, there are financial and technical risks for the first-movers who are keen to lead the way in deploying green fuels. To de-risk pioneer investments and deployments, a 'contracts for difference' (CfD) support scheme could be set to bridge the price gap between what it costs to produce such sustainable marine fuels and what the market is willing to pay for those fuels. The public subsidies could be given to either the producer of the fuel (to help lower the market price) or to the ship owner/operator (to help carry the fuel bill). CfDs have been used effectively in the past to support novel alternative technologies such as renewable electricity (wind, solar).

If the revenues of a maritime ETS were to be reinvested in the sector in such a way, the scheme would go a long way in ensuring that the EU reaches its climate neutrality goals and in giving the sector the right push towards full decarbonisation.

provide the necessary information to determine the percentage of cargo/passengers (un)loaded/(dis)embarked during a suspected evasive port call.

Appendix I: Methodology

The main goal of this report is to determine how shipping operators would react if an ETS CO₂ price is applied to the European maritime sector. One of the biggest concerns raised in relation to a maritime ETS is that it could incentivise ships to make stopovers in nearby non-EEA ports. This would indeed be a relevant concern if it would be financially profitable for ships to deviate from their original route. That is, when an evasive port call creates a net benefit by reducing the ETS compliance costs more than the increase in operational and other costs associated with the evasive port call.

Thus, to evaluate the reaction of the shipping sector to a maritime ETS, we estimated the point where it becomes profitable for a vessel to make an evasive port call at a non-EEA port. We built a model to determine the ETS CO₂ price level required for the costs of compliance to become equal to the costs of evasion (*turning point*), as after this point evasion becomes profitable. Our model is based on two different scenarios. The first scenario is the “business as usual” or *compliance scenario* (*c*), where a ship sails between its port of origin and destination. The second scenario is the *evasion scenario* (*e*), where the vessel makes an additional port call (*evasion port*) in between the port of origin and destination.

We start by setting the total voyage costs in a *compliance scenario* to be equal to the total costs in an *evasion scenario*, as shown in equation 1. In the *compliance scenario*, the total cost is the sum of the operational costs (*OpeCost*), the fuel costs (*FuelCost*) and the ETS CO₂ costs (*CO₂Cost*) for a full and semi-full scope ETS design. In the *evasion scenario*, total costs also include the costs of the evasive port call (*EvPortCost*) and the forgone revenues from the additional journey time, i.e., the opportunity costs (*OppCost*). As the evasion scenario entails additional voyage time and additional time in the evasion port, the *OpeCost* and *FuelCost* will be different in the two scenarios, as well as the amount of CO₂ considered to the *CO₂Cost*.

Equation 1:

$$\begin{aligned} OpeCost_{a,b}^c + FuelCost_f^c + CO_2Cost^c \\ = OpeCost_{a,b}^e + FuelCost_f^e + CO_2Cost^e + OppCost_{a,b,r}^e + EvPortCost_{a,b,p}^e \end{aligned}$$

Where:

- a* - ship type (containership, bulk carrier or oil tanker)
- b* - ship capacity/capacity bin
- r* - route (origin-destination ports)
- p* - evasion port
- f* - fuel type (HFO, VLSFO, MGO/MDO or LNG)

The CO_2Cost in *equation 1* is obtained by multiplying the ETS CO_2 price with the corresponding CO_2 emissions. Thus, to find the turning point, we need to solve *equation 1* with respect to the ETS CO_2 price. The resulting formula is shown in *equation 2*:

$$\text{turning point}_{a,b,r,p,f} = \frac{OppCost_{a,b,r}^e + EvPortCost_{a,b,p}^e + OpeCost_{a,b}(d^e - d^c) + FuelCost_f}{(CO_2^c - CO_2^e)} \quad (2)$$

Where:

d - the number of days spent on the journey between the port of origin and destination (in the *evasion scenario* this refers both to the time at sea and the time at berth in the evasion port)

fc - the fuel consumed during the journey

CO_2 - the level of CO_2 emissions covered in the ETS

To determine the parameters of interest (d , fc and CO_2), we relied on 2016 (AIS) satellite data of the three countries studied in this report. This database covers all voyages to and from these countries, with detailed information about the type and capacity of the ships and the corresponding countries of origin and destination.

To determine the parameter *days of voyage* (d) for each route and ship in the database, we need to consider the particularities of each scenario. In the compliance scenario the number of voyage days, d^c , is simply the time at sea, while in the evasion scenario, d^e is the time at sea plus the time spent at berth in the evasion port. In both cases, the time at sea can be obtained by the following formula:

$$\text{time at sea (days)} = \frac{\text{distance}}{SOG * 24 \text{ hours}} \quad (3)$$

Where:

SOG - speed over ground (nm/s)³²

$distance$ - distance sailed by the ship on the voyage in nautical miles (nm)

As the AIS data at our disposal does not provide information regarding neither the SOG parameter nor the $distance$, we needed to complement it with other sources. We relied on data from the IMO to proxy

³² Speed over ground (SOG) is the speed of the vessel relative to the surface of the earth

the SOG parameter for each ship, using the average operational SOG of all vessels in 2018, categorized by ship type and size/capacity.³³

To calculate the distance parameter, we used the website [sea-distance.org](https://sea-distances.org), which provides the distance sailed by a vessel between two seaports on different possible routes.³⁴ In general, we used the shortest possible distance available between a given origin/destination, as we assumed operators would always favour this alternative. The only exceptions are the cases where the vessel could not use the shortest route (e.g. the Suez or Panama canals), where we used the second possible shortest route.³⁵

As the main database includes only information about the countries of origin and destination, to calculate the distances as accurately as possible, we attributed a main seaport to each country. The choice of seaport was based on the relative importance of the seaports in each country and the type of ships that can berth in specific seaports.

Depending on the scenario, the calculations of the distance sailed can be either:

- The distance sailed between the port of origin/destination and the case-study seaport (*compliance scenario*),
- The distance sailed between the port of origin/destination and the evasion port + the distance sailed between the evasion port and the case-study seaport (*evasion scenario*).

As a reminder, in order to determine the *days of voyage* parameter (*d*) in the evasion scenario, we also need information regarding the time at berth in the evasion port. This can be obtained by using the UNCTADstat data, which provides the average time spent in ports, by country and ship class.³⁶

Finally, using the days of voyage and SOG information, we calculated the *fuel consumption* (*fc*) and the *CO₂ emissions* (*CO₂*) based on the Fourth IMO GHG study methodology³⁷, as well as the vessels' characteristics necessary to this calculation.

Costs calculation

³³ Fourth IMO Greenhouse Gas Study 2020, Table 35 - Detailed results for 2018 describing the fleet analysed using the bottom-up method, column: Avg. SOG at sea.

³⁴ SEA-DISTANCE.ORG - link: <https://sea-distances.org>

³⁵ Only ships with sizes below 120k DWT and 200k DWT can go through the Panama Canal and the Suez Canal respectively.

³⁶ UNCTADstat - Port call and performance statistics: number of arrivals, time spent in ports, vessel age and size, annual - link: <https://unctadstat.unctad.org/EN/BulkDownload.html>

³⁷ Fourth IMO Greenhouse Gas Study 2020

Our methodology relies on four main types of costs, which can be grouped into two broad categories:

- 'running costs', the expenses associated with a ship's regular navigation. They can be subdivided into two major types of costs:
 - fuel costs are related to the fuel consumed by the vessel at sea or at berth
 - operational costs include all the remaining costs associated with the navigation of the ship, including crew costs, insurance, repairs and maintenance.³⁸
- 'evasion costs' incurred as a result of the decision to evade in order to reduce the ETS CO₂ price to be paid. They can be decomposed into:
 - additional port costs, incurred as a result of the extra port-call in the evasion scenario (considering that destination ports do not change their fees as a result of evasion).
 - opportunity costs, which equal the amount of earnings lost due to the increased length of the evasion journey.

In order to calculate the four types of costs for all routes and ships, we needed to complement the limited data publicly available based on a set of assumptions. These, and the calculations we performed to fill in missing data, are detailed below.

Operational costs

The data used to calculate the operational costs was obtained from a *Moore Stephens* presentation.³⁹ This presentation describes the daily operational costs of a set of ships that sailed around the world in 2017. These operational costs include: crew, lubricants, stores, spares, repairs, maintenance, dry docking, insurance (H&M and P&I) and management fees.

For the purpose of our study we need this information for all capacity bins and for each type of vessel. However, the *Moore Stephens*' presentation only covered some capacity bins⁴⁰. To estimate the

³⁸ Capital costs (with depreciations and amortization) and Overheads were not considered, as this information is not available. Additionally, the inclusion of these costs is not likely to change our main results as we assume that under both scenarios (compliance and evasion) vessels have the same amount of working days per year.

³⁹ Ship operating costs: Current and future trends (Richard Greiner, Moore Stephens LLP - 12_2017). link: <http://greece.moorestephens.com/MediaLibsAndFiles/media/greeceweb.moorestephens.com/Documents/1-Richard-Greiner.pdf>

⁴⁰ Covered ship types: Bulk carriers (Handysize, Handymax, Panamax, Capesize), Oil tankers (Product, Handysize Product, Panamax, Aframax, Suezmax, VLCC) and Containers (Feedermax, Container Ship, Main Liner).

information for the missing capacity bins, we relied on linear extrapolation techniques using a trend line, which was fitted from the data available.

The data resulting from the extrapolation process, for the different ship types and capacity bins is presented in Tables A1, A2 and A3.⁴¹

Bulk carrier capacity bin (DWT)	Daily Operational Costs (€)
0 - 10,000	4 338.30
10,000 - 35,000	4 500.00
35,000 - 60,000	4 936.94
60,000 - 100,000	5 101.80
100,000 - 200,000	6 027.93
200,000 - +	6 897.34

Table A1 - bulk carriers daily operational costs by capacity bin

Oil tanker capacity bin (DWT)	Daily Operational Costs (€)
0 - 5,000	6 584.61
5,000 - 10,000	6 696.40
10,000 - 20,000	6 696.40
20,000 - 60,000	6 808.11
60,000 - 80,000	7 244.14
80,000 - 120,000	7 055.86
120,000 - 200,000	8 201.80
200,000 - +	8 963.96

Table A2 - oil tankers daily operational costs by capacity bin

⁴¹ In all cases the monetary amounts were converted from USD (\$) to EUR (€) using an exchange rate of 1.11 USD/Eur, from May 29th of 2020.

Container capacity bin (TEU)	Daily Operational Costs (€)
0 - 1,000	3 938.74
1,000 - 2,000	4 659.46
2,000 - 3,000	6 153.15
3,000 - 5,000	6 153.15
5,000 - 8,000	6 153.15
8,000 - 12,000	7 905.04
12,000 - 14,500	9 604.24
14,500 - +	11 471.84

Table A3 - containers daily operational costs by capacity bin

Fuel costs

The data used to calculate the fuel costs was retrieved from a CE Delft report⁴², which forecasts energy demand and prices, and is displayed in Table A4. We used the table provided in Figure 24: 'Fuel price projections and sensitivity LNG price projections'. The 2020 forecasts for the prices of Heavy Fuel Oil (HFO), Marine Gasoil (MGO) and Low Sulphur Heavy Fuel Oil (LSHFO) obtained from this figure are shown in Table A4.

Fuel Type	Fuel Price (€)
HFO (3% m/m)	419.82
MGO (0.10% m/m)	554.95
LSHFO (<0.50% m/m)	536.04

Table A4 - Fuel prices projection to january 2020 by fuel type

In this study, we considered that ships were using LSHFO, which contains less than 0.5% m/m (mass by mass) of sulphur. This is because a new IMO regulation, in place since January 2020, limits the sulphur content of the fuels used by ships operating outside designated Emission Control Areas.

⁴² CE Delft. (2016). Assessment of Fuel Oil Availability. Retrieved from: https://www.cedelft.eu/assets/upload/file/Presentaties/2016/20161003_Presentation_JF.pdf

Evasion port costs

To determine the charges related to an evasive port call, we used the different pricing brochures of the three evasion ports considered in this study (Haydarpara, Tanger Med and Southampton).⁴³ Each of these ports has its own port charges. These charges consist of 'port dues', applied to ship, cargo, or both for the basic usage of the port, and the 'port tariffs', applied to specific port services.

In this report, we only considered the port tariffs related to berthing and unberthing activities, namely pilotage, towage and mooring. We also assumed that the ship stayed at berth the minimum amount of time possible. The port charges were calculated for each ship type and capacity bin by using averages of Deadweight Tonnage (DWT), Gross Tonnage (GT) and length, draught and beam (measured in meters). The results are shown in tables A5 to A13.

United Kingdom - Southampton

Bulk carrier capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
0 - 10,000	14 556.97	6.92
10,000 - 35,000	117 998.84	6.82
35,000 - 60,000	208 149.89	6.81
60,000 - 100,000	283 015.74	6.81
100,000 - 200,000	599 804.35	6.79
200,000 - +	883 980.12	6.79

Table A5 - Southampton port charges for bulk carriers by capacity bin

Oil tanker capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
0 - 5,000	8 003.27	6.77
5,000 - 10,000	30 743.00	6.73
10,000 - 20,000	66 833.48	6.69

⁴³ Southampton tariff brochure (2020). Retrieved from: http://www.southamptonvts.co.uk/Port_Information/Commercial/Southampton_Tariff/
Tanger-Med tariff brochure (2020). Retrieved from: <http://www.tmpa.ma/wp-content/uploads/2020/02/Cahier-Tarifaire.pdf>

20,000 - 60,000	183 496.30	6.67
60,000 - 80,000	279 569.97	6.68
80,000 - 120,000	402 403.10	6.67
120,000 - 200,000	548 982.99	6.66
200,000 - +	1 064 977.85	6.65

Table A6 - Southampton port charges for oil tankers by capacity bin

Container capacity bin (TEU)	Port Costs (€)	Port Costs (€/GT)
0 - 1,000	44 229.82	6.85
1,000 - 2,000	102 463.96	6.82
2,000 - 3,000	188 949.76	6.81
3,000 - 5,000	291 878.83	6.81
5,000 - 8,000	464 550.82	6.80
8,000 - 12,000	680 668.51	6.79
12,000 - 14,500	987 174.42	6.79
14,500 - +	1 271 326.37	6.78

Table A7 - Southampton port charges for containers by capacity bin

Turkey - Haydarpasa

Bulk carrier capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
0 - 10,000	318.65	0.15
10,000 - 35,000	504.99	0.03
35,000 - 60,000	1 423.48	0.05
60,000 - 100,000	2 181.25	0.05
100,000 - 200,000	5 413.84	0.06
200,000 - +	8 314.99	0.06

Table A8 - Haydarpasa port charges for bulk carriers by capacity bin

Oil tanker capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
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0 - 5,000	358.12	0.30
5,000 - 10,000	590.63	0.13
10,000 - 20,000	1 031.60	0.10
20,000 - 60,000	1 573.46	0.06
60,000 - 80,000	2 864.84	0.07
80,000 - 120,000	4 526.01	0.08
120,000 - 200,000	6 508.95	0.08
200,000 - +	13 492.14	0.08

Table A9 - Haydarpasa port charges for oil tankers by capacity bin

Container capacity bin (TEU)	Port Costs (€)	Port Costs (€/GT)
0 - 1,000	550.95	0.09
1,000 - 2,000	1 024.90	0.07
2,000 - 3,000	1 777.75	0.06
3,000 - 5,000	2 670.86	0.06
5,000 - 8,000	4 176.25	0.06
8,000 - 12,000	6 061.16	0.06
12,000 - 14,500	8 734.26	0.06
14,500 - +	11 213.27	0.06

Table A10 - Haydarpasa port charges for containers by capacity bin

Morocco - Tanger-Med

Bulk carrier capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
0 - 10,000	2 997.29	0.33
10,000 - 35,000	6 710.36	0.18
35,000 - 60,000	10 677.22	0.16
60,000 - 100,000	14 741.52	0.16
100,000 - 200,000	25 423.61	0.16
200,000 - +	38 943.75	0.15

Table A11 - Tanger-Med port charges for bulk carriers by capacity bin

Oil tanker capacity bin (DWT)	Port Costs (€)	Port Costs (€/GT)
0 - 5,000	3 189.14	0.31
5,000 - 10,000	4 896.78	0.21
10,000 - 20,000	6 038.05	0.19
20,000 - 60,000	10 850.92	0.16
60,000 - 80,000	17 190.60	0.17
80,000 - 120,000	25 261.23	0.16
120,000 - 200,000	34 665.53	0.15
200,000 - +	68 096.27	0.15

Table A12 - Tanger-Med port charges for oil tankers by capacity bin

Container capacity bin (TEU)	Port Costs (€)	Port Costs (€/GT)
0 - 1,000	4 886.89	0.22
1,000 - 2,000	8 440.04	0.17
2,000 - 3,000	11 516.21	0.15
3,000 - 5,000	18 315.95	0.16
5,000 - 8,000	27 569.36	0.16
8,000 - 12,000	35 427.15	0.15
12,000 - 14,500	44 089.88	0.15
14,500 - +	51 260.97	0.14

Table A13 - Tanger-Med port charges for containers by capacity bin

Opportunity costs

The opportunity cost is the additional cost or loss of benefits incurred when one alternative is chosen over another. In our case, we calculate the losses of operators when they choose the evasion scenario instead of the compliance scenario. In the evasion scenario, the ship carries out an extended journey compared to the compliance scenario, as the ship performs one additional stop instead of taking the direct route. This extended journey can result in increased time (because of the stop in the evasion port). Assuming that in the compliance scenario a ship does not have idle times, the evasion scenario necessarily leads to a reduction in the total number of voyages carried out. The opportunity cost can

then be calculated as the difference between the revenues in these two scenarios. This is shown in *equation 4*:

$$OppCost = revenues_{compliance} - revenues_{evasion} \quad (4)$$

The opportunity cost per evading voyage can then be calculated as in *equation 5*:

$$OppCost_{a,b,r}^e = revenues_{a,b,r} \cdot \left(\frac{n^c \text{ voyages}^c - n^e \text{ voyages}^e}{n^e \text{ voyages}^e} \right) = revenues_{a,b,r} \cdot \left(\frac{d^e}{d^c} - 1 \right) \quad (5)$$

Where:

a - ship type (containership, bulk carrier or oil tanker)

b - ship capacity/capacity bin

r - route (port of origin-destination)

d^c - number of voyage days in the compliance scenario,

d^e - time at sea plus the time spent at berth in the evasion port in the evasion scenario (obtained as explained above).

To make matters clearer, consider that a given voyage between ports A and B takes 10 days in the compliance scenario, and assume that this voyage is repeated 36 times a year (365/10). Now suppose that in the evasion scenario, the ship stops in port C along its journey from A to B. Given the information about the location of port C and its average port time, it is possible to determine the time taken to sail from A to B calling at C to B, and thus calculate the added time, say 2 days, of this extended journey. Since the evasion increases the total travel time to 12 days, the ship will be able to do less trips per year, $365/12 \approx 30$. To simplify, we assume revenues per voyage are constant, say 10 euros per voyage. This means that the opportunity cost of evading is 60 euros per year, or 2 euros for each trip between A and B that evades via C.⁴⁴

The proxies for the revenues used in this study are derived from three sources: the Clarkson report⁴⁵, UNCTAD report⁴⁶ and freightos website⁴⁷. The procedure applied depends on the type of vessel. For oil

⁴⁴ $OppCosts = 10 \cdot (36/30 - 1) = 2$

⁴⁵ UNCTAD report - link: https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

⁴⁶ Clarkson report - links:

oil tankers - <https://www.crsi.com/acatalog/oil-and-tanker-trade-outlook.html#SID=13>,

bulk carriers - <https://www.crsi.com/acatalog/dry-bulk-trade-outlook.html#SID=13>

⁴⁷ Freightos - link: <https://fbx.freightos.com>

tankers and bulk carriers, the revenues were obtained by multiplying the annual average of the daily charter rates from the Clarkson report (table 2.10, page 43) by the number of days of a voyage in the compliance scenario. Again, as the information in the Clarkson report did not include all the capacity bins required for this study, we resorted to linear extrapolation to estimate the missing values, using a trend line. The average daily charter rates for each vessel type and capacity bin are shown in table A14 and A15.

Bulk carrier capacity bin (DWT)	Daily bulk carrier voyage revenues (€) - year:2018
0 - 10,000	10 400.37
10,000 - 35,000	10 735.47
35,000 - 60,000	10 911.71
60,000 - 100,000	11 590.99
100,000 - 200,000	12 636.04
200,000 - +	13 802.98

Table A14 - Bulk carriers average daily charter rates by capacity bin

Oil tanker capacity bin (DWT)	Daily oil tanker average voyage revenues (€) - year:[2009-2019]
0 - 5,000	8 364.86
5,000 - 10,000	8 713.79
10,000 - 20,000	9 290.88
20,000 - 60,000	11 272.33
60,000 - 80,000	9 885.07
80,000 - 120,000	18 179.22
120,000 - 200,000	23 188.88
200,000 - +	29 324.93

Table A15 - Oil tankers average daily charter rates by capacity bin

For container ships, the revenues can be obtained by multiplying the average freight rate (measured in TEU) by the average capacity of the ship per capacity bin (also measured in TEU). The average freight rates considered depend on the route of the vessel. The freight rates for journeys between Asia

(Shanghai) and Europe (North or Mediterranean areas) were calculated as the average freight rates from the last 10 years, retrieved from the UNCTAD report. For journeys between North America (East Coast) and Northern Europe, the information was taken from the freightos website, and corresponds to the average of the rates in 2019. For the remaining routes, we made the following assumptions:

- Routes between America/Europe (non-EEA countries) and EEA countries: freight rate is the same as between North America East Coast and Northern Europe;
- Routes between Asia/Australia/Africa and Mediterranean countries: freight rate is the same as between Asia (Shanghai) and the Mediterranean;
- Routes between Asia/Australia/Africa and Northern Europe: freight rate is the same as between Asia (Shanghai) and Northern Europe.

The resulting revenues per voyage for container ships are shown in table A16.

Container capacity bin (TEU)	North America East Coast to North Europe (€) - year:[2019/2020]	China/East Asia to North Europe (€) - year:[2010-2018]	China/East Asia to Mediterranean (€) - year:[2010-2018]
0 - 1,000	125 666.30	504 191.76	515 269.32
1,000 - 2,000	294 035.66	1 179 714.49	1 205 633.91
2,000 - 3,000	531 221.48	2 131 339.02	2 178 166.50
3,000 - 5,000	859 141.37	3 447 002.02	3 522 735.83
5,000 - 8,000	1 259 168.01	5 051 967.94	5 162 964.32
8,000 - 12,000	1 932 055.37	7 751 691.37	7 922 003.17
12,000 - 14,500	2 830 349.95	11 355 781.84	11 605 278.83
14,500 - +	3 817 673.35	15 317 069.07	15 653 599.18

Table A16 - Containers revenues per voyage by capacity bin and route

Appendix II: Robustness check of the journey time

To calculate the number of journey days, we used the average operational SOG of all vessels in 2018 and the minimum distance sailed between two seaports, as explained in Appendix I. As the information about the routes only details the countries involved and not the specific ports, further assumptions were required to calculate these distances. Typically, each country has several ports. For simplicity, we attributed a single port to each country, based on their location and/or relative importance. We then calculated the minimum sailing distance between the chosen ports for the country of origin and destination, which we used in all the calculations. Using the average operational SOG may of course disregard particularities of some routes. This is why we decided to conduct a robustness check that models variations in journey time, to check whether our base-case scenario assumptions are solid. We considered an increase/decrease in journey time of 10%, 33% and 50%. The results are shown in Figure A1. As described in section 3.3, the longer the journey (or journey time) from the non EEA port, the higher the risk of evasion.

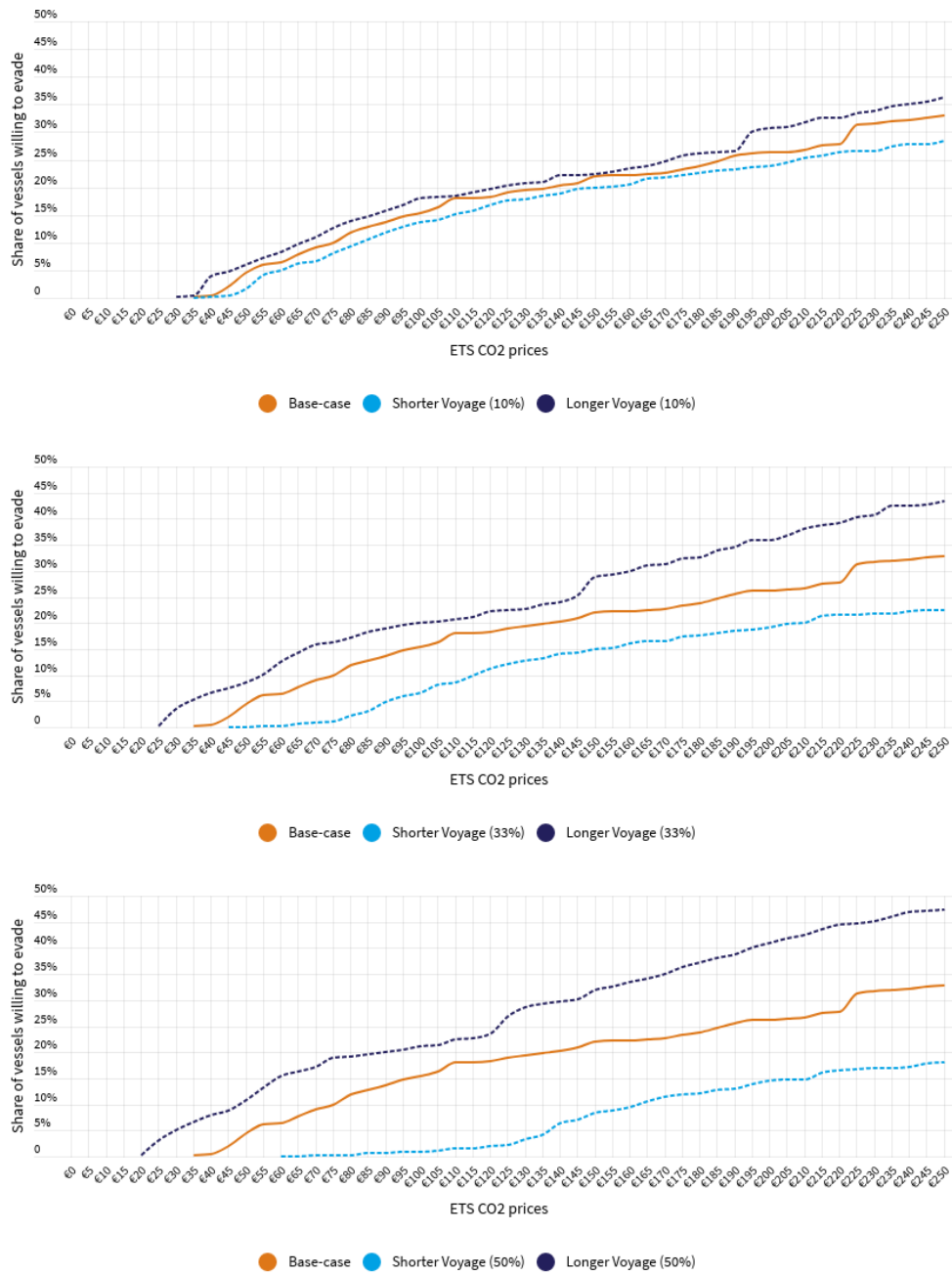


Figure A1 - Risk of evasion with an increase/decrease in journey time of 10% in the top graph, 33% in the middle graph and 50% in the bottom graph (semi-full scope)

As shown in Figure A1 (third graph), a 50% increase in journey time leads to a 5pp higher risk of policy evasion at a CO₂ price of €100/tonne compared to the base case scenario and a 50% decrease in journey time leads to an almost 15pp lower risk.

Appendix III: Robustness check of the port costs

The port costs for the ports analysed in this report were all in the same range with the exception of Southampton. Further investigation revealed that other UK ports near Southampton charge between 10% and 20% for equivalent vessels. To make sure Southampton’s high port charges were not skewing our results, we constructed a robustness test with two scenarios. The first one assumes a reduction of 90% of the port costs considered in the base-case scenario and the second one assumes a reduction of 80%. The results are shown in Figure A2.

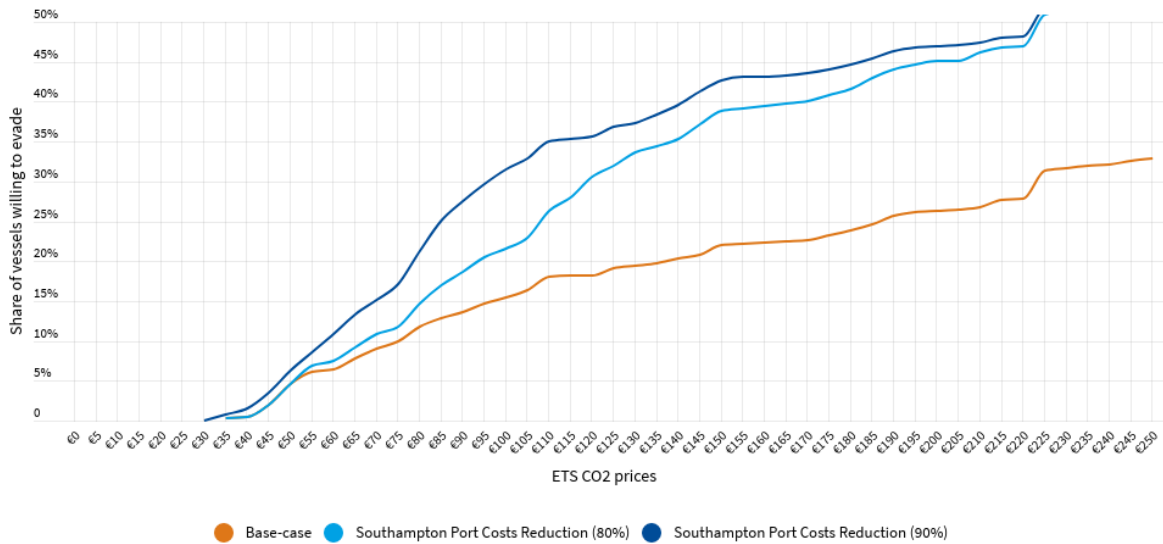


Figure A2 - Risk of evasion with a decrease of port costs in Southampton of 80% and 90% (semi-full scope)

In both scenarios, the CO₂ price where it starts to become financially attractive to evade is very close to the one in the base-case and always higher than €30/tonne. However as ETS CO₂ prices increase, so does the gap between the base-case scenario and the other. For instance for a CO₂ price of €100/tonne, an 80% reduction leads to a 5pp increase in the risk of policy evasion compared to the base-case scenario and a 90% reduction leads to an increase of almost 15pp.