DTU Library

DMA-DTU project on Market Based Measures (MBMs)

Psaraftis, Harilaos N.; Zis, Thalis; Lagouvardou, Sotiria

Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

DMA-DTU project on Market Based Measures (MBMs)

FINAL REPORT

Technical University of Denmark
Department of Technology, Management and Economics

H.N. Psaraftis, T. Zis, S. Lagouvardou

December 16, 2020

CONTENTS

ABBREVIATIONS

BAU	Business As Usual
BIMCO	Baltic and International Maritime Council
CBDR-RC	Common But Differentiated Responsibilities and Respective Capabilities
CBO	Congressional Budget Office (US)
CII	Carbon Intensity Indicator
CLIA	Cruise Line Industry Association
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CWR	Carbon War Room
DCS	Data Collection System
DMA	Danish Maritime Authority
DNV	Det Norske Veritas
DTU	Technical University of Denmark
EC	European Commission
ECSA	European Community Shipowners Associations
EEA	European Economic Area
EEA	European Energy Agency
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EEXI	Energy Efficiency Existing Ship Index
EIS	Efficiency Incentive Scheme
EMSA	European Maritime Safety Agency
EP	European Parliament
ETS	Emissions Trading System
EU	European Union
EVDI	Existing Vessel Design Index
FCC	Federal Communications Commission (US)
GHG	Green House Gas
GRT	Gross Registered Ton
HFO	Heavy Fuel Oil
IA	Impact Assessment
ICAO	International Civil Aviation Organization
ICS	International Chamber of Shipping
IMAREST	Institute of Marine Engineering, Science and Technology
IMF	International Monetary Fund
IMO	International Maritime Organization
IOPCF	International Ocean Pollution Compensation Fund
IPTA	International Parcel Tanker Association
ITF	International Transport Forum
ITS	Intelligent Transport Systems
IUCN	International Union for the Conservation of Nature
LDC	Least Developing Country
LIS	Leveraged Incentive Scheme

MAC	Marginal Abatement Cost
MACC	Marginal Abatement Cost Curve
MBI	Market Based Instrument
MBM	Market Based Measure
MDO	Marine Diesel Oil
MEPC	Marine Environment Protection Committee
METS	Maritime ETS
MGO	Marine Gas Oil
MoS	Motorways of the Sea
MRV	Monitoring, Reporting and Verification
NGO	Non-Governmental Organization
NMFT	No More Favorable Treatment
OECD	Organisation for Economic Cooperation and Development
PSL	Port State Levy
RIS	River Information Services
R&D	Research and Development
SECA	Sulphur Emissions Control Area
SECT	Ship Efficiency and Credit Trading
SEEMP	Ship Energy Efficiency Management Plan
SIDS	Small Island Developing State
STEEM	Ship Traffic, Energy and Environment Model
TEN-T	Trans-European Transport Network
TR	Technical Report
VLSFO	Very Low Sulphur Fuel Oil
UCL	University College London
UK	United Kingdom
UMAS	University Maritime Advisory Services
UNCLOS	United Nations Conference on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Conference on Climate Change
US	United States
USD	United States Dollar
VES	Vessel Efficiency Scheme
VLCC	Very Large Crude Carrier
WSC	World Shipping Council
WTO	World Trade Organization

CHAPTER 0: Executive summary

This report is in the context of the DMA-DTU project on Market Based Measures (MBMs) The aim of this project is to provide an overview and discussion of potential Market Based Measures under the Initial IMO Strategy for the reduction of green house gas (GHG) emissions from ships. In this context, some related developments are also seen as directly relevant to the scope of the project, mainly in the context of the possible inclusion of shipping into the EU Emissions Trading System (ETS).

In 2010 an Expert Group was appointed by the IMO's Secretary General after solicitation of member states and was tasked to evaluate as many as eleven (11) separate MBM proposals, submitted by various member states and other organizations. All MBM proposals described programs and procedures that would target GHG reductions through either 'in-sector' emissions reductions from shipping, or 'out-of-sector' reductions via the collection of funds to be used for mitigation activities in other sectors that would contribute towards global reduction of GHG emissions.

MBM proposals submitted to the IMO were the following:

1) The International Fund for Greenhouse Gas emissions from ships (GHG Fund) originally proposed by Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tanker Association-IPTA (Denmark, 2010).
2) The Leveraged Incentive Scheme (LIS) to improve the energy efficiency of ships based on the International GHG Fund proposed by Japan (Japan, 2010)
3) Achieving reduction in greenhouse gas emissions from ships through Port State arrangements utilizing the ship traffic, energy and environment model, STEEM (PSL) proposal by Jamaica (Jamaica, 2010)
4) The United States proposal to reduce greenhouse gas emissions from international shipping, the Ship Efficiency and Credit Trading (SECT) (USA, 2010)
5) Vessel Efficiency System (VES) proposal by World Shipping Council (WSC, 2010)
6) The Global Emission Trading System (ETS) for international shipping proposal by Norway (Norway, 2010)
7) Global Emissions Trading System (ETS) for international shipping proposal by the United Kingdom (UK, 2010)
8) Further elements for the development of an Emissions Trading System (ETS) for International Shipping proposal by France (France, 2010)
9) Market-Based Instruments: a penalty on trade and development proposal by the Bahamas (Bahamas, 2010)
10) A Rebate Mechanism (RM) for a market-based instrument for international shipping proposal by IUCN (IUCN, 2010)

The following developments took place after the above MBMs were submitted to the IMO:

- A German ETS proposal (Germany, 2010) that was not included in the original MBM list for administrative reasons was reinstated as part of the MBM roster. It was pretty similar to the other three ETS proposals.
- The Expert Group on MBMs produced a detailed report evaluating the MBM submissions (IMO, 2010), however the report expressed no preference or recommendation for an MBM.
- The LIS and VES proposals were combined into what was relabeled the Efficiency Incentive Scheme (EIS) (Japan and WSC, 2011)
- The Bahamian proposal was modified (Bahamas, 2011) and then withdrawn altogether.
- Greece proposed that a short list of MBMs, consisting of only the GHG Fund and ETS proposals, be established, but this was turned down.
- A proposal by the Chairman of the Expert Group, who was also the Chairman of MEPC, to perform an impact assessment of the various MBMs was turned down.
- The MBM discussion at the IMO was suspended in 2013.

At the same time, and given that the IMO has moved to adopt an Initial Strategy in 2018 (IMO, 2018), much more can be said on MBMs. MBMs have been included in the Initial IMO Strategy as a candidate *medium-term* measure (to be finalized and agreed to between 2023 and 2030), as follows: *"New/innovative emission reduction mechanism(s), possibly including Market-based Measures (MBMs), to incentivize GHG emission reduction."*

Note the word "possibly", which means that the fate of MBMs at the IMO is currently unclear. After the ill-fated discussion on MBMs in 2010-2013, visible interest on MBMs at the IMO seems currently limited, however this may change as some Member States have asked for the MBM discussion to reopen. These include submissions by France (2018), a number of Small Island Developing States (SIDS) plus Kenya (Antigua, 2018), the UK (2020) and the Marshall Islands and Solomon Islands (Marshall, 2020). However, other Member States seem opposed to the MBM idea, so at this point in time there is uncertainty on what the future may hold for MBMs at the IMO.

We also note here that reducing maritime GHG emissions *via offsetting* is not included in the Initial IMO Strategy, at least explicitly. By this we mean that it is not clear if the IMO would allow discussion on an MBM that embeds carbon offsetting, if and when the MBM discussion resumes, and assuming that such an MBM is put forward. The use of monies collected under any MBM is anticipated to involve a serious discussion, and it would seem that such use in carbon offsetting activities cannot be a priori ruled out. Also it should be noted that offsetting was the intended main driver behind the GHG Fund MBM proposed by Denmark et al. in 2010.

In parallel, there have been MBM-related developments in Europe. In 2019 the new President of the European Commission (EC) revealed that in the context of the "European Green Deal" (EU, 2019) shipping would be included in the EU ETS. The ETS (which is an MBM) is a major instrument in EU energy policy, covering electricity production and several other major industries (but not shipping, at least thus far). The position of the EC had been to align itself with the IMO process on decarbonization, and essentially refrain from acting on a possible inclusion of shipping into the EU ETS before seeing what the IMO intends to do on GHGs. To that effect, the EC has been closely monitoring the IMO process, starting from what is agreed on the initial strategy in 2018 and all the way to 2023. The EC had always refused to take the ETS option off the table or even to specify what would trigger action on its part. However, as of December 2019, this has changed, and the European Green Deal clearly points to the ETS path for shipping. It is still not clear how this will be implemented.

It should also be mentioned that even though no maritime MBM currently exists, the shipping industry may have missed, by a sheer twist of fate, the chance to witness first-hand a real-world "experiment" on the short-term effects of an MBM. Indeed, the anticipated fuel price increase due to the implementation of the global 0.5% sulphur cap as of 1.1.2020 would be in many respects tantamount to a bunker levy, as many ships would (and did) switch from 3.5% sulphur heavy fuel oil (HFO) to the more expensive 0.5% sulphur marine gas oil (MGO), marine diesel oil (MDO), or very low sulphur fuel oil (VLSFO). Under normal circumstances, these higher fuel prices might result in lower speeds and therefore lower GHG emissions. However, the outbreak of COVID-19 just after the start of the 0.5% sulphur regulation collapsed fuel prices across the board and the above "experiment" never happened. In fact, COVID-19 resulted in phenomena such as containerships on the Far East to Europe route sailing the longer route around Africa at increased speeds as it was cheaper to do so in lieu of paying the Suez canal tolls, and increasing per trip GHG emissions in the process. So to anybody who thought that the global sulphur cap would provide an opportunity to see what an MBM could do, that opportunity was missed.

This report is the output of a project on MBMs, which the Danish Maritime Authority (DTU) commissioned the Technical University of Denmark (DTU) to undertake, with the following terms of reference:

Aim

The aim of this project is to provide an overview and discussion of potential Market Based Measures under IMO's Initial GHG Strategy

Objectives and deliverables

The project objectives and deliverables are:

- Written report including
    - Executive summary
    - Review of MBMs proposed to IMO's Marine Environment Protection Committee
    - Comprehensive literature review of maritime MBMs
    - Literature review of relevant MBMs not previously included in analyses of maritime MBMs
    - Comparative cost-benefit analysis of potential maritime MBMs
- Oral presentation of findings

The cost-benefit analysis is to include the following evaluation criteria:

- GHG reduction effectiveness
- Compatibility with existing legal framework
- Potential implementation timeline
- Potential impacts on States, cf. IMO procedure (MEPC.1/Circ.885)
- Administrative burden
- Practical feasibility
- Avoidance of split incentives between ship-owner and charterer
- Commercial impacts

In order to undertake the analysis, this report breaks down potential MBMs into the following classes:

- Bunker levy/carbon levy MBMs
- ETS (global and/or EU ETS) MBMs
- Other MBM proposals to the IMO

Tables 0.1 and 0.2 below depict our summary evaluations of the MBM classes examined in this report, according to the evaluation criteria listed above.

Table 0.1: Summary evaluation of levy-based and ETS-based MBMs.

Criterion/ MBM	Levy-based	ETS-based
GHG reduction effectiveness	Considerable, depending on the level of the levy	Considerable for a global ETS Questionable for an EU ETS
Compatibility with existing legal framework	May encounter legal obstacles	May encounter legal obstacles.
Implementation timeline	Unclear at global level Industry R&D fund on the table at IMO	Unclear at global level EU ETS is forthcoming
Potential impacts on states	Potentially considerable	Potentially considerable
Administrative burden	Low	Considerable
Practical feasibility	High	Questionable
Avoidance of split incentives	No serious split incentives	Serious split incentives
Commercial impacts	Considerable and in many sectors	Considerable but uncertain due to uncertainty on carbon price

Table 0.2: Summary evaluation of other MBMs submitted to the IMO.

Criterion/ MBM	Bahamas (do nothing)	IUCN (rebate)	STEEM (port based)	EIS (EEDI based)	SECT (EEDI based)
GHG reduction effectiveness	Some CO2 reductions can be achieved	Proposal piggybacks any MBM. Its environmental	Carbon leakage risks exist as some	Lower than GHG Fund, as some	Low. CO2 reduction certainty does not

	even with no MBM.	effectiveness is same as that of MBM implemented.	port states may not implement scheme.	ships will be exempted	exist, as scheme trades on EEDI. No attempt to compute CO_2 directly.
Compatibility with existing legal framework	Fully compatible	Same as that of MBM implemented	Likely to encounter legal obstacles		
Potential implementation timeline	None of these proposals is still alive. There is no indication of any attempt to reinstate.				
Potential impacts on states	None	Could be beneficial to LDCs and SIDs if levy is based on imports	Unclear. May create distortions by diverting traffic to port states that do not implement the scheme.	Unclear. SIDS served by older ships may be at a disadvantage	Unclear. SIDS served by older ships may be at a disadvantage
Administrative burden	Zero	Higher than that of MBM implemented (add costs of administering rebates)	High	Lower than SECT, but higher than GHG Fund.	Worse than ETS.
Practical feasibility	Highest	Lower than that of MBM implemented (add costs of administering rebates)	Low. Practically impossible to monitor emissions.	Higher than SECT but lower than GHG Fund, due to tracking of EEDI for existing ships.	Worse than ETS. Combines problems of ETS with tracking EEDI for existing ships and estimating activity levels.
Avoidance of split incentives	No split incentives	Same as that of MBM implemented.	Unclear	Unclear	Unclear
Commercial impacts	None	Same as that of MBM implemented.	Unclear	May favor countries with strong shipbuilding sector	May favor countries with strong shipbuilding sector

CHAPTER 1: Introduction and background

This document is the final report of the DMA-DTU project on Market Based Measures (MBMs). The aim of this project is to provide an overview and discussion of potential MBMs under the Initial Strategy of the International Maritime Organization (IMO) for the reduction of green house gas (GHG) emissions from ships (IMO, 2018). In this context, some related developments are also examined as directly relevant to the scope of the project, mainly in the context of the possible inclusion of shipping into the EU Emissions Trading System (ETS).

It is recalled that MBMs were examined by the Marine Environment Protection Committee (MEPC) of the IMO between 2010 and 2013 in the context of an Expert Group on MBMs that was established. After many discussions, the Expert Group produced a detailed report evaluating the various MBM proposals (IMO, 2010), but which expressed no preference for any of these proposals. After some additional discussions, the MBM discussion at the IMO was suspended in 2013. This coincided with the rechanneling of the GHG discussion towards the subject of Monitoring, Reporting and Verification (MRV) of CO_2 emissions. Much time has elapsed since that discussion, however we think that some of the related work, which has been very extensive, could conceivably be used so as to not reinvent the wheel whenever the MBM discussion resumes at the IMO. This work could even be useful in the context of the current drive to include shipping within the EU ETS.

At the same time, and given that the IMO has moved to adopt an Initial Strategy in 2018 (IMO, 2018), much more can be said on MBMs. MBMs have been included in the Initial IMO Strategy as a candidate *medium-term* measure (to be finalized and agreed to between 2023 and 2030), as follows: *"New/innovative emission reduction mechanism(s), possibly including Market-based Measures (MBMs), to incentivize GHG emission reduction."*

Note the word "possibly", which means that the fate of MBMs at the IMO is currently unclear. After the ill-fated discussion on MBMs in 2010-2013, visible interest on MBMs at the IMO seems currently limited, however this may change as some Member States have asked for the MBM discussion to reopen. These include submissions by France (2018), a number of SIDS plus Kenya (Antigua, 2018), the UK (2020) and the Marshall Islands and Solomon Islands (Marshall, 2020). However, other Member States seem opposed to the MBM idea, so at this point in time there is uncertainty on what the future may hold for MBMs at the IMO.

In parallel, there have been MBM-related developments in Europe. In 2019 the new President of the European Commission (EC) revealed that in the context of the "European Green Deal" (EU, 2019) shipping would be included in the EU ETS. The ETS (which is an MBM) is a major instrument in EU energy policy, covering electricity production and several other major industries (but not shipping, at least thus far). The position of the EC had been to align itself with the IMO process on decarbonization, and essentially refrain from acting on a possible inclusion of shipping into the EU ETS before seeing what the IMO intends to do on GHGs. To that effect, the EC has been closely monitoring the IMO process, starting from what is agreed on the initial strategy in 2018 and all the way to 2023. The EC had always refused to take the ETS option off the table or even to specify what would trigger action on its part. However, as of December 2019, this has changed, and the European Green Deal clearly points to the ETS path for shipping.[1] It is still not clear how this will be implemented.

It should also be mentioned that even though no maritime MBM currently exists, the shipping industry may have missed, by a sheer twist of fate, the chance to witness first-hand a real-world "experiment" on the short-term effects of an MBM. Indeed, the anticipated fuel price increase due to the implementation of the global 0.5% sulphur cap as of 1.1.2020 would be in many respects tantamount to a bunker levy, as many ships would (and did) switch from 3.5% sulphur heavy fuel oil (HFO) to the more expensive 0.5% sulphur marine gas oil (MGO), marine diesel oil (MDO), or very low sulphur fuel oil (VLSFO). Under normal circumstances, these higher fuel prices might result in lower speeds and therefore lower GHG emissions. However, the outbreak of COVID-19 just after the start of the 0.5% sulphur regulation collapsed fuel prices across the board and the above "experiment" never happened. In fact, COVID-19 resulted in phenomena such as containerships on the Far East to Europe route sailing the longer route around Africa at increased speeds as it was cheaper to do so in lieu of paying the Suez canal tolls, and increasing per trip GHG emissions in the process. So to anybody who thought that the global sulphur cap would provide an opportunity to see what an MBM could do, that opportunity was missed.

This report is the output of a project on MBMs, which the Danish Maritime Authority (DTU) commissioned the Technical University of Denmark (DTU) to undertake, with the following terms of reference:

Aim

The aim of this project is to provide an overview and discussion of potential Market Based Measures under IMO's Initial GHG Strategy

Objectives and deliverables

The project objectives and deliverables are:

- Written report including
    - Executive summary
    - Review of MBMs proposed to IMO's Marine Environment Protection Committee

[1] The intent of the new European Commission President to include shipping within the EU ETS was actually known since the new President's election.

  - Comprehensive literature review of maritime MBMs
  - Literature review of relevant MBMs not previously included in analyses of maritime MBMs
  - Comparative cost-benefit analysis of potential maritime MBMs
- Oral presentation of findings

The cost-benefit analysis is to include the following evaluation criteria:

- GHG reduction effectiveness
- Compatibility with existing legal framework
- Potential implementation timeline
- Potential impacts on States, cf. IMO procedure (MEPC.1/Circ.885)
- Administrative burden
- Practical feasibility
- Avoidance of split incentives between ship-owner and charterer
- Commercial impacts

The rest of this report is organized as follows: Chapter 2 outlines the MBM proposals submitted to the IMO. Chapter 3 performs a comprehensive literature review of maritime MBMs. Chapter 4 performs a literature review of relevant MBMs not previously included in analyses of maritime MBMs. Chapter 5 performs a comparative cost-benefit analysis of potential maritime MBMs, broken down into the following classes:

- Bunker levy/carbon levy MBMs
- ETS (global and/or EU ETS) MBMs
- Other MBM proposals to the IMO

For each of these classes, the evaluation is carried out according to the criteria as outlined above.

Details on some subjects related to Chapter 5 are presented in Appendices A (split incentives) and B (carbon leakage and EU ETS).

CHAPTER 2: Review of MBMs proposed to IMO's MEPC

This chapter is divided into two parts. Section 2.1 looks at the original submissions to the IMO (period 2010-2013) and Section 2.2 looks into more recent submissions (2018-2020). There is no evaluation of MBMs in this chapter; this is done in Chapter 5.

As a preamble, it seems that the idea of the "internalization of costs" to achieve sustainable financing for the prevention, clean up, or compensation of costs caused by "polluters" was first raised internally at the IMO in 1995 (IMO, 1995). However, no immediate follow-up action was taken. The first mention on the potential use of MBMs for obtaining reductions of GHG emissions from shipping can be found in the 1st IMO GHG Study (Skjolsvik et al., 2000).

2.1 Original MBM submissions to the IMO (2010-2013)

Following the completion of the 2nd IMO GHG study (Buhaug et al., 2009), IMO activity on GHGs has been largely on two "parallel" tracks. The first track mainly concerned the so-called Energy Efficiency Design Index (EEDI). EEDI is an index that measures the energy efficiency of a ship, defined as the ratio of CO_2 emissions from the ship divided by the transport work of the ship. In 2011 (MEPC 62), EEDI was made mandatory for new ships of 400 GRT and above and the Ship Energy Efficiency Management Plan (SEEMP) was adopted for all ships. For the shipping industry, this was the first legally binding climate change treaty adopted since the Kyoto Protocol and came into force as of 1 January 2013.

The second GHG track concerned MBMs. It is interesting that discussion on these two tracks has been conducted at the IMO with no apparent connection between the two, even though both tracks concern the same objective (reduce GHG emissions from ships). It will also be seen below that in reality these tracks are not disjoint, as some of the proposed MBMs to the IMO embed EEDI in their formulation.

For MBMs, in 2010 an Expert Group was appointed by the IMO's Secretary General after solicitation of member states and was tasked to evaluate as many as eleven (11) separate MBM proposals, submitted by various member states and other organizations[2]. All MBM proposals described programs and procedures that would target GHG reductions through either 'in-sector' emissions reductions from shipping, or 'out-of-sector' reductions via the collection of funds to be used for mitigation activities in other sectors that would contribute towards global reduction of GHG emissions.

The IMO formulated the following nine (9) criteria for evaluation of GHG reduction measures, including MBMs:

[2] H. N. Psaraftis was a member of that Expert Group, representing Greece at the time.

I. Environmental effectiveness
II. Cost-effectiveness and potential impact on trade and sustainable development
III. The potential to provide incentives to technological change and innovation
IV. Practical feasibility of implementing MBM
V. The need for technology transfer to and capacity building within developing countries, in particular the least developed countries (LDCs) and the small island developing states (SIDS)
VI. The relation with other relevant conventions (UNFCCC, Kyoto Protocol and WTO) and the compatibility with customary international law
VII. The potential additional administrative burden and the legal aspects for National Administrations to implement and enforce MBM
VIII. The potential additional workload, economic burden and operational impact for individual ships, the shipping industry and the maritime sector as a whole, of implementing MBM
IX. The compatibility with the existing enforcement and control provisions under the IMO legal framework.

Brief descriptions of each of the original IMO MBM proposals are as follows (see IMO (2010) for more details):

1. <u>The International Fund for Greenhouse Gas emissions from ships (GHG Fund) originally proposed by Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tanker Association-IPTA (Denmark, 2010).</u>

Liberia and the Republic of Korea were later added as co-sponsors of this MBM. The GHG Fund would establish a global reduction target for international shipping, set by either the United Nations Framework Convention on Climate Change (UNFCCC) or the IMO. Emissions above the target line would be offset largely by purchasing approved emission reduction credits. The offsetting activities would be financed by what the proposers call a ‘contribution’ paid by ships on every tonne of bunker fuel purchased. It is envisaged that contributions would be collected through bunker fuel suppliers (Option 1) or via direct payment from ship owners (Option 2). The contribution rate would be adjusted at regular intervals to ensure that sufficient funds are available to purchase project credits to achieve the agreed target line. Any additional funds remaining would be available for adaptation and mitigation activities via the UNFCCC and R&D and technical co-operation within the IMO framework.

We note that the proposers of the GHG Fund MBM did not call their proposal a ‘levy’ proposal, much less a ‘tax’ proposal, and they actually called funds collected a ‘contribution’. This was done for legal reasons (see also Chapter 5). Substance-wise however, and to the extent that this contribution was not voluntary and would have to be imposed to ships if this MBM was adopted, this proposal essentially involved a levy on fuel.

We also note that one of the basic intended functions of the GHG Fund proposal was to use monies collected so as to purchase “offsets” that could be used to reduce “out-of-sector” CO_2 emissions. This did not preclude “in-sector” CO_2 emissions reductions as a result of this MBM.

2. The Leveraged Incentive Scheme (LIS) to improve the energy efficiency of ships based on the International GHG Fund proposed by Japan (Japan, 2010)

This resembled the aforementioned GHG Fund scheme with an important difference: The concept of the Leveraged Incentive Scheme (LIS) was that a part of the GHG Fund contributions, which would be collected on marine bunker would be refunded to ships meeting or exceeding agreed efficiency benchmarks and labelled as "good performance ships", would be refunded to these ships. To that effect, the EEDI index was the main instrument in determining which ships are efficient and should receive the refunds. In that sense, this MBM was a hybrid one, as it included EEDI as part of its formulation.

We note that even though this proposal was submitted in 2010 (and so were all others), EEDI was not adopted until 2011, so the final form of EEDI was not known when Japan’s proposal was submitted. However in 2010 the preparatory discussion on EEDI was very much on the IMO agenda, and it was known that adoption of the EEDI would not be far ahead.

3. Achieving reduction in greenhouse gas emissions from ships through Port State arrangements utilizing the ship traffic, energy and environment model, STEEM (PSL) proposal by Jamaica (Jamaica, 2010)

Under this MBM, Member States would participate in levying a uniform emissions charge on all vessels calling at their respective ports based on the amount of fuel consumed by the respective vessel on its voyage to that port (not bunker suppliers). The proposal is directly aimed at reducing maritime emissions of CO_2 without regard to design, operations, or energy source. The Port State Levy (PSL) would be structured to achieve the global reduction targets for GHG and could be leveraged in a manner as proposed by Japan to reward vessels exceeding efficiency targets.

4. The United States proposal to reduce greenhouse gas emissions from international shipping, the Ship Efficiency and Credit Trading (SECT) (USA, 2010)

This MBM was designed to focus emission reduction activities just in the shipping sector. Under SECT, all ships, including those in the existing fleet, would be subject to mandatory energy efficiency standards, rather than a cap on emissions or a surcharge on fuel. As one means of complying with the standard, SECT would establish an efficiency-credit trading programme. The stringency level of these efficiency standards would be based on energy efficiency technology and methods available to ships in the fleet. These standards would become more stringent over time, as new technology and methods are introduced. Similar to the EEDI, these efficiency standards would be based on a reduction from an established baseline and would establish efficiency standards for both new and existing ships.

As the LIS MBM by Japan, the SECT MBM by the US was a hybrid MBM, as it embedded EEDI within its formulation. However, the mechanism was different. Under SECT, ships could trade on EEDI. A 'good EEDI' ship could sell credits to a 'bad EEDI' ship.

5. Vessel Efficiency System (VES) proposal by World Shipping Council (WSC, 2010)

VES would establish mandatory efficiency standards for both new and existing ships. Each vessel would be judged against a requirement to improve its efficiency by X% below the average efficiency (the baseline) for the specific vessel class and size. Standards would be tiered over time with increasing stringency. Both new build and existing ships would be covered. New builds must meet the specified standards or they may not operate. Existing ships may comply by improving their efficiency scores through technical modifications that have been inspected and certified by the Administration or recognized organizations. Existing ships failing to meet the required standard through technical modifications would be subject to a fee applied to each tonne of fuel consumed. The total fee applied (non-compliant ships only) would vary depending upon how far the vessel's efficiency (as measured by the EEDI) falls short of the applicable standard.

This was the third example of a hybrid MBM, as it embedded EEDI within its formulation.

6. The Global Emission Trading System (ETS) for international shipping proposal by Norway (Norway, 2010)

This MBM would set a sector-wide cap on net emissions from international shipping and establish a trading mechanism to facilitate the necessary emission reductions, be they in-sector or out-of-sector. As argued by Norway, the use of out-of-sector credits allows for further growth of the shipping sector beyond the cap. In addition the auction revenue would be used to provide for adaptation and mitigation (additional emission reductions) through UNFCCC processes and R&D of clean technologies within the maritime sector. A number of allowances (Ship Emission Units) corresponding to the cap would be released into the market each year. It is proposed that the units would be released via a global auctioning process. Ships would be required to surrender one Ship Emission Unit, or one recognized out-of-sector allowance or one recognized out-of-sector project credit, for each tonne of CO_2 they emit. The Norwegian ETS would apply to all CO_2 emissions from the use of fossil fuels by ships engaged in international trade above a certain size threshold. The proposal also indicated that limited exemptions could be provided for specific voyages to Small Island Developing States (SIDS).

7. Global Emissions Trading System (ETS) for international shipping proposal by the United Kingdom (UK, 2010)

This was very similar in most respects to the global ETS proposal by Norway. Two aspects of the UK proposal that differed from the Norwegian ETS proposal were the method of allocating emissions allowances and the approach for setting the emissions cap.

8. Further elements for the development of an Emissions Trading System (ETS) for International Shipping proposal by France (France, 2010)

This MBM set out additional detail on auction design under a shipping ETS. In all other aspect the proposal was similar to the Norwegian proposal for an international ETS.

9. Market-Based Instruments: a penalty on trade and development proposal by the Bahamas (Bahamas, 2010)

This MBM did not set explicit standards or reductions to be achieved in the shipping sector or out-of-sector for GHG reductions. The proposal clearly set forth that the imposition of any costs should be proportionate to the contribution by international shipping to global CO_2 emissions. The Bahamas indicated that it was assuming that mandatory technical and/or operational measures would be implemented, such as the EEDI.

The Bahamian original proposal was a non-proposal, that is, advocated adopting no MBM, arguing that this would be an obstacle to trade. A ‘do-nothing’ proposal does not necessarily imply zero CO_2 reductions, as the measures that have a negative Marginal Abatement Cost (MAC) (of which more later in this chapter and in Chapter 5) would be implemented and those measures would entail a CO_2 reduction. Fuel price is a key driver to such an outcome.

The Bahamas subsequently submitted an updated MBM proposal (Bahamas, 2011), which was labelled an evolution of their former proposal. In their updated submission, the Bahamas argued that only through operational and technical measures CO_2 emissions can be cut. The new proposal, among other things, envisioned collecting CO_2 statistics through either the collection of EEOI (Energy Efficiency Operational Indicator) data, or simply by recording emissions from the funnel using a suitable sensor. The ship would be required to submit emission records to the flag State or recognized organization for annual verification. The statistics collected would then show how much emissions were actually emitted over the data collection period.

10. A Rebate Mechanism (RM) for a market-based instrument for international shipping proposal by International Union for the Conservation of Nature-IUCN (IUCN, 2010)

This MBM focused on a Rebate Mechanism to compensate developing countries for the financial impact of a MBM. A developing country's rebate would be calculated on the basis of their share of global costs of the MBM, using readily available data on a developing country's share of global imports by value as a proxy for that share (or another metric such as value-distance if data becomes available)[3].

IUCN claimed that the rebate mechanism was compatible with the Common But Differentiated Responsibilies (CBDR) principle[4], while in principle it could be applied to any type of MBM. In that sense, it was a proposal that could ‘piggy back’ on any other MBM proposal. The examples given had some common elements with the GHG Fund proposal, with upper and lower bounds on prices. The rebate mechanism uses a country’s share of global imports as a key without specifying which imports.

The following developments took place after the above MBMs were submitted to the IMO:

- A German ETS proposal (Germany, 2010) that was not included in the original MBM list for administrative reasons was reinstated as part of the MBM roster. It was pretty similar to the other three ETS proposals.
- The Expert Group on MBMs produced a detailed report evaluating the MBM submissions (IMO, 2010), however the report expressed no preference or recommendation for an MBM.
- The LIS and VES proposals were combined into what was relabeled the Efficiency Incentive Scheme (EIS) (Japan and WSC, 2011)
- The Bahamian proposal was withdrawn altogether.
- Greece proposed that a short list of MBMs, consisting of only the GHG Fund and ETS proposals be established, but this was turned down.
- A proposal by the Chairman of the Expert Group, who was also the Chairman of MEPC, to perform an impact assessment of the various MBMs was turned down.
- The MBM discussion at the IMO was suspended in 2013.

---

[3] For many LDCs/SIDS, their imports typically consist of close to 100% of their own consumption but are miniscule in relation to global trade, therefore it is not immediately clear how much would be rebated to these countries or if the scheme would be considered fair by them. As IMO (2010) points out, *“consensus will have to be achieved on the country import statistics to be used for calculating the rebates and crediting. The IMF is cited as the source of statistics to be used, although there could be other sources. However, it is noted that the proposal argues that as the countries themselves report import data to the IMF, it is unlikely that they would challenge or question their own data. It will also have to be considered if the proposed “share of imports”, to be used as a factor for calculating the rebates to developing countries, is a clear reflection of the shipping industry’s contribution to GHG emissions, as imports to a country could be transported via different means and not exclusively by shipping.”*

[4] The principle of Common But Differentiated Responsibilities (CBDR), in later years rebranded as CBDR-RC (RC for Respective Capabilities) has been a widely accepted principle that underlines such international agreements as the Kyoto Protocol. The essence of the CBDR-RC has two aspects. The first is common responsibility, which is raised from the concept of common heritage and common concern of humankind and reflects the duty of countries to equally share the burden of environmental protection for common resources; the second is differentiated responsibility, which addresses different social and economic situations across countries.

Regarding the second bullet point above, the IMO Expert Group that was tasked to evaluate the MBM proposals in 2010 went into considerable effort, which also involved the work of external consultants, to develop and apply a model to make quantitative estimates of emissions reductions, revenues generated, costs and other attributes of each MBM proposal. For instance, modeling scenarios included, inter alia:

- two global GDP growth rates (1.65% and 2.8%)
- three targets lines /caps for GHG Fund and ETS (0%, 10% and 20% below 2007 level)
- two carbon price scenarios (medium and high) and two fuel price scenarios (reference and high)

For instance, Table 2.1 shows the results of some calculations. Emissions are in million tonnes of CO_2 and are projected to year 2030. The "Business As Usual" (BAU) scenario refers to no MBMs.

Table 2.1: Modeling exercise results for various MBMs. Adapted from IMO (2010)[5].

	SECT	VES	Bahamas	GHG Fund	LIS	PSL	ETS (Norway France)	ETS (UK)	RM
Mandatory EEDI (Mt)	123-299	123-299	123-299*						
MBM In sector (Mt)	106-142	14-45		1-31	32-153	29-119	27-114	27-114	29-68
MBM Out of Sector (Mt)				152-584			190-539	190-539	124-345
Total reductions (% BAU)	19-31%	13-23%	10-20%	13-40%	3-10%	2-8%	13-40%	13-40%	13-28%
Potential supplementary reductions (Mt)		45-454		104-143	232-919	917-1232	696-870		187-517

Some non-exhaustive comments are made hereunder on the Expert Group's report (IMO, 2010).

[5] Note (asterisk in the table): Even though the Bahamas did not support EEDI, which was not yet approved by MEPC in 2010, the table included EEDI reductions that would be taken into account in the Bahamas BAU scenario, in case MEPC approved EEDI.

In the modeling effort, a key assumption was made that an increase in fuel prices of 100% over the long-term would result in a 4% reduction in CO_2 emissions below the BAU scenario. However, this assumption is not necessarily correct, as the percentage (4% or other) critically depends on the slope of the Marginal Abatement Cost (MAC) curve at the point it crosses the x-axis. Recall that the MAC of a specific technology is the ratio of the marginal cost of implementing this technology, divided by the CO_2 it can avert. It is expressed in USD per tonne of CO_2 averted. If one examines a set of feasible measures to reduce CO_2 and compute the MACs for such measures applied to the world fleet, one comes up with what is known as the MAC curves (or MACCs).

Several attempts to construct MACCs are known, see for instance DNV (2009), Eide et al (2010), and IMAREST (2011). Figure 2.1 shows such a curve, taken from the Expert Group's report (IMO, 2010) and carried out by former Norwegian classification society Det Norske Veritas (DNV), which was commissioned by the IMO for the task.

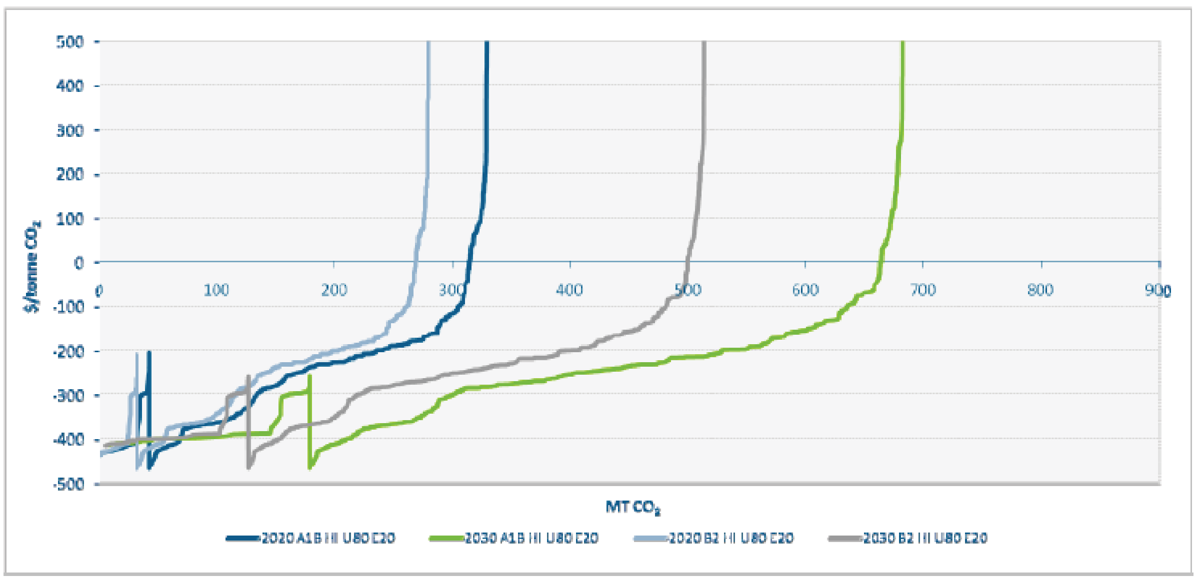

Figure 2.1: Sample MACCs by DNV. Source: IMO (2010).

We point out that the fixed 4% slope assumption stated above is not necessarily correct. As illustrated by the DNV MACCs for the 72 scenarios examined and in Figure 2.1, the slope of a MACC can vary widely from very low to very high, projected future fuel price being the main determinant of where the MACC crosses the x axis. In that sense, reservations are expressed on the numerical results of the Expert Group's modeling approac.

In addition, the DNV MAC model that was used by the Expert Group entailed another serious issue, which is very much relevant in the context of MBMs. It is well known that an important short term response of ship owners to a fuel price increase (and therefore also to a levy) is slow steaming, which obviously has important implications on the CO_2

emissions generated by a ship. For any given fuel price, the optimal speed chosen by the ship operator is a function of that price and the state of the market and specifically the spot rate (boom, slump, or other). The DNV MAC model included “speed reduction” as a possible *abatement measure*, and thus ignored that slow steaming is primarily a *response* of ship operator to fuel price increases. In fact, the DNV MAC model had *two speed reduction variants*, one which was accompanied by port efficiency measures that led to reduced port time and was found to have a MAC<0, and one which was based on additional ships and was found to have a MAC>0. The model did not capture the ship operator’s response to fuel price changes (or to a bunker levy, for that matter). That response is actually the single most important short-term impact of a levy.

Table 2.2 summarizes all the proposals discussed at the IMO during the period 2010-2013.

Table 2.2: MBM proposals at the IMO, 2010-2013. Adapted from Lagouvardou et al (2020).

Type of MBM	MBM Proposal	Proponents	Brief Description	Mechanism for Reduction	
				In sector	Out of sector
Levy on bunker fuels	The International Fund for Greenhouse Gas emissions from ships (GHG Fund)	Cyprus, Denmark, the Marshall Islands, Nigeria, Republic of Korea and IPTA	UNFCCC and IMO set a global emission reduction target for shipping. Emissions above the target are offset by purchasing approved emission reductions credits. Ships emitting above the target will finance their offsetting activities by paying a fee based on the amount of bunker fuel purchased.	It sets a global reduction target and increases the cost of bunker fuels.	Purchase of project offset credits through the revenues.
ETS	The Global Emission Trading System for international shipping	Norway	A cap-and-trade system where credits are traded in-sector or out-of-sector. The system uses an auctioning system while it releases into the market emissions allowances (corresponding to the cap) yearly.	It sets a global cap and a price on emissions from shipping—purchase of in-sector offset credits.	Purchase of project offset credits.
	Global Emissions Trading System for international shipping	UK	Same concept with Norway's proposal but a different method for allocating emissions allowances and a different approach to determining the cap.	It sets a global cap and a price on emissions from shipping—purchase of in-sector offset credits.	Purchase of project offset credits.
	Further elements for the development of an Emissions Trading System for International Shipping	France	The same concept with Norway's proposal but adds some detail on auctioning design.	It sets a global cap and a price on emissions from shipping—purchase of in-sector offset credits.	Purchase of project offset credits.
	Design and implementation of a worldwide Maritime Emission Trading Scheme (METS)	Germany	In favor of an ETS, Germany provided a scientific study that examines global ETS and concludes that it is an effective, cost-efficient, and applicable instrument to enforce.	It sets a global cap and a price on emissions from shipping—purchase of in-sector offset credits.	Purchase of project offset credits.
Hybrid with EEDI as a benchmark	The Leveraged Incentive Scheme (LIS) to improve the energy efficiency of ships based on the International GHG Fund	Japan	The same concept with the GHG Fund but vessels labeled as "good performance ships" (i.e., they meet predetermined EEDI targets) will be refunded their contribution to the GHG Fund.	Refund policy and EEDI inclusion incentivize investments in zero-carbon technology.	Purchase of project offset credits through the fund.
	The US proposal to reduce GHG emissions from international shipping, Ship Efficiency, and Credit Trading (SECT)	US	Ships have to meet mandatory efficiency standards that will become stricter over time. SECT establishes an efficiency-credit trading program that trading is based on vessels EEDI.	Trading based on EEDI incentivizes for investments in energy-efficient technologies.	N/A
	Vessel Efficiency System (VES)	WSC	Establishment of mandatory efficiency standards for both new and existing ships. New builds must meet the standards to operate, whereas existing ships are forced to improve their efficiency by utilizing the respective technology. Ships that do not meet the standards will be subject to a levy based on how far the measured EEDI falls short from the standard.	Mandatory efficiency standards. EEDI incentivizes for investments in zero-carbon technology.	Purchase of project offset credits through the revenues.
Other	Market-based instruments: a penalty on trade and development	Bahamas	A “do-nothing” MBM.	N/A	N/A
	Achieving a reduction in GHG emissions from ships through Port State arrangements utilizing the ship traffic, energy, and environment model, Port State Levy (PSL)	Jamaica	A uniform emissions charge will be agreed upon for any vessel calling at their ports. Vessels will pay a levy based on the fuel consumption of their voyage to the respective port. Ships with exceeding energy efficiency targets will be leveraged.	Sets efficiency standards and incentivizes for investments in zero-carbon technology	Purchase of project offset credits through the revenues.
	A rebate mechanism (RM) for a market-based instrument for international shipping proposal by the International Union for Conservation of Nature	IUCN	An add-on to any MBM proposal that aims to compensate developing countries for the financial impacts of MBMs based on their share of global imports and costs.	The approach based on the chosen MBM	The approach based on the chosen MBM

2.2 More recent MBM submissions to the IMO (2018-2020)

There have also been some more recent MBM submissions to the IMO. In 2018, France expressed the belief that MBMs can create the appropriate economic context towards low/zero-carbon fuels and technologies (France, 2018). The French proposal consisted of a progressively increasing carbon price based on the quantity of carbon a vessel emits. This action would benefit low and zero-carbon fuel users and boost technological advances in this direction. Ships that meet the specified standards are exempt from any fees, penalties, or costs other than those associated with the installation of energy-efficient technologies. Ships that do not meet the standards would be required to pay a fee on the consumed fuel based on the difference between the attained efficiency and the agreed standards. As such, the per-unit fee applied per tonne of fuel is based on the relative efficiency of the vessel.

Additionally, in 2018, a number of SIDS plus Kenya submitted a proposal urging for financial incentives, R&D investment, and regulation in order to meet the levels of ambition in the Initial Strategy (Antigua, 2018). They expressed their preference towards an easily implemented and transparent carbon tax or levy on bunker fuel. The level of the levy should be reviewed frequently and increased over time. Furthermore, the co-sponsors convey their belief that the generated revenues should compensate the impacts on SIDS and LDCs, and mitigate the effects of climate change by the most vulnerable.

In 2019, Norway submitted a proposal urging the need of flexible compliance mechanisms for meeting the CO_2 and GHG requirements (Norway, 2019). According to the submission, the introduction of alternative low/zero-carbon fuels is essential for meeting the 2050 ambitions even in low market growth scenarios, and it would be challenging for existing ships to meet the targets. The proposal suggested that those ships could compensate for their emissions by utilizing "fleet averages, annual accounting, out-of-sector fund or in-sector fund." Another compliance mechanism could be the contribution to a certified IMO GHG R&D Fund. IMO would establish an equivalent CO_2 reduction fee as a financial contribution to the Fund based on the price of CO_2 in existing markets. Finally, the revenues of the Fund would be used to stimulate a transition towards low/zero-carbon fuels and technologies.

There has been no IMO action on the above proposals.

In 2020, we note a submission by the United Kingdom (UK, 2020), submitted under agenda item 8 (any other business) of the 7th intersessional meeting on GHGs. In it, the UK outlined five different MBM options for economic incentives, including levies, taxes, ETS, subsidies and R&D, without expressing a preference or recommendation for any of them. Discussion on this submission was postponed for a future meeting.

We also note a submission by the Marshall Islands and the Solomon Islands to MEPC 75 (Marshall, 2020) to MEPC 75. The submission, along with some comments on the 4th IMO GHG study, urged the IMO to reopen the MBM discussion as soon as possible, and more specifically to revise the Initial IMO Strategy so as to bring the MBM discussion forward to the short-term measures and establish an additional intersessional meeting on MBMs before MEPC 76.

Last but not least, discussion at MEPC 75 included a submission by all major shipping associations, which was not named an MBM (ICS, 2019). The measure proposed the establishment of a mandatory contribution fund per tonne of fuel oil purchased. Revenues are estimated at 5 billion USD, aiming to enhance R&D towards low and zero-carbon fuel, and promote the development of commercially viable zero-carbon emission ships by the early 2030s. Based on the assumption that the yearly fuel oil consumption is approximately 250 million tons, the co-sponsors propose that the quantum of the R&D contribution would be 2 USD per tonne of marine fuel purchased, and the program would last over ten years.

MEPC 75 (November 2020) discussed the last two proposals and deferred action for a future meeting. There was considerable spread of opinion among IMO Member States and other stakeholders on the necessity and urgency of either proposal.

CHAPTER 3: Comprehensive literature review of maritime MBMs

This chapter provides a comprehensive literature review of maritime MBMs. To that effect, the review is divided into two main parts. Section 3.1 is on MBMs in the scientific literature and Section 3.2 is on MBMs in the grey literature. Some (but not all) of this material draws from the recent survey paper by Lagouvardou et al. (2020).

3.1 MBMs in the Scientific Literature

This section collects, categorizes, and examines the research conducted on MBMs, as found in the scientific literature. The section also attempts to classify the literature according to the type of MBM examined, even though some publications examined more than one MBMs. To that effect, the following categories are examined in the sections that follow: bunker levy, rebate mechanism (RM) built into a GHG Fund, global maritime ETS (METS), policy mix tax on emissions and direct subsidy, global tax and cap and global sectoral crediting, EU ETS, and miscellaneous literature.

3.1.1 Bunker Levy

It should be mentioned at the outset that there is a large body in the maritime logistics/ transportation science/ operations research literature that deals with ship speed optimization, that is, papers that formulate and solve optimization problems in which ship speed is one of the decision variables. To the extent that fuel price is one of the main inputs influencing ship speed, some of these publications also examine, either directly or indirectly, the impact of a bunker levy on ship speed. In parallel, there are also other publications, falling more under the maritime economics umbrella, that examine the impact of a bunker levy. See Psaraftis and Kontovas (2013) and Psaraftis (2019b) for surveys of speed models.

One of these papers is by Gkonis and Psaraftis (2012), who, in the context of developing models that optimize the speed of tankers, estimated the CO_2 reductions for tankers for several bunker levy scenarios, and found that a 50% emission reduction for a single VLCC can be achieved with a fuel price at USD 1000 per tonne. In an earlier study, Devanney (2010) investigated the emissions reduction potential of a significant bunker levy. In his study, he estimated that with a price of HFO at USD 465 per tonne, a bunker levy at USD 50 per tonne would achieve a 6% reduction in total Very Large Crude Carrier (VLCC) emissions. A USD 150 per tonne levy would result in an 11.5% reduction.

Cariou and Cheaitou (2012) compared an international bunker levy and speed limits in the EU. The study concluded that, firstly, a regional speed limit does not automatically reduce the amount of CO_2 emitted on a global scale, and secondly, by assessing the two options, a regional speed limit is a suboptimal measure than a global levy on bunker fuels. The paper concluded that although an internationally agreed bunker levy is taking too long to agree upon, the IMO policy option, based on the polluter pays for the marginal damage generated and therefore, remains the preferable option comparing to a speed limit.

Lema et al. (2017) developed a fuzzy logic model that addressed the proposed MBMs submitted at the IMO. The developed tool synthesized a large amount of information and compared them with the results of the feasibility study conducted by the expert group at the IMO. The results showed that the GHG Fund and the ETS have similar results in emissions reduction potential, but have a significant difference in cost. More specifically, the study concluded that the GHG Fund could achieve the highest emission reductions with minimum cost.

Kosmas and Acciaro (2019) studied the allocation of the costs from the enforcement of the levy between the ship-owners and shippers, and concluded that the market conditions, the freight rates, and the level of capacity utilization affect it. In their paper, also, they analyzed the economic and environmental implications of two types of levy on shipping bunker fuels; a unit-tax per tonne of fuel and an ad-valorem tax enforced as a percentage of fuel prices. Both scenarios lead to speed and a fuel consumption reduction equivalent to an improvement in energy efficiency, and result in the industry's profit decline, the extent of which depends on the structure of the levy and the market conditions. By utilizing the pass-through cost theory (i.e., widely used by many industries to explore cost allocation among the supply chain), the paper concluded that when the market conditions are favorable for the shipping industry, with buoyant demand and high freight rates, cargo beneficiaries will pay a higher percentage of the tax costs and vice versa.

Psaraftis (2019a) compared speed limits and a bunker levy, both on a global scale. The paper reached the conclusion that even though GHG emissions can be reduced by both measures, speed limits entail various distortions and would not incentivize improving energy efficiency. For a rudimentary containership scenario, he estimated that on a base bunker price of USD 500 per tonne, a levy of equal magnitude would achieve 50% reductions in CO_2, taking also into account the CO_2 emitted by the extra ship capacity deployed to maintain throughput.

Giovannini and Psaraftis (2019) developed an optimization model for a fixed route liner shipping scenario which, among other parameters, incorporated the influence of fuel prices into the overall decision process. A flexible frequency scenario was considered and it was seen that increases in fuel prices could lead to significant reduction of speeds and therefore CO_2 emissions.

Zis and Psaraftis (2019) investigated various operational measures to mitigate and reverse the potential reverse modal shifts due to the possible increase of fuel prices as a result of the 0.1% sulphur limit as of 1.1.2015 in northern Europe. More specifically, the study focused on the RoRo sector and examined the effects of higher costs due to compliance with the lower sulphur requirements in Sulphur Emission Control Areas (SECAs) to the ship's speed. The study concluded that in the case of high fuel prices, reducing the sailing speed, along with decreasing the time spent in port, provide higher fuel savings than the loss in revenue. Finally, the study showed that with low fuel prices, the investment in low sulphur technology has a long payback period even on the most fuel-demanding vessels.

Psaraftis and Lagouvardou (2019) argued that revenues from a carbon levy could be used to boost R&D and technology deployment. The Norwegian NO_x-fund is an investment RM (rebate mechanism) that has been applied with excellent results and aims to stimulate the uptake of abatement technology. However, in the case of a low levy, then the industries will not have enough incentives to invest in a new, environmentally friendly technology. The risk of their investment will have a lower return outcome than simply paying the fee. Therefore, the levy's level and the parties that will bear the administrative role of the levy collector are important parameters of the scheme and should be further analyzed.

The same study addressed some of the challenges of implementing a bunker levy in shipping. More specifically, regarding which ships will be subject to the levy, the authors conclude that for competition distortion avoidance, all ships should be subject to the levy, possibly exempting ships of very small size (below 400 GRT). Any exclusion, differentiation, or rebate schemes should be carefully designed and include criteria such as the ship type, size, flag, and age or a benchmark on EEDI, on the attained speed and on any technological advances that are incorporated on the vessel's equipment and therefore, improve their efficiency. The authors also agreed that the levy should be a function of the type of fuel used. Fuels with a low carbon footprint should be taxed less in comparison with carbon-intense fuels like fossil fuels. Furthermore, regarding the level of the levy, a low levy between USD 0.5–5 per tonne of CO_2e would have negligible effects and would mainly raise money for R&D. A medium levy between USD 5–75 per tonne of CO_2e would have moderate effects, whereas a high level of tax of more than USD 75 per tonne of CO_2e would achieve more significant results, rendering the alternative fuel solutions more cost-efficient. Besides, regarding the timing of the levy, the study proposes a gradual phase-in schedule starting in 2023 and progressively increasing until 2050. Additionally, regarding the administrative body, the authors do not conclude but list the options (individual body of the IMO scheme based on the International Oil Pollution Compensation Fund (IOPCF)). The final question that the paper tried to address is regarding how and to whom the proceeds of the levy will be distributed. To such a complicated matter, the authors mentioned the challenges of carbon leakage and competition distortion among the participants, and raise the concerns that strict auditing is needed in any case.

Last but not least, Psaraftis and Haralambides (2020) considered a combined bunker levy and speed limit scenario. The purpose of that work was to examine combinations of these two sets of measures and evaluate trade-offs between the two so as to reduce maritime GHG emissions. To that effect, iso-GHG curves were introduced and recommendations were made as to what combinations of speed limit and bunker levy could best achieve a prescribed GHG reduction target.

3.1.2. Rebate Mechanism (RM) built into a GHG Fund

This measure, initially proposed at the IMO by the International Union for the Conservation of Nature (IUCN) in 2010 (IUCN, 2010) (see also Chapter 2), aimed at the compensation of developing countries from the financial impact of an MBM. In their paper, Shi (2016) conducted a comprehensive assessment of the several proposals submitted at the IMO. Their investigation concluded that among the proposals, the GHG Fund is much more environmentally practical and cost-effective. However, the study supports that the scheme standalone embraces neither the Common But Differentiated Responsibilities (CBDR) and the No More Favorable Treatment (NMFT) principles. Therefore, the authors argued that an add-on Rebate Mechanism built into a global GHG Fund is more likely to be environmentally practical, cost-effective, and feasible. Finally, because it incorporates economic incentives and the CBDR and NMFT principles, it would be more attractive for developing countries.

3.1.3. Global Maritime Emission Trading System (METS)

The implications of a global METS have attracted the interest of the scientific community. Shi (2016) argued that due to the staunch opposition of its primary stakeholders, the implementation of METS is infeasible. The doubts rely on the creation of distortions in international trade. The study also supports that a METS is expected to face significant opposition from developing countries. Current METS proposals at the IMO have incorporated both the CBDR and the NMFT principles, not in a cost-effective way. Norway's approach, for example, incorporates the CBDR principle by providing exemptions for ships below specific sizes and ships on international voyages to SIDS and LDCs.

Ben-Hakoun et al (2016) discussed different MBMs, and narrowed these down into two main avenues; the international compensation fund, and a maritime ETS. They quantitatively analysed the potential of an ETS on emissions reduction from shipping compared with a business as usual scenario. They ran their model for several fuel price scenarios and shipping sectors, and conclude that a global ETS could result in a reduction between 54 and 93% from 2007 to 2030, whereas under BAU there would be a 324% increase. However, we do note that such results (following sensitivity analyses on too many parameters) should be treated cautiously.

Zhu et al. (2018) tried to investigate the effects of METS on a container fleet operation formation strategies and the respective CO_2 emission levels achieved. The results showed that a METS can incentivize operators to implement new technologies on their vessels and invest in renewing instead of retrofitting the existing fleet. More specifically, the authors argued that the ratio of bunker costs to total voyage costs, even at exorbitant CO_2 prices, is much higher than the ratio of CO_2 allowance expenses to total voyage costs. Therefore, the higher the bunker prices, the more noticeable the impact of a METS will be in achieving the decarbonization targets.

Gu et al. (2019) supported that the scheme will incentivize the industry to invest in carbon neutral technology in the long term. Moreover, the increased cost in allowances may force companies to adjust their operational practices by, for example, utilizing slow steaming in the short term. However, other parameters such as bunker prices and charter rates can influence the operational decisions significantly. Therefore, the final total reductions on emissions will rely on the market conditions. The study supported that the implementation of METS can even lead in emissions increase in cases where, for example, bunker prices and charter rates are low, allowances cost is significantly high, or the scheme, instead of being global, is applied on a regional base.

Balcombe et al. (2019) supported that the implementation of a METS poses various challenges. METS will increase transaction costs related to trading, monitoring, and verification of the allowances for both participants and regulators. This increase in transaction costs, also in combination with a low volume of allowances, will create sub-optimal trading conditions, which may not result in emissions reduction. Another drawback of the system is that developing countries will be burdened by the financial consequences more than their developed counterparts. However, the authors support that precertification and approval of the credits will minimize the risk of carbon leakage. With regards to the utilization of the system by ship-owners, the study claims that borrowing credits must be restricted in order to eliminate the risk of companies simply offsetting emissions and not restricting them. The high volatility of price in a METS will help companies to save in allowances when the price is lower and use them in the future when carbon prices rise again. Finally, the study welcomes any subsidy or rebate mechanism as it could accelerate the transition to low carbon technologies and may also assist in mitigating the economic burden on developing countries.

According to Wang et al. (2019), the imposition of a METS implicates a surcharge on the bunker fuel used (from the tramp operator point of view). The induced cost is a product of the trading price of CO_2 allowances in the spot market (P) and the emission factor (3.2 tonnes of CO_2 per tonne of fuel). Provided that the volume and price of the allowances are both inputs, the incorporation of METS indicated the introduction of an additional fee of $P \times 3.2$ for each tonne of fuel consumed, irrespective of the volume and price of CO_2 allowances initially. An increased price of CO_2 could induce shipping companies to cut back on long-term contracts or decrease their fleet cover for their increased expenses. This may result in modal changes from short sea shipping to land-based modes of transportation and potential carbon leakage. Setting the emissions and deciding the amount of free allowances given away by public authorities are significant challenges of the system. Companies may purchase allowances through auctioning, and taking advantage of low prices usually comparable to the spot market to avoid meeting their obligations later on where the spot price may fluctuate widely. Both cases can lead to carbon leakage and pose the risk of emissions from shipping to increase.

Chai et al. (2019) focused on the operational challenges of the scheme. More specifically, the large number of ships trading internationally requires many resources dedicated to setting up, operating and reviewing the system. Moreover, the high variability in each ship’s fuel consumption increases the complexity of allowances allocation significantly. The study supported that a METS with full auctioning of credits would be equivalent to a bunker levy in the amount of funds generated. Taking all the above under consideration, the authors concluded that a bunker levy is more effective than METS for regulating shipping.

Tran et al. (2020) investigated and ranked the critical success factors (CSF) of sustainable shipping management (SSM) by utilizing a fuzzy analytic hierarch process. The analysis showed that (1) the stakeholders' focus, (2) the intra-firm management, (3) new technology acceptance, (4) the inter-firm collaboration, and (5) the strategic fit are the factors of high importance in descending order. The results can assist in the policy formulation progress and indicate the critical aspects that shipping companies should focus on in order to reach the sustainability goals.

On a comparative assessment, Psaraftis and Lagouvardou (2019) argued that experience from existing ETS applied globally showed a tendency of weak carbon prices due to an oversupply of emissions certificates (i.e., too many allowances were given free of charge, and demand was overestimated, given unforeseen market developments). Additionally, methods to adjust the price were not included in the scheme's architecture. As a result, the price was not strong enough to incentivize the desired investments in low carbon technologies. On the other hand, a carbon levy has stable carbon prices, and therefore, energy producers invest without the fear of volatile regulatory costs. Moreover, in the case that unexpected market conditions lead to significantly low carbon prices, the implementation of a levy has the advantage to establish a specific and continuous price signal, whereas a cap-and-trade does not encourage reductions beyond the emissions target.

3.1.4. Policy Mix Tax on Emissions and Direct Subsidy

Tanaka and Okada (2019) developed a model that analyzed the investment behavior of a shipping company, the expected results in fuel efficiency and CO_2 emissions after the imposition of a bunker levy. The study claims that a policy mix that comprises of the levy and a direct subsidy is the optimal solution for an international shipping company. Based on a numerical analysis that clarifies the relationships between fuel price, including MBM tax, capital investment, and efforts towards fuel efficiency, the study shows that when the fuel price increases, the firm will seek to improve fuel efficiency and extend voyage distance, considering adequate cargo demand. According to the authors, as the fuel price with a tax increases, CO_2 emissions decrease. However, it is possible that, due to the rebound effect, companies will extend their voyage distance in order to earn additional revenue to counteract the financial burden caused by the policy. In this case, CO_2 emissions can even increase in the long term. Therefore, the level of the levy has a crucial role in the emissions reduction potential and, if set very high, can lead to an increase of the effort cost and, therefore, to a rise in the marginal costs of emission reduction.

The same study argued that a policy mix consisting of a tax on emissions and a direct subsidy can eliminate the rebound risk by rewarding companies for their effort to improve fuel efficiency. Vessels that incorporate energy-efficient technologies to achieve emissions reductions will be funded back by the revenue from the emission tax. This study provided insightful results that can be further analyzed, and incorporated technical information as well as details on actual econometric values that apply in Shipping.

3.1.5. Global Tax and Cap and Global Sectoral Crediting

Miola et al. (2011) proposed a Maritime Emission Reduction Scheme (MERS). MERS is a hybrid system that consists of a total CO_2 emissions cap and tax on all emissions. Revenues will be collected to a fund and be used in various means, such as for in-sector technical and operational improvements, offset credits purchasing in the emission trading markets, or adaptation mechanisms for developing countries. The authors examine the case with an emission charge of 40% of the market price for CO_2 allowances and a predetermined cap based on the 2005 emission levels, which decreases by 1% annually. A tax of USD 10 per tonne and a global fleet coverage of more than two-thirds, would collect USD 3 billion annually to the fund. According to the report, the levy would lead to total environmental benefits in terms of lower abatement of 15 GT CO_2 before 2050 due to the technical and operational industry improvements and 8 Gt CO_2 due to emission offsets. The proposed scheme outweighs a global METS as it avoids the operational costs of setting up, monitoring and reviewing of a global trade system.

The same authors also investigated a Maritime Sector Crediting Mechanism (MSCM), a voluntary scheme utilizing baselines for the entire sector's emissions. A reduction of emissions below that baseline will generate tradable credits for the whole sector. Creating carbon marketable incentivizes the industry to reduce the CO_2 emissions, but due to the voluntary nature of the scheme, there is no enforcement to support the system. Generally, this mechanism aims to encourage developing countries to engage in GHG emissions reduction. Since, according to the system's architecture, there is a need for demand in offsetting credits, MSCM can only be enforced as complementary to a cap-and-trade system. As MSCM is voluntary, the supply and demand of credits from this system is highly erratic.

3.1.6. EU ETS

Miola et al. (2011) also examined the inclusion of shipping in the EU ETS. Regional policies, such as at a European level, face several obstacles when enforced in international sectors like, for example, emissions allocation, carbon leakage, allocation of permits, handling the great diversity of ship types, sizes, and fuel consumption, and unpredictable transaction costs. The above aspects, and with the fact that ships can easily change their jurisdiction under a flag of convenience, have set barriers to the United Nations Framework Conference on Climate Change (UNFCCC) and the IMO to implement a clear-cut GHG reduction policy.

More specifically, the study argued that both global and regional trading policies may induce high transaction costs. As economies of scale emerge, this issue can affect more ships with low carbon emissions and result in raising the cost of European shipping along with creating competitive distortion in the whole sector naturally. Therefore, excluding small installations from their monitoring and reporting requirements by minimizing, for example, the frequency of compulsory inspection visits or by exempting them from the trading system altogether, can be beneficial for the implementation of an ETS. However, anticipating and integrating these dynamic issues under the NMFT principle for all ships would possibly manage to address possible challenges for vessels regarding compliance with the legislation.

Wang et al. (2015) argued that the implementation of a regional scheme could induce competition distortions. For example, risks of route networks' reconfiguration are significantly crucial. In this way, ships can avoid compensation for their emissions in an EU ETS scenario. The hypothetical case includes transshipments in the port of Dubai right before entering the EU ETS waters. This would lead to adjustments in frequency, voyage distance, and fuel consumption of vessels, and render Dubai a developed hub. It would be beneficial for the scope of the analysis if extended models were created that take into consideration additional inputs that include the outcomes and trade-offs between conformity and carbon leakage under a regional ETS. The model shall incorporate a stochastic demand specification since market conditions in shipping are incredibly uncertain. However, within the framework of this study, a static economic model is developed that investigates the effects of ETS under current market conditions, global competition, and available technology. The results show that companies can alter their energy efficiency either through building new vessels (longer to medium- term) or by incorporating energy efficiency operational measures (short-term). However, more accurate conclusions regarding the response of the industry in an EU ETS scenario should be further investigated using dynamic models that address the related managerial decisions.

Koesler et al. (2015) addressed the inclusion of Shipping in the EU ETS from an economic and a legal point of view. The authors analyzed the research question using a general equilibrium approach. The results showed that economic-wise implementing a regional scheme would burden disproportionately the routes on EU territorial waters and impede cost-efficient emission abatement among regulated ships. Furthermore, from a legal point of view, the study claimed that an EU ETS violates the World Trade law and poses a serious dilemma for future inclusion of shipping in the scheme.

3.1.7 Miscellaneous Scientific Literature on Maritime MBMs

Below we list some additional MBM references for which it was not obvious where in the previous classification scheme they could fit.

Lema and Papaioanou (2013) raised concerns regarding the decision on which MBMs should be enforced in shipping as the issue is mainly a political decision. The paper outlined several groups of opinions regarding the need for an MBM. According to the authors, the final decision is a matter of political strength that each country has at the IMO. In their opinion, what should be considered is that cost effective operational and technical emission reduction measures are available to the shipping sector, although there might be some barriers in the uptake of many of these measures.

Rahim et al. (2016) discussed the accountability practices amongst shipping corporations and related regulations. The authors call that stakeholders in the shipping industry explore the potential of MBMs as a means to encourage and mandate the disclosure of shipping emissions reduction performance. The authors after discussing these issues, proceed with an example from the CO2 emissions of the top 10 corporations as ranked by alphaliner.com. The authors analyzed data based on the annual reports of these corporations and conclude that the disclosed information in these is insufficient, and it is not possible to calculate the emissions based on these data. The authors then discussed several MBMs peripherally, by grouping them into 3 classes; environmental fees, tradable permit schemes, and liability rules, that all share a goal of pushing corporations to internalize the cost of their GHG emissions. The authors mentioned the seven classes of MBMs put in the table by the IMO, and note without going into much detail that probably a mixture of two or three MBMs would be necessary in order to provide solutions for the different flaws presented in each MBM. The authors concluded that current measures (at the time of writing) did not encourage change fast enough to achieve progress and a combination of MBMs would be required.

Zhang (2016) presented the main technological and operations measures for emissions reduction in shipping, and also briefly summarized the 11 MBMs under consideration in the IMO, and focuseded mainly on the issue of CBDR, considering also the current economic downturn. The author concluded that both sides (developed and developing countries) must reach some sort of compromise on how to go about reducing emissions from shipping.

Morimoto (2018) considered different approaches under discussion for the reduction of GHG emissions in international shipping. The author first presented the main differences in targets (absolute level reductions, and intensity improvements), and then argued that an intensity target is more appropriate for the case of shipping. We do note that the paper was written before the Initial IMO Strategy that actually set goals on both absolute and intensity levels. Then the author subsequently presented three potential types of mitigation; a carbon budget approach, a similar reduction, and an efficiency based approach. The first approach considers an available budget for the shipping sector, based on the Kyoto targets for the 2 C limit on global warming. The similar reduction refers to setting the same “pace” of reductions as in other sectors, or setting the targets in a way that the Marginal Abatement Costs required to achieve reductions are the same as in other sectors (so that it is a fair approach). Finally, the efficiency based approach considers the technical feasibility of emissions reductions based on existing and up and coming technologies. Morimoto (2018) speculated that if the Initial strategy would have included a reduction target for international shipping (which at the end it did), then MBMs could play a significant role in later stages of this quest. These MBMs could also provisionally include offsetting (buying credits from other sectors), but the author notes that uncertainties on price of credits would complicate this procedure.

Bai and Ma (2018) focused on Arctic shipping, but from a different perspective in the sense that they explore how regulation could limit shipping activities in these areas due to the more severe environmental damage from Black Carbon (BC) emissions (for more on the effects of BC on climate change see Zis et al., 2014). The main narrative of the paper was on the targets of the Paris agreement and their implications on reducing international shipping emissions. The authors briefly presented the 11 MBM proposals as presented in MEPC60 (2010), and concluded that MBMs could also be used to strike an agreement between states and the industry so as to protect the more vulnerable Arctic environment.

Cullinane and Cullinane (2019) focused on the effects on ports from attempts to reduce emissions from shipping. While the paper focused on ports, MBMs were described and grouped into the following main categories; an international fund (as proposed by Denmark and Japan) whereby flag states via contributions to it would offset emissions, a global ETS (open cap and trade) that would involve full auctioning, or a trading scheme using energy efficiency credits based on the EEDI. The authors discussed the impacts of this measures on port operations, as the affected ships would spend part of their time in the proximity of and at ports.

Varela (2019) presented a historical overview of MBMs in shipping and relevant discussions at the IMO. After a very critical presentation of what has already transpired and what the author perceived as missed opportunities (Kyoto and Paris Agreements), the author raised doubts whether MEPC "works", and whether the 2018 strategy is an environmentally friendly strategy, or merely an industry lobby with profit oriented policies.

Ding et al. (2020) examined the impacts of a carbon tax on route choice, considering a Europe to North-East Asia service and the option of using the Suez canal vs the Arctic (via the Northern Sea) passage which is approximately 40% shorter in sailing distance. The authors compare various levels of carbon tax (fixed or progressively higher values) and different configurations of fuel used (from low sulphur fuel up to LNG). The authors estimate that a carbon tax would result in being responsible for between 12 and 30% of the total voyage cost, which could significantly affect the profitability of the service.

3.2. MBMs in the Grey Literature

The following publications refer to research conducted on the field of MBMs by authors or organizations outside traditional academic publishing and peer-review.

A New Climate Institute report (Kachi et al. 2015) on behalf of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety studied three different options for an MBM for international shipping, utilizing four criteria for choosing the appropriate scheme. The examined MBMs were (i) an offsetting scheme that requires ships to pay for their GHG emissions by purchasing emission reduction credits, (ii) a METS that places a cap on the total GHG emissions and allows companies to trade their credits and (iii) a "climate levy" that places a price on every tonne of GHG emitted from ships. The report concluded that a climate levy imposed at an appropriate price level is most likely to lead the sector in reaching its decarbonization targets, can address both the NMFT and CBDR-RC principles, and has significantly lower transaction costs than the other options. A "climate levy" that increases progressively based on the cost difference of alternative and fossil fuels can induce the change needed towards no fossil fuels. According to the authors, and compared to a METS, a "climate levy" provides foreseeable and stable price signals, which leads to greater certainty over investments in low carbon technologies. Furthermore, the authors find a METS to be more of a composite measure to apply, and the experience of highly volatile prices is likely to provide investors with a clear carbon price incentive. Additionally, the authors claim that a METS can lead to market manipulation since the six largest companies that have a market share of 50% can have significant effects on transaction costs.

A report published by UMAS (Smith et al., 2016) aimed to investigate the potential routes and scenarios in the context of broader decarbonization consistent with the Paris Agreement (COP21). The study investigated various cases with targets ranging from achieving full decarbonization by around 2035 (temperature stabilization 1.5 degrees above pre-industrial levels) to keeping CO_2 emissions from shipping at current levels. This study considered a selection of assumptions to simulate how the shipping sector will evolve to meet the examined targets in its total CO_2 emissions. The model ran from 2010 until 2050 in the baseline year of 2010 and stimulated the evolving decisions made by different stakeholders in the industry. The model used a carbon price to achieve the specified reduction goal for CO_2 emissions. The results from the simulations showed that with no further policy, expectations are that CO_2 emissions from international shipping will rise by at least 50%. Shipping would need to decrease its total carbon intensity by more than can be accomplished with energy measures alone, in order to achieve absolute reductions while meeting an expected increase in transport demand. The study also suggested that the use of extremely low operating speeds in conjunction with fossil fuels is preferable to renewable fuels such as biofuels and hydrogen, along with energy efficiency interventions. As for the offsetting schemes, the study showed that it is quite dangerous to assume that shipping decarbonization can be achieved entirely through offsets because their high volatile price can even lead to increased emissions.

A report of the International Monetary Fund-IMF (Parry et al., 2018) concluded that a carbon tax is preferable to a trading system or other offsetting mechanism because it provides certainty over prices, is simpler to administer, and leads towards technological and operational opportunities for both new and existing vessels. Taxes should be collected at an international level through the establishment of a fund administered by the IMO. Rates should be following other pricing schemes (around USD 5–30 per tonne of CO_2) for avoiding distortions in completion among transportation modes. The report studies the establishment of a carbon tax starting at USD 75 per tonne of CO_2 in 2030 (USD 240 per tonne of bunker fuel) and rising to USD 150 per tonne in 2040. Results show emissions below business-as-usual (BAU) reduced by 15% in 2030 and by 25% in 2040, total revenues gathered about USD 75 billion in 2030, and USD 150 billion in 2040 while shipping costs increased by 0.075% of GDP in 2030. The report highlighted that establishing a performance standard (EEDI) for new ships has only one-third of the effectiveness of carbon taxes (for the implied CO_2 price). Finally, regarding compensation mechanisms for developing countries, the report claimed that because the financial burden of maritime carbon taxation is generally small concerning countries' GDP, any global enforcement of the tax should be feasible.

A report by BHP Group et al (2019) (also including DNV GL) examined whether a levy on bunker fuels can be an effective way to reduce GHG emissions from shipping. The report highlighted that substantial decarbonization needs a carbon pricing mechanism that provides disincentives for the consumption of carbon-intensive fuels and incentives for R&D. The report argued that in comparison with an ETS, a bunker levy is a more structured and transparent mechanism as it consists of a predetermined contribution that will stimulate the uptake of abatement technology at an early stage. Proceeds should be deployed for research, trials, implementation, and scaling of alternative fuels and zero-carbon technology to ensure that cost to the buyer reduces over time. When collected by a supranational entity like IMO, the risk of carbon leakage among the states is reduced. Finally, revenues generated by the levy can be distributed to the UNFCCC Green Climate Fund (GCF) and the UN Global Environment Facility (GEF).

Krammer and Smith (2017) provided an analysis of impacts of various GHG mitigation measures on New Zealand, including the territory of Tokelau, of potential IMO targets and measures to control greenhouse gas (GHG) emissions from international shipping, including MBMs. Among other findings, if a carbon price of 25 USD per tonne of CO_2 is introduced in international shipping, the study found that New Zealand's real income would drop by approximately 16USD per person. These price changes materialize into a drop of 0.076 USD billion in GDP or a drop of 0.038% in GDP respectively and on a once only basis if the carbon price remains constant over time. On Tokelau the study found that it is very likely that Tokelau is more prone to price shifts in international transport. The study argued that if Tokelau is included in the IMO GHG reduction policies, its economic impacts from MBMs in international shipping are likely to be above world average.

NZIER (2018) assessed the economic and environmental impact of international maritime measures on New Zealand. A model of the New Zealand economy was used to estimate the potential economic impacts of higher fuel prices and a shift to more slow/super-slow steaming that will be associated with New Zealand acceding to MARPOL VI. Neither scenario is found to result in significant economic costs, with GDP impacts between USD2 million and USD33 million in the higher fuel price scenario; and between USD4 and USD10 million for slow or super-slow steaming. The commodities affected by slow or super-slow steaming are chilled exports to the EU, which account for just 2.6% of total merchandise exports.

A working paper of the World Bank Group (Halim et al., 2019) investigated the economic impacts of various GHG mitigation measures on states, using model-based analysis. Specifically, the results of the analysis showed that the enforcement of GHG mitigation measures will raise transportation costs and import prices of goods, and will reduce the number of commodities traded internationally. Based on that, the study focused on the impact of a carbon price applied to bunker fuels on state gross domestic product (GDP) and concludes that in the range of USD 10–50 per tonne of CO_2, transport costs will increase by 0.4% to 16%. This increase, however, would only marginally raise the import prices of goods (by less than 1%). Therefore, the impact of a carbon price set between USD 10–90 per tonne of CO_2 on national economies is expected to be modest (−0.002% to −1% of GDP).

We note here that we shall revisit the issue of impact on states in Chapter 5, as it is one of the criteria of the comparative cost-benefit analysis.

A report by Transport and Environment (Abbasov, 2019) gathered and analyzed raw ship performance data from the EU Shipping MRV for translating them into policy, relevant and transparent to the relatable public knowledge information. The study revealed that a container shipping operator, MSC, together with coal power plants, were on the list of the top 10 EU emitters for 2018. That year the company was responsible for 11 million tonnes of CO_2 from operations falling under the EU MRV scope. If shipping were part of the EU ETS, the report claims that MSC would be the EU's 8th most emitting operator. Furthermore, the report compared the amount of CO_2 emitted by ships traveling to or from some EU countries with the amount of CO_2 emitted by the total national passenger cars of those countries. There are many examples of EU Members where the shipping emissions attributed to their ports are more significant or comparable with the total amount of CO_2 emitted from passenger cars. Therefore, Abbasov claimed that not regulating shipping emissions not only exempts abundant sources of CO_2 in major European cities and countries but also obliterates the decarbonization gains achieved by other sectors. Finally, the report recommended including EU shipping in the ETS to ensure that the sector will compensate for its carbon pollution. According to the author, despite that EU ETS has been characterized by low carbon prices and has failed to bring the expected technological innovation, experience with the scheme allows the policymakers to re-design it in a way that maximizes its practical relevance. The establishment of a European Maritime Climate Fund (MCF) under the EU ETS, in which ships would pay directly to the fund a CO_2 levy proportional to their MRV emissions, was also a suggested solution according to the report. Responding to tax allocation challenges, the report concluded that in 50 euros per tonne of CO_2 price scenario, the extra amount paid by the consumers would be insignificant and a maximum of 0.55% of their initial price.

In February 2020, UNCTAD published a study that estimated the fleet renewal trends in shipping based on scrapping patterns (Hoffmann, 2020). Motivated by the recent statements of the Getting To Zero Coalition, of the urge for commercially viable zero emission vessels to enter the global fleet by 2030 in order to reach the decarbonization targets, the study used past scrapping patterns to show the future expected trend on demolitions. The study concluded that regardless of the percentages of the different type of vessels being demolished until 2030, new builds are not likely to burn alternative fuels by 2030. Therefore, the sector is urged to develop, implement and test the appropriate technology in order to meet the decarbonization targets.

Furthermore, in March 2020, another study of UNCTAD (Hoffmann et al., 2020) focused on the regulatory role of Flag States for enforcing the IMO rules on GHG emissions. Except from validating the compliance of the vessel with the regulations on emissions, each Flag State could provide individual incentives for ships under their jurisdiction to promote decarbonization. Major Flag States such as Panama, Liberia and Marshall Islands are significantly affected by the impacts of climate change and have a self-interest in applying the respective regulations. The aforementioned Flag States accounted for approximately 33% of global CO_2 emissions from shipping in 2019 and represented 34.86% of the world gross tonnage the same year. The study aims to encourage discussions on the role of Flag States for regulating the CO_2 emissions, and quantifies that commercial ships above 1000 DWT registered in the top 10 economies accounted for 67.15% of maritime CO_2 emissions. As of 1 January 2020, these 10 Flag States own 48.52% of the world fleet and 65.73% of the world gross tonnage. Finally, the study indicated that maritime CO_2 emissions have risen by 8% from 2014 to 2019 and CO_2 emissions among the top 10 Flag States have risen more steeply by 14%.

A report by the Swedish Lighthouse consortium (Lighthouse, 2020) assessed the overall design and consequences of including maritime transport in the EU ETS. The included aspects are geographical scope, allocation of allowances, time frame of implementation, as well as impacts on GHG emissions, economic impacts for the maritime sector as well as on early movers and modal split. The report examined several design alternatives both on global and regional cap-and-trade systems to address the GHG emitted by maritime transport, a few specifically addressing the EU ETS. Given the non-specificity of what exactly an EU ETS system may entail for shipping, the authors mentioned that the costs for the shipping sector would be determined mainly by 1) the price of allowances and 2) if allowances are given for free or if they are auctioned. A case with a price of allowances assumed at EUR 25 per tonne of CO_2, and where only 5% of the allowances are auctioned, was estimated to result in an estimated cost increase of 0.2 billion Euro for the included shipping sector. The other case, where the price is assumed to be EUR 70 per tonne of CO_2, and 100% of allowances are auctioned, would generate an estimated cost increase of 12.5 billion Euro. Assuming the same price level as in the low case (EUR 25) but different levels of auctioned allowances gives a range of 0.2 - 4.4 billion Euro. To set these cost increases into a context, the authors estimate that this would generate a price increase of between 0.6% and 33% per tonne of marine gas oil, assuming a price of EUR 630 per tonne of fuel.

How the maritime sector will respond to this price incentive is, according to this study, difficult to predict. Looking at the available data on abatement costs for the sector, the study found that there are some measures with low or even negative costs, mainly operational, meanwhile technical measures in the shipping sector are estimated to cost more also in comparison to abatement measures in other sectors included in the EU ETS. This, according to the authors, indicates that the inclusion of shipping in the EU ETS might not initially be enough to incentivize the implementation of significant abatement measures for the included shipping sector. However, the abatement costs are uncertain and will likely change in the future.

A study by Erasmus University (Streng et al, 2020) analysed the impact of emission pricing in the Green Deal on Dutch and European maritime transportation. The study discussed four types of market-based measures: 1) EU-ETS, 2) a levy/tax on fuel, 3) a levy/tax on emissions and 4) a brief elaboration on the alternative of subsidizing sustainable maritime transportation. The elaboration of the scenario analysis is carried by means of two critical uncertainties, a European versus global approach and second uncertainty is pricing versus subsidies. The study found that different market-based measures have positive and negative elements, which should be balanced by various stakeholders. It was also argued that the EU-ETS provides certainty about emission reductions, due to the cap of emissions which is set by the governance of the system. A downside is that the emission rights are at least partially traded on a marketplace, providing uncertainty about tariffs. For both the fuel levy as well as the emission levy, there is certainty about the tariffs, which provides the market with a fixed framework. In case of a fuel levy, the administrative burden is relatively low, which is however not the case for an emission levy. Both levy options lead to uncertainty about emission reductions, due to the possible evasion of the system. This evasive nature of the shipping sector is something that should be considered while implementing an emission pricing scheme. Flagging out, re-routing and bunkering elsewhere are options that have a high probability of happening for some shipping markets, which provides a high risk to the effectiveness and efficiency of the policy and thus carbon leakage. For increasing the effectiveness in pricing emissions in shipping, the study found that effective carbon pricing requires a combination of policies which is likely to be more dynamically efficient and attractive than a single policy.

A study commissioned by the International Chamber of Shipping (ICS) and the European Community Shipowners Associations (ECSA) commented on the inclusion of shipping into the EU ETS (Hughes, 2020). In the study, the legal, technical, practical and political implications of application of the EU-ETS to international shipping, and potential benefits of alternative Market-Based Measures (MBMs), were analyzed. The study identified a multitude of problems if a such a scheme goes forward. Among other things, the study argued that some non-EU governments may reasonably ask why they should continue to work on an internationally negotiated instrument if EU Member States are actively pursuing their own unilateral measure. The consequences of this could be that other nations/regions decide to develop their own unilateral schemes independently of IMO, or deliberations are moved back under the UNFCCC which is ill-equipped to deliver progress for this international transport sector, which is why this mandate – with the full support of EU States – was given to IMO. Undermining the progress being made by IMO to reduce global shipping emissions also presents a significant risk for the efficiency of the shipping sector, as a proliferation of regional and national schemes to address GHG emissions from international shipping would in effect create a patchwork quilt of regulations globally, introducing barriers to smooth operation of ships on international voyages and so to international trade.

A similar stance was taken by another shipping association, the World Shipping Council (WSC), which represents container carriers. In a recent discussion paper (WSC, 2020) many problems (legal and other) were identified should the EU proceed with an inclusion of shipping in the EU ETS in which the coverage is the same as the coverage as that of the EU MRV. The study recommended that if the EU goes ahead with such a scheme, coverage should be limited to intra-EEA trips only. Among other things, the WSC examined what would happen if, perhaps as a retaliation, countries like the US, China or Brazil move to implement similar regional ETS measure as well. The WSC argued that adopting an ETS with a large extraterritorial impact is likely to present a significant impediment to the development of a global solution because once in place, national or regional initiatives – particularly where revenue is concerned – are unlikely to be unwound or modified. Thus, instead of catalyzing global action, adoption of a regional regime with extraterritorial effect may preclude global action at the IMO.

Complementing the shipping industry's major associations opposition to an ETS was the recent stance of a major industry association representing charterers, Trafigura, which has recently come out with a report endorsing a substantial bunker levy (Trafigura, 2020). Trafigura argued that a levy between 250 and 300 USD per tonne of CO_{2e} should be imposed so as to make zero- and low-carbon fuels more economically viable and more competitive, and that this should be introduced at the IMO level. This translates into a levy between roughly 750 and 900 USD per tonne of fossil fuel. The proposed levy was calculated so that low carbon or zero carbon alternative fuels could become economically viable. Trafigura is against including shipping in the EU ETS.

CHAPTER 4: Literature review of relevant MBMs not previously included in analyses of maritime MBMs

This chapter briefly reviews other references on MBMs that have been considered in other sectors. The common objective of such instruments is to reduce negative externalities (typically environmental) via policies that affect economic variables and influence market decisions. Increasing the cost of a product or service can address the market failure of externalities, and succeed in partially internalizing these external costs. MBMs can therefore provide financial incentives for polluters to reduce their impacts, as well as lead to technological innovation with improved environmental performance. Chapter 3 has presented a literature review on MBMs in the maritime sector, and here we will present selectively some MBMs in other sectors that could under certain conditions be considered transferable at some level for maritime shipping.

4.1 Examples on environmental pollution

The European Environmental Agency (EEA) produced its fourth report on market-based instruments (MBIs)[6] for environmental policy in Europe, with an objective to list and review available market-oriented instruments for environmental policy makers. (Vos, 2005). The EEA categorizes MBIs into five main types:

- Tradable permits
- Environmental taxes
- Environmental charges
- Environmental subsidies and incentives
- Liability and compensation schemes

Permits work by providing a market incentive to trade rights of use (or emissions levels). Taxes directly influence price and thus the behavior of affected producers and consumers, while also raising revenues that could be redistributed to research and development. Environmental charges can partially or fully cover the costs of environmental services (for example waste water treatment and disposal). Subsidies and incentives can stimulate the development of new technologies, and encourage changes in consumer behaviour. Finally, liability and compensation schemes aim to ensure adequate compensation for damage resulting from harmful activities to the environment. An example of an EU-designed subsidy scheme in the maritime sector had been the subsidies for users switching to a maritime mode (Ro-Ro ship) through the Ecobonus system, or the Marebonus incentive for ship owners, to promote switching from road to maritime modes. Another maritime example is the International Oil Pollution Compensation Fund (IOPCF) that has been set up to compensate cleanup costs and damages from oil spills, even though IOPCF also covers liability issues that may not be relevant for an emissions setting. The exemption of international marine and aviation fuels

[6] The term MBI is more commonly used in this context.

from taxation can also be considered a subsidy, in the sense that such an exemption does not exist in land-based modes.

These systems have also been considered briefly in the academic literature. Carrese et al. (2020) reviewed the Marco Polo and Motorways of the Sea (MoS) programs in the development of the Trans-European Transport Network (TEN-T). The authors focused on the attention to short-sea shipping in the efforts of the EU to promote actions to encourage SSS. The subsidies to the user or the shipping companies are shown to be effective in leading to this modal shift. On a similar analysis, Zis et al. (2019) considered whether subsidies could be used as a potential mitigation measure for the negative impacts of the low-sulphur requirements for Ro-Ro shipping, that could on their own lead to a reverse modal shift towards land-based modes.

The same report presented a checklist for effective MBIs that should be directly transferable for the maritime sector as well. For example, the checklist among others suggested that the developed measures should be realistic (charge rates not higher than what is affordable), simple in their design and implementation, examining the potential trade-offs across the three pillars of sustainable development, inclusive of stakeholders etc.

4.2 Transport related actions

Perhaps the most comprehensive list of mitigation measures on the decarbonization of transport was provided by OECD's International Transport Forum (ITF). In their "Transport Climate Action Directory", a list of over 60 measures is provided with an overview of each candidate measure, its impact on CO_2 emissions, and a brief presentation of costs and co-benefits. All modes of transport are covered. The database is designed to help decision makers to translate their decarbonization ambitions into actions and achieve their climate objectives. It provides them with a range of options that can deliver concrete decarbonization outcomes for transport in their specific context. An online tool is also provided. See here for more details: https://www.itf-oecd.org/tcad [7]

As part of the database, some key references on related research are provided for each measure. Table 4.1 presents a breakdown of the considered measures per category (urban, national, international), adapted from the ITF list.

[7] We as DTU were invited to contribute to the database, which we did.

Table 4.1: A taxonomy of the decarbonization and mitigation measures in the Transport Climate Action Directory. Source: ITF.

	Education and awareness	Economic	Infrastructure	Innovation R&D	Regulatory	Logistics
Urban	Campaigns, public transport information	Road tolls, pricing measures, parking pricing, congestion charges	Express lanes, land use planning, park and ride, walking/cycling, urban rail, alternative fuel, integrated tickets	Bike sharing, ride sharing, on-demand public transport, mobility as a service	Incentives for low emissions/alt. fuel vehicles, parking regulation, car restriction, access regulation, speed limits	Urban consolidation centres, drop-off/pick-up points, electric vehicle delivery
National	Vehicle and fuel labelling	Road tolls, port pricing for international shipping, carbon tax for road vehicles, vehicle purchase/ownership tax, aviation fuel tax	Support on-shore power, promote inland waterways, park and ride facilities, electrification of rail, ITS to increase capacity, alternative fuel, multimodal freight interface	Rural mobility as a service, voluntary programs for logistics, digital platforms and asset sharing for freight	Green procurement, company car taxation & treatment of business travel, access regulation (high occupancy vehicles/ low emission lanes), high capacity vehicles, efficiency standards, incentives for low emission/alt. fuel regulation, internal combustion bans	Voluntary programs, ITS to increase capacity via automation/digitalisation
International	Voluntary programs to reduce emissions	Carbon pricing for shipping, aviation fuel tax, emissions trading (aviation), carbon offsetting (aviation)	ITS to increase capacity, rail for freight, multimodal freight interfaces	Voluntary programmes, asset sharing and digital platform	Vessel speed reduction, energy efficiency, high capacity vehicles, low-carbon fuel standards	Maritime logistics performance, voluntary programmes, ITS

The presented measures are not necessarily MBMs, but do have the potential to improve the energy efficiency of transport operations. Some of the measures pertain to a specific transport mode and are therefore not transferable to maritime shipping. For example, road tolls to decrease congestion, or parking schemes, cannot be envisioned for maritime transport. However, major maritime infrastructures that are now tolled have been around (for instance, canals).

In a European road transport setting, economic instruments such as fuel taxes, congestion charges, infrastructure charges and other MBMs can be critical in shaping user behavior, investor response, and ultimately, sector efficiency and emissions produced. The so-called "Eurovignette Directive" (1999/62/EC) set requirements for toll and user charge systems, where Member States choose to implement these on the trans-European road network. From 10 June 2008, with certain limited exceptions, these requirements apply to trucks weighing 12 tonnes or more. Directive 2006/38/EC of 17 May 2006 amended the Directive with a view to establishing a new Community framework for charging for the use of road infrastructure.

River tolls are also widely used in Europe. RIS (for River Information Services), legally specified by the EU framework directive EC/2005/44 and taken up in various EU policy papers (e.g., the 2011 White paper on transport) aims at simplifying the exchange of information between inland waterway operators and users across ountries' frontiers by standardization and harmonization. However, such tolls mostly aim at paying for infrastructure costs rather than reducing GHG emissions in inland navigation.

An interesting point can be made here as regards maritime canal tolls. As a result of the COVID-19 outbreak in early 2020 and the resulting precipitous drop of fuel prices, several container carriers on the Far East to Europe trade chose to sail the longer route around Africa so as to avoid paying the Suez canal tolls. This was actually done at higher speeds than before, as doing so proved cheaper than paying the Suez canal tolls. Sailing a longer route at a higher speed obviously entails a higher fuel consumption and more GHG emissions. In that sense, a toll that in other settings is used as a tool to reduce GHGs has in this particular situation resulted in doing just the opposite.

The ITF presents some information on specifically maritime-related measures, spanning from voluntary initiatives (support for cold ironing, port pricing for clean vessels) to actual MBMs such as ETS or carbon taxes. The other measures may not be directly relevant for maritime shipping, but could be transferable at some level. For example, the ITF considers that Intelligent Transport Systems (ITS – typically associated with road transport) can be used to increase the capacity of vehicles. Such approaches could also be used to improve the capacity utilization of vessels (for example Ro-Ro and containers), but also improve the capacity of the carried cargo itself (e.g. a more full container, or trailer transported on the ship). We must emphasize that the ITF merely presents a list of available options, and does not suggest that these could or should be enforced. Still, some positive elements of these measures could be considered in the future for the maritime sector as well, subject to tailoring these to be transferable for ships.

The ITS equivalent to maritime transport is the use of digitalization to improve logistical efficiency, load factor and other aspects of the shipping operation. Schemes such as virtual arrival, single windows, port call optimization, just-in-time arrival and better network design can play a critical role in the quest to decarbonize shipping, and the port sector is gradually increasing its visibility within the IMO discussions. The use of digitalization for sustainable shipping does not explicitly involve MBMs, even though an MBM could incentivize an increased use of digital technologies. For an analysis of the relevant issues see Fjørtoft and Berge (2019).

4.3 Carbon offsetting

The ITF lists "carbon offsetting" as an *aviation measure* and points to the International Civil Aviation Organisation's (ICAO) "Carbon Offsetting and Reduction Scheme for International Aviation" (CORSIA)[8]. Even though CORSIA also includes schemes on (for instance) sustainable aviation fuels and other measures that would reduce "in-sector" GHG emissions, one of its main thrusts is reducing GHG emissions via "out-of-sector" actions, that is, actions that reduce GHGs in sectors outside aviation. These actions are to be funded via "carbon offsets". A typical example of a carbon offset is paying an additional charge to make a traveller's trip carbon neutral. All major airlines offer such an arrangement. Making such a payment is of course on a voluntary basis. Among out-of-sector decarbonization actions, planting trees figures centrally within the CORSIA scheme.

The ITF estimates a requirement of a cumulative 630 million tonnes of CO_2 offsets until 2030 to achieve carbon-neutral growth from 2020. Current costs of carbon offsets are estimated between USD 1.6 - 4.6 per tonne, and under CORSIA the cost of offsetting for airlines will represent up to 1.1% of fuel costs in 2030. However, uncertainty is expressed on the extent that ICAO will be able to enforce CORSIA. It is also fair to say that, as things stand, there is no independent verification or certification of how monies raised under CORSIA are used.

Some academic studies have considered CORSIA and its impact on decarbonization. Scheelhaase et al. (2018) compared CORSIA with the EU ETS. They noted that originally the EU ETS was intended to regulate all flights to, from, and within the EEA, but was only applied to intra-EEA flights after considerable reaction from non-EU countries (see also Section 5.2.3 on legal issues related to EU ETS). The authors estimated that only 1.1% of global passenger traffic related emissions in 2017 were mitigated, as only emissions exceeding the "cap" – so called "Reduced Scope" (95% of 2004-6 average) needed compensation. They concluded that the "Full Scope" ETS would lead to the largest reductions in the short and medium term, higher than CORSIA. The overall recommendation was for the EU to continue the "Reduced Scope" regime beyond 2020, with a parallel coverage of international flights by CORSIA.

Lyle (2018) considered that the ICAO's basket of measures will not suffice for the reduction in global aviation emissions, and examined CORSIA from a legal and

[8] https://www.icao.int/environmental-protection/CORSIA

governance point of view. The author proposed a derivative of CORSIA and a more ambitious strategy that includes the incorporation of international aviation emissions in the nationally determined contributions (NDCS) of parties to the Paris Agreement.

In the same context, a report by NGO Transport and Environment (Murphy, 2019) argued that due to the weakness of the CORSIA target, issues inherent to offsetting, and concerns with how ICAO operates, implementing CORSIA in Europe represents a direct threat to Europe's existing climate commitments under the Paris Agreement. Over the period 2021-2030, the report argues that such a move would increase Europe's aviation emissions by 683.8 million tonnes of CO_2, which is equivalent to the 2017 CO_2 emissions of Poland and France combined.

Also, a report commissioned by the Environmental Defense Fund and undertaken by UMAS (Rehmatulla et al., 2020) outlined how the IMO can use the work done by ICAO on Sustainable Aviation Fuels as a starting point to guide the development of its own rules on low and zero-emission fuels. The report identified areas where ICAO's approach to Sustainable Aviation Fuels might be relevant to the definition and development of low and zero-carbon fuels for shipping. It also highlighted the potential shortcomings in ICAO's methodology.

Reducing maritime GHG emissions via offsetting is not included in the Initial IMO Strategy, at least explicitly. By this we mean that it is not clear if the IMO would allow discussion on an MBM that embeds carbon offsetting, if and when the MBM discussion resumes, and assuming that such an MBM is put forward. The use of monies collected under any MBM is anticipated to involve a serious discussion, and it would seem that such use in carbon offsetting activities cannot be a priori ruled out. Also it should be noted (see also Chapter 3) that offsetting was the intended main driver behind the GHG Fund MBM proposed by Denmark et al. in 2010.

Container lines such as MSC and CMA CGM have recently introduced carbon offsetting schemes for their customers. For instance, CMA CGM is providing four services enabling customers to analyze their environmental footprint, use cleaner alternative energy sources, and to offset the emissions generated during the transport of their goods. By mixing and matching the various solutions available, CMA CGM says its customers can make their cargo carbon-neutral while contributing to the overall energy transition in the shipping sector.

We have not been able to evaluate the merits of such schemes as regards how much GHG emissions can be reduced via them, mainly due to lack of information and time. We also note with respect to CMA CGM that the company seems to have embraced the use of LNG as a central decarbonization tool, even though there currently exist serious reservations on the use of LNG due to methane slip and lifecycle GHG emissions (see Psaraftis and Zachariadis (2019) for an exposition of the relevant issues).

4.4 Other examples

In a broader sense, there are policies designed to reduce certain activities that do not fall into the environmental agenda. For example, the limitation of tobacco or alcohol use is sought after via the introduction of increasingly higher taxes on these products. Other externalities include gambling addiction. Alexius and Grossi (2018) reviewed how Sweden addressed the issue and introduced “responsible gambling” as a concept. A balance was sought after between profit maximization and responsible gambling, ie not seeking maximizing profits by offering products that make it challenging for people to control their gambling. In practical terms, this was achieved through a reduction in marketing costs and advertisement, a relocation of machines from unsuitable locations, setting betting limits, and introducing voluntary blocking of the players themselves (account-blocking, restrictions on operating hours). The authors also presented “market-based decoupling” and the introduction of tools for online gambling, which forced users to provide information on the amounts of money (and time) they were willing to lose playing online. Interestingly, the “responsibility before profits” slogan was at contrast with the increasing dividends of the Svenska Spel (fully state-owned enterprise) to the state in the examined period.

While not directly applicable to the maritime sector, some lessons can be perceived as transferable, particularly with regards to the use of communication efforts. In general, it can be expected that any MBM will at some level increase the operating costs of shipping companies. As a result, this may be partially passed on to shippers, and consequently cargo owners and eventually the consumer. This was already seen following the lower sulphur limits within SECAs in 2015. Certain ship operators announced that the fuel price differential between low-sulphur fuel and HFO would be used in the calculation of the Bunker Adjustment Factor of their services. Therefore, the affected shippers were informed in advance of the higher transport costs they could be facing once the new limits were implemented. It will be therefore important to ensure that the public become aware of how any MBMs will be affecting the price they pay, and how they can actually contribute to an improvement in the environmental performance of the sector.

More generally, communication campaigns targeting shippers who can contribute to the greening of the maritime transport, for instance by purchasing carbon offsets that can be used for out-of-sector GHG emissions reductions (as per the previous section), are generally expected to increase the chances of success of these schemes. However, how much GHG emissions reductions can actually be achieved via such campaigns is not clear.

Finally, the allocation of radio and TV licences via the auction mechanism designed by the Federal Communications Commission (FCC) in the US was examined by De Vany (1998). The objective of the FCC was to achieve a high degree of allocational efficiency, while revealing the enormous value of the spectrum property rights. De Vany drew some parallels with the oil and gas drilling rights, where auctions are also used to allocate leases on federal lands. The author discussed several issues on the quest to realize the vision of a spectrum market, and concludes that over the years these licenses evolved to have property-like attributes. The main issues in the examined examples have to do with the reallocation of licenses, and the author provides an example where a licensee can sell a spectrum band high, and buy a different one low. This spread between the bid and offer prices would be the gain in efficiency from reallocation. Unless the government receives this spread on each transaction, there will be no revenue for the treasury and the motives for the auctions will vanish.

In a maritime MBM setting, auctions are typically associated with an ETS, however the design of the auction may vary and will not necessarily follow auction schemes established in other sectors. In a general setting, we note that there are various formats of auction mechanisms and not solely the more intuitive form where the highest bidder wins the auctioned item. In this most common form (typically known as "ascending-bid" or English auction), the auctioneer opens at a reserve price, which is typically the lowest price they are willing to accept. Subsequently, once a bidder has shown interest at that price, the auctioneer solicits higher bids until no bidder is willing to increase the bid further. A different format is the "Dutch" or descending-bid auction where the auctioneer starts at a high price, and keeps decreasing the bid until a bidder calls the price, and receives the item (or permit) at this value. In the former two mechanisms, all bidders receive information as their competitors bid. There are mechanisms where this information is not known. For example, the so called "first-price, sealed-bid" auction where each bidder submits a single bid in a sealed envelope. The auctioneer then opens all "sealed" bids and the highest bidder is announced. A variation of this mechanism is the "second-price, sealed-bid" auction, where the same procedure is followed, but the highest bidder wins the item at the second highest bid price. Additional variations exist when it comes to numerous items (or permits) being auctioned in the same format, where the auction continues until all items have been sold. The previous formats are used in different settings depending on which format fits best each type of auctioned item/permit. Which mechanism is selected will depend on the objective of the auctioneer (for example maximize the price of the item, capitalize on the risk-averse vs risk-prone nature of the bidders, guarantee equal-access to permits/rights).

If now an ETS is to be applied to shipping, important policy decisions should include which auction format should be selected, by which criteria (maximize price, avoid creating oligopolies, minimize GHG emissions, or other), and how often would the auction be needed (e.g. a one-off allocation of permits once a year, a "rolling horizon" continuous auction scheme, some kind of redistribution, or a different structure). In addition, there should be some protection so that there is no collusion between the shipping companies bidding for permits. This is also the case if an open ETS is used, that is, if carbon allowances can be traded between the maritime sector and other sectors that use ETS (for instance, the energy sector). The inherent unpredictability of the carbon price in an ETS setting is very much connected to the way auctions are designed, including the possibility that some allowances are offered as free, according to some criteria.

CHAPTER 5: Comparative cost-benefit analysis of potential maritime MBMs

The purpose of this chapter is to perform a comparative cost-benefit analysis of potential maritime MBMs, according to the following evaluation criteria:

- GHG reduction effectiveness
- Compatibility with existing legal framework
- Potential implementation timeline
- Potential impacts on States, cf. IMO procedure (MEPC.1/Circ.885)
- Administrative burden
- Practical feasibility
- Avoidance of split incentives between ship-owner and charterer
- Commercial impacts

The rest of the chapter is organized as follows. Section 5.1 deals with bunker levy/carbon levy variants. Section 5.2 deals with ETS variants. Section 5.3 deals with the rest (other than GHG Fund or ETS) MBMs submitted to the IMO in 2010. Finally Section 5.4 deals with other MBMs, not currently under consideration. Evaluation is performed only in sections 5.1 to 5.3.

5.1 Bunker levy/carbon levy variants

5.1.1 General

There can be several variants of a bunker levy/ carbon levy MBM. These include:

A. The International Fund for Greenhouse Gas emissions from ships (GHG Fund) originally proposed by Cyprus, Denmark, the Marshall Islands, Nigeria, and the International Parcel Tanker Association-IPTA, submitted to the IMO in 2010 (Denmark, 2010)- see Chapter 2 for a description.
B. A pure levy on bunker fuel.
C. A pure levy on CO_2-equivalent (CO_{2e}) emissions.
D. Variants that include restrictions on which ships would be subject to the levy or differentiation of the levy according to some criteria.
E. Eliminating the tax-free status of marine fuels at a European level.

We clarify that variant E, proposed to be investigated under the European Green Deal (EU, 2019)[9], will not be evaluated, as it is considered unlikely to occur. It is likely that its adoption would open a giant loophole, operators purchasing cheaper fuel from non EU

[9] From EU (2019): *"Fossil-fuel subsidies should end and, in the context of the revision of the Energy Taxation Directive, the Commission will look closely at the current tax exemptions including for aviation and maritime fuels and at how best to close any loopholes."*

sources, some of which could actually be geographically very close to the EU. This alternative would work only if marine fuels are taxed at a global level (variants A to D), and actually if this is so it would only be necessary so as to enforce the global tax by EU member states.

We also mention at the outset that variant A, together with all other MBM proposals submitted to the IMO in 2010 (as per Chapter 2), is *not* currently on the table at the IMO or elsewhere. However we mention it here for completeness purposes and in case something along these lines is proposed again in the future.

Variants B and C are simpler variants of A, imposing a prescribed surcharge on bunker fuel, or a prescribed price on CO_2 or CO_{2e} emissions. Variant C includes a sub-variant in which CO_2 or generally GHG emissions are directly monitored via a device in the ship's stack (Devanney, 2011a).

Psaraftis and Lagouvardou (2019) touched upon some of the key elements that need to be addressed assuming that a levy is contemplated. These include:

- which ships will be subject to the levy
- the levy as a function of type of fuel used
- the price level of the levy
- the timing of the levy
- who will be collecting the levy
- how and to whom the proceeds of the levy will be distributed

For instance, the price level of the levy should be considered after an analysis that would recommend the level that would maximize the chances of compliance with the IMO GHG reduction target in 2050. Such an analysis would examine and analyze both the short-term and long-term effects of the levy. As regards the short-term effects, an analysis could be conducted for the world fleet, on what speed reductions (and hence CO_2 emissions reductions) could be achieved due to the levy. The long-term effects analysis would have to examine the levy in conjunction with the Marginal Abatement Costs (MACs) of potential energy saving devices and alternative fuels, again for the world fleet.

In general one would envision the following general options on the price level of the levy, together with their anticipated impacts as regards GHG emissions reduction.

Table 5.1: Price levels of levy. Adapted from Psaraftis and Lagouvardou (2019).

Price level of levy	**Range (USD/tonne of CO_{2e})**	**Range (USD/tonne of HFO/MGO/MDO)**	**Expected GHG reduction**
Low	0.5 - 5	1.5 - 15	None or negligible
Medium	5 - 75	15 - 225	Moderate
High	>75	> 225	Significant

The “low” option would mainly collect monies for R&D. The 5 billion USD fund by ICS et al (2019) proposed a 2 USD per tonne of fuel surcharge, which is equivalent to about 0.65 USD per tonne of CO_{2e}. The “medium” option would achieve some GHG reductions, mainly in the short-term, in the form of slow steaming. How much will be reduced is currently unclear. Finally the “high” option is a full blown MBM that would have both short-term and medium term effects, the medium-term effects being the provision of incentives to develop low/zero fossil carbon fuels and ship technologies that would reduce GHGs that are not currently viable (long-term objective/effects).

If the levy is assessed on CO_2 equivalent emissions, low carbon fuels, which are exactly the fuels that are desirable to reduce GHG emissions, would be levied less (on a per tonne of fuel basis) than conventional fossil fuels, because their carbon coefficient would be lower, and the levy on zero carbon fuels (should these be developed eventually) would be 0. So whenever zero carbon fuels are eventually used, there would be no levy on these fuels, and a levy would be confined only to fuels that have a carbon footprint, such as fossil fuels. The lower the carbon footprint, the lower the levy.

In the recent report by commodity trading company Trafigura (2020), a levy much higher than the highest levy of Table 5.1 was proposed. In a much publicized proposal, Trafigura argued that a levy between 250 and 300 USD per tonne of CO_{2e} should be imposed so as to make zero- and low-carbon fuels more economically viable and more competitive, and that this should be introduced at the IMO level. This translates into a levy between roughly 750 and 900 USD per tonne of fossil fuel. The proposed levy was calculated so that low carbon or zero carbon alternative fuels could become economically viable[10].

According to Psaraftis and Lagouvardou (2019) and in order to avoid distortions of competition and a level playing field, all ships should be subject to the levy, possibly excluding ships of very small size (eg, ships below 400 GRT)[11]. According to that paper, schemes *to be avoided* include schemes that:

- exclude some ships from the levy, under some criteria
- differentiate the level of the levy among certain ships,
- provide a rebate on the amount of the levy.

On the other hand, policy makers may want to institute such exclusion/differentiation /rebate schemes, so as to selectively reward certain ships or penalize others. Criteria on the basis of which such schemes would apply may include any or all of the following:

- ship type, size, flag, age, ownership, route, ports visited

[10] The Trafigura report acknowledges, among other references, the Lagouvardou et al. (2020) paper as one that provides an excellent overview of MBM proposals.

[11] It is noted here that if shipping is included into the EU ETS, the size threshold will likely be 5,000 GRT, as specified in the EU MRV Regulation.

- other criteria, such as for instance an EEDI below a certain level, a speed below a certain level, the technical characteristics of the ship including waste heat recovery devices, hybrid propulsion, exhaust cleaning devices, or others.

Still, levy variant D may impose such restrictions or differentiations on which ships would be subject to the levy. We shall examine variant D (which is actually not a single variant) in Sections 5.3 and 5.4 of this chapter.

5.1.2 GHG reduction effectiveness

How much CO_2 can be reduced by a substantial global bunker levy? By "substantial" we mean at least two orders of magnitude higher than the USD 2 per tonne surcharge recommended to the IMO by the major shipping associations to establish an R&D fund to decarbonize shipping (ICS, 2019), i.e. at least USD 200 per tonne HFO. Such a levy would induce both technological changes in the long run and logistical measures in the short run. In the long run, it would lead to changes in the global fleet towards vessels and technologies that are more energy efficient, more economically viable and less dependent on fossil fuels than those today. In the short run, it would lead to slow steaming and hence reduced CO_2 emissions.

As mentioned in Chapter 2 (see also Table 2.1), the IMO Expert Group on MBMs provided, in its report to the IMO (IMO, 2010), some estimates of CO_2 emissions reductions. For the baseline scenario, "in-sector" CO_2 emissions reductions of the GHG Fund were estimated to be very moderate, ranging from 1 to 31 million tonnes a year, whereas "out-of-sector" reductions were estimated to range from 152 to 584 million tonnes a year, confirming that the main intended effect of the GHG Fund MBM would be out of sector reductions realized by the issuance and application of offsets. However, due to the reservations expressed in Chapter 2 on the modeling methodology applied by the Expert Group, we place little weight on the above numbers, and in fact it can be argued that there is enough evidence to the effect that the in-sector reductions that could be realized by the GHG Fund MBM could be significantly higher, and probably higher than the GHG Fund proposers themselves were willing to admit.

In fact, some prior estimates of CO_2 emissions reduction due to a levy do exist in the literature. As also mentioned in Chapter 3, Devanney (2010) estimated that with a base HFO price of USD 465 per tonne, a USD 50 per tonne bunker levy would achieve a 6% reduction in total Very Large Crude Carrier (VLCC) emissions over their life cycle and that for a USD 150 per tonne levy the reduction would be 11.5%. Some estimates of CO_2 emissions reductions for tankers and handymax bulk carriers, and for several bunker levy scenarios, were made in Gkonis and Psaraftis (2012) and in Kapetanis et al (2014) respectively. These estimates showed CO_2 emissions reductions of more than 50% for a single VLCC if fuel price rises from 400 to 1,000 USD per tonne, with similar reductions for bulk carriers. Psaraftis (2019a) estimated for a rudimentary containership scenario that a doubling of bunker prices from 500 to 1,000 USD per tonne would achieve a 50% reduction in CO_2 emissions, taking also into account the extra CO_2 emissions of the additional ships that would be deployed to account for loss of throughput.

At the strategic level, a substantial bunker levy would incentivize the development of alternative, low or zero carbon fuels and other energy saving technologies for which MAC>0 under current conditions. Such a levy could make such fuels and technologies obtain a MAC<0, which would make them win-win solutions. How much CO_2 emissions would be reduced would depend on the MACCs that are established. However, unless MACCs are properly established (see comment on the DNV MACCs in Chapter 2) estimates of CO_2 emissions reductions could not be reliable.

The 4th IMO GHG study (IMO, 2020), released in July of 2020, has produced, among other things, some MACCs, and based on these has projected some scenarios on how the shipping industry can move to meet the 2050 GHG reduction targets. Reviewing the 4th IMO GHG study is a major task which is not within the scope of this document, however we can state that MBMs are not explicitly mentioned in that study as possible measures to reduce GHG emissions.

A possible side-effect of a bunker levy that should also be looked at is shifts to other modes of transport, ultimately leading to more CO_2 emissions overall. These shifts could be due to (a) higher maritime transport costs due to the levy, and/or (b) the speed reduction that would ensue as a result of the levy. Both (a) and (b) would encourage some cargoes (and essentially the more expensive or perishable cargoes) to shift to rail, road or even to air transport, particularly if such other modes are spared a similar fuel price increase.

This situation is relevant to both deep-sea and short-sea shipping. Psaraftis and Kontovas (2010) developed a methodology to estimate modal shifts due to speed reduction in deep-sea routes and investigate, among other things, possible shifts to the railway mode in the Far East to Europe corridor as a result of speed reduction in the maritime mode. A binomial logit model was used, which can also account for freight rate changes. Zis and Psaraftis (2017, 2019) performed a similar analysis for European short-sea (RoRo) routes. Finally the analysis of the Chilean cherry case in the impact assessment of the goal-based measure submitted by Denmark, France and Germany (Denmark, 2020) included a modal shift analysis of cherry exports shifting to the air mode in case ship speed is reduced. In all cases the methodology was based on the generalized cost concept which takes into account time and costs including freight rates, value of time and inventory costs.

The European modal shift analysis is also very relevant in the context of the EU ETS (see Section 5.2 later).

5.1.3 Compatibility with existing legal framework

As also mentioned in Chapter 2, the GHG Fund MBM proposal judiciously avoided the use of the words “levy” or “tax” to characterize the MBM measure, using the word “contribution” for that purpose, even though this would be a mandatory contribution, and therefore, for all practical purposes, a tax. This was done specifically so as to avoid legal obstacles in trying to institute an international tax. The same is the case for the R&D Fund recently proposed by a number of shipping associations (ICS, 2019), which is actually not considered an MBM even by its proposers. These associations have however stated that the architecture of that proposal could be borrowed should a bunker levy be instituted by the IMO.

It should be noted here that the IMO MBM Expert Group had established an “administrative and legal” task-group to examine legal issues. This task-group highlighted some of the policy sensitivities inherent when discussing compatibility with the UNFCCC and its Kyoto Protocol. The experts recognized that the principle of Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) applied in the context of the UNFCCC and its Kyoto Protocol and the IMO Convention specifies non-discrimination in IMO instruments. However there were different views on application of these principles among the legal experts. One view was that the UNFCCC provides the central policy infrastructure for global climate change action and the proposed MBMs must take into account the principle of CBDR-RC. Another view was that the principles of the UNFCCC do not apply in the IMO and that all of the MBMs that aim to reduce emissions are therefore consistent with the UNFCCC. Division of opinion was also manifested regarding whether each of the MBM proposals would fit under MARPOL or would require a new convention.

It is therefore speculated that if and when the political will to institute a levy MBM is manifested, appropriate legal language could be drafted so as to avoid legal obstacles. However, differences of legal opinion may make this task non-trivial.

5.1.4 Potential implementation timeline

There is no specific timeline for a levy at the present time. MBMs are included in the set of medium-term candidate measures of the Initial IMO Strategy, that is, to be agreed upon and implemented between 2023 and 2030. Plus, their adoption is only a possibility (“possibly including MBMs”), meaning that MBMs may not be pursued by the IMO, after all. Even though the EU is pressing with the inclusion of shipping in the EU ETS (in the context of the European Green Deal- see Section 5.2 below), MBMs are currently almost invisible within the IMO agenda.

5.1.5 Potential impacts on States, cf. IMO procedure (MEPC.1/Circ.885)

We first clarify that to date, there has been no comprehensive impact assessment by the IMO (or by anybody else for that matter) of the potential impacts of MBMs on States. A proposal by Andreas Chryssostomou, the then chairman of MEPC, who was also the chairman of the IMO Expert Group on MBMs (2010-2013) for such an impact assessment study to be carried out was turned down. Most recently, the 5 billion USD R&D fund proposed to MEPC 75 by a consortium of shipping associations (ICS, 2019) encountered serious objections by many IMO Member States (developing countries and other), on the ground that a comprehensive impact assessment of the two (2) dollars per tonne surcharge on bunker fuel should be conducted before the discussion on the proposal continues. Note that such a proposal was not labelled an MBM even by its proposers, meaning that the issue of an impact assessment will be raised again, and whenever the MBM discussion reopens at the IMO. If an impact assessment was requested for a fuel surcharge that is well below the "noise" of daily fuel price fluctuations, one could imagine what would be requested if a full blown MBM is put forward at the IMO.

In the discussion at the IMO 7th intersessional meeting of the working group on GHG emissions from ships (October 2020), and on the subject of the detailed impact assessment studies associated with short-term measures, an independent evaluation by UNCTAD identified, among other things, many of the challenges of a comprehensive impact assessment (IMO, 2020). Even though the said impact assessment studies did not concern MBM measures, such challenges identified by UNCTAD are also very much relevant in any MBM impact assessment that is to be conducted in the future.

In the context of DTU's detailed impact assessment for the mandatory short-term operational measure proposed by Denmark, France and Germany (Denmark, 2020), several references that investigated the possible impacts of a carbon levy on states were reviewed in Chapter 3. Specifically, we reviewed the Halim et al (2019) study on potential impacts on SIDS/LDCs, as well as the Krammer and Smith (2017) and NZIER (2018) studies on potential levy impacts on New Zealand including the territory of Tokelau. These reviews need not be repeated here. All indicate that the potential impacts of a bunker or carbon levy on states can not be ignored.

We also recall (as per Chapter 1) that a number of SIDS including Antigua and Barbuda, Marshall Islands, Palau, Solomon Islands, Tonga, and Tuvalu proposed that the MBM discussion should reopen (see Antigua (2018) and more recently Marshall (2020)).

The implicit assumption of these submissions is that SIDS believe they would incur significant (negative or disproportionately negative) impacts as a result of a carbon tax or levy (and of the resulting increase in freight rates), hence their suggestion to channel most of the revenues generated by such MBM to such states. A related implication is that these states believe that they would suffer negative impacts from freight rate increases due to other reasons as well, not just due to a carbon levy. However, in contrast to other (operational or technical measures) MBMs can generate income that can be used to compensate for such negative impacts.

How much of the MBM revenues would be channeled to such states is subject to discussion, whenever the MBM discussion reopens at the IMO.

5.1.6 Administrative burden

In the GHG Fund MBM by Denmark et al, and, by extension, in a bunker levy MBM, there are several options: Option 1 collects the money at the bunker supplier level and Option 2 collects it at the ship level. At first glance it would seem that Option 1 has a lower administrative effort, as involving a lower number of transactions than Option 2. In fact one might consider yet another option, Option 3, to collect the money at the refinery level. Theoretically, the higher one goes up the fuel chain, the easier it would be to administer it due to the reduced number of transactions. However, it is not yet clear how each of these options could work in practice, not only from an administrative burden viewpoint, but also in terms of enforcement and evasion avoidance. Some actually believe that none of the above options is viable, and instead propose the money to be collected via Option 4, by direct measurement of CO_2 or GHG emissions, via a suitable ultra-sound device within a ship's stack (Devanney, 2011a). However, ship owner circles have raised questions on the reliability of such systems.

5.1.7 Practical feasibility

A simple levy would be rather practical to implement, particularly if Options 1, 3 or 4 (see above) are exercised. If Option 2 is used, some additional administrative difficulty might be experienced in cases of time charters. A levy might act as an "invisible hand" that would affect user behavior towards reducing GHG emissions, both in the short term and in the long term. The scheme could be implemented by using, for instance, a scheme similar to the IOPCF (International Oil Pollution Compensation Fund), even though IOPCF also covers liability issues that may not be relevant for an emissions setting. The structure proposed by the ICS (2019) R&D Fund proposal could also be borrowed.

5.1.8 Avoidance of split incentives between ship-owner and charterer

What are split incentives? A split incentive situation occurs if the ship owner and the time charterer have different incentives in adopting energy saving devices or alternative fuels. The basic split incentive hypothesis is that for ships on time charter, in which the fuel is being paid for by the charterer, ship owners do not have any serious incentive to invest in energy savings technologies. This is so allegedly because fuel is being paid for by the charterer and not by the ship owner.

Advocates of the above hypothesis include organizations such as RightShip, Carbon War Room (CWR), and University College London (UCL). See for instance Rehmatulla and Smith (2015) for an exposition advocating such a hypothesis. We note here that RightShip and CWR have been funding some of the work of UCL, so it is not a surprise that they are on the same page on this issue (without implying of course a causal relationship).

These advocates argue that such split incentives constitute a serious "market imperfection" or "market barrier", and one which prohibits technologies or alternative fuels that have a negative Marginal Abatement Cost (MAC) from being implemented. A negative MAC would mean that the ship owner would want to adopt a specific GHG reduction measure as he would profit from such a measure and would not need the regulator to mandate it. In other words, these advocates argue that such technologies and/or fuels (that have a negative MAC) do exist today, but they are not implemented precisely because of these market barriers.

There are also skeptics of the split incentive hypothesis. In a Center for Tankship Excellence[12] paper, Devanney (2011b) argues that the above hypothesis is incorrect, and that ship owners and time charterers are not stupid. A former MIT Professor who went into the tanker business for several decades, he argues that in all chartering negotiations

[12] www.c4tx.org

he has been engaged in, the fuel consumption vs speed curve has been front and center, and that there is really no split incentive issue. In Kontovas and Psaraftis (2016), a more neutral approach is taken.

A central premise of the split incentive hypothesis is that owners of ships on time charter may have little or no incentive to adopt measures for the reduction of fuel consumption (and hence emissions) of their ships, since the fuel is paid for by the charterers and not by themselves. In such a case, a scheme such as EVDI, used by RightShip (EVDI for Existing Vessel Design Index), comes in and supposedly assists charterers in their selection of a fuel efficient ship.

The counter argument to the split incentive hypothesis is that when a ship is on time charter, the ship's consumption at various speeds is clearly described in the charter agreement. The ship's capacity and consumption are evaluated by the charterer before the contract is signed. A ship with a higher consumption at a given speed will receive a lower time charter rate than a similar ship with a better consumption curve. If during the charter the ship does not fulfil the agreement terms regarding fuel consumption, the charterer will lodge a claim on the ship and deduct monies accordingly as compensation for his contractual loss. 'Speed claims' are common and they may end in arbitration or in court. Thus the owner of a ship on time charter has every incentive to economize on fuel consumption while on time charter. This is corroborated by some studies. In a study of some 10,000 Panamax bulk carrier term charters, Wijnolst and Bartelds (1995) found a clear correlation between fuel consumption and charter rate. The sum of the fuel cost per day and the time charter rate was roughly equal for almost all the charters in the sample.

The rest of this section attempts to shed more light into the issue, via the Marginal Abatement Cost (MAC) concept, and also examines the impact of a bunker levy.

Recall again that the MAC of a specific technology is the ratio of the marginal cost of implementing this technology, divided by the CO_2 it can avert. It is expressed in USD/tonne of CO_2 averted.

In Psaraftis (2012) a formula for MAC was derived. Below we refer to the MAC of a specific energy savings technology. It can be shown that

$$MAC = \Delta GC/\Delta CO_2 - P/F \qquad (1)$$

where

- ΔGC is the cost of the technology
- ΔCO_2 are the tonnes of CO_2 averted by that technology
- P is the fuel price
- F is the carbon coefficient of the fuel

If the ship owner pays for the fuel, a MAC<0 means that the ship owner would have an incentive to adopt such a technology. It would be a win-win situation for him.

Equation (1) also means that any technology can be made to have MAC<0 if the price of fuel P is high enough. Hence the potential role of a bunker levy to make this happen.

What is not mentioned (at least we have not seen it) in any MAC discussion is that in formula (1), and *in the case of a time charter scenario*, the positive term $\Delta GC/\Delta CO_2$ is paid for by the ship owner, and the negative term - P/F is "paid for" by the charterer. More precisely, -P/F represents the charterer's *savings* (per tonne of CO_2 averted). In fact the charterer's savings (per tonne of fuel not used) are P, the price of fuel.

Let us assume, for the sake of the argument, the following scenario. The ship owner retrofits the ship with a hypothetical energy saving device (for instance, waste heat recovery) for which the following are true (all numbers are hypothetical):

$\Delta GC/\Delta CO_2$ = 200 USD/tonne (of CO_2 averted)

P= 350 USD/tonne

F= 3.11 (for HFO)

Then MAC = 200-112.54 = 87.46 USD/tonne (of CO_2 averted)

That is, for each tonne of CO_2 averted by this specific technology, the ship owner has to pay 200 dollars. The charterer will have an economic benefit of 112.54 dollars per tonne of CO_2 averted, or 350 dollars per tonne of fuel saved due to the lower fuel consumption that is due to the specific technology. The question then is, why should the ship owner pay for a benefit that will go to the charterer?

Before we address this question, assume that a levy L is imposed. Then P will increase to P+L, and the MAC will be reduced by L/F. The ship owner will still pay $\Delta GC/\Delta CO_2$, but the charterer's benefit will be P+L (per tonne of fuel saved) and (P+L)/F per tonne of CO2 averted, ie the charterer will have an *additional* benefit of L (per tonne of fuel not used) and L/F (per tonne of CO2 averted).

If for instance L= 300 USD/tonne, the new MAC will be

MAC new= 200- (350+300)/3.11 = - 9 USD/tonne <0.

In this case MAC is negative, however the question still is, in a time charter scenario, why should the ship owner invest in this technology, if all benefits go to the charterer? It clearly looks like a split incentive situation.

The answer to this question is, *the owner of a more fuel efficient ship will be able to negotiate a higher time charter (TC) rate with the charterer*, due to the fact that the energy savings device he has installed will reduce fuel consumption. This higher TC rate is a benefit to the ship owner and should be factored in the MAC equation in a time charter scenario.

If this is the case, it can be shown (see Appendix A) that the MAC equation (1) is also valid for the time charter case. The upper bound on what the ship owner can charge for better fuel efficiency over and above the TC (monthly or daily) rate of the original, less energy efficient ship is the difference of (monthly or daily) fuel costs between the two ships.

In that sense, it can be argued that this supports the hypothesis that *a bunker levy is not likely to exhibit serious split incentive issues. What a bunker levy could do is to facilitate the adoption of technologies whose original MAC is positive, by making the MAC of such technologies negative.*

Such a hypothesis is reinforced by the fact that a major industry association representing charterers, Trafigura, has recently come out with a report endorsing a substantial bunker levy (Trafigura, 2020). By contrast, Trafigura is against including shipping in the EU ETS.

Less clear is what happens as regards split incentives when an ETS is imposed. In fact it can argued that in the ETS case, serious split incentives are likely to occur. This will be examined in Section 5.2.8.

5.1.9 Commercial impacts

Depending on the level of the levy, its commercial impacts are potentially very significant and may be manifested in a variety of ways. The exposition below is non-encyclopedic.

As regards the competitive position of shipping companies vis-à-vis other transport modes, if a bunker levy is not accompanied by an equivalent increase in the fuel prices of the other modes, then the potential shift of cargoes to these modes (either because of higher maritime transport costs, or because of increased sailing times, or because of both), as per Section 5.1.2, may result in loss of income to the shipping companies that are impacted by such modal shifts. Such shifts would be seen mainly in the more expensive and perishable products trades and are likely to be confined to liner shipping.

As regards competition within shipping, shipping companies that use ships that have slender designs that exhibit a lower resistance especially in non-calm weather conditions are likely to have a commercial advantage over shipping companies that do not.

Similarly in the long run, a levy is likely to favor companies that have the financial resources to invest in energy efficient technologies and alternative fuels, vis-à-vis those that do not.

It is also clear that if the level of the levy is significant, in the long run it will boost the business prospects of a wide variety of companies, including alternative low/zero carbon fuel developers, manufacturers of engines that can use such fuels, manufacturers of energy saving devices and other equipment (wind sails, flettner rotors, air bubbles, energy recuperation devices, specialized propellers, etc), shipyards that build energy efficient ships, and others. Conversely, enterprises such as fossil fuel producers and vendors, or companies that do not sell energy efficient technologies will be at a commercial disadvantage.

Should a scheme of direct taxation of GHG emissions be adopted at some point, manufacturers of emissions measuring equipment will reap significant commercial benefits.

Last but not least, commercial impacts would include the entire chain of stakeholders that are "downstream" after money is collected, and this depends on what is decided on the uses of this money and how the whole scheme is administered. This, in and of itself, is a subject of major discussion. The ICS (2019) R&D fund proposal describes one of the possible architectures that can be used, being run by the shipping industry, but as far as who will benefit from the collected funds it only concerns R&D. The potential beneficiaries of a full blown levy scheme are much wider and these include banks, fund administrators, emissions certifiers, shipyards, alternative fuel developers and vendors, ports, and others which actually may not be connected to the shipping industry at all (for instance, a wind farm in Indonesia that is funded by the proceeds of the levy and is used as an out-of-sector GHG emissions reduction mechanism). All these are expected to enjoy significant commercial benefits once a levy is established.

Situations to be avoided include the possible distortion of competition if, for instance, funds would be used in-sector, or if rebate schemes are used. If monies collected are to be given to developing states for capacity building and technical cooperation, it should be avoided that these funds are given to shipping companies of these countries that can enhance their competitive position vis-à-vis other companies that do not receive such funds. Care should be exercised if funds are given as subsidies to import-competing industries, as this might distort trade.

In all of the above cases, the precise degree of commercial impact is case-specific and can not be pinpointed in advance.

5.2 ETS variants

5.2.1 General

There can be several variants of the Emissions Trading System (ETS) as applied to maritime GHG emissions. These include:

A. Those that called for a *global* ETS, as submitted to the IMO in 2010 by Norway, UK, France and Germany. These four ETS proposals were submitted to the IMO independently but their main philosophies were very much similar. See Norway (2010), UK (2010), France (2010) and Germany (2010). See also Chapter 2 for a description.
B. Those that call for a *regional* ETS, as contemplated by the EU in the context of the European Green Deal (EU, 2019) and the intended inclusion of shipping into the EU ETS.

As regards variant A above, and after the suspension of the MBM discussion in 2013, there has not been any updated submission of these ETS proposals or of any variant. An example on variant A is Norway's ETS proposal in 2010 (Norway, 2010). The British (UK, 2010), French (France, 2010) and German (Germany, 2010) ETS proposals were very similar, but not completely identical to the Norwegian ETS. All had a global coverage basis. See Chapter 2 for more details.

As regards variant B, and other than the declared intent of including shipping into the EU ETS, and related action on the legislative and impact assessment front, neither of which is currently finalized, there is currently much uncertainty on the precise way that this would happen.

In contrast to the above *global* ETS proposals, which were pretty concrete and well defined and detailed, the inclusion of shipping into the EU ETS (variant B), as per the European Green Deal (EU, 2019), is substantially lacking in key elements at this point in time. The reason is that such elements are under investigation as regards impact and consequences and under negotiation among legislative stakeholders (European Parliament- EP, European Commission- EC, and the Council) and possibly industry and other stakeholders. One thing seems reasonably plausible: that the EU ETS proposal will be connected to the EU Regulation on the Monitoring, Reporting and Verification (MRV) of CO_2 emissions (EU, 2015) and that CO_2 emissions data collected via the THETIS MRV database would be used in the context of an EU ETS in shipping.

We note here parenthetically that the Commission already put forward a proposal to amend the EU MRV Regulation in order to take appropriate account of the IMO global Data Collection System (DCS) for ship fuel oil consumption data. This means that it is likely that the EU MRV system will be harmonized with the IMO DCS system, which is less stringent as regards the amount and type of information collected, mainly as regards the cargo carried by the ship. We also note that ENVI Committee of the the European Parliament (EP) recently voted to incorporate in the above amendment the inclusion of ships of 5,000 GRT and above into the EU ETS. Per rapporteur Jutta Paulus's opinion, *"Today, we are sending a strong signal in line with the European Green Deal and the climate emergency: Monitoring and reporting CO2 emissions is important, but statistics alone do not save a single gram of greenhouse gas! That's why we are going further than the Commission proposal and demanding tougher measures to reduce emissions from maritime shipping."* Needless to say, the above vote, which surely does not prejudice the position of either the EP or of the EC (not to mention of the Council), is tantamount to including shipping into the EU ETS via the back door.

Anyway, the European Maritime Safety Agency (EMSA) published in May of 2020 the first account of CO_2 emissions that are subject to the MRV Regulation, with results pertaining to 2019 (EMSA, 2020). According to it, in 2019 more than 138 million tonnes of CO_2 emissions were recorded via data from more than 11,000 ships. Other than (a) CO_2 emissions at berth, which are approximately 6% of total CO_2 emissions, the rest of the CO_2 emissions are about equally split among (b) intra- European Economic Area (EEA) trips, (c) EEA incoming trips and (d) EEA outgoing trips.

EU ETS prices are broadly fluctuating, but assuming an indicative price of €20 per tonne of CO_2, which was in the range of carbon prices within 2019, it would seem at first glance that a total of €2.75 billion could be raised had such an ETS price been applied to the 2019 CO_2 emissions. A recent report by the World Shipping Council (WSC, 2020) (as per Chapter 3) assumed a (very similar) carbon price of of €25 per tonne of CO_2 as indicative for pre-COVID-19 2020 prices and came up with a figure of €3.45 billion as revenue raised.

Such crude calculations may give a first-glance indication of how much money could be collected, but have a basic flaw: they ignore changes in shipping operator behavior that would be triggered as a result of the inclusion of shipping in the EU ETS.

These changes could:

- Entail a reconfiguration of ship speeds, routes and networks
- Potentially impact any or all four components (a), (b), (c) and (d) of the total CO_2 emissions, as stated above.
- Impact CO_2 emissions per ship sector in different ways.

If anything, one of the objectives of the European Green Deal is to incentivize a shift to greener technologies and energy saving practices, which would lead to CO_2 emissions reductions vis-à-vis Business As Usual (BAU). Precisely what such a shift would entail, or in fact whether there would be such a shift, or actually whether there might be side-effects that could lead to carbon leakage, remains to be seen. This would critically depend on the architecture of the EU ETS as applied to shipping. This architecture is at this point in time not very clear.

Elements of the EU ETS architecture that are not clear at this point in time include the following (list may not be complete):

i. whether the coverage of the EU ETS will be the same as that of the EU MRV or will only be limited to intra-EEA trips
ii. what would be the mechanism of issuing, allocating, auctioning and redeeming carbon allowances
iii. whether it will be an open or closed ETS
iv. whether there would be any free allowances and if yes how many and how would they be allocated
v. whether time charterers would be allowed to trade carbon allowances or that would be limited to ship owners

With respect to element i, if only intra-EEA trips are covered, this would significantly limit the scope and the impact of the scheme. Note that this has been ultimately the case with the inclusion of aviation within the EU ETS, mainly due to the reaction of countries like the United States, China and Russia- and this might actually create a legal precedent- see also Section 5.2.3 below.

In mid- September 2020, the EP voted to include shipping into the EU ETS. This includes the creation of an "Ocean Fund" from 2023 until 2030, financed by revenues from auctioning allowances under the ETS, to make ships more energy-efficient. However, and as this report was being finalized, the way the scheme would work remained unclear. Discussions with the EC and the Council would determine the details of the scheme. We also understand that a study that would, among other things, investigate impacts and consequences of several variants of the scheme, is under preparation, and that this study would be released in the summer of 2021. Until then, the only justification for including shipping into the EU ETS is from a prior Impact Assessment (IA) conducted by the European Commission (EC) circa 2013 (EC, 2013), in which the EC examined several GHG reduction options and concluded that ETS was the best one. Supporting documentation for the IA came in a detailed Technical Report (TR) commissioned by the EC and prepared by a consortium of partners, see Ricardo et al. (2013).

As mentioned in Lagouvardou et al. (2020), both the IA and the TR were very comprehensive; however, neither contained information on the model that evaluated the various policies for reducing maritime GHG emissions. The model was based on the so-called TIMES energy model and was specifically developed for the IA. We were unable to access or find in the literature any specific information regarding the structure, methodology, or inputs and parameters of that model. We also note that even though the TR contained no recommendation on which of the GHG reduction measures was the best, the IA made its ETS choice based on the contents in the technical report.

So to the best of our knowledge, the major policy decision to include shipping in the EU ETS has been, at least thus far, based on models that are non-transparent or not open to scrutiny, and also entails other issues that are unclear or unresolved.

Another interesting fact is that the two processes, IMO and EU, appear to be completely disconnected. The IMO process currently focuses on short-term measures and the relevant discussion has been delayed due to COVID-19. There is no substantial mention of EU ETS in any of the current items on the IMO GHG agenda. There is nothing in the IMO current GHG agenda to discuss the potential repercussions of EU ETS to what is being discussed at the IMO, even though the implementation of the measure may render measures such as for instance the recent combined EEXI/SEEMP/CII proposal (China, 2020), a version of which was approved by MEPC 75, not fully relevant if implemented in parallel with the EU ETS, unless there is an attempt to link it somehow with the EU ETS in Europe (see also Section 5.4 below). In contrast, the EU process is very much up and running, as stated earlier. Moreover, the MBM discussion at the IMO is still under the horizon, as MBMs are under the medium-term measure category and only as a possibility.

In view of the uncertainties associated with the EU ETS proposal, it is clear that no complete cost benefit analysis on it can be conducted at the present time. Some of that analysis will be conducted in the context and time frame of the MBM SUSHI project at DTU, with DMA in the project's Advisory Committee.

At the same time, it can be argued that something can still be said on ETS, as regards the evaluation criteria. This is done in the sections that follow.

5.2.2 GHG reduction effectiveness

As argued among ETS advocates (see also Norway (2010)), the main selling point of the various *global* ETS proposals at the IMO was what was claimed as "full certainty on the emission reductions achieved by the mechanism". This means that if one sets a cap on emissions, that cap will absolutely be met. This stems from the fact that CO_2 emission allowances (or permits) will be auctioned (at a price that is established by the market) and if no more such allowances exist, a ship that does not have such allowances would not be able to legally emit CO_2. The cap would be adjusted downwards yearly so that at 2050 the 50% reduction target could be met, vis-à-vis 2008 levels.

The issuance of free allowances could potentially undermine the above full certainty and could potentially lead to carbon leakage. Also, and so as to limit its administrative complexity, a global ETS may entail other forms of exemptions, such as for instance applicability only to ships above a certain size, or geographical exemptions, for instance to SIDS/LDCs. Such exemptions may lead to carbon leakage as well.

But even if one is to assume that a way forward is found for a global ETS allowance cap to function with full reduction certainty, it is not yet clear how such a cap would be set and implemented *on a regional basis*, that is, for the EU ETS. It could be a cap concerning only CO_2 emissions on trips to and from EEA ports, including intra-EEA trips, but this is still not clear. For instance, if 2018 CO_2 emissions were 138 million tonnes, and the implementation of the EU ETS starts in 2022, a cap of 83 million tonnes could be set in 2030 (40% reduction vs 2018), and intermediate caps could be set from 2023 to 2029. Then no one would be allowed to emit over the respective annual cap, as far as the EEA is concerned. However, presumably no such restriction would exist outside the EEA geographical coverage if nothing similar is instituted by the IMO at the same time (which does not look likely at this point in time). In other words, even if ships meet the European cap, if no similar mechanism is set by the IMO on a global basis, it is not clear how the IMO 2050 targets would be met. There would have to be a global ETS to achieve that.

Whether global or regional ETS, another problem may be, even though one may reach the cap that is selected, the carbon price that would be established would be completely unknown, being a function of future supply and demand for carbon. Also, as soon as the cap would be approached and allowances would be in short supply, carbon prices may skyrocket. Market fears and expectations may skyrocket prices, which may in turn collapse as was the case with the EU ETS, where carbon prices dropped precipitously as a result of the 2008 economic crisis (and also as a result of COVID-19 in 2020).

The IMO MBM Expert Group report that evaluated the MBM proposals submitted to the IMO (IMO, 2010) came to the apparent conclusion that the GHG Fund proposal by Denmark et al was *a weak driver* for uptake of in-sector technological measures to reduce emissions, whereas the various ETS proposals were *strong drivers*. In fact, the opposite argument can also be made, to the effect that a levy would result in a larger reduction in CO_2 emissions than an ETS with the same average permit price. This is further explained below.

To achieve the same amount of CO_2 reduction, if we assume equal efficiency for both systems (which can be debated), the carbon levy and the ETS carbon price must be the same. Policy-makers get to choose either the target reduction (for the ETS proposal) or the carbon levy. Either can be high or low. The target reduction and the target levy being the policy-maker's choice should aim at the same result, i.e. either the same target levy or the same target reduction. If one goes for a modest target reduction, the carbon price will be low, in fact close to zero. However, a levy can be fixed for a longer period (a year or more). Permit prices by their nature are both volatile and unpredictable. Owners who are unsure of the carbon price will be facing great difficulty justifying expensive investments in carbon reduction technology.

The US Congressional Budget Office (CBO) document "Policy Options for reducing CO_2 emissions" (CBO, 2008) compares cap-and-trade with a levy system. The CBO paper compared the efficiency and CO_2 reduction potential of ETS vs. levy and concluded that a levy on emissions would be the most efficient incentive-based option for reducing emissions and could be relatively easy to implement. Further analysis in said document showed that the CO_2 reductions would be nearly double with a levy scheme than a cap and trade scheme. In other words, according to CBO a levy can bring the same environmental result (alternatively: can have the same environmental impact) at half the price of ETS or even less.

If the EU ETS is to be compatible with the EU MRV, as it would seem the reasonable thing to do, it would be applicable to ships of 5,000 GRT and above. This might lead to some carbon leakage for ships below that threshold. One may see side-effects like many ships of 4,900 GRT being built so as to avoid being subject to the ETS. These would proportionally emit more CO_2.

An even more serious carbon leakage may occur if ships use non-EEA ports close to the EEA to transship cargoes to and from the EEA. These ports may be for instance Felixstowe, Kaliningrad, Izmir, Beirut, or ports in northern Africa. By transshipping in these ports just before or after an EEA port call, not only revenues collected via an EU ETS would be reduced, but CO_2 emissions reduction might be problematic as well. Appendix B develops a rudimentary hypothetical scenario of a containership using the (non-EEA) port of Felixstowe as a transshipment port on a container route from Shanghai to Antwerp, and shows that an EU ETS would achieve much lower CO_2 emissions reductions than those achievable by a global levy. Also the funds collected by a global levy are shown to be much higher, even if the global levy is much lower than the ETS price.

We understand that the EP and/or the EC are very much aware of the above possibility of carbon leakage and may try to preempt it by an appropriate description of how a "port of call" is defined. How or if this could be achieved is not clear. If by a suitable definition of port of call all of the emissions of a ship going from (say) Shanghai to Piraeus are counted even if the last non-EEA port before Piraeus is (say) Izmir, then the loophole could be closed. However, doing something like this would likely entail similar changes in the EU MRV Regulation and might entail non-trivial legal issues brought about by non-EU Member States (or even by some EU Member States).

As with a levy, another possible side-effect of an ETS that should also be looked at is shifts to other modes of transport, ultimately leading to more CO_2 emissions overall. Similar considerations apply for the EU ETS case, and particularly in case the scheme involves only intra-EEA trips, where short sea shipping may compete with land-based modes. A main difference vis-à-vis the levy case is the inherent unpredictability of the ETS price. Any shifts to land-based modes would go against the EU policy to promote short-sea shipping and move cargoes from land to sea. The works of Zis and Psaraftis (2017, 2019) are relevant here again.

5.2.3 Compatibility with existing legal framework

At the regional level, both the EU MRV (which concerns shipping but has no pricing mechanism) and the EU ETS (which has a pricing mechanism but does not concern shipping) are already well-defined from a legal perspective. Thus it would seem, at least at first glance, that combining the two schemes so as to include shipping into the EU ETS would use well-established legal platforms and as a result would not encounter serious legal issues.

However, if aviation is any precedent, the inclusion of air transport into the EU ETS was marred by considerable reaction from non-EU countries such as the US, China and Russia, which banned their airlines from paying into the scheme and at the end the result was the scheme being applied only to intra-EEA flights. As mentioned in Evans (2016), the primary stated reason for this opposition was that it violated the Chicago Convention, which prohibits the taxation of jet fuel, and that such a scheme should be international in nature, and organized instead under the auspices of the International Civil Aviation Organization (ICAO). A similar reason may very well be valid and create a legal precedent for the maritime EU ETS as well. Already Japan and Korea have recently voiced their opposition to the inclusion of shipping into the EU ETS, and several EU countries (for instance, Greece) do not seem to be sympathetic to the idea either. One would imagine that countries such as Brazil, Argentina, India or Saudi Arabia would not be sympathetic either. The stance of the US under a Biden administration is likely to be more proactive on climate change and hence also maritime GHGs than it was under the Trump administration, however its stance on MBMs (and in particular ETS) is likely to be similar to its stance on the inclusion of aviation in the EU ETS.

In fact, and as also mentioned in Lagouvardou et al. (2020), from a legal point of view, there are several authors that claim that a including shipping into the EU ETS is not compatible with international law (mainly UNCLOS), for various reasons (see for instance, Hermeling (2015) and Koesler et al. (2015)- see also Chapter 3). A recent study commissioned by the International Chamber of Shipping (ICS) and the European Community Shipowners Associations (ECSA) on the inclusion of shipping into the EU ETS (Hughes, 2020)- see again Chapter 3- also identifies important legal issues. How all this will play out in the EU legislative process is not clear.

The recently released study by the World Shipping Council (WSC, 2020), which is a international container shipping association based in the US, identifies many problems (legal and other) should the EU proceed with an inclusion of shipping in the EU ETS in which the coverage is the same as the coverage as that of the EU MRV. The study recommends that if the EU goes ahead with such a scheme, coverage should be limited to intra-EEA trips only. As also mentioned in Chapter 3, among other things the WSC examines what would happen if, perhaps as a retaliation, countries like the US, China or Brazil move to implement similar regional ETS measure as well.

So by and large the opposition of major shipping associations, including ICS, ECSA and WSC, plus various national shipping associations, to ETS in general (both global and regional) has been on record. Even when Germany and Norway were for ETS at the IMO, their national ship owners associations were against. To what extent and towards which direction such associations can influence the EU legislative process remains to be seen. Also it is not clear what the overall strategy of each of these stakeholders would be, if in fact there is one: (a) give an all-out fight to prevent ETS from happening in the first place, or (b) accept that shipping would be eventually included into the EU ETS and negotiate the best (or least bad) scheme for this to implemented.

Option (a) appears to be the approach of ECSA and ICS (Hughes, 2020) and also of Trafigura (2020), however it is not clear which, if any, IMO stakeholder would bring forward the Trafigura idea to the IMO.

On the other hand, if (b) is the case, any form of EU ETS would be incompatible with non-ETS types of MBMs whenever the MBM discussion at the IMO resumes. In fact, the inclusion of shipping into the EU ETS would have another very serious ramification: it could pave the way for *a global ETS*, should the IMO eventually adopt an MBM on a global level. It would seem (at least at first glance) easier to choose *a global ETS path*, or see how various other regional ETS schemes can be interconnected, rather than mix an EU ETS with (say) a global levy. If this is the case, there could be additional legal issues associated with an extension of an ETS from a regional to a global scale and these could be considerable. The disagreement of legal experts on legislative compatibility of MBM proposals (see Section 5.1.3) is noted again. Compatibility with the principle of

CBDR-RC is likely to be one and not necessarily the only one of the issues to be resolved[13].

5.2.4 Potential implementation timeline

There is no timeline for a global ETS, because the IMO has not reopened the MBM discussion as of yet. As far as the EU ETS is concerned, and assuming that the updated impact assessment study will be completed in the summer of 2021, it all depends on the speed of the legislative process afterwards. Assuming no legal glitches (which may be a big assumption), a very crude guestimate is that the relevant process is completed in 2022 and the kickoff of the EU ETS will be in 2023, coinciding with the end of the 5-year phase after the adoption of the Initial IMO strategy in 2018. This would also coincide with the implementation start of the combined EEXI/SEEMP/CII short-term measures decided by MEPC 75. This would make this an interesting (but possibly messy) interface of two classes of GHG reduction measures, the preparation of which was carried out in parallel and with little or no consideration of the impact that one could have on the other. See however Section 5.4 about the possibility of a combined IMO/EU measure.

5.2.5 Potential impacts on States, cf. IMO procedure (MEPC.1/Circ.885)

To our knowledge, for an ETS there has been no work equivalent to that described in Section 5.1.5 for the carbon levy case. However, most of the relevant considerations relevant for a levy are also valid for ETS. Plus, and on top of whatever problems that a levy might create, the uncertainty of the ETS price would constitute an additional problem. In addition, if, in order to reduce the ETS administrative costs or potential negative impacts (see Section 5.2.6), exemptions are granted to some LDCs/SIDS, possible distortions and carbon leakage may occur. SIDS could establish themselves as mega hubs just to avoid the ETS. Note that SIDS include countries such as Singapore, even though that country is one of the best connected countries in the world.

On top of that, the LDCs/SIDS that asked for the MBM discussion to reopen at the IMO (Antigua, 2018) suggested a levy, not an ETS.

5.2.6 Administrative burden

The administrative costs for ETS include all those administrative costs associated with Option 2 of the GHG Fund proposal (the one which is ship based)-see Chapter 2, plus, many more additional costs associated with issuing the allowances, trading, monitoring compliance, avoiding fraud, and others. Therefore among these two systems, ETS seems heavier administrative-wise.

---

[13] In a recent Global Maritime Forum event (see https://www.globalmaritimeforum.org/virtual-high-level-meeting-2020/livestreams), some shipping companies came out in favor of an EU ETS as a parallel approach to a global carbon levy. This seems to be along the lines of case (b). However, it is not clear if this approach has any official industry association interest, either at the IMO or elsewhere.

Of course, the EU has already a well-defined administrative system to manage the EU ETS carbon market, and this could be conceivably adapted to shipping. The EU has also a well-defined procedure for the EU MRV. However, from a shipping company's perspective, the additional clerical burden of ETS and of combining the two systems could be substantial.

5.2.7 Practical feasibility

It is clear that the costs of ETS enforcement will be on the high side. The certified verifiers that engage in MRV verification could take up this task, at an additional cost obviously. For the reasons outlined in previous sections, and also in Section 5.2.8 that follows, the practical feasibility of a maritime ETS is considered to face substantial challenges, whether this is a global ETS or a regional ETS.

5.2.8 Avoidance of split incentives between ship-owner and charterer

In addition to the above, we think that a serious split incentive between ship owner and charterer may occur under an ETS. The exposition below draws from Psaraftis (2012). Let us look at the time charterer issue. While a ship is on time charter, the charterer is the effective owner. He decides where the ship goes and at what speed. Legally, he is the disponent owner. This is recognized in the charter party which puts fuel expense to the charterer's account. If an ETS is going to impact the charterers' decision on what speed the ship will go, it has to do the same. This means a shipping ETS not only has to do all of the above, but it also has to keep track of whether or not the ship was on charter and, if so, who the charterer was when the fuel was purchased. Also a chartered ship can be sub-chartered, and so on.

If alternatively the ETS ignores the ship's charter status and requires permits *from the owner* for all the fuel consumed on his ship regardless of what the charterer does, looking to the owner to recover the permit cost from the charterer, this would put the owner in an untenable position. He would be responsible for emissions from bunkers which are not his, and permit expenses over which he has no control, and which in many cases are not known until well after the charter is complete. In this way the uncertain price of the permits, purchased at an earlier time, would not influence the charterer to reduce speed in order to reduce fuel consumption. All of this is a non-issue for a levy scheme. Whoever pays for the fuel also pays the levy. Incidentally, a levy MBM can handle slow steaming automatically, by directly impacting the speed decision of either the ship owner (in case of a spot charter) or the charterer (in case of time charter). Under an ETS, it becomes difficult or impossible to link the price of a permit purchased by the ship owner at a certain time and the speed decision of the time charterer at a different time.

We note again the opposition of a major chartering association (Trafigura), as well as the opposition of all shipping industry associations, to an ETS.

5.2.9 Commercial impacts

It would seem that the commercial impacts discussed in Section 5.1.9 for a levy scenario could also apply for the ETS case as well. In particular the “downstream” commercial impacts of an EU ETS, depending on how the proceeds of the fund are administered, would also be valid under such a scheme.

Again, a major difference vis-à-vis the levy is the inherent unpredictability of the carbon price under an ETS. Another difference is the high administrative burden and lower practical feasibility of an ETS. All this might significantly dampen incentives to invest in energy efficient technologies or alternative, low carbon fuels.

In another difference versus the levy scheme, which weighs in favor of an ETS, ETS would be an excellent business opportunity for whoever is tasked to administer ETS allowances and all clerical tasks associated with an ETS. As the administrative burden of the scheme would be substantial, substantial income would be generated for ETS administrators for their services. Obviously such income would come from the shipping companies who would hire such administrators, even though the shipping companies would pass on this cost to the charterers.

Table 5.1 below focuses on the two major classes of MBMs, the levy-based MBMs and the ETS-based MBMs and summarizes our evaluation of these MBMs according to the evaluation criteria, and as per Sections 5.1 and 5.2.

Table 5.1: Summary evaluation of levy-based and ETS-based MBMs.

Criterion/ MBM	Levy-based	ETS-based
GHG reduction effectiveness	Considerable, depending on the level of the levy	Considerable for a global ETS Questionable for an EU ETS
Compatibility with existing legal framework	May encounter legal obstacles	May encounter legal obstacles.
Implementation timeline	Unclear at global level Industry R&D fund on the table at IMO	Unclear at global level EU ETS is forthcoming
Potential impacts on states	Potentially considerable	Potentially considerable
Administrative burden	Low	Considerable
Practical feasibility	High	Questionable
Avoidance of split incentives	No serious split incentives	Serious split incentives
Commercial impacts	Considerable and in many sectors	Considerable but uncertain due to uncertainty on carbon price

5.3 Other MBMs submitted to the IMO

As per Chapter 2, in addition to the GHG Fund and the various ETS proposals, some additional MBM proposals were submitted to the IMO in 2010. Since at this point in time we have no reasonable indication that any of these proposals would be resurrected and resubmitted to the IMO, we shall only comment on each of the cost-benefit criteria *in summary form*.

It would also seem that the LIS scheme by Japan falls under the D variant of levy MBMs defined in Section 5.1, as it would provide a differentiated levy (or no levy) to ships with a good EEDI. To the same category also belongs the IUCN rebate MBM, to the extent it piggy-backs the GHG Fund MBM.

Table 5.2 below summarizes our evaluation of these MBMs according to the evaluation criteria. The table is adapted from a similar analysis in Psaraftis (2012).

Table 5.2: Summary evaluation of other MBMs submitted to the IMO. Adapted from Psaraftis (2012).

Criterion/ MBM	Bahamas (do nothing)	IUCN (rebate)	STEEM (port based)	EIS (EEDI based)	SECT (EEDI based)
GHG reduction effectiveness	Some CO2 reductions can be achieved even with no MBM.	Proposal piggybacks any MBM. Its environmental effectiveness is same as that of MBM implemented.	Carbon leakage risks exist as some port states may not implement scheme.	Lower than GHG Fund, as some ships will be exempted	Low. CO2 reduction certainty does not exist, as scheme trades on EEDI. No attempt to compute CO2 directly.
Compatibility with existing legal framework	Fully compatible	Same as that of MBM implemented	Likely to encounter legal obstacles		
Potential implementation timeline	None of these proposals is still alive. There is no indication of any attempt to reinstate.				
Potential impacts on states	None	Could be beneficial to LDCs and SIDs if levy is based on imports	Unclear. May create distortions by diverting traffic to port states that do not implement the scheme.	Unclear. SIDS served by older ships may be at a disadvantage	Unclear. SIDS served by older ships may be at a disadvantage
Administrative burden	Zero	Higher than that of MBM implemented (add costs of administering rebates)	High	Lower than SECT, but higher than GHG Fund.	Worse than ETS.

Practical feasibility	Highest	Lower than that of MBM implemented (add costs of administering rebates)	Low. Practically impossible to monitor emissions.	Higher than SECT but lower than GHG Fund, due to tracking of EEDI for existing ships.	Worse than ETS. Combines problems of ETS with tracking EEDI for existing ships and estimating activity levels.
Avoidance of split incentives	No split incentives	Same as that of MBM implemented.	Unclear	Unclear	Unclear
Commercial impacts	None	Same as that of MBM implemented.	Unclear	May favor countries with strong shipbuilding sector	May favor countries with strong shipbuilding sector

5.4 Other MBMs

We are not aware of other MBM proposals, however in this section we want to very briefly discuss the possibility of combining ship operational measures with MBMs. This might take one of the following forms (list below is not exhaustive):

i. Use a global carbon levy but ships that have a “good” Carbon Intensity Indicator (CII) get a discount or rebate (with CII and “good” appropriately defined, for instance ships with climate rating A or B).
ii. Same as i except levy is paid only if CII is above an appropriately defined threshold.
iii. In the EU ETS, ships with a “good” CII can trade allowances with ships with a “bad” CII (again, “good” and “bad” are appropriately defined).
iv. Same as iii except ETS is applied only if CII is above an appropriately defined threshold.
v. Same as iii except a combination of the EU ETS and the new EEXI/SEEMP/CII combined short-term measure agreed upon at MEPC 75 is considered.

MBMs similar to some of the above cases have already been proposed, in the context of the prior IMO MBM discussion. For instance, case i looks similar to Japan’s LIS or WSC’s VES MBM proposals, and case iii resembles the USA’s SECT proposal, all circa 2010. In that sense, the discussion of the previous chapter is relevant.

Perhaps more interesting is case v, the possible combination of an EU ETS with the recent EEXI/SEEMP/CII combined short-term measure, which looks like it will be IMO’s way ahead as regards a short-term measure. To our knowledge no such combination has been proposed, and the analysis of such a combination is outside the scope of this report. However, should both measures go ahead, one could foresee a scenario in which the two measures are combined instead of being applied in parallel and independently. Obviously the coverage of such a scenario would be limited to the coverage of the EU ETS, whatever that might be.

Under such a scheme, one could envision a “revenue neutral” scheme in which ships that fall in the “bad” ship categories of the EEXI/SEEMP/CII scheme (classes D and E) would be asked to pay the EU ETS carbon price, whereas classes A and B might conceivably get some revenue. Alternatively, class D and E ships could purchase carbon allowances that are held by high performing ships (classes A and B). Other combination schemes could also be considered.

Investigating such a combination would obviously be interesting from a research point of view. It would seem that combining two measures both of which entail a non-trivial degree of complexity would probably result in a more complex measure that would be difficult to enforce and whose benefits would be hard to document. Such a combination might also detract from the global MBM discussion, or even be an impediment to it, whenever that discussion resumes at the IMO. However, such a combination might be attractive in the sense that it would combine the two processes, of the IMO and of the EU, which are running in parallel at this point in time.

ACKNOWLEDGMENTS

This work has been in the context of a project on market based measures commissioned by the Danish Maritime Authority to the Technical University of Denmark (DTU) and supported by the Danish Maritime Fund under the umbrella project “Maritime DTU, Forskningsbaseret maritim rådgivning 2019-2020.”

REFERENCES

Abbasov, F. (2019). EU Shipping's Climate Record. Report by Transport and Environment. Available online: https://www.transportenvironment.org/sites/te/files/publications/Study-EU_shippings_climate_record_20191209_final.pdf

Alexius, S., and Grossi, G. (2018). Decoupling in the age of market-embedded morality: responsible gambling in a hybrid organization. *Journal of Management and Governance*, *22*(2), 285-313.

Antigua (2018). Action Plan for implementing the IMO GHG Strategy and candidate measures, submitted by Antigua and Barbuda, Kenya, Marshall Islands, Palau, Solomon Islands, Tonga, and Tuvalu. IMO doc ISWG-GHG 4/2/3.

Bahamas (2010) Market-Based Instruments: a penalty on trade and development proposal by the Bahamas, IMO doc. MEPC 60/4/10.

Bai, J. Y., and Ma, Y. (2018). The post-Paris approach to mitigating Arctic warming—perspectives from shipping emissions reduction. *Adv. Polar Sci*. *29*(1), 40-50.

Balcombe, P.; Brierley, J., Lewis, C., Skatvedt, L.. Speirs, J.; Hawkes, A.; and Staffell, I. (2019). How to decarbonise international shipping: Options for fuels, technologies and policies. *Energy Convers. Manag.* , *182*, 72–88

Ben-Hakoun, E., Shechter, M., and Hayuth, Y. (2016). Economic evaluation of the environmental impact of shipping from the perspective of CO 2 emissions. *Journal of Shipping and Trade*, *1*(1), 5.

BHP Group Limited BW Group DNB DNV GL–Maritime (2019). Carbon Levy Evaluation-Could a Carbon Levy in Shipping be an Effective Way to Help; Global Maritime Forum: Singapore, Republic of Singapore*;*

Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D. et al. (2009). Second IMO GHG Study 2009.

Cariou, P.; Cheaitou, A. (2012) The effectiveness of a European speed limit versus an international bunker-levy to reduce CO_2 emissions from container shipping. *Transp. Res. Part D* , *17*, 116–123,

Carrese, S., Nigro, M., Petrelli, M., and Renna, A. (2020). Identifying policies for intermodal logistics chains based on domestic Ro-Ro services. *Maritime Supply Chains* 149-165.

CBO (2008). Policy Options for reducing CO2 emissions, The Congress of the United States, Congressional Budget Office, February.

Chai, K.-H.; Lee, X.N.; Gaudin, A. (2019)- A Systems Perspective to Market–Based Mechanisms (MBM) Comparison for International Shipping. *Ssrn Electron. J.* doi:10.2139/ssrn.3347448.

China (2020). Proposal for a mandatory goal-based technical and operational short-term measure with combination of EEXI, SEEMP, CII and rating mechanism. Submitted by China, Croatia, Denmark, France, Germany, Ghana, India, Italy, Japan, Malaysia, Nigeria, Norway, Singapore, Spain, United Arab Emirates and ICS. IMO doc. ISWG-GHG-7/2/26.

Cullinane, K., and Cullinane, S. (2019). Policy on reducing shipping emissions: implications for “green ports”. In *Green Ports* (pp. 35-62). Elsevier.

Denmark, (2010). The International Fund for Greenhouse Gas emissions from ships (GHG Fund) proposed by Cyprus, Denmark, the Marshall Islands, Nigeria and IPTA, IMO doc. MEPC 60/4/8.

Denmark, (2020). Detailed impact assessment of the mandatory operational goal-based short-term measure, submitted by Denmark, France and Germany, IMO doc. ISWG-GHG-7/2/20.

Devanney, J.W. (2010). The Impact of EEDI on VLCC Design and CO2 Emissions, Center for Tankship Excellence, USA www.c4tx.org

Devanney, J. (2011a). Direct taxation is the best way to curb CO2 emissions, Lloyds List, May 4, 2011.

Devanney, (2011b). Are owners and charterers really that stupid? Center for Tankship Excellence, USA www.c4tx.org.

De Vany, A. (1998). Implementing a market-based spectrum policy. *The Journal of Law and Economics*, *41*(S2), 627-646.

Ding, W., Wang, Y., Dai, L., & Hu, H. (2020). Does a carbon tax affect the feasibility of Arctic shipping?. *Transportation Research Part D: Transport and Environment*, *80*, 102257.

DNV (2009). Pathways to Low Carbon Shipping, DNV report, 2009.

EC (2013). Proposal from the Commission to the European Parliament and Council for the Inclusion of GHG Emissions from Maritime Transport in the EU’s Reduction Commitments Impact Assessment (Parts I, II).

Eide, M.S., Endresen, Ø.; Skjong, R., Longva, T., and Alvik, S. (2010). Cost-effectiveness assessment of CO2 reducing measures in shipping, *Maritime Policy and Management* Vol. 36, No. 4, 367 – 384.

EMSA (2020). 2019 Annual Report on CO2 Emissions from Maritime Transport, European Commission report C(2020) 3184 final.

EU (2013). Proposal for a Regulation of the European Parliament and of the Council on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport and amending Regulation (EU) No 525/2013, COM(2013) 480 final, Brussels, 28.6.2013.

EU (2015). European Parliament and the Council. Regulation (EU) 2015/757 Of 29 April 2015 On the Monitoring, Reporting and Verification of Carbon Dioxide Emissions from Maritime Transport, and Amending Directive 2009/16/EC; European Parliament and the Council: Strasbourg, France, 2015.

EU (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "the European Green Deal" (Com/2019/640 Final)

Evans, A. (2016). Emissions and Aviation: Towards Greener Air Transport, in Psaraftis, H.N. (ed.), *Green Transportation Logistics: The Quest for Win-Win Solutions*, Springer.

France (2010). Further elements for the development of an Emissions Trading System (ETS) for International Shipping proposal by France, submitted by France, IMO doc. MEPC 60/4/41.

France (2018). Proposal to include work on Market-Based Measures in the programme of follow-up actions of the Initial IMO GHG Strategy, submitted by France, IMO doc. ISWG-GHG 4/2/11.

Germany (2010). Impact Assessment of an Emissions Trading Scheme with a particular view on developing countries, IMO doc. MEPC 60/4/54.

Giovannini, M., and Psaraftis, H.N., (2019). The profit maximizing liner shipping problem with flexible frequencies: logistical and environmental considerations, *Flexible Services and Manufacturing Journal* 31:567–597.

Gkonis, K.G., and Psaraftis, H.N. (2012). Modelling tankers' optimal speed and emissions, Archival Paper, *2012 SNAME Transactions*, Vol. 120, 90-115.

Gu, Y., Wallace, S.W. and Wang, X. (2019). Can an Emission Trading Scheme really reduce CO2 emissions in the short term? Evidence from a maritime fleet composition and deployment model. *Transp. Res. Part D*, *74*, 318–338, Halim, R. A., Smith, T., and Englert, D., (2019), Understanding the Economic Impacts of Greenhouse Gas Mitigation Policies on Shipping: What Is the State of the Art of Current Modeling Approaches? Policy Research paper 8695, World Bank Group, January.

Hermeling, C. (2015). Sailing into a Dilemma. *Transp. Res. Part A*, *78*, 34–53, doi:10.1016/j.tra.2015.04.021.

Hoffmann, J. (2020), Decarbonizing Maritime Transport: Estimating Fleet Renewal Trends Based on Ship Scrapping Patterns. UNCTAD.
Available online: https://unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2288

Hoffman, J., Rydbergh, T., and Stevenson, A. (2020). Decarbonizing Shipping: What role for flag states?. UNCTAD.
Available online: https://unctad.org/en/pages/newsdetails.aspx?OriginalVersionID=2309

Hughes, E. (2020). Implications of application of the EU Emissions Trading System (ETS) to international shipping, and potential benefits of alternative Market-Based Measures (MBMs), study conducted for the International Chamber of Shipping and the European Community Shipowners Associations, July.

ICS (2019). Proposal to establish an International Maritime Research and Development Board (IMRB) Submitted by BIMCO, CLIA, ICS, INTERCARGO, INTERFERRY, INTERTANKO, IPTA, and WSC. IMO doc. MEPC 75/7/4.

IMAREST (2011). Marginal Abatement Costs and Cost Effectiveness of Energy-Efficiency Measures, IMO doc. MEPC 62/INF.7.

IMO (1995). Financial Matters: Proposals for Long-Term Financing of the Integrated Co-Operation Programme; TC 41/7(c) Note by the Secretariat; IMO: London, UK.

IMO (2010). Full report of the work undertaken by the Expert Group on Feasibility Study and Impact Assessment of possible Market-based Measures, IMO doc. MEPC 61/INF.2.

IMO (2018). Resolution MEPC.304(72) (adopted on 13 April 2018), Initial IMO Strategy on reduction of GHG emissions from ships, IMO doc. MEPC 72/17/Add.1, Annex 11.

IMO (2020). Review of impact assessments by UNCTAD, Note by the Secretariat, IMO doc. ISWG-GHG-7/2/36.

IUCN (2010), A Rebate Mechanism (RM) for a market-based instrument for international shipping proposal by IUCN, IMO doc. MEPC 60/4/55.

Jamaica (2010). Achieving reduction in greenhouse gas emissions from ships through Port State arrangements utilizing the ship traffic, energy and environment model, STEEM (PSL) proposal by Jamaica, IMO doc. MEPC 60/4/40.

Japan (2010). The Leveraged Incentive Scheme (LIS) to improve the energy efficiency of ships based on the International GHG Fund proposed by Japan, IMO doc. MEPC 60/4/37.

Japan and WSC (2011). Consolidated proposal of "Efficiency Incentive Scheme" based on the Leveraged Incentive Scheme and the Vessel Efficiency System, IMO doc. GHG WG 3/3/2.

Kachi, A. Mooldijk, S. and Warnecke, C. (2019). Carbon Pricing Options for International Carbon Pricing Options for International Maritime Emissions. Available online: https://newclimate.org/2019/03/19/carbon-pricing-options-for-international-maritime-

Kapetanis, G.N., Gkonis, K., and Psaraftis, H.N. (2014) Estimating the Operational Effects of a Bunker Levy: The Case of Handymax Bulk Carriers, TRA 2014 conference, Paris, France, April.

Kontovas, C.A. and Psaraftis, H.N. (2016), Transportation Emissions: Some Basics, in Psaraftis, H.N. (ed.), *Green Transportation Logistics: The Quest for Win-Win Solutions*, Springer.

Koesler, S., Achtnicht, M., and Köhler, J. (2015). Course set for a cap? A case study among ship operators on a maritime ETS. *Transp. Policy, 37*, 20–30, doi:10.1016/j.tranpol.2014.10.009.

Kosmas, V. and Acciaro, M. (2017). Bunker levy schemes for greenhouse gas (GHG) emission reduction in international shipping. *Transp. Res. Part D*, *57*, 195–206.

Krammer, P. and Smith, T. (2017), Impact assessment of IMO Greenhouse Gas Reduction Strategies on New Zealand's economy, UCL Energy Institute, London, UK, November.

Lagouvardou, S., Psaraftis, H.N., Zis, T., (2020), A Literature Survey on Market-Based Measures for the Decarbonization of Shipping, *Sustainability*, 12(10), 3953; https://doi.org/10.3390/su12103953

Lema, E. and Papaioanou, D. (2013). Policy instruments and recent advances of the greenhouse gas regulating framework in shipping. *Interdiscip. Environ. Rev.* , *14*, 238.

Lema, E., Karaganis, A. and Papageorgiou, E. (2017). A Fuzzy Logic Modeling of Measures Addressing Shipping CO2 Emissions. *J. Intell. Syst.* , *26*, 439–455.

Lighthouse (2020), Including maritime transport in the EU Emission Trading System addressing design and impacts. Report by Lighthouse, Gothenburg, Sweden.

Lyle, C. (2018). Beyond the ICAO's CORSIA: Towards a more climatically effective strategy for mitigation of civil-aviation emissions. *Climate Law*, *8*(1-2), 104-127.

Marshall (2020). Comments on the Fourth IMO GHG Study 2020 and Encouraging Further Ambitious Action to Reduce GHG Emissions. Submitted by the Marshall Islands and Solomon Islands, IMO doc. MEPC 75/7/17.

Miola, A., Marra, M., and Ciuffo, B. (2011), Designing a climate change policy for the international maritime transport sector: Market-based measures and technological options for global and regional policy actions. *Energy Policy*, *39*, 5490–5498,

Morimoto, S. (2018). Analyzing Approaches to Set Greenhouse Gas Reduction Targets in Anticipation of Potential "Further Measures" for International Shipping. In *Trends and Challenges in Maritime Energy Management* (pp. 29-40). Springer, Cham.

Murphy, A. (2019). Why ICAO and CORSIA cannot deliver on climate. Report by Transport and Environment, September.

Norway (2010). The Global Emission Trading System (ETS) for international shipping proposal by Norway, IMO doc. MEPC 61/4/22.

Norway (2019). *The Need for a Flexible Compliance Mechanism Submitted by Norway;* IMO doc. ISWG-GHG 6/7; IMO: London, UK.

NZIER (2018), MARPOL IV and VI: Assessing the economic and environmental impact of international maritime measures on New Zealand. NZIER report to Ministry of Transport, November.

Parry, I., Heine, D., Kizzier, K., and Smith, T. (2018). Carbon Taxation for International Maritime Fuels: Assessing the Options. IMF working paper 18.

Psaraftis, H.N. (2012) Market Based Measures for Green House Gas Emissions from Ships: A Review, *WMU Journal of Maritime Affairs* 11, 211-232.

Psaraftis, H.N., (2019a), Speed Optimization vs Speed Reduction: are speed limits better than a bunker levy? *Maritime Economics and Logistics* 21, 524–542, doi.org/10.1057/s41278-019-00132-8

Psaraftis, H. N., (2019b) Speed Optimization for sustainable shipping, in H.N. Psaraftis (ed.) *Sustainable shipping: a cross-disciplinary view*, Springer.

Psaraftis, H.N., and Haralambides, H. (2020). Combining speed and MBM measures to reduce GHG emissions from ships: science versus politics, IAME 2020 conference, Hong Kong, China, June.

Psaraftis, H.N., and Kontovas, C.A., (2010), Balancing the Economic and Environmental Performance of Maritime Transportation, *Transportation Research Part D* 15, 458-462.

Psaraftis, H.N., and Kontovas, C.A. (2013). Speed Models for Energy-Efficient Maritime Transportation: A Taxonomy and Survey," *Transportation Research Part C: Emerging Technologies* 26, 331–351, 2013.

Psaraftis, H.N., and Lagouvardou, S., (2019), Market Based Measures for the reduction of green house gas emissions from ships: a possible way forward, *Samfundsøkonomen* 4/19, 60-70.

Psaraftis, H.N., and Zachariadis, P. (2019). The way ahead, chapter in H.N. Psaraftis (ed.) *Sustainable shipping: a cross-disciplinary view*, Springer.

Rahim, M. M., Islam, M. T., and Kuruppu, S. (2016). Regulating global shipping corporations' accountability for reducing greenhouse gas emissions in the seas. *Marine Policy*, *69*, 159-170.

Rehmatulla, N. and Smith, T. (2015) Barriers to energy efficient and low carbon shipping, *Ocean Engineering* 110,102–112.

Rehmatulla, N., Piris-Cabezas, P., Baresic, D., Fricaudet, M., Raucci, C., Cabbia Hubatova, M., O'Leary, A., Stamatiou, N., and Stratton, A. (2020) Exploring the relevance of ICAO's Sustainable Aviation Fuels framework for the IMO, London, UK.

Ricardo, AEA, Milieu, IHS, Amec, and Marintek, (2013). Support for the Impact Assessment of a Proposal to Address Maritime Transport Greenhouse Gas Emissions, Report for European Commission-DG Climate Action. 2013.

Scheelhaase, J., Maertens, S., Grimme, W., and Jung, M. (2018). EU ETS versus CORSIA–A critical assessment of two approaches to limit air transport's CO2 emissions by market-based measures. *Journal of Air Transport Management*, *67*, 55-62.

Shi, Y. (2016). Reducing greenhouse gas emissions from international shipping: Is it time to consider market-based measures? *Mar. Policy*, *64*, 123–134.

Skjolsvik, K.; Andersen, A.; Corbett, J.; Skjelvik, J. (2000). Study of Greenhouse Gas Emissions from Ships Final Report to the International Maritime Organization.

Smith, T.; Raucci, C.; Haji Hosseinloo, S.; Rojon, I.; Calleya, J.; De La Fuente, S.; Wu, P.;and Palmer, K. (2016), CO2 Emissions from International Shipping Possible

Reduction Targets and Appendix and Operational Intervention Assumptions. Report by UMAS, London, UK.

Streng, M., van Saase, N., Jansen, M., and Kuipers, B. (2020), The impact of emission pricing in the Green Deal on Dutch and European maritime transportation. Report by the Erasmus Centre for Urban, Port and Transport Economics, Rotterdam, Netherlands.

Tanaka, H.; Okada, A. (2019). Effects of market-based measures on a shipping company: Using an optimal control approach for long-term modeling. *Res. Transp. Econ.*, *73*, 63–71,

Trafigura (2020), A proposal for an IMO-led global shipping industry decarbonisation programme. Report by Trafigura, October.

Tran, T.M.T.; Yuen, K.F.; Li, K.X.; Balci, G.; Ma, F. (2020), A theory-driven identification and ranking of the critical success factors of sustainable shipping management. *J. Clean. Prod.*, *243*, doi:10.1016/j.jclepro.2019.118401.

UK (2010) Global Emissions Trading System (ETS) for international shipping proposal by the United Kingdom, IMO doc. MEPC 60/4/26.

UK (2020) Economic incentives to reduce GHG emissions from international shipping Submitted by the United Kingdom, IMO doc ISWG-GHG-7/8/1.

USA (2010) The United States proposal to reduce greenhouse gas emissions from international shipping, the Ship Efficiency and Credit Trading (SECT), IMO doc. MEPC 60/4/12.

Varela, J. C. (2019). Climate change, international shipping and market-based measures. In *Environmental Tax Studies for the Ecological Transition. Comparative Analysis Addressing Urban Concentration and Increasing Transport Challenges* (pp. 397-412). Civitas.

Vos, H. (2005). Market-based instruments for environmental policy in Europe. EEA Technical Report 8/2005, European Environmental Agency, Copenhagen.

Wang, K.; Fu, X.; Luo, M. (2015) Modeling the impacts of alternative emission trading schemes on international shipping. *Transp. Res. Part A*, *77*, 35–49.

Wang, X.; Norstad, I.; Fagerholt, K.; Christiansen, M. (2019) Green Tramp Shipping Routing and Scheduling: Effects of Market-Based Measures on CO2 Reduction, in H.N. Psaraftis (ed.) *Sustainable shipping: a cross-disciplinary view,* Springer.

Wijnolst, N. and Bartelds, M. (1995) Analysis of the Panamax bulk carrier charter market 1989-1994 in relation to the design characteristics, Delft University Press, 1995.

WSC (2010) Vessel Efficiency System (VES) proposal by World Shipping Council, IMO doc. MEPC 60/4/39.

WSC (2020), EU ETS discussion paper, report by the World Shipping Council, September.

Zhang, H. (2016). Towards global green shipping: the development of international regulations on reduction of GHG emissions from ships. *International Environmental Agreements: Politics, Law and Economics*, *16*(4), 561-577.

Zhu, M.; Yuen, K.F.; Ge, J.W.; Li, K.X. (2018). Impact of maritime emissions trading system on fleet deployment and mitigation of CO2 emission. *Transp. Res. Part D* , *62*, 474–488

Zis, T., North, R. J., Angeloudis, P., Ochieng, W. Y., and Bell, M. G. H. (2014). Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports. *Maritime Economics & Logistics*, *16*(4), 371-398.

Zis, T., Psaraftis, H.N., (2017), The implications of the new sulphur limits on the European Ro-Ro sector, *Transportation Research Part D*, 52, 185-201.

Zis, T. P., Psaraftis, H. N., Panagakos, G., and Kronbak, J. (2019). Policy measures to avert possible modal shifts caused by sulphur regulation in the European Ro-Ro sector. *Transportation Research Part D*, *70*, 1-17.

Zis, T. & Psaraftis, H.N. (2019). Operational measures to mitigate and reverse the potential modal shifts due to environmental legislation, *Maritime Policy & Management*, 46:1, 117-132.

APPENDIX A: A split incentive scenario

This appendix provides more insights into the split incentive issue.

We rewrite again the MAC formula:

$$MAC = \Delta GC/\Delta CO_2 - P/F \qquad (1)$$

where

- ΔGC is the cost of the technology
- ΔCO_2 are the tonnes of CO_2 averted by that technology
- P is the fuel price
- F is the carbon coefficient

We assume two ships, A and B, that belong to the same owner and which are offered for time charter.

SHIP A: At sea fuel consumption function $f_A(v)$ at ship speed v (in tonnes/mo)[14].

SHIP B: At sea fuel consumption function $f_B(v)$ (in tonnes/mo).

Ship B is identical to A, except it also has an energy saving device, which can be installed at a cost of C. Due to this device, $f_B(v) < f_A(v)$.

Assume that both fuel consumption functions are accurate and that they are also known to the charterer, in addition to the ship owner. Assume that the ship owner does not play games by stating a false fuel consumption function in order to attract customers.

We ignore:

- In port fuel consumption
- At sea fuel consumption dependency on payload
- Downtime of ship due to inspections, class surveys

Including either or all will make the algebra more hairy but will not change the essence of the results.

Interconnected questions:

- Is it worth investing in the gadget?
- How much more can the ship owner charge the time charterer to hire ship B instead of ship A?

Define the following variables:

[14] we put it in tonnes per month to simplify the calculations.

T: time charter duration (years).

TC_A, TC_B: time charter rates for ships A, B ($/DWT tonne/mo)

DWT: ship deadweight (tonnes)

OPEX: monthly operating costs of the ship (other than fuel)

i: discount rate

Assume T is large, equivalent to the remaining lifetime of the ship. If we relax this assumption, analysis may be a bit more tedious.

Then we can compute the NPV of profits for the ship owner for ships A and B:

$NPV_A = 12(TC_A\ DWT\text{-}OPEX)\ \sum_{k=1}^{T}(1+i)^{-k}$

$NPV_B = -C+12(TC_B\ DWT\text{-}OPEX)\ \sum_{k=1}^{T}(1+i)^{-k}$

The NPV difference is

$\Delta NPV = NPV_B - NPV_A = -C + 12DWT(TC_B - TC_A)\ \sum_{k=1}^{T}(1+i)^{-k}$

Or $\Delta NPV = -C + mDWT(TC_B - TC_A)$

With $m = 12\sum_{k=1}^{T}(1+i)^{-k}$

$\Delta NPV > 0$ if and only if

$TC_B - TC_A > C/mDWT$ (2)

Or, the minimum TC rate differential the ship owner can charge for ship B over ship A is C/mDWT.

The question of course is if the time charterer will accept TC_B.

Let's see things from the charterer's perspective.

His net present cost for ships A and B are:

$NPC_A = m\ (TC_A DWT + P\ f_A(v))$

$NPC_B = m\ (TC_B DWT + P\ f_B(v))$

We assume that speeds for ships A and B are the same, otherwise we will need a different number of ships to satisfy throughput. We also assume that they are constant through T.

Relaxing these assumptions will make calculations more hairy, but I speculate that the general conclusions will not change.

The charterer will prefer ship B to ship A so long as $NPC_B < NPC_A$. This means that

$TC_A DWT + P\ f_A(v) > TC_B DWT + P\ f_B(v)$, or

$(TC_B - TC_A) < P(f_A(v) – f_B(v))/DWT$ (3)

If we want both (2) and (3) to be valid (ie both ship owner and charterer want the contract to happen with ship B), then we will have to have:

$C/mDWT < TC_B - TC_A < P(f_A(v) – f_B(v))/DWT$ (4)

This means that, for any given TC rate for ship A, the TC rate for ship B has to be within the following bracket:

Lower bound: $TC_B > TC_A + C/mDWT$ (5a)

Upper bound: $TC_B < TC_A + P(f_A(v) – f_B(v))/DWT$ (5b)

So the upper bound on what the ship owner can charge over and above the TC rate for ship A is the difference of monthly fuel cost between the 2 ships, per DWT tonne. This is not a big surprise. Of course the fuel cost over the next T years will not be constant and cannot be predicted in advance, whereas the TC rate has to be agreed in advance, but this is another issue.

Per tonne of fuel saved, the upper bound of the extra TC income the owner can receive, which is $(TC_B – TC_A)DWT$, is P.

This means that the MAC equation (1) is also valid for the time charter case, since the term –P/F is (per tonnes of CO_2 averted) the maximum benefit that the ship owner can receive from the charterer in the form of increased TC rate.

Of course, the lower bound of (5a) has to be lower than the upper bound of (5b). Thus, a necessary (but not sufficient) condition for (4) to happen is

$C/mDWT < P(f_A(v) – f_B(v))/DWT$, or

$C < mP(f_A(v) – f_B(v))$ (6)

If this is the case, a TC rate can always be found for ship B so that both ship owner and charterer are better off with ship B rather than ship A.

In case a levy L is imposed, (6) can be rewritten as follows:

$C < m(P+L) (f_A(v) – f_B(v)$ (7)

In other words, even for the time charter scenario, technologies that are more expensive and non-viable without a levy can now become viable, AND, the ship owner will have an incentive to invest in them.

APPENDIX B: A rudimentary carbon leakage scenario

The European Parliament (EP) rapporteur on the subject of EU ETS Jutta Paulus has discounted concerns that ships may deliberately transship cargoes at non-EU ports located near the EU, on the ground that there may not be available capacity in such ports, or that doing so may not bring benefits to the shipping lines. The EP has also hinted that it may redefine what is meant by "port of call". Whether this is true or not is not clear, however in this appendix we make some very crude calculations to examine such a scenario.

Assume a mainline containership going between a port in the Far East (eg Shanghai) and a port in Europe (eg, Antwerp). If the EU ETS is applied, the mainline service terminates at Felixstowe, UK (assumed out of EU) instead of Antwerp, and cargo to Antwerp goes by feeder ship. Same with the opposite direction. Assume there are no other ports in between (the analysis with intermediate ports is more involved but is not expected to change the conclusions of the analysis).

We want to compare the following 3 scenarios:

SCENARIO 0 (baseline scenario): Direct service Shanghai to Antwerp. No levy. No ETS.

SCENARIO A: Direct service Shanghai to Antwerp, global bunker levy equal to q.

SCENARIO B: Service Shanghai to Antwerp via Felixstowe, EU ETS.

Obviously in scenario B, only the fuel consumption between Felixstowe and Antwerp (both ways) will be subject to paying the ETS, and the rest of the trip will not, whereas in scenario A, all of the fuel consumption will be subject to the levy.

For the ETS, we will assume that ships will buy allowances at a given ETS price q. q is determined by the EU ETS market.

In both cases we run numbers for various values of q.

Distances:

SHA-ANT: L_1=10530 nm

SHA-FEL: L_2=10456 nm

FEL-ANT: L_3=141 nm

Note that 10456+141=10597>10530.

Simplifying assumption: 0 port times, 0 port emissions! If we relax the 0 port time assumption, things will get even worse for ETS.

Another assumption: Feeder ship is same type and size as mother ship. If feeder ship is smaller, things will get even worse for ETS. In our scenario, cargoes at Felixstowe may not even have to leave the ship, since they will be unloaded and loaded onto a feeder of same size.

We use same ship as in Psaraftis (2019a).

Table B.1: Assumed inputs

Input	Value
Ship capacity, Q	10,000 TEU
Trip distances, L	L_1=10530 nm L_2=10456 nm L_3=141 nm
Freight rate, R (base case)	750 USD/TEU
Load factor, u	0.6
Fuel price p (base case)	500 USD/tonne
Minimum speed, v_{min}	16 knots
Maximum speed, v_{max}	26 knots
Operating expenses, OPEX, other than fuel	7,500 USD/day

We assume that fuel consumption FC (tonnes/day) = kv^3, where k is such that FC= 144 tonnes/day when v=22 knots. The value of k for which this is the case is $9.7827*10^{-7}$ (v in the formulas is in nm/day).

We assume that ships choose speeds so as to maximize average daily profits.

We ignore the fact that when in scenario B the ship buys ETS allowances the owner may not know what the ETS price would be, and would be able to optimize ship speed under a known ETS price. Relaxing this assumption would make things worse for ETS, as there would be no speed reduction and no GHG emissions reduction under the ETS scheme.

If this is the case, we apportion the freight rate R into 2 parts, one per distance sailed. We do this as in the calculation of the optimal speed, R/L is the ratio that goes into the calculation (Psaraftis, 2019a).

Then for any given overall rate R, it is apportioned into 2 parts, R_2, the rate from Shanghai to Felixstowe and R_3, the rate from Felixstowe to Antwerp, as follows:

$R_2 = RL_2/(L_2+L_3) = 0.98669$

$R_3 = RL_3/(L_2+L_3) = 0.01331$

In both cases, the ratio R to L is the same in the 2 legs, therefore in the absence of ETS one would expect equal ship speeds in both legs. If an ETS is applied, ship speed will be reduced only at the leg from Felixstowe to Antwerp (and vice versa). It will stay the same from Shanghai to Felixstowe (and vice versa). This, by itself, means that no GHG reductions will be seen at the long leg of the trip. The avoidance of such GHG reductions would constitute a serious carbon leakage.

If we do this, we can decompose the speed optimization problem under the ETS scenario into two disjoint speed optimization problems, one from Shanghai to Felixstowe with no levy and one from Felixstowe to Antwerp with a levy equal to the ETS price that will be established. The difference with the global levy scenario is that the price of the levy is known, whereas the ETS price will be determined by the market.

The basic results are shown in Tables B.2 and B.3 below.

Table B.2: Levy summary

LEVY	usd/tonne	0	100	200	300	400	500
Speed	knots	22.49	20.53	19.00	17.78	16.76	16.00
Adjusted CO2 per day	tonnes/day	478.16	398.46	341.54	298.85	265.64	242.10
Delta CO2 per day	tonnes/day	0	79.69	136.62	179.31	212.51	236.05
Levy income per roundtrip	usd	0	500,000	857,143	1,125,000	1,333,333	1,518,978
Levy income per day	usd/day	0	11,696	18,563	22,790	25,466	27,696
Adjusted by throughput factor	usd/day	0	12,812	21,964	28,828	34,166	38,923

Table B.3: EU ETS summary

ETS price	usd/tonne	0	100	300	500
Speed SHA-FEL	knots	22.41	22.41	22.41	22.41
Speed FEL-ANT	knots	22.41	20.46	17.72	16.00
Adjusted CO2 per day	tonnes/day	473.63	472.58	471.26	470.54
Delta CO2 per day	tonnes/day	0	1.05	2.36	3.09
ETS income per RT	usd	0	6,653	14,969	20,340
ETS income per day	usd/day	0	168.65	378.61	513.52
Adjusted by throughput factor	usd/day	0	168.86	379.94	516.26

It can be seen that the EU ETS achieves much lower CO_2 emissions reductions than those achievable by a global levy. Also the funds collected by a global levy are much higher, even if the global levy is much lower than the ETS price.

Obviously this is a very crude scenario. Our conjecture is that a more realistic scenario would lead to more or less similar conclusions.