Int Environ Agreements (2021) 21:445–467
https://doi.org/10.1007/s10784-020-09523-2

ORIGINAL PAPER

Impact assessment of a mandatory operational goal-based short-term measure to reduce GHG emissions from ships: the LDC/SIDS case study

Harilaos N. Psaraftis[1] · Thalis Zis[1]

Accepted: 22 December 2020 / Published online: 3 January 2021

Abstract

The purpose of this paper is to describe the impact assessment of a mandatory operational goal-based short-term measure to reduce green house gas (GHG) emissions from ships. The specific measure has been proposed by Denmark and other co-sponsors in the context of the relevant discussion at the International Maritime Organization (IMO) and in particular the so-called Initial IMO Strategy. The IMO is a specialized United Nations agency that regulates shipping. The Initial IMO Strategy, adopted in 2018, has been the most recent major international environmental agreement on how to reduce GHG emissions from ships at a global level. The central research question in this paper is to ascertain the potential impacts of the aforementioned measure to least developed countries (LDCs) and small island developing states (SIDS). There are concerns that such states may be negatively impacted, or even disproportionately negatively impacted, by whatever measure is decided by the IMO. After gaps in the literature and data are identified, our methodology develops a list of potential negative impacts, and looks at a set of factors that may influence these impacts. Then, we discuss how the goal-based measure may impact LDCs/SIDs as regards each of the identified negative impacts. The analysis argues that for LDCs and SIDS a risk for negative and disproportionately negative impacts exists. The only negative impact of which both the probability and the consequence are considered high is the difficulty to finance retrofitting of old ships or investment in new ships. As such, this is likely a disproportionally negative impact. At the same time, the degree of share (or responsibility) of the goal-based measure with respect to such potential negative impacts, vis-à-vis the share of other factors contributing to these impacts, cannot be precisely ascertained, even though we conjecture this share to be low.

Keywords Green house gases · Shipping · Impact assessment · IMO · Least developed countries · Small island developing states

✉ Harilaos N. Psaraftis
hnpsar@dtu.dk

Thalis Zis
tzis@dtu.dk

[1] Department of Technology, Management and Economics, Technical University of Denmark, 2800 Lyngby, Denmark

1 Introduction

The International Maritime Organization (IMO) is a specialized United Nations agency that regulates shipping. The so-called "Initial IMO Strategy" to reduce green house gas (GHG) emissions from ships was adopted by the IMO in 2018 and is currently the most important international environmental agreement as regards what the shipping community plans to do on climate change on a global basis (IMO 2018). The strategy classifies potential measures to reduce GHG emissions into three classes: short-term measures, medium-term measures, and long-term measures. Respectively these measures are to be agreed upon and implemented between 2018 and 2023, between 2023 and 2030, and between 2030 and 2050. Emissions reduction targets basically fall into two categories: (a) to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts toward 70% by 2050, compared to 2008; and (b) to reduce total annual GHG emissions by at least 50% by 2050 compared to 2008.

It should be mentioned here that according to the recently released 4th IMO GHG study (IMO 2020d), in 2018 the overall CO_2 emissions per transport work, as an average across international shipping, and measured by the so-called AER (annual efficiency ratio) or by the EEOI (energy efficiency operational indicator), was, respectively, 21% or 29% better than in 2008. At the same time, the study found that total international maritime GHG emissions did increase from 2008 to 2018 (the actual amount of the increase depending on the calculation method). The latter should be a cause of concern, given that by 2050 GHG emissions will have to be at most 50% of what they were in 2008.

Indicative short-term measures include, among several others, speed reduction and speed optimization, mainly because fuel consumption and hence GHG emissions can be reduced if the ship reduces or optimizes its speed. Market based measures (MBMs) such as a bunker levy or a cap-and-trade scheme belong to the medium-term category (see Lagouvardou et al. (2020) for a survey of MBMs), whereas alternative low carbon fuels are included in the long-term class (see OECD (2018) for a survey of such fuels).

As expected, much of the discussion after the adoption of the strategy in 2018 has focused on short-term measures, and specifically on how such measures can help achieve the 2030 target: reduce CO_2 emissions per transport work, also known as "carbon intensity", as an average across international shipping, by at least 40% by 2030, compared to 2008.

A typical dichotomy among short-term measures is among the so-called "prescriptive measures" and the so-called "goal-based measures". Both aim to reach the 2030 target and outline how this can be done. Goal-based measures do not prescribe the means how the target can be reached, leaving these to the discretion of the ship owner, whereas prescriptive measures also specify the means. Prime examples of prescriptive measures are speed limits, also known as "speed regulation" (CE Delft 2017). See Psaraftis (2019) on a discussion about a comparison of speed limits vs. a bunker levy. A more recent category of prescriptive measures is power limits, as proposed by Greece and independently by shipping industry association BIMCO. However, these measures were subsequently superseded by the so-called EEXI measure (of which more below).

In 2019 Denmark proposed what is officially known as a "mandatory operational goal-based short-term measure" so as to meet the 2030 target. The proposal was co-sponsored by Germany and Spain. More recently, Denmark submitted more details on the above proposal, and the amended proposal was co-sponsored by France and Germany (IMO 2020a). For abbreviation purposes, in the rest of the paper we shall refer to this proposal as the "goal-based measure" and to its sponsors as "Denmark et al.".

In broad terms, and according to this measure, each ship will have its own annual "Carbon Intensity Indicator" (CII), defined as the ratio of annual CO_2 emissions divided by the product of ship capacity times distance sailed by that ship in a year. This definition coincides with that of AER, therefore this specific proposal has AER as the relevant CII. For each year from 2023 to 2030, the ship will have to follow a prescribed schedule of reductions, versus a corresponding baseline figure in 2008, which is determined by a specific method (see also Sect. 2). The ship owner will be free to use any means to achieve such reductions, either by operational or by technical means. An elaborate enforcement scheme of the goal-based measure was prepared by Lloyds Register.

Even though the focus of the Denmark et al. measure is reducing GHG emissions by *operational* means (for instance, by speed reduction), and its co-sponsors do not exclude *technical* means from the roster of possible actions the ship owner may take. Technical means include optimized hull shapes, more efficient engines, energy recuperation devices, alternative fuels, and others. By contrast, the main competitor of the Denmark et al. proposal before the IMO discussion is focusing only on technical means. This is the so-called EEXI measure, as proposed by Greece, Japan, Norway, Panama, United Arab Emirates, and shipping industry associations ICS (International Chamber of Shipping), BIMCO and Intertanko. EEXI is another goal-based measure and stands for energy efficiency existing ship index. Its implementation involves the use of technical measures to reduce GHG emissions, with engine power limitation (EPL) being the main one (IMO 2020b).

After considerable discussion, prescriptive measures such as speed limits, as originally proposed by the Clean Shipping Coalition (CSC), a Non-Governmental Organization (NGO), did not get enough support from IMO stakeholders, and their adoption has been ruled out. Instead, and in seeking how to implement the Initial IMO Strategy, the IMO stated that these two classes of measures (CII and EEXI) may ultimately be combined. And in fact, and as this paper was being finalized, the main co-sponsors of these measures submitted a combined proposal to the IMO (IMO 2020e). After more discussion, a version of this combined proposal was approved by the IMO in November 2020 (more on this in Sect. 6).

Comparing the various short-term measures before the IMO in terms of GHG reduction potential or other attributes is a major undertaking and as such is outside the scope of this paper. Rather, the purpose of the paper is to describe the *detailed impact assessment* of the goal-based measure proposed by Denmark et al. In fact, one of the criteria for the comparative evaluation of any short-term measure under discussion at the IMO is the so-called "impact assessment". This means an assessment of the potential impact of the measure to IMO member states, and in particular to developing states, including least developed countries (LDCs) and small island developing states (SIDS). This is so because concerns have been raised that such states may be put in a comparative disadvantage whenever a specific GHG reduction measure is implemented, or may suffer adverse economic impacts by the measure. So any measure has to be accompanied by an impact assessment.

We note here parenthetically that the assessment of impacts to states including LDCs/SIDS as a result of measures to reduce GHG emissions is not unique to maritime transport and the IMO, but can be encountered in a much broader context. To that effect, such an assessment also pertains to a wide variety of other activities that consider measures to combat climate change, such as in other segments of the transport sector (for instance road, rail, and air transport), and in other energy consuming sectors (for instance electricity production, construction, and industrial production). The concerns and specific needs of developing states in combating climate change are always at the centre of discussions in fora such as the United Nations Framework Conference on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the United Nations Conference on Trade and Development (UNCTAD), and possibly others.

In the context of the IMO discussion, all sponsors of short-term measures, including Denmark et al., produced *initial* impact assessments of their proposed measures. As per IMO terms of reference, these initial impact assessments identified which impacts should be assessed, taking into account, as appropriate, (1) geographic remoteness of and connectivity to main markets; (2) cargo value and type; (3) transport dependency; (4) transport costs; (5) food security; (6) disaster response; (7) cost-effectiveness; and (8) socio-economic progress and development.

In the case of Denmark et al., the initial impact assessment of the goal-based measure identified several *positive impacts*, which included the following, among others:

1. Securing a level playing field and reducing emissions across the fleet by targeting the existing fleet and not just new ships;
2. Possibly lower transport cost;
3. Cost-effective energy efficiency gains;
4. Incentivizing development and integration of better ship designs, technological innovations, and efficient operation of ships;
5. Incentivizing the shift toward sustainable alternative fuels;

At the same time, the initial impact assessment also identified the following *expected negative impacts*, among others:

(1) Possibly higher costs on states that export or import large amounts of high-value goods; and
(2) A few ships could be laid-up or scrapped earlier than expected at time of purchase possibly leading to extra costs for the ship owner (depending on efficiency gains and lower fuel costs).

As a follow-on to this process, the IMO invited the proposers of the various measures to further elaborate and conduct *detailed impact assessments*. The Danish Maritime Authority commissioned the Technical University of Denmark to lead the detailed impact assessment of the goal-based measure. To that effect, this paper describes the main elements of this work, focusing on the case study for LDCs and SIDS. The detailed impact assessment as submitted to the IMO (IMO 2020c) also included a case study for South American developing economies such as Argentina, Brazil, Chile and Peru, as well as one for India. But due to size limitations these case studies will not be described in this paper.

Per IMO guidelines, the detailed impact assessment should pay particular attention to the needs of developing countries, especially LDCs and SIDS, and include, among others, a detailed qualitative and/or quantitative assessment of specific *negative* impacts on states, including *disproportionately negative* impacts.

The central research question in this paper is to ascertain the potential impacts of the aforementioned measure to LDCs and SIDS. To that effect, and after gaps in the literature and data are identified, our methodology first develops a list of potential negative impacts. These include undesirable degradation of the quality of cargo, increased in-transit inventory costs, cargo shifts to other modes of transport, higher freight rates, decrease in product FOB prices and/or increase in product CIF prices, higher lifecycle GHG emissions and the difficulty to finance retrofitting of old ships or investment in new ships. The methodology also includes looking at fleet, port connectivity, main trade partners, distance and freight rates as factors that may influence these impacts. Then, we attempt to apply this methodology and analyze how the goal-based measure may impact LDCs/SIDs as regards each of the identified impacts.

To achieve the above, the rest of this paper is organized as follows: Sect. 2 provides a brief overview of the goal-based measure. Section 3 performs a literature survey on impact assessment. Section 4 presents a list of possible negative impacts on states, including disproportionately negative impacts. Section 5 examines the LDCs/SIDS case study and Sect. 6 makes some final remarks.

2 Brief overview of the goal-based measure

A brief overview of the goal-based measure by Denmark et al. is presented next. For full details see IMO (2020a). The concept of the measure consists of several elements:

1. The general concept of the proposal is to apply to all ships an annual required carbon intensity reduction factor (Xr);
2. The 2008 base year's reference point for each ship is based on a carbon intensity indicator (CII) reference line, which is calculated on the basis of energy efficiency design index (EEDI) reference lines for different ship types, adding different correction factors;
3. The International Energy Efficiency Certificate (IEEC) is already partly issued on the basis of the ship's Ship Energy Efficiency Management Plan (SEEMP). It is proposed that the ship's SEEMP must include, among others, the annual required carbon intensity reduction factor (Xr);
4. The IEEC's period of validity is proposed to be five years and should include annual verification audits of the IEEC (on the anniversary date of the IEEC) and a renewal audit of the IEEC within a window of the three months following the fifth anniversary date;
5. A combination of effective enforcement by flag state verification audits and port state control would safeguard against inappropriate compliance strategies and the challenge of charterers for ships engaged in voyage and time charters; and
6. A review of the measure based on concrete data and evidence to particularly analyze the need for any changes to the measure.

The mandatory operational goal-based short-term measure should include all ships of 400 gross tonnage and above. Each ship will have its own CII, defined as the ratio of CO_2 emissions in a year divided by the product of ship capacity times distance sailed in the year, and expressed in grams of CO_2 per tonne-mile.

The targets for each ship type will be set based on data from the 4th IMO GHG Study (IMO 2020d), and other relevant data. They can be adjusted according to the operational and technical capacity of each ship's type to contribute to the overall emission reduction objectives. After the adjustment, the total reduction in emissions should be at least equal to what it would have been if each category of ship had reduced its emissions by transport work by 40% in 2030 compared to 2008.[1]

[1] Note that the 4th IMO GHG study (IMO, 2020d) was released several months after the Denmark et al. proposal (IMO, 2020a) was submitted.

Targets for individual ships are set as a nominal required carbon intensity reduction factor (Xnr) in relation to a ship type specific carbon intensity indicator (CII) reference point for 2008, as proposed in Table 1 below.

Each ship type will have its own CII reference line for 2008. In this way, correction factors are introduced to set the 2008 reference line as close as possible to actual 2008 carbon intensity, and to account for specificities of some ship types.

The CII reference line for 2008 is defined as:

$$= a \times K1 \times K2 \times \text{capacity}^{-c}$$

where

- $K1$ is the correction factor applied to move the reference line from 2013 to 2008 which is the reference year. K1 will be defined in the Guidelines to be developed by the IMO.
- $K2$ is the correction factor which accounts for the specificities of some ship types as defined in the Guidelines to be developed by the IMO.
- Parameters a and c have been defined by the IMO for each ship type after regression analyses of the world fleet.
- Parameter *capacity* is the one used for the calculation of EEDI.

IMO (2020a) provides full details of the approach.

What can a ship owner do to reduce the CII of a ship so as to meet the 2030 target (and the intermediate targets in between)? Actions can basically come in two levels:

At the *operational/logistics level*, the owner can consider the following: implement speed reduction, perform speed optimization and/or optimized routing, institute better fleet management, improve ship capacity utilization, and have a better coordination with ports (virtual arrival/port call optimization). Any of these actions would reduce CO_2 and therefore carbon intensity.

At the *technical level*, the owner may do the following: Buy a new ship/scrap or sell an old one, retrofit the ship to reduce resistance (e.g., bulbous bows, propellers, etc.), perform an engine retrofit (derating) to reduce power, install energy saving devices (waste heat recovery, etc.), install a device that limits engine power, change to electric/hybrid propulsion, switch to alternative fuels, and use better hull coatings to reduce resistance. Again, any of these actions would reduce CO_2 and therefore carbon intensity.

Due to the goal-based nature of the measure, it is up to the ship owner to choose which of the above actions, or combinations thereof, will be implemented.

3 Literature survey

It should be noted that for the purposes of the impact assessment assignment, and even though relevant specific data was solicited from selected LDCs/SIDS, not much was available by the time the IMO submission was being finalized. This was true particularly as regards transport costs and freight rates and in particular for LDCs and SIDS it was stated that reliable data collection for the specific purpose would be a long-term undertaking, impossible to be carried out under the existing time schedule. The above gap in data impacted the methodology used in the assignment, which was decided to be by and large *qualitative* (see more in Sect. 4).

Table 1 Proposal for annual nominal required carbon intensity reduction factors (Xnr) for individual ships (in %) for the CII relative to CIIref. *Source*: IMO (2020a)

Ship type	Year								
	2008 (%)	2023 (%)	2024 (%)	2025 (%)	2026 (%)	2027 (%)	2028 (%)	2029 (%)	2030 (%)
Nominal reduction factor (Xnr)	0	[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Bulk carrier		[27]	[29]	[31]	[32]	[34]	[37]	[39]	[41]
Gas carrier		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Tanker		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Containership		[27]	[29]	[32]	[35]	[38]	[41]	[43]	[45]
General cargo ships		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Refrigerated cargo carrier		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Combination carrier		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
LNG carrier		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Ro-ro cargo ship (vehicle carrier)		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]
Ro-ro cargo ship		[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
Ro-ro passenger ship		[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
Cruise passenger ship having non-conventional propulsion		[26]	[28]	[30]	[32]	[34]	[36]	[38]	[40]

In addition, and strictly speaking, none of the previous studies on impact assessment in the literature addressed the impact of this specific goal-based measure on states. In that sense, the knowledge gap in the literature complements the gap in the data. Among the *general* literature that is related to various LDCs/SIDS topics as regards impact assessment and climate change, one can refer to (among others) UNFCCC (2005), Briguglio et al. (2010), Scobie (2013), UNCTAD (2014), Adelman (2016), Shi (2016), Krammer and Smith (2017) and NZIER (2018).

At the same time, some of the studies in the literature examined the impact of *speed reduction* on states. These studies can be useful in our analysis, as one of the possible responses to meet the goal-based measure is speed reduction. Other studies examined the impact *of a carbon levy* on states. Again, to the extent that this can be translated into an assessment of the impact of *freight rates* on states, these can be useful in our analysis. We briefly comment on some of these studies below.

ICS (2018) outlined the broad spectrum of measures toward meeting the IMO targets. Among other things, the document indicated a strong opposition to the concept of IMO establishing a mandatory system of operational efficiency indexing for application to individual ships.

Parry et al. (2018) discussed the possibility of a carbon tax as a key element of GHG mitigation policy for international maritime transport. The paper discussed the case for the tax over alternative mitigation instruments, options for the practical design issues, and then presented estimates of the impacts of carbon taxation and other instruments from an analytical model of the maritime sector.

Halim et al. (2019) reviewed research on the economic impacts of GHG mitigation measures on states, using model-based analysis. Specifically, the paper identified four areas of economic impacts and their relationships, compiled the latest findings on the estimated magnitudes of these impacts, and presented relevant modelling approaches.

APEC (2019) investigated the impacts of slow steaming to distant economies, with a focus on South American economies. Depending on the commodity, the study found slow steaming to have a different impact. For nonperishable products, the study found the impact of delay due to slow steaming to be minimal. For perishable products the study found the impact due to the delay caused by slow steaming to be considerable and that it may result in a shift to air freight.

A more focused part of the literature deals with studies that capture a country's level of integration into global liner shipping networks, which is very important for LDCs and SIDS. UNCTAD's liner shipping connectivity index (LSCI)[2] is relevant in that regard.

It should be noted that this index is relevant only for the liner shipping market, since the carriage of unitized cargoes may involve a number of transshipments and since monopolistic/oligopolistic situations may conceivably occur in the sector. There is no equivalent index in tramp shipping markets (drybulk and tanker), in which bulk shipments typically follow direct routes and in which freight rate formation is typically competitive, with little room for monopolistic/oligopolistic scenarios.

In a study conducted for Caribbean LDCs/SIDS (Wilmsmeier and Hoffmann 2008), a high LSCI for a country was found to imply a reduced risk of monopolistic/

[2] LSCI takes into account factors that include the number of other countries that are connected to a specific country through direct liner shipping services, the number of scheduled ship calls per week in the country, the deployed annual capacity in TEU, the number of regular liner shipping services from and to the country, and others that pertain to how well connected that country is to the rest of the world.

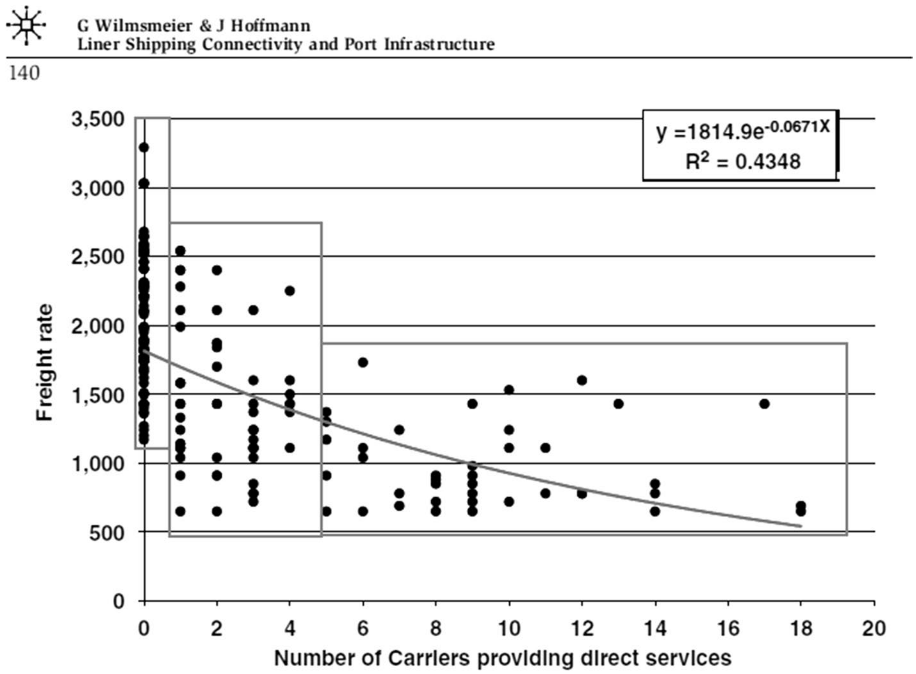

Fig. 1 Relationship between number of carriers providing direct service and freight rates. *Source*: Wilmsmeier and Hoffmann (2008)

oligopolistic schemes and hence reduced freight rates, vis-à-vis situations of a low connectivity index, which imply the opposite. In Fig. 1, it is seen that as the number of carriers that provide direct services to and from a country goes up, the average freight rate goes down. This is due to the fact that the existence of more carriers increases competition and induces lower freight rates. By contrast, fewer carriers may result in monopolistic or oligopolistic situations which in turn could lead to higher freight rates.

As regards the Pacific, and according to Fugazza and Hoffmann (2017), for the 14 Pacific developing member countries of the Asian Development Bank for the time period 2011–2013, a direct shipping connection more than doubles trade in goods imports. Using a gravity model approach based on a dataset on maritime connections for a sample of 178 countries collected over the 2006–2012 period found that the absence of a direct connection was associated with a drop in exports value varying between 42 and 55%. Similar conclusions pertain for South Africa (Hoffmann et al. 2019).

To complement this argument, we also show Fig. 2 from UNCTAD (2017), which shows freight cost as a percentage of value of imports for various world regions.

It can be seen that LDCs and SIDS have the highest transport costs as a percentage of the value of their imports, in comparison with the world average, let alone vis-à-vis developing economies.

Yet another related figure is Fig. 3, which shows (on a logarithmic scale) the LSCI for members of the Association of South Eastern Asian Countries (ASEAN). It can be

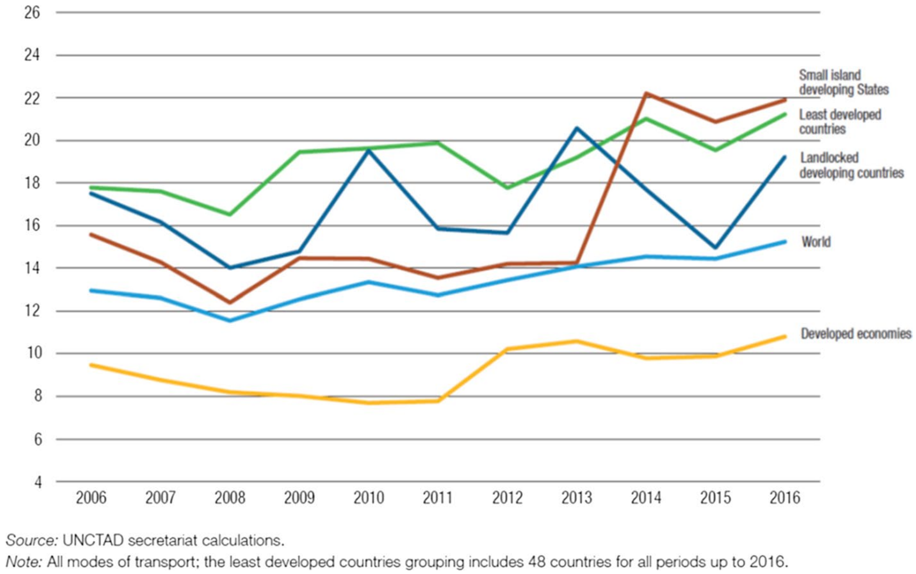

Fig. 2 Transport and insurance costs as a percentage of value of imports. *Source*: UNCTAD (2017)

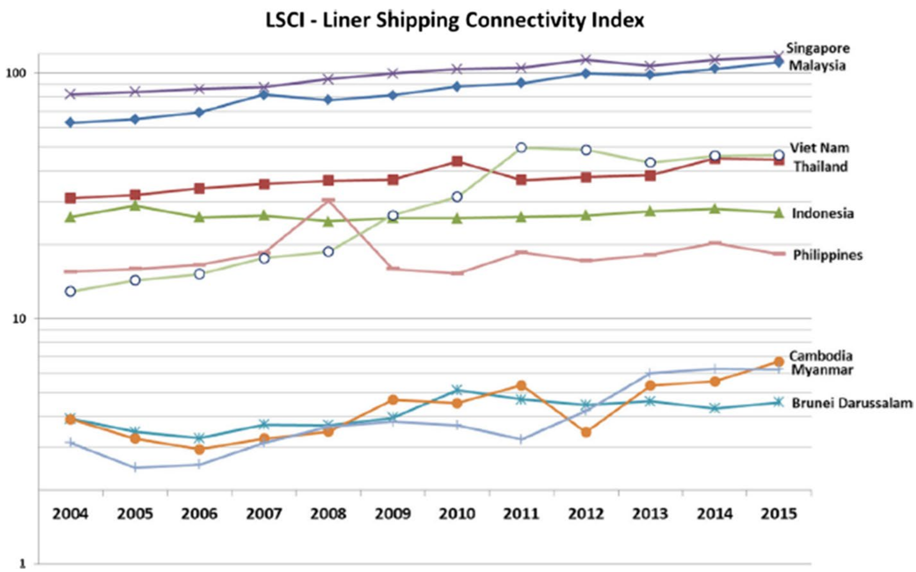

Fig. 3 LSCI for ASEAN countries. *Source*: Lun and Hoffmann (2016)

seen that some countries in Southeast Asia have extremely low connectivity indices as compared to other countries in the area (for instance Singapore and Malaysia).

Note that Singapore, even though a SIDS, is one of the best connected countries in the world, with a LSCI comparable to China's, which has the world's highest LSCI (All LSCIs are calibrated vis-à-vis China's, which scores 100 for 2006).

4 Impact assessment methodology I: list of potential negative impacts

Our methodology starts by trying to answer the following question: what can be the potential negative impacts of the goal-based measure?

At the operational/logistics level, a possible outcome of the measure can be an increase in sailing time, to the extent that the measure would induce speed reduction to comply with the carbon intensity target.

At the technical level, retrofitting existing ships, for instance with energy saving technologies or for the use of alternative fuels, or investing in new ships that use such technologies or fuels, could entail costs whose financing may be difficult. In both cases, negative impacts on states may be experienced.

The following list identifies some of these potential negative impacts.

(1) *Undesirable degradation in the quality of the cargo:* This is particularly true for perishable agricultural or other cargoes, which may lose quality if in-transit for more than a certain duration, even if frozen. See for instance Mills et al. (2014) for spoilage and shelf-life of lamb.
(2) *Increased cargo in-transit inventory costs:* More sailing days will imply increased in-transit inventory costs for the shipper, which are proportional to (a) the value of the cargo and (b) the increase in sailing time. These costs could translate into lower FOB prices for exports and/or higher CIF prices for imports, depending on import/export elasticities (see also point 5 below).
(3) *Cargo shifts to faster modes of transport:* Slower maritime speeds may encourage some cargoes to shift to other, faster modes of transport, including road, rail or air. This may increase overall GHG emissions. See Psaraftis and Kontovas (2010) for a methodology to estimate modal shifts due to speed reduction in deep-sea routes and Zis and Psaraftis (2017) for a similar analysis in short-sea routes. Modal shifts would also result because of higher freight rates (see also point 4 below).
(4) *Higher freight rates:* This may be a potential *short-term* consequence of speed reduction, or of the development of monopolistic/oligopolistic situations among carriers. Freight rates are functions of shipping supply and demand and any contraction of the ship supply curve due to speed reduction could result in higher freight rates, which could be unfavorable for the shippers.
(5) *Decrease of product FOB prices and/or increase of product CIF prices*: Any potential increase in freight rates would translate into a combination of decrease in the FOB prices of the products exported and/or an increase in the CIF prices of these products. The extent of these price changes would depend on the export/import elasticities of the product. See Imbs and Mejean (2017) for an exposition of elasticities in selected countries.
(6) *Higher lifecycle GHG emissions:* Even though in the short-term freight rates may increase, in the long-term, and after idle fleet is absorbed, more ships will be needed to sustain trade throughput in the face of a reduced speed regime. Building these additional ships would produce additional GHG emissions due to shipbuilding and

recycling (lifecycle GHG emissions). See Chatzinikolaou and Ventikos (2016) for an analysis of relevant issues.

(7) *Difficulty to finance retrofitting of old ships or investment in new ships:* The carbon intensity target can conceivably be met by replacing existing ships by newer, more energy efficient ships, or by larger ships, as ship capacity is in the denominator of carbon intensity. It can also be met by retrofitting old ships with energy saving technologies or for use of alternative fuels. However, states whose trade depends on ageing fleets or on fleets not controlled by these states may have a problem going down that path.

Even though the identification of the above seven potential negative impacts is an important methodological first step, the pertinent question is, to what extent these impacts can be assessed? As explained in the relevant IMO submission (IMO 2020c), lack of key data from LDCs/SIDS and a very tight IMO timetable have prevented a *quantitative* assessment, one that would evaluate quantitatively all seven of the impacts identified above, or would perform a complete life cycle assessment (LCA) of each possible option and, or would use purchasing power parity (PPP) to assess the impacts on LDCs/SIDS. Even if there were a model that could map the entire process from assembling all of the required inputs to ultimately determining the impacts on LDCs/SIDS, the lack of data and lack of time would make such a model not particularly useful. To our knowledge, such a model does not exist, and such difficulties were also recognized by an independent evaluation by UNCTAD of all impact assessment studies recently submitted to the IMO (IMO 2020f).

These difficulties notwithstanding, we were still able to make a *qualitative* assessment of the above impacts for the LDC/SIDS case study. The case study itself is presented in Sect. 5 that follows and the assessment is in Sect. 5.6.

5 The LDC/SIDS case study

5.1 Scope

We clarify here that our analysis focuses primarily, but not exclusively, on states that belong to both the LDC and SIDS categories. SIDS that are not LDCs or LDCs that are not SIDS do not belong to the mainline scope of this paper. For those SIDS that are not LDCs (for instance, Singapore), we speculate that many of the potential negative impacts are not relevant. For LDCs that are not SIDS (for instance, Cambodia), we think that many of the issues are very similar to (although perhaps not as pronounced as) the situation for states that are both LDCs and SIDS, which are likely to suffer from any negative impacts the most.

There are several categorizations of states as SIDS. The largest group of SIDS is the one suggested by the United Nations Department of Economic and Social Affairs (UN DESA) which lists 52 SIDS.[3] These are further classified into three groups based on geographical criteria: Caribbean, Pacific, and Africa, Indian Ocean, Mediterranean, and South China Sea (AIMS). Another important group is the intergovernmental organization Alliance of Small Island States (AOSIS) that consolidates the voices of SIDS as regards global warming. It consists of 39 UN members and 5 observers. UNCTAD uses a smaller, unofficial list

[3] https://www.un.org/esa/sustdev/sids/sidslist.htm.

Table 2 List of SIDS and their LSCIs. *Sources*: UNCTAD, UNCTADSTAT[a], AOSIS

Caribbean	LSCI	Pacific	LSCI	AIMS	LSCI
Anguilla	4.39	American Samoa	7.47	Bahrain	25.71
Antigua and Barbuda	5.32	Cook Islands	2.68	Cape Verde	6.49
Aruba	9.51	Federated States of Micronesia	4.47	Comoros	6.72
Bahamas	31.36	Fiji	11.2	Guinea Bissau	4.55
Barbados	7.44	French Polynesia	10.79	Maldives	7.42
Belize	11.49	Guam	8.3	Mauritius	28.01
British Virgin Islands	5.5	Kiribati	2.01	Sao Tome and Principe	6.32
Cuba	9.61	Marshall Islands	4.92	Seychelles	9.11
Dominica	6.21	Nauru	2.2	Singapore	108.08
Dominican Republic	38.78	New Caledonia	11.02		
Grenada	6.08	Niue	NA		
Guyana	9.23	Northern Mariana Islands	5.12		
Haiti	11.12	Palau	3.4		
Jamaica	33.19	Papua New Guinea	12.63		
Montserrat	4.39	Samoa	8.07		
Netherlands Antilles	NA	Solomon Islands	10.66		
Puerto Rico	NA	Timor-Lest	2.91		
St. Kitts and Nevis	6.64	Tonga	7.59		
St. Lucia	6.67	Tuvalu	2.01		
St. Vincent	6.97	Vanuatu	7.91		
Suriname	9.06				
Trinidad and Tobago	15.43				
US Virgin Islands	NA				

[a]https://unctadstat.unctad.org/EN/.

of 28 SIDS on its website.[4] Table 2 presents a consolidated list of the SIDS from various sources and under different definitions accompanied by their most recent LSCIs.

5.2 Fleet statistics on SIDS

To better understand the impacts of the goal-based measure on SIDS, it is important to have a proper understanding of the fleet for each SIDS. Table 3 presents information on the ownership of the merchant fleet for these countries, as well as the number of vessels by flag of registration for the examined SIDS.

Table 3 should be interpreted with caution as flag information may not be directly relevant. For instance, the Marshall Islands is a major international registry and most of the ships under its flag are foreign owned. In the same vein, many of the ships of Table 3 are engaged in global trades and may seldom call at the respective SIDS. Also it is not clear from Table 3 how many ships are engaged in domestic vs international trade. What is mostly of interest in Table 3 is the observation that the majority of the SIDS have a very

[4] https://unctad.org/en/pages/aldc/Small%20Island%20Developing%20States/UNCTAD%C2%B4s-unofficial-list-of-SIDS.aspx.

Table 3 SIDS fleet statistics. Adapted from UNCTADSTAT

Caribbean	Vessels		Pacific	Vessels		AIMS	Vessels	
	Flag	Owner		Flag	Owner		Flag	Owner
Anguilla	2	9	American Samoa		NA	Bahrain	NA	137
Antigua and Barbuda	780	3	Cook Islands	205	8	Cape Verde	44	10
Aruba	1	NA	Federated States of Micronesia	39	NA	Comoros	230	NA
Bahamas	1401	1058	Fiji	64	7	Guinea Bissau	2	NA
Barbados	132	NA	French Polynesia	17	18	Maldives	62	87
Belize	786	30	Guam	3	NA	Mauritius	28	94
British Virgin Islands	29	130	Kiribati	89	1	Sao Tome and Principe	15	6
Cuba	52	51	Marshall Islands	3537	632	Seychelles	25	268
Dominica	108	NA	Nauru	2	NA	Singapore	3433	2727
Dominican Republic	37	NA	New Caledonia	19	2			
Grenada	6	2	Niue	61	NA			
Guyana	56	37	Northern Mariana Islands		NA			
Haiti	4	10	Palau	203	NA			
Jamaica	39	NA	Papua New Guinea	171	123			
Montserrat	0	NA	Samoa	13	54			
Netherlands Antilles	0	NA	Solomon Islands	23	NA			
Puerto Rico	NA	NA	Timor-Lest	1	0			
St. Kitts and Nevis	218	19	Tonga	36	1			
St. Lucia	0	2	Tuvalu	243	1			
St. Vincent	810	11	Vanuatu	369	3			
Suriname	10	9						
Trinidad and Tobago	105	8						
US Virgin Islands	NA	NA						

small number of vessel that are "beneficially owned", that is, controlled by the SIDS themselves. From a GHG perspective, this means that for most of these SIDS the responsibility to achieve appropriate GHG emissions reductions will fall onto ship owners from other countries serving these SIDS.

5.3 Number of ports and port connectivity

The port liner shipping connectivity index (PLSCI) is an annual number provided by UNCTAD for each port to reflect its position in the global liner shipping network. As with LSCI, a higher PLSCI indicates better port connectivity. Indices have been calibrated so that China has an index of 100 in 2006. Table 4 shows the number of existing ports for each of the SIDS, and the PLSCI (average, minimum, and maximum) as retrieved from the UNCTADSTAT database (2006–2019).

Additional analysis of this data revealed that for most SIDS the PLSCI is increasing relative to previous years. However, even if the index is increasing, it is increasing from a very low base. For SIDS with multiple ports, the risk of low connectivity is smaller as there are more options available. Taking into account the considerations of Sect. 3, a low connectivity implies a risk of higher freight rates for these states, something that will be confirmed in Sect. 5.5 below.

5.4 Main trading partners and distance

A related concern regarding SIDS revolves around a potential increase in freight rates as a result of the measures or the degradation of the connectivity with the main markets. In this section, we present data collected from the International Trade Statistics database (COMTRADE[5]) as cleaned by the BACI[6] team of the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). In Table 5, we show the value of exports and imports for 2017 (the most recent available data), and we provide the top two trading countries for each of the SIDS to draw the picture of their trade.

Certain observations can be made here. All SIDS have a trade deficit which for certain states is very significant. The imports are usually from major economies that either are closer geographically, or have historical ties. For most SIDS, major imports include food, pharmaceuticals, machinery, vehicles and refined petroleum products to cover their energy requirements. When it comes to energy imports these are typically sourced from a small number of major economies with which they have geographically or historically close ties (Pacific SIDS source from Australia New Zealand, Southeast Asia and USA, Caribbean SIDS source from USA, Brazil, Colombia, etc.). Storage of fuels is however an issue as several Pacific SIDS that do not have ability to stockpile regularly run out of fuel if no ship arrives in time. Most fuel is imported through Southeast Asia and transshipped through Fiji.

Exports are typically local agricultural products, timber, minerals, and recreational and harbor craft boats. Many are heavily exporting fish products (for example Cook Islands 65.1%, Kiribati 79.9%, Tuvalu 50%). In general, we believe that SIDS that are heavily

5 https://comtrade.un.org/labs/data-explorer/.

6 http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37.

Table 4 SIDS port liner connectivity index (PLSCI), 2006–2019. *Source*: UNCTADSTAT

SIDS	Number of ports	Average PLSCI	Min PLSCI	Max PLSCI
Anguilla	1	3.02	1.82	4.05
Antigua and Barbuda	1	4.15	2.75	5.19
Aruba	2	6.74	3.02	9.02
Bahamas	6	8.68	0.71	30.35
Barbados	1	7.05	6.13	10.32
Belize	2	4.84	2.27	8.75
British Virgin Islands	2	3.41	1.84	4.52
Cuba	4	4.58	1.61	9.84
Dominica	1	3.81	2.77	6.04
Dominican Republic	7	8.08	0.61	33.45
Grenada	1	5.16	4.12	6.44
Guyana	1	8.15	6.53	10.97
Haiti	3	5.40	1.24	10.08
Jamaica	2	15.69	2.11	32.65
Montserrat	1	2.75	1.84	3.36
Netherlands Antilles	5	6.83	3.18	9.58
Puerto Rico	2	11.38	1.92	16.93
St. Kitts and Nevis	3	3.34	1.84	5.05
St. Lucia	2	4.73	2.82	5.73
St. Vincent	2	4.27	1.74	5.62
Suriname	1	7.79	6.50	10.54
Trinidad and Tobago	2	11.49	6.85	17.27
US Virgin Islands	3	3.75	1.04	4.72
American Samoa	1	6.79	5.32	9.60
Cook Islands	2	1.94	0.64	3.09
Federated States of Micronesia	4	2.11	1.31	3.90
Fiji	2	10.13	7.29	13.92
French Polynesia	2	8.86	0.81	13.16
Guam	1	8.67	7.48	9.42
Kiribati	1	3.72	1.84	4.87
Marshall Islands	2	3.54	1.55	6.59
Nauru	1	1.88	1.19	2.48
New Caledonia	2	10.64	2.38	13.91
Niue	1	1.33	1.19	1.61
Northern Mariana Islands	1	4.29	1.86	7.45
Palau	1	3.14	2.23	3.65
Papua New Guinea	14	5.48	0.74	14.64
Samoa	1	7.11	5.97	9.69
Solomon Islands	2	6.59	2.79	10.86
Timor-Lest	1	3.07	0.72	6.76
Tonga	2	4.69	1.19	7.40
Tuvalu	1	1.97	0.58	3.32
Vanuatu	2	5.48	1.84	8.50
Bahrain	1	17.73	6.27	29.91

Table 4 (continued)

SIDS	Number of ports	Average PLSCI	Min PLSCI	Max PLSCI
Cape Verde	6	4.08	0.80	6.69
Comoros	2	4.99	1.35	6.58
Guinea Bissau	1	4.52	3.31	5.76
Maldives	1	5.09	2.58	7.49
Mauritius	2	17.49	0.90	28.80
Sao Tome and Principe	1	5.00	1.82	6.89
Seychelles	2	6.03	2.02	8.81
Singapore	2	105.07	8.99	128.10

trading with a small number of countries could be more vulnerable if the freight rates increase disproportionally for these pairs.

6 Illustrative freight rates for five countries

In this section, we present some illustrative freight rates for unitized shipments between some of the SIDS, and their major trading partners as listed in Table 6. These freight rates are estimates provided by "World Freight Rates[7]" as collected during December 2019. These should only be used for illustrative and comparison purposes.

We can observe that for the Pacific SIDS exporting fish to Japan, the freight rates are quite significant. In general, freight rates are higher when there is transshipment taking place, as this can significantly increase the transportation cost (which agrees with the overall assessment that a low connectivity index results in higher transportation costs). A noteworthy example is the case of Comoros. For Comoros, it is much more expensive to ship from Tanzania (535 NM) than it is from China (6300 NM). At the same time, sending a container from China to Tanzania would cost approximately USD850, which shows that the freight rates are not always strictly correlated with distances. In the Pacific, it is more expensive to ship from Fiji to Tonga, a distance of 417 NM (USD 5.68 per NM and FEU) than from Singapore to Fiji, a distance of 4751 NM (USD 0.45 per NM and FEU).[8]

6.1 Impact assessment methodology II: assessment of potential negative impacts

This section attempts to perform an assessment of the seven potential negative impacts identified in Sect. 4 as these pertain to LDCs and SIDS, and taking also into account the exposition of the previous sections. It should be emphasized that due to lack of data and various other gaps in knowledge, such an assessment is by necessity qualitative and is subject to review once additional information or other data that may alleviate these gaps becomes available.

We next look at the potential negative impacts one by one:

[7] https://worldfreightrates.com/.

[8] Unpublished data Fiji collected from 30 freight companies in 2018.

Table 5 SIDS main trading partners. *Source*: COMTRADE

SIDS	Exports USD million	Destination (% of value)		Imports USD million	Origin (% of value)	
		1st	2nd		1st	2nd
Anguilla	9.6	USA (40)	France (13)	77.4	USA (56)	France (22)
British Virgin Islands	353	Cyprus (33)	Switzerland (11)	829	USA (25)	Italy (18)
Comoros	74	India (33)	France (29)	295	Tanzania (30)	China (22)
Dominica	40.5	Indonesia (32)	Netherlands (7.3)	275	USA (48)	China (12)
Grenada	36.3	USA (32)	German (9.5)	187	USA (35)	UK (6.8)
Montserrat	8.92	Antigua-Barbuda (61)	France (9)	14.3	USA (46)	UK (14)
St. Kitts and Nevis	71.9	USA (58)	Turkey (8.8)	385	USA (52)	Germany (10)
St. Lucia	77.6	Suriname (39)	UK (9.6)	1710	Colombia (35)	USA (26)
St. Vincent	258	France (39)	Jordan (29)	372	USA (34)	Trinidad and Tobago (14)
Cook Islands	38.9	Japan (44)	China (14)	108	New Zealand (48)	Fiji (12)
Federated States of Micronesia	29.8	China (38)	Philippines (26)	154	South Korea (33)	USA (22)
Fiji	950	USA (28)	Australia (17)	2440	Singapore (18)	New Zealand (17)
Kiribati	51.5	Mexico (35)	Philippines (19)	92.4	Fiji (24)	Australia (17)
Marshall Islands	325	Netherlands (22)	Indonesia (18)	8790	South Korea (78)	Germany (5.1)
Nauru	24.7	Australia (24)	Japan (24)	35.6	Australia (63)	Fiji (12)
Niue	63.3	Indonesia (98)	South Africa (0.4)	11.1	New Zealand (75)	UK (15)
Palau	24	Japan (81)	Turkey (4.8)	159	USA (33)	Singapore (14)
Timor-Lest	108	Singapore (62)	USA (9.6)	651	Indonesia (31)	China (17)
Tonga	15	USA (28)	South Korea (23)	103	New Zealand (29)	China (27)
Tuvalu	4.02	Japan (50)	France (22)	35.6	China (30)	Fiji (27)
Comoros	74	India (33)	France (20)	295	Tanzania (30)	China (22)
Sao Tome and Principe	15.7	Poland (24)	Netherlands (11)	140	Portugal (56)	China (6.9)
Vanuatu	207	Mauritania (34)	Japan (32)	244	China (27)	Australia (17)

Table 6 Illustrative freight rates (USD/TEU). *Source*: World Freight Rates

	Export freight rate		Import freight rate	
Anguilla	USA (Miami) 1050	France 1700	USA (Miami) 1020	France 650
Comoros	India 2300	France 2750	Tanzania 3500	China 850
Cook Islands	Japan (reefer) 2900	China (Shanghai) 2850	New Zealand 1300	Fiji 1000
Fiji	USA (LA) 2750	Australia 680	Singapore 2050	New Zealand 1400
Tuvalu	Japan (reefer) 2700	France 2400	China 2450	Fiji 1000
Vanuatu	Mauritania 3350	Japan 2700	China 2350	Australia 1050

Undesirable degradation in the quality of the cargo: This could be a direct consequence in case speed reduction is chosen as the main means to implement the goal-based measure. As speed reduction is one of the plausible scenarios, we think that the probability for such undesirable degradation to happen is moderate. However, should this happen, its (negative) consequence can be high, and could result in serious economic loss for the shippers, and by extension, to the LDC/SIDS, both for imports and exports. This result conforms to a similar conclusion by APEC (2019) which focused on South America.

Increased cargo in-transit inventory costs: This again will happen in case speed reduction is chosen as the main instrument to implement the goal-based measure. In IMO (2020c) an analysis was made to compute such in-transit inventory costs for the case of agricultural exports of South American economies to Asia, and a very low impact was estimated. We do not see a reason the LDC/SIDS case should be much different from the above, and we conjecture such impact to be low in terms of both probability and consequence. Again, a similar result was found in APEC (2019).

Cargo shifts to faster modes of transport: The same is the case as regards the potential impact due to cargo shifting to faster modes of transport due to speed reduction in the maritime mode. About the only such faster mode is air, and we think that even though some sensitive cargoes are already carried to and from LDCs/SIDS by aviation, the chance that one will see *a significant shift* from the maritime mode to air in case ships reduce their speed is ascertained to be low, and the consequences of such a shift are also judged to be low.

Higher freight rates: By contrast, and due to the high degree of monopolistic/oligopolistic situations that one can see mainly due to low connectivity and high freight rates (as per previous sections), we think that the probability of such rates going up is moderate in case of speed reduction, and that the (negative) consequences of such higher freight rates can be high. LDCs/SIDS are in a much worse situation than other countries as regards this impact.

Decrease of product FOB prices and/or increase of product CIF prices: Similar to the above, and due to generally low import and export elasticities in LDCs/SIDS, any increase in freight rates is likely to be reflected in a decrease in FOB prices and/or in an increase in CIF prices, both cases entailing a high (negative) impact for LDCs/SIDS.

Higher lifecycle GHG emissions: If in the long run more ships are built to sustain the reduced throughput due to speed reduction, some lifecycle GHG emissions will be generated due to building the new ships and recycling the old ships. How much these lifecycle emissions can be cannot be precisely ascertained, however, it is conjectured to be much lower than operational emissions?

Difficulty to finance retrofitting of old ships or investment in new ships: This is the only impact which we rate as serious in both probability and consequence, and this is due to the reasons outlined in Sect. 5.2. To the extent, LDCs/SIDS depend mainly on third country ship owners for their trade, there is a risk of these states being left with few options to modernize their fleets (for instance, to be able to use alternative low carbon fuels), particularly in case foreign ship owners allocate their most efficient ships elsewhere. Such an outcome is judged to fall under the umbrella of disproportionately negative impact.

On the basis of the above, it is seen that some negative impacts or even some disproportionately negative impacts may occur for LDCs/SIDS as a result of the goal-based measure. Actual numerical estimates of such impacts could not be calculated due to gaps in data and other knowledge on the LDC/SIDS case study.

Even less clear is the degree of share (or responsibility) of the goal-based measure with respect to the potential negative (and disproportionately negative) impacts outlined above, vis-à-vis the share of *the many other factors* that may contribute to such impacts. This share cannot be precisely ascertained. To give an example, the implementation of the 0.5% global sulphur cap as of 1.1.2020—another major international environmental agreement on maritime emissions- is likely to cause major changes in freight rates globally and this may impact trade to and from LDCs/SIDS far more than any short-term operational measure is chosen by the IMO. As such, it could also impact GHG emissions. The same can be said regarding other exogenous factors, such as for instance the potential impact of the COVID-19 pandemic on international trade especially for LDCs/SIDS, which could trigger an extended period of economic downturn much more serious than any possible negative impact of the goal-based measure. It would be very difficult to impossible to dissect the impact of the global sulphur cap, or of COVID-19, from the impact of any short-term measure to reduce GHG emissions. On the basis of all information at our disposal, our conjecture is that the degree of share (or responsibility) of the goal-based measure with respect to the potential negative (and disproportionately negative) impacts to LDCs/SIDS that are caused by a variety of other factors is low. In that sense, the hypothesis that LDCs or SIDS would suffer negative (and disproportionately negative) impacts just from the goal-based measure is not proven by evidence or other information at our disposal. However, this is only a conjecture, and additional data and analysis are necessary to shed more light on this issue.

7 Final remarks

The central research question in this paper has been to ascertain the potential impacts of the goal-based measure proposed by Denmark et al. to LDCs and SIDS. To that effect, the paper developed a methodology that assessed a number of possible negative impacts. In that sense, we believe that this paper has improved the state of the art in the area. The analysis, which was by necessity qualitative, argued that for LDCs and SIDS a risk for negative and disproportionately negative impacts exists. The main issue that was seen to involve a risk of disproportionate negative impact was as regards the difficulty to finance retrofitting of old ships or investment in new ships, particularly since most of the external trade of SIDS falls onto ship owners of other countries serving these SIDS. Even so, our conjecture is that the degree of share (or responsibility) of the goal-based measure with respect to the potential negative (and disproportionately negative) vis-à-vis the share of *the* *many other factors* that may contribute to these impacts, cannot be precisely ascertained and is conjectured to be low.

Ships solely engaged in domestic trades are to be excluded from the measure, and various special cases are to be granted temporary exemptions, such as for instance (among others) ships conducting trials for the development of ship emission reduction and control technologies and engine design programs. Other than those, we think that possible exemptions to the goal-based measure to ships serving LDCs/SIDS should be avoided, as these are likely to make the competition situation worse and would not incentivize technological innovation. Such exemptions would violate the principle that all ships should be treated equally, might introduce loopholes and other distortions that could lead to carbon leakage and possibly fraud, and would condemn LDCs/SIDS to being served by ships that will eventually become technologically and economically obsolete.

In terms of IMO's mandate, potential mitigation measures can be considered in terms of capacity building, technical assistance, R&D support and financial assistance to LDCs/SIDS. However, these cannot happen in the context of the goal-based measure per se, but would need to be discussed and designed through other appropriate fora and instruments.

The COVID-19 pandemic forced the IMO to postpone both the 7th intersessional meeting of the working group on reduction of GHG emissions from ships, and the 75th session of the MEPC (MEPC 75), both originally scheduled to be held in the spring of 2020. These two meetings were to discuss, among other things, short-term GHG reduction measures, including the one discussed in this paper. These two meetings were moved and held online in October and November 2020, respectively, and as this paper was being finalized.

As mentioned in Sect. 1, the IMO decided at MEPC 75 to approve *a combination* of the goal-based measure of Denmark et al. (IMO 2020a) and of the EEXI measure (IMO 2020b). Significant discussions at the 7th intersessional meeting that preceded MEPC 75 went into considerable detail on the exact provisions of the combined measure. In terms of impact assessment, an important implication of such a combination was that a comprehensive impact assessment *of the combined measure* was deemed necessary, even though the detailed impact assessments of its original components have already been submitted to the IMO. Such comprehensive impact assessment is due before MEPC 76, scheduled for June 2021.

Even though it is too early to tell what the results of the impact assessment of the combined measure may entail, it is our opinion that the detailed impact assessment of the goal-based measure of Denmark et al. (IMO 2020c) will provide important input into the assessment of the combined measure. We also believe that issues such as those identified in this paper will be useful in that assessment, especially as regards LDCs and SIDS.

Last but not least, we believe that the approach outlined in this paper may also provide useful insights in contexts outside maritime transport, in the quest of assessing the impacts to LDCs/SIDS that are due to other measures to combat climate change.

Acknowledgements This work was commissioned by the Danish Maritime Authority (DMA) and was supported by the Danish Maritime Fund under the umbrella project "Maritime DTU, Forskningsbaseret maritim rådgivning 2019–2020." The views expressed in this paper are those of the authors and do not necessarily represent the position of the DMA. The authors would like to thank the Editor and three anonymous reviewers for their comments on a previous version of the paper.

References

Adelman, S. (2016). Climate justice, loss and damage and compensation for small island developing states. *Journal of Human Rights and the Environment, 7*(1), 32–53.

APEC. (2019). Analysis of the impacts of slow steaming for distant economies, APEC Transportation Group, APEC Project: TPT 03 2018A, Produced by Starcrest Consulting Group for the Asia-Pacific Economic Cooperation Secretariat, December.

Briguglio, L., Cordina, G., Vella, S., & Vigilance, C. (2010). *Profiling vulnerability and resilience: A manual for small states*. London: Commonwealth Secretariat and the Islands and Small States, Institute University of Malta.

CE Delft. (2017). Regulating speed: A short term measure to reduce maritime GHG emissions, study by CE Delft for the Clean Shipping Coalition, 18 October.

Chatzinikolaou, S., & Ventikos, N. (2016). Critical analysis of air emissions from ships: lifecycle thinking and results. In H. N. Psaraftis (Ed.), *Green transportation logistics: the quest for win–win solutions*. Cham, Switzerland: Springer.

Fugazza, M., & Hoffmann, J. (2017). Liner shipping connectivity as determinant of trade. *Journal of Shipping and Trade, 2,* 1. https://doi.org/10.1186/s41072-017-0019-5.

Halim, R. A., Smith, T., & 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.

Hoffmann, J., Saeed, N., & Sødal, S. (2019). Liner shipping bilateral connectivity and its impact on South Africa's bilateral trade flows. *Maritime Economics & Logistics*. https://doi.org/10.1057/s41278-019-00124-8.

ICS. (2018). *Reducing CO_2 emissions to zero: The 'Paris Agreement for Shipping' implementing the initial strategy on reduction of GHG emissions from ships (adopted by the UN International Maritime Organization) emissions to zero: The 'Paris Agreement for Shipping' implementing the initial strategy on reduction of GHG emissions from ships (adopted by the UN International Maritime Organization)*. London, UK: International Chamber of Shipping.

Imb, J., & Mejean, I. (2017). Trade elasticities. *Review of International Economics, 25*(2), 383–402.

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. (2020a) Proposal for a mandatory operational goal-based short-term measure, submitted by Denmark, France and Germany, IMO doc. ISWG-GHG 7/2/9.

IMO. (2020b). Draft amendments to MARPOL Annex VI to incorporate the goal-based energy efficiency improvement measure utilizing Energy Efficiency Existing Ship Index (EEXI), submitted by Greece, Japan, Norway, Panama, United Arab Emirates, ICS, BIMCO and INTERTANKO, IMO doc. ISWG-GHG-7/2/6.

IMO. (2020c). 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.

IMO. (2020d). Fourth IMO GHG Study 2020—Final report. IMO doc. MEPC 75/7/15.

IMO. (2020e). 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.

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

Krammer, P., & Smith, T. (2017). *Impact assessment of IMO greenhouse gas reduction strategies on New Zealand's economy*. London, UK: UCL Energy Institute.

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.

Lun, V., & Hoffmann, J. (2016). Connectivity and trade relativity: the case of ASEAN. *Journal of Shipping and Trade, 1,* 11. https://doi.org/10.1186/s41072-016-0015-1.

Mills, J., Donnison, A., & Brightwell, G. (2014). Factors affecting microbial spoilage and shelf-life of chilled vacuum-packed lamb transported to distant markets: A review. *Meat Science, 98*(1), 71–80.

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.

OECD. (2018). Decarbonising maritime transport. Pathways to zero-carbon shipping by 2035, Report of the Organisation for Economic Cooperation and Development, International Transport Forum, Paris, France, March.

Parry, I., Heine, D., Kizzier, K., & Smith, T. (2018) Carbon taxation for international maritime fuels: Assessing the options, IMF working paper WP 18/2013, International Monetary Fund, Washington, DC.
Psaraftis, H. N. (2019). Speed optimization vs speed reduction: Are speed limits better than a bunker levy? *Maritime Economics and Logistics*. https://doi.org/10.1057/s41278-019-00132-8.
Psaraftis, H. N., & Kontovas, C. A. (2010). Balancing the economic and environmental performance of maritime transportation. *Transportation Research Part D, 15*(8), 458–462.
Scobie, M. (2013). Climate regulation: Implications for trade competitiveness in Caribbean states. In W. Leal Filho., F. Mannke., R. Mohee., V. Schulte., & D. Surroop (Eds.), *Climate-smart technologies*. Berlin, Heidelberg: Springer.
Shi, Y. (2016). Reducing greenhouse gas emissions from international shipping: Is it time to consider market-based measures? *Marine Policy, 64,* 123–134.
UNCTAD. (2014). *Closing the distance: partnerships for sustainable and resilient transport systems in SIDS*. Geneva, Switzerland: United Nations Conference Trade and Development.
UNCTAD. (2017). *Review of maritime transport 2017*. Geneva, Switzerland: United Nations Conference on Trade and Development.
UNFCCC. (2005). Climate change, small island developing states. Issued by the Climate Change Secretariat (UNFCCC), Bonn, Germany.
Wilmsmeier, G., & Hoffmann, J. (2008). Liner shipping connectivity and port infrastructure as determinants of freight rates in the Caribbean. *Maritime Economics and Logistics, 10,* 130–151.
Zis, T., & Psaraftis, H. N. (2017). The implications of the new sulphur limits on the European Ro-Ro sector. *Transportation Research Part D: Transport and Environment, 52,* 185–201.