

INTERSESSIONAL MEETING OF THE  
WORKING GROUP ON REDUCTION OF  
GHG EMISSIONS FROM SHIPS  
7th session  
Agenda item 2

ISWG-GHG 7/2/8  
7 February 2020  
ENGLISH ONLY

**FURTHER CONSIDERATION OF CONCRETE PROPOSALS TO IMPROVE THE  
OPERATIONAL ENERGY EFFICIENCY OF EXISTING SHIPS, WITH A VIEW TO  
DEVELOPING DRAFT AMENDMENTS TO CHAPTER 4 OF MARPOL ANNEX VI AND  
ASSOCIATED GUIDELINES, AS APPROPRIATE**

**Additional information on impact assessment of the goal-based  
energy efficiency improvement measure on existing ships (EEXI)**

**Submitted by Greece, Japan, Norway and ICS**

**SUMMARY**

*Executive summary:* In accordance with paragraph 12 of the *Procedure for assessing impacts on States of candidate measures* (MEPC.1/Circ.885), this document provides additional information on the impact assessment of the goal-based energy efficiency improvement measure on existing ships (EEXI) as proposed in document ISWG-GHG 6/2/3 (Japan and Norway), for which an initial impact assessment is provided in document ISWG-GHG 6/2 (Japan and Norway). The additional information shows that implementation of the EEXI will reduce ship running costs while increasing interest and insurance costs. The overall transport costs will not be negatively impacted under the proposed level of the required EEXI.

*Strategic direction, if applicable:* 3

*Output:* 3.2

*Action to be taken:* Paragraph 8

*Related documents:* MEPC 74/7/2, MEPC 74/INF.23; ISWG-GHG 6/2, ISWG-GHG 6/2/3; MEPC.1/Circ.885; ISWG-GHG 7/2/6 and ISWG-GHG 7/2/7

**Introduction**

1 The sixth meeting of the Intersessional Working Group on Reduction of GHG Emissions from Ships (ISWG-GHG 6) considered concrete proposals to improve the operational energy efficiency of existing ships. Prior to the meeting, Japan and Norway

submitted a concrete proposal for a goal-based energy efficiency measure utilizing the Energy Efficiency Existing Ship Index (EEXI) (ISWG-GHG 6/2/3), along with the initial impact assessment (ISWG-GHG 6/2) in accordance with paragraph 6 of the *Procedure for assessing impacts on States of candidate measures* (MEPC.1/Circ.885).

2 Following the discussion, ISWG-GHG 6 agreed that goal-based measures should be pursued and that two approaches, i.e. technical approach and operational approach, should be further developed in parallel. In this regard, interested Member States and organizations informally coordinated together to further elaborate the EEXI, and developed draft amendments to MARPOL Annex VI to incorporate the EEXI as set out in document ISWG-GHG 7/2/6 and draft guidelines to implement the EEXI as set out in document ISWG-GHG 7/2/7.

3 ISWG-GHG 6 also invited the sponsor(s) of proposed measures to continue their work on impact assessment, paying particular attention to the needs of developing countries, especially SIDS and LDCs, in accordance with the procedure approved by the Committee, and to submit their assessment to the next meeting.

4 Following the invitation from ISWG-GHG 6 to continue working on the impact assessment, the co-sponsors further conducted an analysis of potential impact of the proposed EEXI. Summarizing the results of the analysis, this document provides additional information on the impact assessment of the EEXI, in accordance with paragraph 12 of MEPC.1/Circ.885.

#### **Additional information on impact assessment of the EEXI**

5 The additional information on the impact assessment of the EEXI is set out in annex to this document. The additional information contains a quantitative analysis of the impact of the EEXI with the proposed level of stringency set out in document ISWG-GHG 6/2/3 on transport costs in relation to trade value.

6 In order to obtain quantitative data, a case study on different shipping routes was undertaken. In order to cover major types of commodities, different pairs of exporting and importing countries, including LDCs and SIDS and major ship types and ship sizes, eight illustrative shipping routes were chosen for the analysis.

7 In summary, based on the case study of the eight illustrative shipping routes, the following key findings are shown:

- .1 implementation of the proposed level of EEXI requirements, under an assumption that all ships will choose the engine power limit (EPL), will reduce ship running costs, as efficiency improvement reduces fuel costs for main engines, which are the major component of the ship running costs;
- .2 benefits from efficiency improvement depends on volatile market conditions (i.e. fuel price and charter costs). With higher fuel price and lower charter costs, ships will benefit more from efficiency improvement;
- .3 implementation of the EEXI by means of EPL will increase interest and insurance costs, as these costs will proportionally increase with days of each voyage. Such trend is more prominent in cases of longer distance routes;
- .4 additional transport costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) are drawn as a "U-shaped curve", in

which the transport costs decrease up to a certain point (optimizing point) and then start increasing beyond that point;

- .5 the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) corresponding to the optimizing point varies depending on the shipping route, type of commodity, ship type, ship size and other market conditions (e.g. fuel price and charter costs); and
- .6 the proposed level of required EEXI is below or within the range of the optimizing point. Therefore, it is shown that improving energy efficiency of ships at least to the level to comply with the EEXI requirements will not bring negative impacts on transport costs.

#### **Actions requested of the Working Group**

8 The Group is invited to note the additional information on the impact assessment of the EEXI set out in the annex to this document and take action as appropriate.

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## ANNEX

### ADDITIONAL INFORMATION ON IMPACT ASSESSMENT OF THE EEXI

#### 1 Methodology

##### 1.1 Structure of the analysis

1.1.1 The additional information on impact assessment of the goal-based technical energy efficiency improvement measure on existing ships (EEXI) provides quantitative analysis on impact of the EEXI with the proposed level of stringency set out in document ISWG-GHG 6/2/3 on transport costs in relation to the trade value.

1.1.2 The analysis is focused on the impact of slow steaming on transport costs, based on the assumption that existing ships covered by the measure would choose engine power limit (EPL) as an option to comply with the requirement. The assessment is made by quantifying the potential change of transport costs due to slow steaming and by comparing those cost changes with the value of transported commodity.

1.1.3 In the analysis, a case study was conducted covering eight illustrative shipping routes with different exporting and importing country pairs, commodities, ship types and sizes. The choice of these shipping routes were intended to cover various regions or economies including the least developed countries (LDCs) and the small island developing States (SIDS), in particular Pacific SIDS, and their major trading commodities. Section 1.2 of this Annex provides the details of these illustrative shipping routes and criteria for selection.

1.1.4 Estimated effect on transport costs is analyzed as one of the potential impacts of the EEXI. In the analysis, the transport cost is defined as follows:

Transport cost = Ship running cost + Interest and insurance cost

where

*Ship running costs* is the total sum of voyage costs (i.e. fuel costs for main and auxiliary engines) and charter costs (which would inherently include operating costs (e.g. manning costs, marine insurance costs, repair and maintenance costs, and capital costs); and

*Interest and insurance costs* represent the inventory costs and cargo insurance costs that are borne by shippers.

The appendix to this annex provides the detail and assumption of each component of the above-mentioned costs.

1.1.5 Consequently, the impact of EEXI on transport cost can be quantified through the estimated changes in transport cost due to slow steaming by means of EPL assumed to be adopted by ships in order to comply with the EEXI requirement (see section 1.3).

$$\begin{aligned} \Delta \text{Transport cost (by EEXI) (\$/ton)} \\ = \Delta \text{Ship running cost (\$/ton)} + \Delta \text{Interest and insurance cost (\$/ton)} \end{aligned}$$

1.1.6 Noting that transport costs are a part of overall costs associated with global trade, the impact of changes in transport cost on the trade value by means of EEXI can be assessed as a ratio to the trade value of the commodity in the same shipping route, as follows:

$$\Delta\text{Transport cost (\% of Trade value)} = \frac{\Delta\text{Transport cost (by EEXI) (\$/ton)}}{\text{Trade value (\$/ton)}}$$

## 1.2 Illustrative shipping routes

1.2.1 The analysis is conducted for eight illustrative shipping routes which are chosen to cover major regions or economies including LDCs and SIDS as well as their major trading commodities and partners. These shipping routes are chosen in light of the following criteria:

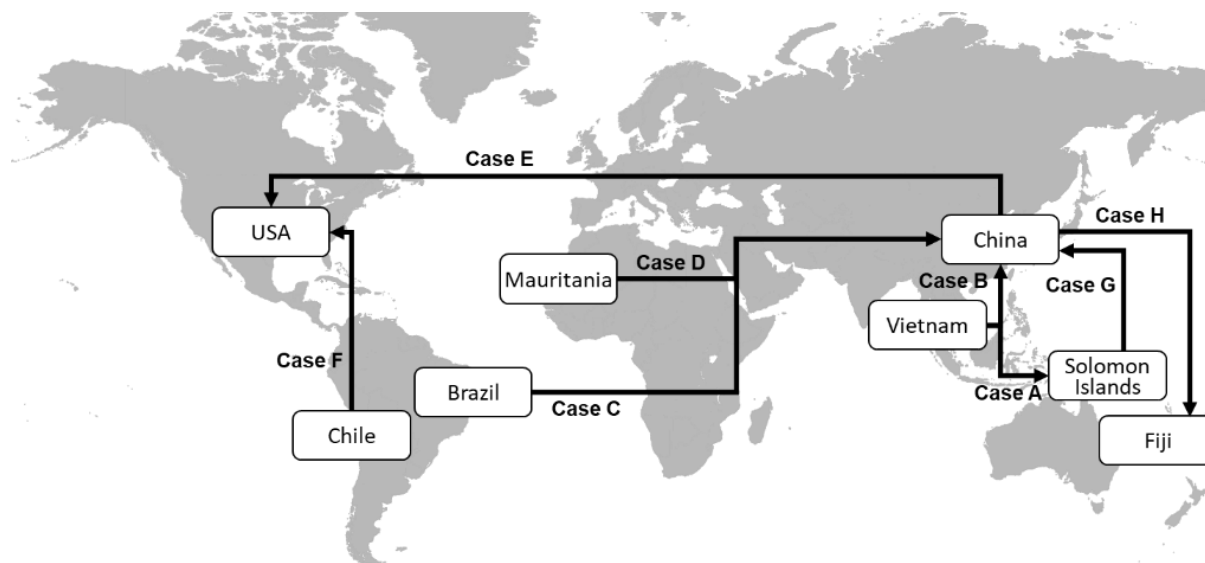
- .1 availability of data;
- .2 coverage of geographic distribution including LDCs and SIDS;
- .3 coverage of major commodities traded by selected countries including perishable goods; and
- .4 coverage of major ship types and sizes.

1.2.2 In light of the above criteria, countries included in the top-five among all countries as well as top-ten among SIDS in terms of annual export and import values in 2017 based on the UN Comtrade database were selected. Then, major commodities exported to and from those high-trading countries and their trading partners were identified.

1.2.2 As a result, the eight illustrative shipping routes were chosen as summarized in Table 1 and depicted in Figure 1.

**Table 1: Summary of illustrative shipping routes**

Case	Export country	Import country	Commodity	HS Code	Ship type	Ship size
A	Vietnam	Solomon Islands	Rice	1006	Bulk carrier	35-60k DWT
B	Vietnam	China	Rice	1006	Bulk carrier	35-60k DWT
C	Brazil	China	Iron ore	2601	Bulk carrier	>200k DWT
D	Mauritania	China	Iron ore	2601	Bulk carrier	>200k DWT
E	China	United States	Motor vehicle parts	8708	Container ship	5-8k TEU
F	Chile	United States	Apricots, cherry etc	0809	Container ship	8-12k TEU
G	Solomon Islands	China	Wood	4403	General cargo ship	>10k DWT
H	China	Fiji	Frozen fish	0303	Container ship	1-2k TEU



**Figure 1: Image of illustrative shipping routes**

### 1.3 Effect of the EEXI

1.3.1 The impact of the EEXI depends on stringency of the requirement level (reduction factors of the required EEXI) and stringency of enforcement to prevent non-compliant ships from being operated. Although the reduction factors are still subject to a decision by the Committee, the analysis tentatively referred to those proposed in document ISWG-GHG 6/2/3 (Japan and Norway), which were aligned with the 2022 level of the EEDI requirements for new ships. As the EEXI is a mandatory pre-certification measure, ships will not be allowed to operate unless compliance to EEXI is certified by the Administration. Therefore, the analysis assumed that all ships subject to the EEXI would comply with the requirements.

**Table 2: EEXI reduction factors (in percentage) proposed in document ISWG-GHG 6/2/3**

Ship type	Size	Reduction factor
Bulk carrier	20,000 DWT and Above	20
	10,000 and above but less than 20,000 DWT	0-20*
Gas carrier	15,000 DWT and above	30
	10,000 and above but less than 15,000 DWT	20
	2,000 and above but less than 10,000 DWT	0-20*
Tanker	20,000 DWT and above	20
	4,000 and above but less than 20,000 DWT	0-20*
Containership	200,000 DWT and above	50
	120,000 and above but less than 200,000 DWT	45
	80,000 and above but less than 120,000 DWT	40
	40,000 and above but less than 80,000 DWT	35
	15,000 and above but less than 40,000 DWT	30

	10,000 and above but less than 15,000 DWT	15-30*
General cargo ship	15,000 DWT and above	30
	3,000 and above but less than 15,000 DWT	0-30*
Refrigerated cargo carrier	5,000 DWT and above	15
	3,000 and above but less than 5,000 DWT	0-15*
Combination carrier	20,000 DWT and above	20
	4,000 and above but less than 20,000 DWT	0-20*
LNG carrier	10,000 DWT and above	30
Ro-ro cargo ship (vehicle carrier)	10,000 DWT and above	15
Ro-ro cargo ship	2,000 DWT and above	20
	1,000 and above but less than 2,000 DWT	0-20*
Ro-ro passenger ship	1,000 DWT and above	20
	250 and above but less than 1,000 DWT	0-20*
Cruise passenger ship having non-conventional propulsion	85,000 GT and above	30
	25,000 and above but less than 85,000 GT	0-30*

\* Reduction factor to be linearly interpolated between the two values dependent upon ship size. The lower value of the reduction factor is to be applied to the smaller ship size.

1.3.2 As the EEXI is a goal-based measure which does not limit the option to a specific measure, there will be various ways for ships to comply with the requirement. A ship might choose engine power limit (EPL) as an option while another ship might choose combination of energy-saving device and EPL. It is assumed that each ship will choose the most cost-effective option for compliance with the EEXI taking into account each ship's circumstances.

1.3.3 Although the impact of the EEXI may depend on options taken by each ship for compliance, it can be estimated by assuming that all ships subject to the EEXI will choose only EPL as an option. This assumption may not reflect the real situation of shipping sector as some or a number of ships may choose other options such as fuel change or energy-saving device instead of EPL. However, recalling that each ship is assumed to choose the most cost-effective option for compliance, cost-effectiveness of the EEXI in the real world should be always better than that in the EPL-only assumption. Consequently, negative impact of the EEXI in the real world should be smaller than that in the EPL-only assumption. Therefore, assuming that all ships will choose only EPL as an option should lead to a conservative result in the impact assessment.

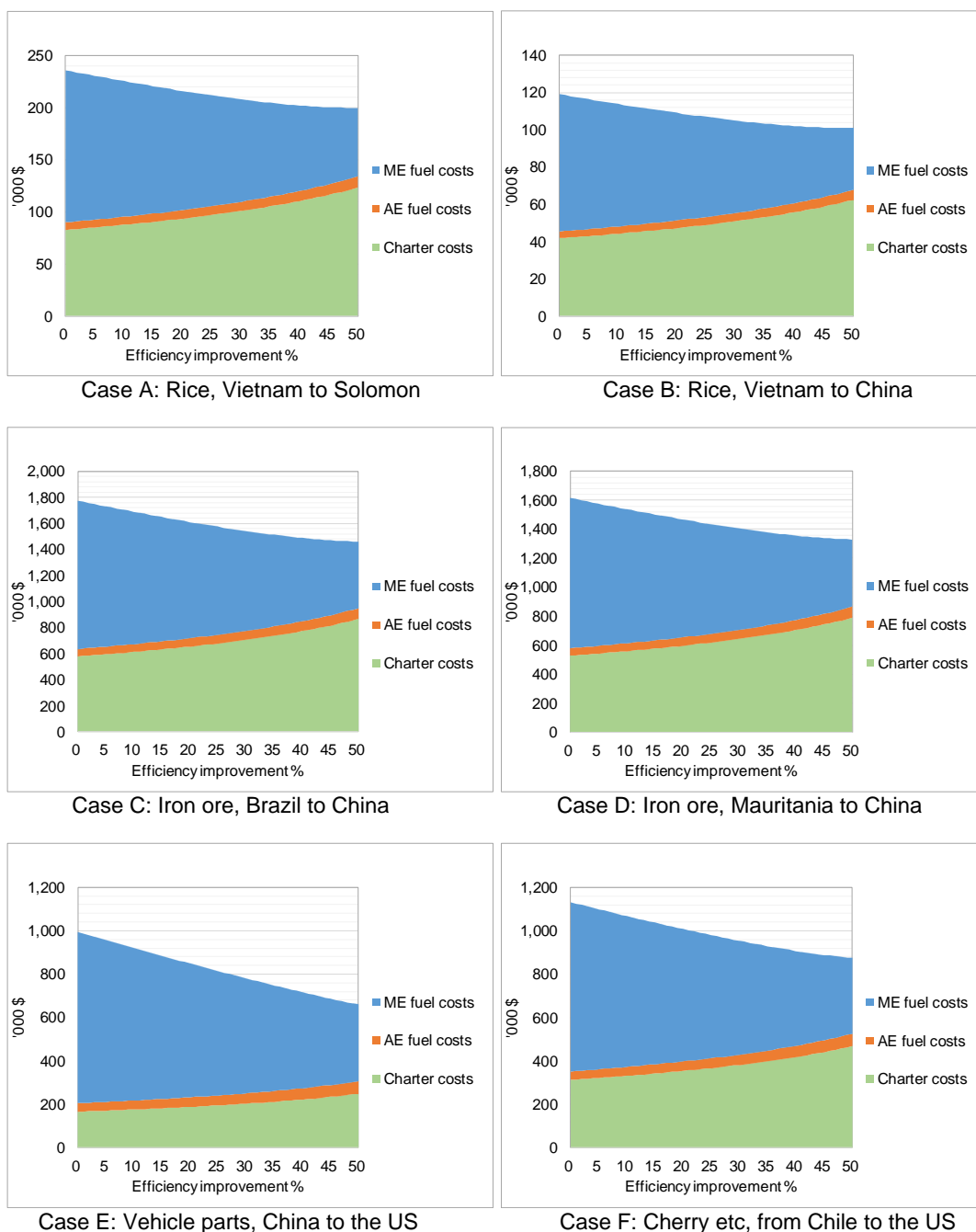
$$\text{Negative impact of EEXI (real situation)} < \underbrace{\text{Negative impact of EEXI (EPL only)}}_{\text{Scope of analysis}}$$

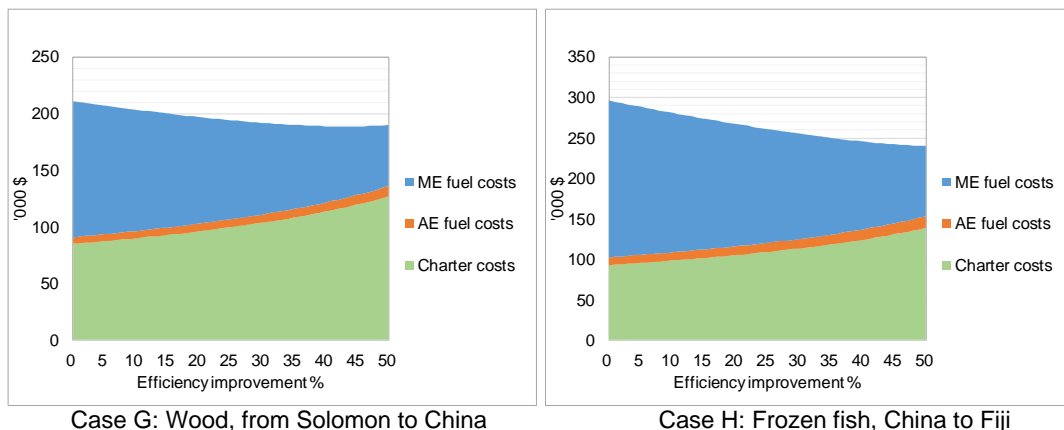


## 2 Results

### 2.1 Ship running cost

2.1.1 Ship running costs of a ship per voyage in each shipping route are analysed, as summarized in Figure 2 below. The figure shows how fuel costs for main and auxiliary engines as well as charter costs, in which operating costs and capital costs are implicitly included, change with the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) achieved by slow steaming by means of EPL assumed to be adopted by ships covered by the EEXI (see appendix for details of the relationship between the level of speed reduction and efficiency improvement or CO<sub>2</sub> reduction per transport work). The changes of these costs are compared with the baseline level in 2008.



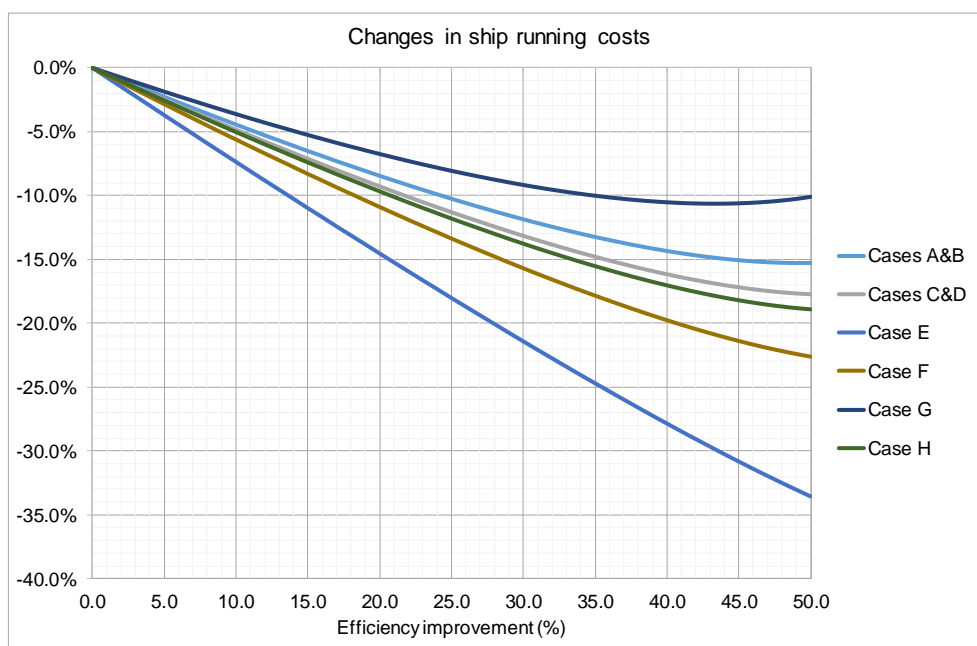


**Figure 2: Ship running cost per voyage (US\$)**

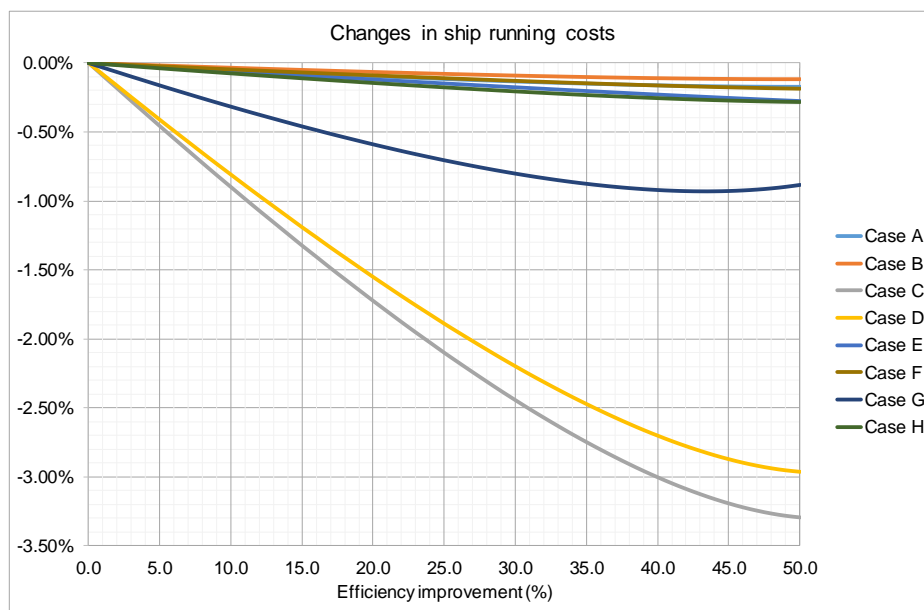
2.1.2 The results in Figure 2 show a general trend that the fuel costs for main engines, which accounts for majority of ship running costs, significantly decrease in accordance with the level of efficiency improvement or in other words with CO<sub>2</sub> reduction per transport work achieved by implementation of EEXI by means of EPL. By definition, better energy efficiency results in lesser fuel consumption.

2.1.3 On the other hand, ship running costs other than the fuel costs for main engines increase with the level of efficiency improvement (CO<sub>2</sub> reduction per transport work). This trend reflects the assumption that ships will comply with the energy efficiency requirements only by means of EPL (leading to lesser operating speed) which will result in longer hours of operation per voyage.

2.1.4 Figures 3-1 and 3-2 below compare the ship running costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) achieved by slow steaming by means of EPL in each shipping route.



**Figure 3-1: Comparison of additional ship running costs (% of original ship running costs)**

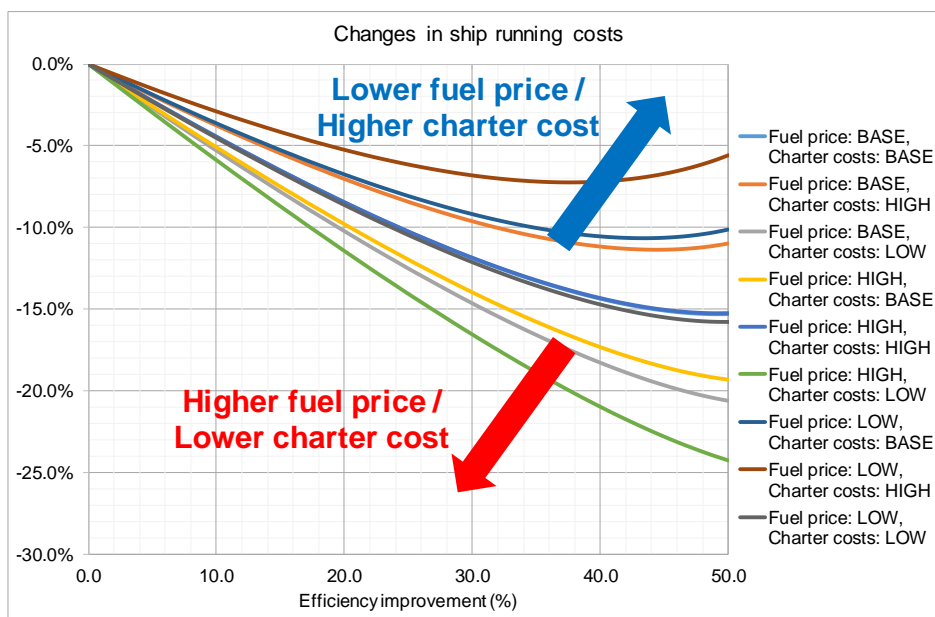


**Figure 3-2: Comparison of additional ship running costs (% of cargo value)**

2.1.5 From Figure 3-1, it is found that containerships (cases E, F and H) benefit more from efficiency improvement (CO<sub>2</sub> reduction per transport work) than the other ship types, due to higher ratio of fuel costs for main engines to the total ship running costs as shown in Figure 2.

2.1.6 However, as shown in Figure 3-2, when compared with the cargo value, it is found that transport of commodities with lower unit cargo value (cases C, D and G) benefit more from efficiency improvement (CO<sub>2</sub> reduction per transport work) than the other routes, as the ratio of ship running costs to cargo value becomes higher in these routes.

2.1.7 Figure 4 below compares the ship running costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) for case A under different fuel price and charter costs scenarios (see appendix for details and assumptions).



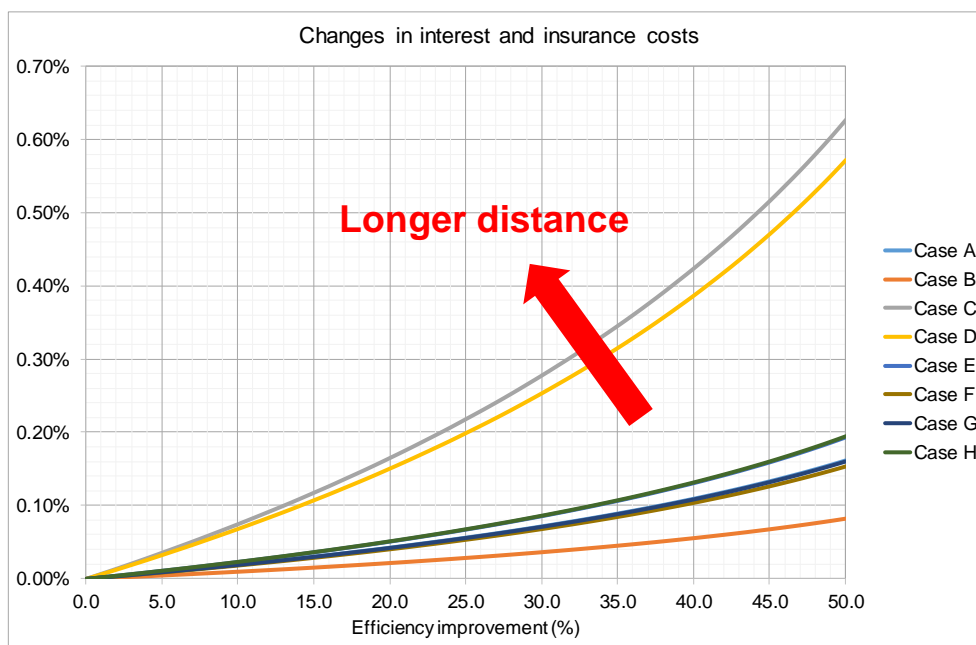
**Figure 4: Comparison of additional ship running costs by fuel price and charter costs (case A, % of original ship running costs)**

2.1.8 From Figure 4, it is found that higher fuel price or lower charter costs shift the curves downwards, in other words improves the benefit (incentive) of efficiency improvement; in contrary lower fuel price or higher charter costs shift the curves upwards, in other words reduce the benefit (incentive) of efficiency improvement. The same findings can be applied to other cases (cases B to H) as well. Therefore, in a circumstance where fuel price is high or charter rate is low, ships are likely to slow down to gain efficiency, and vice versa.

## 2.2 Interest and insurance costs

2.2.1 In addition to ship running costs, the EEXI, in particular when EPL is chosen as a measure, may affect other costs associated with transport of commodities. In particular, interest and insurance costs may increase with longer operation hours.

2.2.2 Figure 5 below compares additional interest and insurance costs per unit of cargo value in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) achieved by slow steaming by means of EPL in each shipping route.



**Figure 5: Comparison of additional interest and insurance costs (% of cargo value)**

2.2.3 As shown in Figure 5, unlike ship running costs, interest and insurance costs increases as ships slowdown in order to improve efficiency. By comparing different routes, it is found that additional interest and insurance costs are more prominent in cases of longer distance routes (cases C and D). In other words, benefits of efficiency improvement led by fuel savings are more likely to be compensated by additional interest and insurance costs due to longer operation hours.

## 3 Summary

### 3.1 Transportation cost

3.1.1 As described in section 1 of this annex, the transport cost can be calculated as the total sum of ship running cost, and interest and insurance cost.

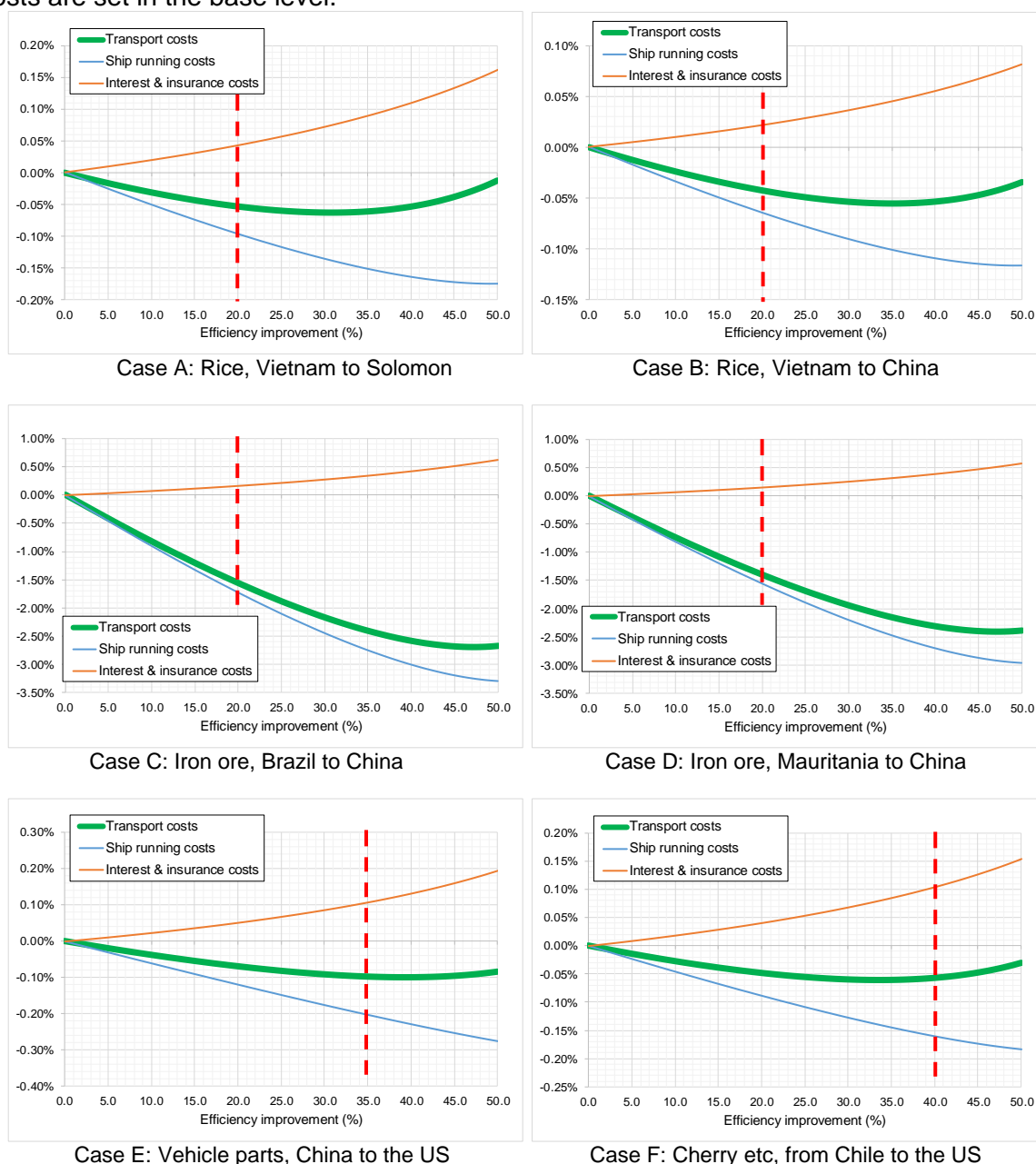
$$\text{Transport cost} = \text{Ship running cost} + \text{Interest and insurance cost}$$

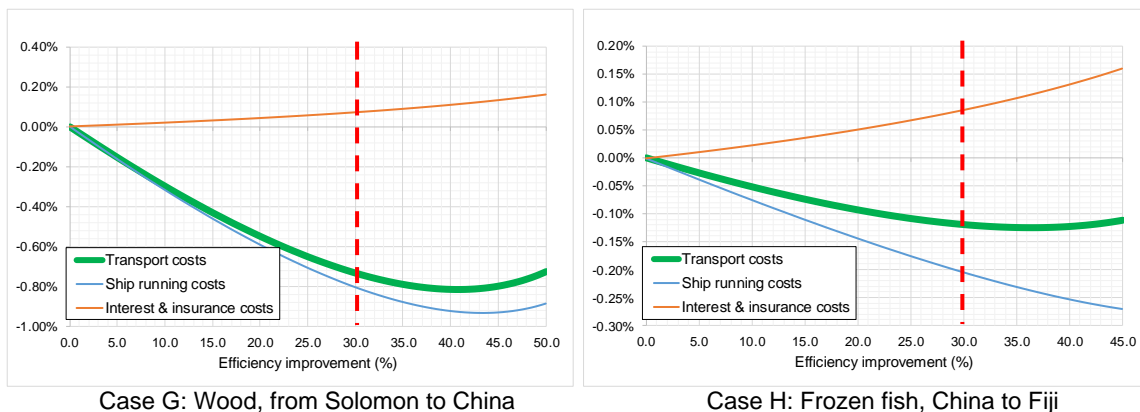
Consequently, the impact of the EEXI on transport cost as well as its ratio to the trade value of the commodity in the same shipping route can be estimated as follows:

$$\Delta\text{Transport cost (by EEXI) (\$/ton)} = \Delta\text{Ship running cost (\$/ton)} + \Delta\text{Interest and insurance cost (\$/ton)}$$

$$\Delta\text{Transport cost (\% of Trade value)} = \frac{\Delta\text{Transport cost (by EEXI) (\$/ton)}}{\text{Trade value (\$/ton)}}$$

3.1.2 Figure 6 below shows additional transportation cost per unit of cargo value in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) achieved by slow steaming by means of EPL in each shipping route. The level of efficiency improvement (CO<sub>2</sub> reduction per transport work) corresponding to the required EEXI to be applied to the category of the ship in each case is highlighted with the red line. In Figure 6, both fuel price and charter costs are set in the base level.

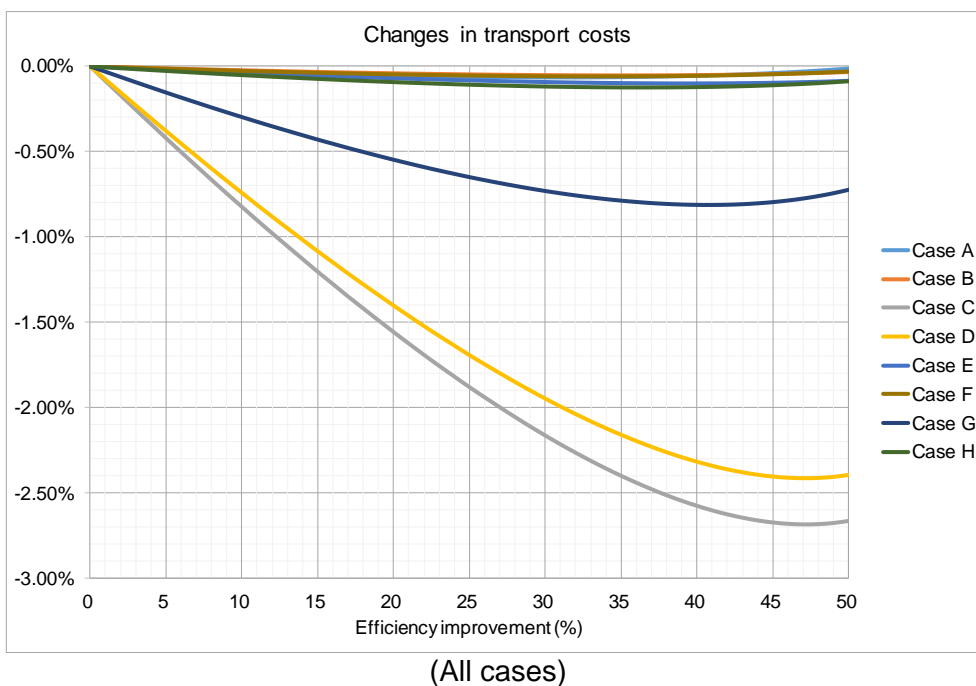




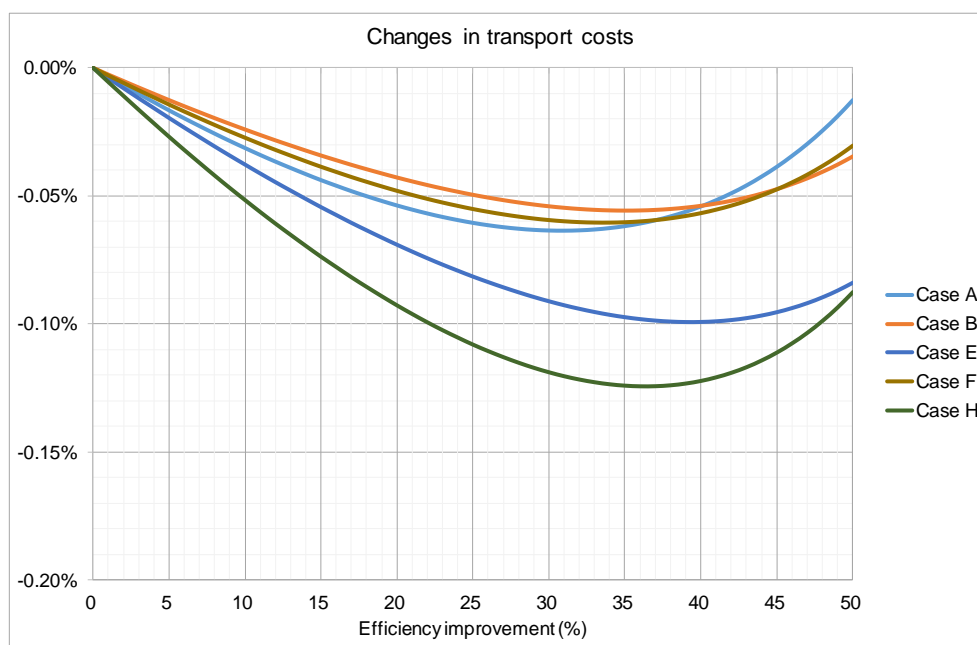
**Figure 6: Additional transport costs (% of cargo value)**

3.1.3 As Figure 6 shows, additional transport costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) are drawn as a "U-shaped curve", in which the transport costs decrease up to a certain point and then start increasing beyond that point. This point is called "optimizing point" hereafter (see section 3.2).

3.1.4 Figure 7 below compares additional transportation cost per unit of cargo value in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) in each shipping route. In Figure 7, both fuel price and charter costs are set in the base level.



(All cases)



(Cases A, B, E, F and H)

**Figure 7: Additional transport costs (% of cargo value)**

3.1.5 From Figure 7, it is found that transports of bulk cargo, in particular for long distance (cases C and D), tend to benefit more from efficiency improvement (CO<sub>2</sub> reduction per transport work) than the other cases. As discussed in sections 2.1 and 2.2, transport costs of these long-distance routes are likely to be influenced by reduction in ship speed both in terms of efficiency improvement and longer operation hours. As fuel costs are the major component among overall transport costs, reduction of fuel costs results in reduction of overall transportation costs.

3.1.6 Table 3 below shows the results shown in Figure 7 (additional transportation cost per unit of cargo value) for different patterns of fuel price and charter costs.

**Table 3: Additional transport costs (% of cargo value)**

**Fuel price: Base, Charter costs: Base**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.10%	-0.14%	-0.16%	0.04%	0.07%	0.11%	-0.05%	-0.06%	-0.05%
B	Vietnam	China	Rice	-0.06%	-0.09%	-0.11%	0.02%	0.04%	0.06%	-0.04%	-0.05%	-0.05%
C	Brazil	China	Iron ore	-1.72%	-2.44%	-3.00%	0.17%	0.28%	0.42%	-1.56%	-2.17%	-2.58%
D	Mauritania	China	Iron ore	-1.55%	-2.20%	-2.70%	0.15%	0.25%	0.39%	-1.40%	-1.95%	-2.32%
E	China	U.S.	Vehicle parts	-0.12%	-0.18%	-0.23%	0.05%	0.09%	0.13%	-0.07%	-0.09%	-0.10%
F	Chile	U.S.	Cherry etc	-0.09%	-0.13%	-0.16%	0.04%	0.07%	0.10%	-0.05%	-0.06%	-0.06%
G	Solomon Is.	China	Wood etc	-0.59%	-0.80%	-0.92%	0.04%	0.07%	0.11%	-0.55%	-0.73%	-0.81%
H	China	Fiji	Frozen fish	-0.14%	-0.20%	-0.25%	0.05%	0.09%	0.13%	-0.09%	-0.12%	-0.12%

**Fuel price: Base, Charter costs: High**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.09%	-0.12%	-0.14%	0.04%	0.07%	0.11%	-0.04%	-0.05%	-0.03%
B	Vietnam	China	Rice	-0.06%	-0.08%	-0.09%	0.02%	0.04%	0.06%	-0.04%	-0.04%	-0.04%
C	Brazil	China	Iron ore	-1.41%	-1.92%	-2.20%	0.17%	0.28%	0.42%	-1.25%	-1.64%	-1.78%
D	Mauritania	China	Iron ore	-1.27%	-1.73%	-1.98%	0.15%	0.25%	0.39%	-1.12%	-1.47%	-1.60%
E	China	U.S.	Vehicle parts	-0.12%	-0.17%	-0.22%	0.05%	0.09%	0.13%	-0.06%	-0.08%	-0.09%
F	Chile	U.S.	Cherry etc	-0.08%	-0.12%	-0.15%	0.04%	0.07%	0.10%	-0.04%	-0.05%	-0.04%
G	Solomon Is.	China	Wood etc	-0.54%	-0.71%	-0.79%	0.04%	0.07%	0.11%	-0.50%	-0.64%	-0.68%
H	China	Fiji	Frozen fish	-0.13%	-0.19%	-0.23%	0.05%	0.09%	0.13%	-0.08%	-0.10%	-0.09%

**Fuel price: Base, Charter costs: Low**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.11%	-0.15%	-0.19%	0.04%	0.07%	0.11%	-0.07%	-0.08%	-0.08%
B	Vietnam	China	Rice	-0.07%	-0.10%	-0.13%	0.02%	0.04%	0.06%	-0.05%	-0.07%	-0.07%
C	Brazil	China	Iron ore	-2.00%	-2.92%	-3.72%	0.17%	0.28%	0.42%	-1.84%	-2.64%	-3.30%
D	Mauritania	China	Iron ore	-1.80%	-2.62%	-3.35%	0.15%	0.25%	0.39%	-1.65%	-2.37%	-2.96%
E	China	U.S.	Vehicle parts	-0.12%	-0.18%	-0.24%	0.05%	0.09%	0.13%	-0.07%	-0.10%	-0.11%
F	Chile	U.S.	Cherry etc	-0.09%	-0.14%	-0.17%	0.04%	0.07%	0.10%	-0.05%	-0.07%	-0.07%
G	Solomon Is.	China	Wood etc	-0.64%	-0.88%	-1.05%	0.04%	0.07%	0.11%	-0.60%	-0.81%	-0.94%
H	China	Fiji	Frozen fish	-0.15%	-0.22%	-0.28%	0.05%	0.09%	0.13%	-0.10%	-0.14%	-0.15%

**Fuel price: High, Charter costs: Base**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.13%	-0.18%	-0.22%	0.04%	0.07%	0.11%	-0.08%	-0.11%	-0.11%
B	Vietnam	China	Rice	-0.08%	-0.12%	-0.15%	0.02%	0.04%	0.06%	-0.06%	-0.08%	-0.09%
C	Brazil	China	Iron ore	-2.23%	-3.20%	-4.01%	0.17%	0.28%	0.42%	-2.06%	-2.92%	-3.59%
D	Mauritania	China	Iron ore	-2.00%	-2.88%	-3.61%	0.15%	0.25%	0.39%	-1.85%	-2.63%	-3.22%
E	China	U.S.	Vehicle parts	-0.15%	-0.22%	-0.28%	0.05%	0.09%	0.13%	-0.10%	-0.13%	-0.15%
F	Chile	U.S.	Cherry etc	-0.11%	-0.16%	-0.21%	0.04%	0.07%	0.10%	-0.07%	-0.09%	-0.10%
G	Solomon Is.	China	Wood etc	-0.80%	-1.12%	-1.34%	0.04%	0.07%	0.11%	-0.76%	-1.05%	-1.23%
H	China	Fiji	Frozen fish	-0.18%	-0.27%	-0.34%	0.05%	0.09%	0.13%	-0.13%	-0.18%	-0.20%

**Fuel price: High, Charter costs: High**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.12%	-0.16%	-0.20%	0.04%	0.07%	0.11%	-0.07%	-0.09%	-0.09%
B	Vietnam	China	Rice	-0.08%	-0.11%	-0.13%	0.02%	0.04%	0.06%	-0.06%	-0.07%	-0.08%
C	Brazil	China	Iron ore	-1.92%	-2.68%	-3.21%	0.17%	0.28%	0.42%	-1.75%	-2.40%	-2.79%
D	Mauritania	China	Iron ore	-1.72%	-2.41%	-2.89%	0.15%	0.25%	0.39%	-1.57%	-2.15%	-2.50%
E	China	U.S.	Vehicle parts	-0.14%	-0.21%	-0.27%	0.05%	0.09%	0.13%	-0.09%	-0.13%	-0.14%
F	Chile	U.S.	Cherry etc	-0.11%	-0.15%	-0.19%	0.04%	0.07%	0.10%	-0.07%	-0.09%	-0.09%
G	Solomon Is.	China	Wood etc	-0.75%	-1.03%	-1.21%	0.04%	0.07%	0.11%	-0.71%	-0.96%	-1.10%
H	China	Fiji	Frozen fish	-0.17%	-0.25%	-0.31%	0.05%	0.09%	0.13%	-0.12%	-0.16%	-0.18%

**Fuel price: High, Charter costs: Low**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.14%	-0.20%	-0.25%	0.04%	0.07%	0.11%	-0.09%	-0.13%	-0.14%
B	Vietnam	China	Rice	-0.09%	-0.13%	-0.17%	0.02%	0.04%	0.06%	-0.07%	-0.10%	-0.11%
C	Brazil	China	Iron ore	-2.51%	-3.67%	-4.73%	0.17%	0.28%	0.42%	-2.34%	-3.39%	-4.30%
D	Mauritania	China	Iron ore	-2.26%	-3.30%	-4.26%	0.15%	0.25%	0.39%	-2.11%	-3.05%	-3.87%
E	China	U.S.	Vehicle parts	-0.15%	-0.22%	-0.30%	0.05%	0.09%	0.13%	-0.10%	-0.14%	-0.16%
F	Chile	U.S.	Cherry etc	-0.12%	-0.17%	-0.22%	0.04%	0.07%	0.10%	-0.08%	-0.10%	-0.12%
G	Solomon Is.	China	Wood etc	-0.85%	-1.20%	-1.47%	0.04%	0.07%	0.11%	-0.81%	-1.13%	-1.36%
H	China	Fiji	Frozen fish	-0.20%	-0.28%	-0.36%	0.05%	0.09%	0.13%	-0.14%	-0.20%	-0.23%



**Fuel price: Low, Charter costs: Base**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.07%	-0.09%	-0.10%	0.04%	0.07%	0.11%	-0.02%	-0.02%	0.01%
B	Vietnam	China	Rice	-0.04%	-0.06%	-0.07%	0.02%	0.04%	0.06%	-0.02%	-0.02%	-0.01%
C	Brazil	China	Iron ore	-1.22%	-1.69%	-2.00%	0.17%	0.28%	0.42%	-1.06%	-1.41%	-1.57%
D	Mauritania	China	Iron ore	-1.10%	-1.52%	-1.80%	0.15%	0.25%	0.39%	-0.95%	-1.27%	-1.41%
E	China	U.S.	Vehicle parts	-0.09%	-0.14%	-0.17%	0.05%	0.09%	0.13%	-0.04%	-0.05%	-0.04%
F	Chile	U.S.	Cherry etc	-0.06%	-0.09%	-0.11%	0.04%	0.07%	0.10%	-0.02%	-0.02%	-0.01%
G	Solomon Is.	China	Wood etc	-0.38%	-0.49%	-0.50%	0.04%	0.07%	0.11%	-0.34%	-0.42%	-0.39%
H	China	Fiji	Frozen fish	-0.10%	-0.14%	-0.17%	0.05%	0.09%	0.13%	-0.05%	-0.06%	-0.04%

**Fuel price: Low, Charter costs: High**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.06%	-0.07%	-0.08%	0.04%	0.07%	0.11%	-0.01%	0.00%	0.03%
B	Vietnam	China	Rice	-0.04%	-0.05%	-0.05%	0.02%	0.04%	0.06%	-0.02%	-0.01%	0.00%
C	Brazil	China	Iron ore	-0.91%	-1.17%	-1.20%	0.17%	0.28%	0.42%	-0.74%	-0.89%	-0.77%
D	Mauritania	China	Iron ore	-0.82%	-1.05%	-1.08%	0.15%	0.25%	0.39%	-0.67%	-0.80%	-0.69%
E	China	U.S.	Vehicle parts	-0.09%	-0.13%	-0.16%	0.05%	0.09%	0.13%	-0.04%	-0.04%	-0.03%
F	Chile	U.S.	Cherry etc	-0.06%	-0.08%	-0.10%	0.04%	0.07%	0.10%	-0.02%	-0.02%	0.00%
G	Solomon Is.	China	Wood etc	-0.33%	-0.40%	-0.36%	0.04%	0.07%	0.11%	-0.29%	-0.33%	-0.26%
H	China	Fiji	Frozen fish	-0.09%	-0.12%	-0.14%	0.05%	0.09%	0.13%	-0.04%	-0.04%	-0.01%

**Fuel price: Low, Charter costs: Low**

Case	Country pair		Commodity	Additional costs per value of cargo in relation to efficiency improvement								
				Ship running costs			Interest & insurance costs			Total costs		
	Export	Import		20%	30%	40%	20%	30%	40%	20%	30%	40%
A	Vietnam	Solomon Is.	Rice	-0.08%	-0.11%	-0.13%	0.04%	0.07%	0.11%	-0.04%	-0.04%	-0.02%
B	Vietnam	China	Rice	-0.05%	-0.07%	-0.09%	0.02%	0.04%	0.06%	-0.03%	-0.04%	-0.03%
C	Brazil	China	Iron ore	-1.50%	-2.16%	-2.71%	0.17%	0.28%	0.42%	-1.34%	-1.88%	-2.29%
D	Mauritania	China	Iron ore	-1.35%	-1.94%	-2.44%	0.15%	0.25%	0.39%	-1.20%	-1.69%	-2.06%
E	China	U.S.	Vehicle parts	-0.10%	-0.14%	-0.18%	0.05%	0.09%	0.13%	-0.05%	-0.06%	-0.05%
F	Chile	U.S.	Cherry etc	-0.07%	-0.10%	-0.13%	0.04%	0.07%	0.10%	-0.03%	-0.03%	-0.02%
G	Solomon Is.	China	Wood etc	-0.43%	-0.57%	-0.63%	0.04%	0.07%	0.11%	-0.39%	-0.50%	-0.52%
H	China	Fiji	Frozen fish	-0.11%	-0.16%	-0.20%	0.05%	0.09%	0.13%	-0.06%	-0.07%	-0.07%

3.1.7 Table 3 shows a similar trend as Figure 4 does, that higher fuel price or lower charter costs improve the benefit of efficiency improvement while lower fuel price or higher charter costs reduce the benefit of efficiency improvement.

### 3.2 Optimizing point

3.2.1 From the results shown in Figures 6 and 7, it is found that, for each case of the illustrative shipping route, there exists an optimizing point at the certain level of the EEXI reduction rate where the transport costs start increasing with the level of efficiency improvement (CO<sub>2</sub> reduction per transport work). Table 4 below shows the level of efficiency improvement corresponding to the optimizing point for each scenario for fuel price and charter costs.

**Table 4: Optimizing point**

	Optimizing point (efficiency %)			Required EEXI (%)
	Fuel price	Base	High	
Charter cost	Base	Low	High	
A	31%	41%	17%	20%
B	35%	45%	21%	20%
C	47%	58%	31%	20%

D	47%	58%	31%	20%
E	39%	46%	29%	35%
F	34%	42%	22%	40%
G	41%	49%	29%	30%
H	36%	45%	24%	30%

3.2.2 Although there are variations of optimizing points due to volatile market conditions (i.e. fuel price and charter costs), the proposed level of required EEXI is below or within the range of the optimizing point in each case. Therefore, it is shown that improving energy efficiency of ships at least to the level to comply with the EEXI requirements will not bring negative impacts on transport costs.

3.2.3 Nevertheless, these results do not mean that ships will necessarily reduce CO<sub>2</sub> to the level of the optimizing point on their own. First, from a technical perspective, improving energy efficiency more than 30% only by means of slow steaming (reducing engine load) would be challenging in particular for bulk carriers and tankers, as these ships usually install engines with small MCR relative to those capacity and thus there is limited room for cutting the engine load. Second, from a commercial perspective, there would be incentives for shippers to set the schedule to minimize days of voyage in order to have more spare time in the overall trade of the commodity.

3.2.4 Therefore, in order to ensure a certain level of efficiency improvement (CO<sub>2</sub> reduction per transport work), establishing mandatory measure on energy efficiency of ships is necessary. At the same time, in order to avoid any potential negative impacts, it is essential to set the required EEXI at an appropriate level in terms of technical capacity for each category of ship type and ship size.

### 3.3 Other potential impact

3.3.1 As described above, it is found that the overall transport costs will not be negatively impacted under the proposed level of the required EEXI. Nevertheless, there could be potential impact other than those accounting for the transport costs (e.g. additional operation costs, capital costs, interest and insurance costs) associated with additional days (shown in Table 5 below) of voyage due to implementation of EPL to comply with the EEXI requirement.

**Table 5: Additional days of operation per voyage associated with efficiency improvement by means of EPL**

Case	Country pair		Distance nm	Days per voyage (2008) Day	Additional days in relation to efficiency improvement		
	Export	Import			20%	30%	40%
A	Vietnam	Solomon Is.	3,037	9.96	1.15	1.79	2.50
B	Vietnam	China	1,533	5.08	0.59	0.91	1.27
C	Brazil	China	11,589	39.42	4.54	7.09	9.88
D	Mauritania	China	10,554	36.26	4.18	6.52	9.09
E	China	U.S.	5,617	12.37	1.43	2.22	3.10
F	Chile	U.S.	4,596	9.93	1.14	1.79	2.49
G	Solomon Is.	China	3,061	10.52	1.21	1.89	2.64
H	China	Fiji	4,350	12.82	1.48	2.31	3.21

3.3.2 For example, additional days of voyage may impact the overall logistic chain, covering supply of raw materials, manufacturing, in-land transport, cargo-handling at ports, distribution to retailers and end-users. As shipping is an integral part of such a logistic chain, changes in days allocated to shipping may necessitate adjustment of schedules and business practices in

the other area of the logistic chain. However, such changes have happened frequently in the global logistics caused by various market factors (e.g. changes in fuel price, speculative investment in fleets) and non-market external conditions (e.g. economic crisis, natural disasters). Therefore, it is not feasible to quantitatively expect causal effect of the EEXI in such a broad logistic chain.

3.3.3 The installation of EPL may weaken market competitiveness of the ship, as charterers would prefer having additional power to have spare time in the schedule. In fact, this is currently rather a potential barrier for new ships having lesser engine power in order to meet the latest EEDI, while current old ships are allowed to maintain superfluous engine power. Therefore, the EEXI will resolve potential market inequality among new efficient ships and old inefficient ships.

## 4 Conclusion

Based on case studies on transport costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) to comply with the EEXI requirements by means of EPL, for eight illustrative shipping routes, the following key findings are shown:

- .1 implementation of the proposed level of EEXI requirements, under an assumption that all ships will choose EPL, will reduce ship running costs, as efficiency improvement reduces fuel costs for main engines, which are the major component of the ship running costs;
- .2 benefits from efficiency improvement depends on volatile market conditions (i.e. fuel price and charter costs). With higher fuel price and lower charter costs, ships will benefit more from efficiency improvement;
- .3 implementation of the EEXI by means of EPL will increase interest and insurance costs, as these costs will proportionally increase with days of each voyage. Such trend is more prominent in cases of longer distance routes;
- .4 additional transport costs in relation to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) are drawn as a "U-shaped curve", in which the transport costs decrease up to a certain point (optimizing point) and then start increasing beyond that point;
- .5 the level of efficiency improvement corresponding to the optimizing point varies depending on shipping route, type of commodity, ship type, ship size and other market conditions (e.g. fuel price and charter costs); and
- .6 the proposed level of required EEXI is below or within the range of the optimizing point. Therefore, it is shown that improving energy efficiency of ships at least to the level to comply with the EEXI requirements will not bring negative impacts on transport costs.

## 5 Reference

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## Appendix

### Details and assumptions for each component of the transport cost

#### 1 Ship running cost

1.1 Ship running cost normally consists of voyage costs, operating costs (which include manning costs, marine insurance costs, etc.), capital costs, and other costs, including cargo-handling costs and periodic maintenance. However, in order to assess the impact of transport costs from shippers' viewpoint, noting that transport costs are usually defined as monetary expenses borne by shippers to transport goods from their origin to their destination (Halim et al., 2019), it is assumed here that, for the analysis, ship running cost consists of the following three cost items:

- .1 fuel costs for main engines;
- .2 fuel costs for auxiliary engines; and
- .3 charter costs.

1.2 The above-mentioned items were selected based on the idea that fuel costs account for the majority of voyage costs and that charter costs would inherently cover ship owners' expenses for the purchase, operation and maintenance of each ship.

#### *Fuel costs for main and auxiliary engines*

1.3 Fuel costs for main and auxiliary engines per voyage are expressed as follows:

$$\text{Fuel cost}_{ME,AE} (\$/\text{voyage}) = \text{Fuel price} (\$/\text{ton}) \times \text{daily fuel consumption}_{ME,AE} (\text{tons}/\text{day}) \times \text{days of operation per voyage}$$

1.4 Three different scenarios for fuel price are assumed as set out in Table A-1.

**Table A-1: Scenarios for fuel price**

	low	base	high
Fuel price (US\$/ton)	400	500	600

1.5 Daily fuel consumption for main engine is calculated based on IMO (2015) average fuel consumption data and average ship speed data in 2008 for each ship category, whereas daily fuel consumption for auxiliary engine is assumed to be 5% of main engine fuel consumption rate, as shown in Table A-2 below.

1.6 If a ship chooses engine power limit (EPL) to comply with the EEXI requirement, its operating speed will be reduced, resulting in either decrease or increase of the aforementioned fuel costs per voyage. Based on the cube law, daily fuel consumption of main engine will decrease in proportion to the cube of the reduction in ship operating speed relative to its design speed. Therefore, average fuel consumption and average ship speed data in Table A-2 are used to calculate the daily fuel consumption for main engine in accordance with the reduction level of ship speed from the base year (2008). Daily fuel consumption of auxiliary engine is independent from the change in operating speed.

1.7 Days of operation per voyage are calculated based on the distance between the two country pairs and ship's operating speed. Naturally, speed reduction will increase the number of days required to carry out the voyage.

**Table A-2: Average ship speed and fuel consumption in 2008**

Case	Ship type	Size category	Average ship speed (knots)		Average fuel consumption (tons/day)	
			Design	Operation	Main engine	Auxiliary engine
A & B	Bulk carrier	35-60k dwt	15.0	12.7	29.3	1.5
C & D	Bulk carrier	>200k dwt	15.6	12.5	59.0	2.9
E	Container ship	5-8k TEU	26.5	19.7	132.5	6.6
F	Container ship	8-12k TEU	28.4	20.3	165.2	8.3
G	General cargo ship	>10k dwt	15.9	12.9	24.3	1.2
H	Container ship	1-2k TEU	20.3	15.2	32.4	1.6

Source: IMO (2015)

Note: Average main engine fuel consumption is derived from the total annual fuel consumption and average days of operation provided in IMO (2015) for each ship category.

1.8 If a ship chooses the engine power limit (EPL) to comply with the EEXI requirement, the ship speed ( $V$ ) will decrease, resulting in either decrease or increase of the aforementioned fuel cost. According to the cube law, daily fuel consumption of main engines is proportional to the cube of ship speed ( $V^3$ ), while days of operation is proportional to  $1/V$ . Therefore, fuel costs for main engines per voyage are proportional to  $V^2$ . On the other hand, daily fuel consumption of auxiliary engines is independent from ship speed. Therefore, fuel costs for auxiliary engines per voyage are proportional to  $1/V$ .

1.9 Therefore, change of fuel costs per voyage after implementation of the EEXI for main and auxiliary engines can be expressed as follows, respectively:

$$\Delta \text{Fuel cost}_{ME} (\$/\text{voyage}) = \text{Original fuel cost}_{ME} \times [(V_{EPL}/V_{base})^2 - 1]$$

$$\Delta \text{Fuel cost}_{AE} (\$/\text{voyage}) = \text{Original fuel cost}_{AE} \times (V_{base}/V_{EPL} - 1)$$

where,

$V_{base}$  is the average ship speed in the base year (2008); and

$V_{EPL}$  is the assumed average ship speed after the EPL is installed.

#### Charter costs

1.10 Daily charter costs, in which operating costs and capital costs are implicit, are given for each case, based on the time charter rate of different ship categories obtained from Clarksons Research Shipping Intelligence Network. As shown in Table A-3 below, three different scenarios are set, based on the average level of charter rates from 2013 to 2018, reflecting the fluctuations observed in the same period for each segment.

1.11 Charter costs per voyage are assumed to be proportional to days of operation or  $1/V$ . Therefore, the change of charter costs per voyage after implementation of the EEXI can be expressed as follows:

$$\Delta \text{Charter costs} (\$/\text{voyage}) = \text{Original charter costs} \times (V_{base}/V_{EPL} - 1)$$

**Table A-3: Scenarios for charter costs (US\$/day)**

Case	Ship type	Size category	Low	Base	High
A & B	Bulk carrier	35-60k dwt	6,500	8,300	10,000
C & D	Bulk carrier	>200k dwt	9,700	15,300	20,900
E	Container ship	5-8k TEU	10,900	14,000	17,200
F	Container ship	8-12k TEU	27,400	33,200	39,000
G	General cargo ship	>10k dwt	7,700	8,600	9,600
H	Container ship	1-2k TEU	6,500	7,800	9,200

*Total ship running costs*

1.12 The total ship running costs per voyage can be calculated by adding up the three cost components. Therefore, the change of total ship running costs after implementation of the EEXI in terms of \$/voyage can be expressed as follows:

$$\Delta \text{Ship running costs (\$/voyage)} \\ = \text{Original fuel cost}_{ME} \times [(V_{EPL}/V_{base})^2 - 1] + \text{Original non}_{ME} \text{ cost} \times (V_{base}/V_{EPL} - 1)$$

where  $Non_{ME} \text{ cost}$  is the total sum of  $Fuel \text{ costs}_{AE}$  and charter costs.

1.13 The change of total ship running costs per cargo unit can then be calculated by dividing the cost change per voyage with the assumed volume of cargo carried by each ship. The lower threshold for each size category is used as the assumed volume of cargo to calculate cost change in terms of \$/ton for each case (e.g. 35,000 dwt for Case A & B), as expressed as follows:

$$\Delta \text{Ship running costs (\$/ton)} \\ = \Delta \text{Ship running costs (\$/voyage)} / \text{cargo volume (ton/voyage)}$$

1.14 Following the cube law, and the aforementioned assumption that daily fuel consumption for auxiliary engine equals 5% of that of main engine, reduction of ship speed can be converted into reduction of CO<sub>2</sub> emissions per transport work, as expressed as follows:

$$\Delta \text{CO}_2 \text{ per transport work (\%)} = 0.95 \times (V_{EPL}/V_{base})^2 + 0.05 \times (V_{base}/V_{EPL})$$

Table A-4 estimates how the ship speed will be converted to the level of efficiency improvement (CO<sub>2</sub> reduction per transport work) in terms of EEXI reduction rate.

**Table A-4:  $V_{EPL}$  corresponding to the EEXI reduction rate**

EEXI Δ%	$V_{EPL}$ Δ%
5%	2.7%
10%	5.6%
15%	8.5%
20%	11.5%
25%	14.7%
30%	18.0%
35%	21.4%
40%	25.1%
45%	28.9%
50%	33.1%

## 2 Interest and insurance costs

2.1 Interest and insurance costs represent the inventory costs and cargo insurance costs that are borne by shippers. The additional interest and insurance costs incurred due to slow steaming were estimated by multiplying the rates for each cost item with the total value of each commodity exported between the two country pairs in 2017 and with the share of number of additional days required for transportation per year, in line with the methodology applied in the literature (Faber et al., 2017), as expressed as follows:

$$\begin{aligned} \text{Additional interest and insurance costs (\$/year)} \\ = E \times (r_1 + r_2) \times \text{additional days}/365.25 \end{aligned}$$

$$\begin{aligned} \text{Additional interest and insurance costs (\$/unit of cargo)} \\ = E' \times (r_1 + r_2) \times \text{additional days}/365.25 \end{aligned}$$

where,

$E$  is total value of the traded commodity per year;

$E'$  is unit value of the traded commodity per year; and

$r_1$ , and  $r_2$  are the annual interest rate and insurance rate, respectively.

The annual interest rate ( $r_1$ ) and insurance rate ( $r_2$ ) are assumed as 10% and 2%, respectively, as provided in Faber et al (2017).

2.2 Export values for each commodity traded between designated countries in each case is shown in Table A-5.

**Table A-5: Export values of commodities in 2017 (million US\$)**

Case	Export country	Import country	Commodity	HS code	Export value
A	Vietnam	Solomon Islands	Rice	1006	16
B	Vietnam	China	Rice	1006	1,027
C	Brazil	China	Iron ore	2601	10,393
D	Mauritania	China	Iron ore	2601	410
E	China	United States	Motor Vehicle parts	8708	10,073
F	Chile	United States	Apricots, cherries, etc.	0809	109
G	Solomon Islands	China	Wood	4403	284
H	China	Fiji	Frozen fish	0303	27

2.3 As these costs are proportional to days of operation per voyage or  $1/V$ , additional ship interest and insurance costs after implementation of the EEXI both in term of \$/year and \$/ton can be expressed as follows:

$$\begin{aligned} \Delta \text{Interest and insurance costs} \\ = \text{Original interest and insurance costs} \times (V_{base}/V_{EPL} - 1) \end{aligned}$$

2.4 Following the cube law as described in paragraph 1.6 of this appendix, reduction of ship speed can be converted into the level of efficiency improvement (CO<sub>2</sub> reduction per transport work).