Impact of slow steaming for different types of ships carrying bulk cargo

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1. Introduction

The Marine Environmental Protection Committee (MPEC) of the International Maritime Organization (IMO) adopted an 'Initial IMO strategy on [the] reduction of GHG emissions from ships' on the 13th of April, 2018 (MEPC 2018). Within the initial strategy, the level of ambition for the reduction of GHG emissions from international shipping aimed for emissions to peak as soon as possible and 'to reduce the total annual GHG emissions by at least 50 % by 2050 compared to 2008' (MEPC 2018). The initial strategy also outlines an intention to phase out emissions from international shipping, which would ensure 'a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals' (MEPC 2018). In order to achieve the ambition set out in the initial strategy, a range of mitigation options are proposed that are categorised into short, medium and long-term measures.

The concept of slow steaming is specifically referred to in Section 4.7 (4) of the initial strategy as:

'the use of speed optimization and speed reduction as a measure, taking into account safety issues, distance travelled, distortion of the market or trade and that such measure does not impact on shipping's capability to serve remote geographic areas'.

The adoption of slow steaming results in a reduction in fuel consumption. Given that fuel oil is the single most important item in voyage costs (Stopford 2009), any reduction in operating costs via a reduction in fuel consumption enhances the competitiveness of a carrier as well as lowering its output of CO_2 emissions. Interestingly the magnitude of the change of speed is relatively minor compared to the economic and environmental benefits (Stopford 2009). However, it also needs to be taken into account that the extended duration of a ship's voyage due to slow steaming will also lead to additional operating expenditures for the carrier to cover the additional employment, insurance and other costs associated with the operation of more ships at any given time in order to maintain levels of delivery.

The focus of this study is on the impact of slow steaming on dry bulk carriers. These vessels transport iron ore, coal, grain and similar cargo, which according to UNCTAD (2018) account for the largest share of total cargo-carrying capacity (in terms of dead-weight tonnage) at 42.5 %.[1] The impact of slow steaming on bulk freight costs has been assessed for several types of bulk carrier based on different assumptions with regards to the price of fuel; daily earnings and the relationship between the use of main power and electric power on the vessel (refer to Section 3.1). The outcome of the study can be applied to any shipping route for bulk carriers (i.e. iron ore exports from Australia or Brazil to China) as the result will show the relative change in bulk freight costs for different speed reductions (refer to Section 3.2). The implications of the study for bulk carriers will be further discussed in the concluding remarks in Section 4.

[1] Oil tankers carrying crude oil and its products account for 29.2% of total cargo-carrying capacity and container ships carrying goods at a higher unit value account for 13.1% of total cargo-carrying capacity (UNCTAD 2018).

2. Literature Review

According to Stopford (2009), the following three categories account for the majority of shipping costs:

(1) Capital costs (i.e. the capital cost of purchasing or leasing vessels together with interest payments and depreciation);

(2) Operational costs (i.e. those incurred when a ship is put into service)

   a. Crew (i.e. labour costs, training etc.)

   b. Insurance (i.e. marine insurance to cover both the vessel and cargo)

   c. Other (i.e. routine repairs and maintenance, ship registration

(3) Voyage costs (i.e. fuel, port charges and other voyage specific costs).

In order to illustrate how the total cost of shipping is distributed across the different categories, Stopford (2009) cites that capital costs and voyage costs accounted for 42 % and 40 % of the total shipping costs respectively for a 10 year old capesize bulk carrier[2] (based on 2005 prices) with operational costs accounting for a further 14 % of the total shipping cost. The remaining costs were due to period maintenance and cargo-handling costs.[3]

The capital costs associated with shipping depend mainly on the purchase price of the ship that is strongly influenced by the freight rate[4], which has historically been very volatile due to changes in demand and supply. Polo (2012) describes the prices paid for both new build and secondhand ships in October 2007, just before the onset of the economic recession, as being ‘astronomical’ but financially justifiable on the basis of the extraordinarily high freight rates that enabled a very quick return on the capital. However, the collapse in freight rates after the economic recession due to a lack of global demand was followed by a considerable reduction in the capital cost of ships. For example, the capital cost of an 81K DWT Panamax Bulkcarrier (new build) peaked in 2008 at approximately $65 million (after adjusting for inflation) but by the end of 2017 the capital cost of the ship declined to around $25 million (Kemene 2018). These fluctuations in freight rates have considerable financial implications for charter rates[5] or interest rates and levels of depreciation.

The operating costs associated with bulk carriers varies depending upon the size as illustrated in Table 1, which provides an overview of the daily operating costs in 2017 based upon OpCost data. The operating costs take into account crew costs (i.e. wages, provisions etc.), stores (i.e. lubricating oils), repair and maintenance, insurance (i.e. P&I insurance, marine insurance) and administration (i.e. registration costs, management fees and sundry expenses) and shows that the highest operating costs in 2017 are associated with tanker vessels. According to Stopford (2009), insurance costs account for 32 % of the total operating costs of a ten year old capesize bulk carrier followed by crew costs (31 %), maintenance and repairs (15%), stores and consumables (11 %) and general costs (11 %).

2 Bulk carriers are specifically designed to transport raw materials such as iron ore and coal.
3 Stopford (2009) states that the cost shares are only indicative as they rely upon many factors that change over time.
4 The freight rate is the price at which a certain cargo is delivered from one point to another.
5 The shipping rate agreed between the owner of a vessel and the person or firm wanting to use the vessel in a charter party agreement.

Table 1 Operating daily costs by different types of bulk carrier in 2017

Ship Type	Size	Daily Rate
	TEU	US$
Bulk carrier	Handysize	4,995
Bulk carrier	Handymax	5,480
Bulk carrier	Panamax	5,663
Bulk carrier	Capesize	6,691

Source: Greiner (2017).

Fuel oil is the single most important item in voyage costs (Stopford 2009). Given the fluctuation in the price of bunker fuels over time, this cost item has had a significant impact on total shipping costs and therefore at times of high bunker prices has led to enhanced efforts to improve the efficiency of fuel consumption and the adoption of slow steaming.

In operation, the ship's fuel consumption depends on its hull condition and the speed of travel. Vessels are designed in such a way that the hull and power plant are optimized for a certain design speed. Operating a vessel at lower speeds therefore results in fuel savings because of the reduced water resistance, which is proportional to the cube of the proportional reduction in speed (Stopford 2009). The following formula to express this relationship was advanced by Stopford (2009):

$$F = F^{*} (S/S^{*})^{a}$$

where: F is the actual fuel consumption (tons/day), S is the actual speed, F* the design fuel consumption, and S* the design speed. The exponent (a) is equivalent to a value of 3 for diesel engines following the cube rule that the level of fuel consumption is strongly influenced by speed.

This relationship is exemplified by Stopford (2009) for a panamax bulk carrier in Table 2 to show how lower speeds can significantly reduce fuel consumption. However, fuel consumption, in reality, is likely to also vary depending upon additional factors such as the ship's draft and displacement, weather force and direction, hull and propeller roughness (Bialystocki and Konovessis 2016).

Table 2 Impact of speed on fuel consumption for a panamax bulk carrier

Speed	Main engine fuel consumption	Fuels savings
[kn]	[tons/ day]	[%]
16	44	0%
15	36	17%
14	30	35%
13	24	45%
12	19	58%
11	14	67%

Source: Stopford (2009), own calculations.

The IMO (2014) details the deviation between average at sea operating speed relative to the design speed, the average at sea main engine load factor relative to the installed power produced by the main engine and the average at sea main engine daily fuel consumption for bulk carriers of different sizes. Table 3 shows that many of the larger sized bulk carriers experienced reductions in daily fuel consumption between 2007 and 2012 above the average for all sizes of bulk carrier.

Table 3 Indicators of slow steaming for bulk carriers between 2007 and 2012

Ship type	Size category	Units	Year	Average at sea speed to design speed	Average at sea main engine load factor	At sea consumption
				Ratio	[% MCR]	[tons/ day]
Bulk carrier	10,000 – 34,999	dwt	2007	0.86	68%	22.2
	35,000 – 59,999			0.88	73%	29.0
	100,000 – 199,999			0.89	77%	55.5
Bulk carrier	10,000 – 34,999	dwt	2012	0.82	59%	17.6
	35,000 – 59,999			0.82	58%	23.4
	100,000 – 199,999			0.81	57%	42.3

Note: Deadweight tonnage (dwt); maximum continuous rating (MCR).
Source: IMO (2014).

Despite the potential to lower the fuel consumption through the adoption of slow steaming, the expected increase in efficiency is offset, at least to a certain extent, by the greater number of ships (or more days at sea) that are required to do the same amount of transport work (IMO 2014). Indeed, Mallidis et al. (2018) demonstrate through a modelling exercise that slow steaming is only economically viable up until a 'breakpoint distance travelled' that 'effectively balances the marginal operational cost increases under slow steaming, as voyage days increase, to the marginal fuel cost reductions as voyage speeds and thus voyage fuel increases'.

Based upon the outcomes of previous research into the impact of slow steaming, the financial benefits are likely to offset the additional operational costs, at least in theory, especially if the carrier maximises all the advantages of slow steaming i.e. such as enabling the carrier to absorb excess fleet capacity during periods of low demand. Several studies have moved beyond theoretical considerations to see whether slow steaming impacts the import prices of certain products, if additional operating costs occur, and are passed through to consumers.

Krammer (2016) estimated the value of time for seaborne shipping for multiple types of manufactured goods, which ranged from € 0.04 per tonne per hour for manufactured food to € 1.08/ tonne per hour for machinery and vehicles. Based upon the formula by Krammer (2016) that time costs are equal to the value of time multiplied with the transit time, a key finding from the study is that a longer travel time will result in relatively higher costs for machinery and vehicles than for manufactured food products. However, it is important to firstly acknowledge that the share of the shipping cost in the total value of the import is likely to be considerably lower for products with a higher value to weight ratio and secondly the longer travel time may not necessarily result in switching from distant exporters to nearby exporters as it crucially depends upon whether exporter substitutes are available to the importing country.

According to CE Delft (2017), 'the impacts of slow steaming on [the] economies of exporting countries that are far removed from their main markets are modest'. In their study, CE Delft (2017) focus on trade from Argentina to the Netherlands for two products (i.e. oil cake and chilled beef products) and estimate for each the extra transit days associated with a speed reduction of 10 %, 20 % and 30 % and to then calculate the additional interest expense (derived by multiplying the value of exports in year t by an assumed annual interest rate of 10% and by the ratio of the extra days travelled relative to the number of days in a year) and the additional insurance expense (derived by the multiplying the extra travel days by an assumed fixed daily insurance cost of 2 % of the total value). For both products, the study illustrates that the additional expenses calculated as a result of a speed reduction were minimal ranging from 0.08 % to 0.31 % of the total value for oil-cake exports and from 0.06 % to 0.23 % of the total value of beef exports.

It is important to acknowledge that maritime transport costs only account for a minor share of the total transport costs for a product as around 80 % of the transport costs for a product are attributable to transportation on land from the port to the point of delivery (Rodrigue and Notteboom 2012). Furthermore, average transport costs represent around 21 % of the value of imports for least developed countries (UNCTAD 2017). This means that on average maritime freight costs are only responsible for approximately 4 % of the final product cost. A small change of bulk freight costs will therefore have a negligible impact in almost all cases. For other countries the potential impact of slow steaming on product prices will be even smaller as average world transport costs only represent 15 % of the value of imports (UNCTAD 2017). Furthermore, the risk of slow steaming leading to a shift to other modes of transport has also been recently dismissed by Halim et al. (2018) on the basis that demand for shipping is inelastic.

3. Estimating the impact of slow steaming

3.1. Methodology

For this study the impact of slow steaming on bulk freight costs has been assessed. We assumed that the vessel will not carry any cargo during the return trip, i.e. the costs of slow steaming in both directions will need to be covered by the freight rate to the destination. If a vessel can transport cargo for (parts of) the return trip this would reduce any potential negative effects of slow steaming on freight costs.

Different elements of total transport costs will be affected by slower steaming:

- Elements increasing costs:
    - **Operation and travel costs (without fuel)**: Due to the longer time at sea for the same trip a larger share of the annual cost for the crew, insurance, maintenance etc. will need to be financed by this trip. For the calculations it has been assumed that operational costs are a fixed value per day.
    - **Fuel consumption (auxiliary engines)**: Auxiliary power is needed for electricity generation for on-board systems and thus depends on the time at sea, not the speed of a vessel. Depending on ship type and size the auxiliary power is 5-15 % of the main power (German de Melo and Ignacio Echevarrieta)
    - **Capital cost**: The total investment costs (incl. interest) for a new ship needs to be recovered over the lifetime of the vessel. Based on Stopford (2009) it has been assumed that a typical life-time of a ship is 25 years and that the value depreciation is roughly linear over this time. The annual capital costs are then 4 % of the original investment for a new ship. This value can also be expressed in daily capital costs; additional days at sea will lead to higher total capital costs for a trip.
    - **Earnings**: Ship owners want to make a profit beyond recovering expenses. UNCTAD (2018) includes daily earnings for bulk carriers over the last decade. If ship owners want to keep their earnings they will include it in the costs associated with the additional time at sea.

- Elements decreasing costs:
  - **Fuel consumption (main engines)**: The main objective of slower steaming – to reduce energy consumption and thereby CO_2 emissions – will bring the freight costs down. Unlike the other elements discussed here this parameter does not depend on the extra days at sea for each trip. The relationship between speed reduction and fuel consumption is based on Stopford (2009).

The cost-increasing elements depend only on the time at sea and scale reciprocally with the speed reduction. The fuel consumption of the main engines on the other hand decreases by a cubic function. Speed reductions closer to the standard speed will have the highest relative fuel saving compared to additional reductions when already steaming well below the standard speed. Due to these two contravening effects there is a break-even point where additional speed reductions will not be viable from an economic point of view.

To investigate this, we have assessed the impact of slow steaming at speed reductions from 0% to 50% below the standard speed for the different bulk carriers based upon a range of assumptions that further influence bulk freight costs (refer to Table 4). In addition we have used different assumptions for the fuel price based on historic prices; the current Brent Oil price is around \$500/ton, the high fuel price scenarios uses \$750/ton and the low fuel price scenario \$250/ton.

Distance is the main factor determining absolute transport costs. Despite this, it has no impact in the model used here to estimate the relative cost change compared to standard speeds: a speed reduction by 10 % corresponds to a trip duration which is 10 % longer independently of the actual distance sailed. An overview of the underlying data used for the estimation of bulk freight costs is further provided in Table 5 of the Annex for only a selection of illustrative routes under different fuel prices and assuming average earnings and auxiliary fuel consumption as outlined in in Table 4.

Table 4 Overview of the parameters used in the scenarios

Ship type	Fuel consumption	Auxiliary fuel consumption	Speed	Operation costs	Capital costs	Earnings
	[t/day]	[%]	[kn]	[$/day]	[$/day]	[$/day]
Panamax	37.7	10 (5 – 15)	13.8	5 700	2 700	10 000 (5 000 – 15 000)
Handysize	22.2	10 (5 – 15)	12.7	5 000	2 200	7 500 (4 000 – 12 000)
Capesize	55.5	10 (5 – 15)	13.6	6 700	5 500	12 500 (5 000 – 20 000)

Source: IMO (2014); Greiner (2017); Kemene (2018); UNCTAD (2018)

3.2. Results

The impact of slow steaming on the relative change in bulk freight costs are estimated for three types of bulk carrier (i.e. handysize, panamax and capesize) under a range of speed reductions assuming different fuel costs, different daily earnings and a different relationship between the use of main power and electric power on the vessel.

Importantly, it is also assumed in all of the following scenarios that the vessel will not carry any cargo during the return trip. This may therefore underestimate the economic benefit of slow steaming if a vessel also transports cargo on the return trip.

3.2.1. Handysize bulk carrier

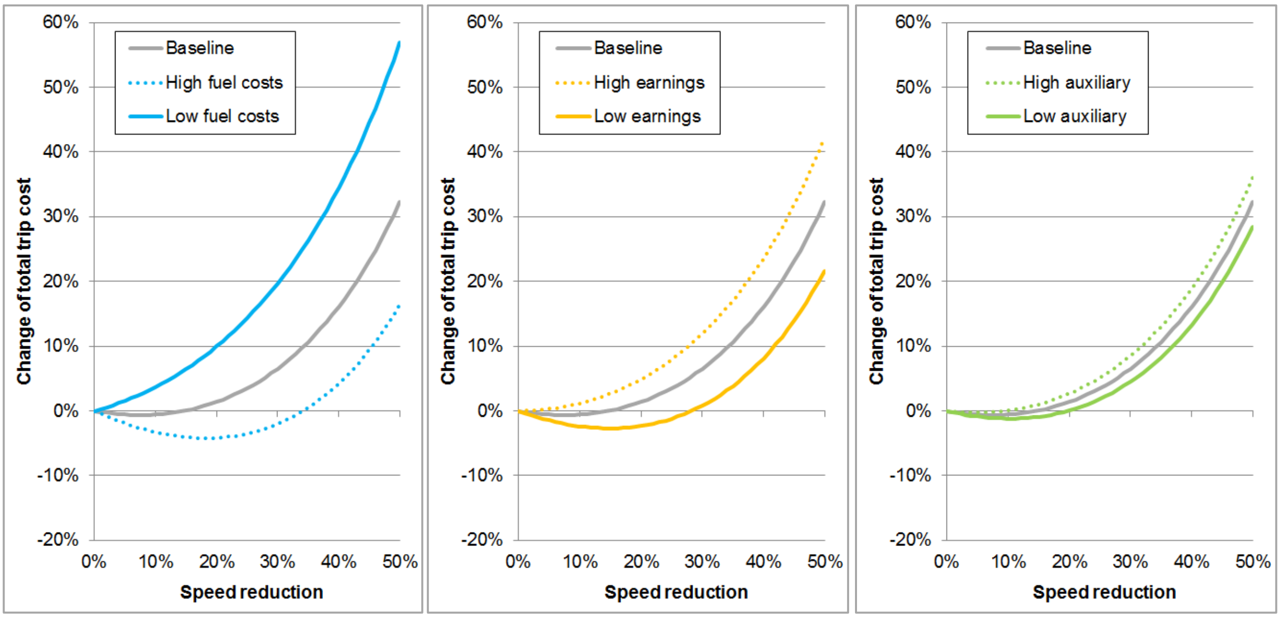
Under the baseline scenario for a handysize bulk carrier fuel costs are estimated at $500/ton, earnings are estimated at an average of $7 500/day and it is assumed that the auxiliary fuel consumption is equivalent to 10 % of the main engine; Figure 1 shows that the break-even point beyond which additional speed reductions are not economically viable is 14 % (i.e. refer to the grey line).

Figure 1 (left) shows that if the fuel cost is assumed to be at the higher cost of $750/ton then the economic viability of slow steaming increases considerably with the break-even point extending to speed reductions of up to 34 % (refer to the dotted blue line). Alternatively if the fuel cost is assumed to be at a lower cost of $250/ton then slow steaming is not economically viable at any speed reduction (i.e. refer to the blue line).

Figure 1 (middle) shows that the impact of varying the daily earnings may also result in a considerable difference in the economic viability of slow steaming. If the baseline scenario is adjusted to take into account a lower daily earning of $4 000 then the break-even point for slow steaming would be a speed reduction of 28 % (i.e. refer to the orange line). In contrast, if a higher daily earning of $12 000 is assumed, slow steaming would not be economically viable at any speed reduction (i.e. refer to the dotted orange line).

Figure 1 (right) shows that the relationship between the use of main power and auxiliary electric power is of relatively less significance deviating slightly from the baseline scenario (refer to the green (low auxiliary) and dotted green (high auxiliary) lines).

Figure 1 Impact of slow steaming on handysize bulk carriers



Source: Own calculations based on IMO (2014); Greiner (2017); Stopford (2009); Kemene (2018); German de Melo and Ignacio Echevarrieta

3.2.2. Panamax bulk carrier

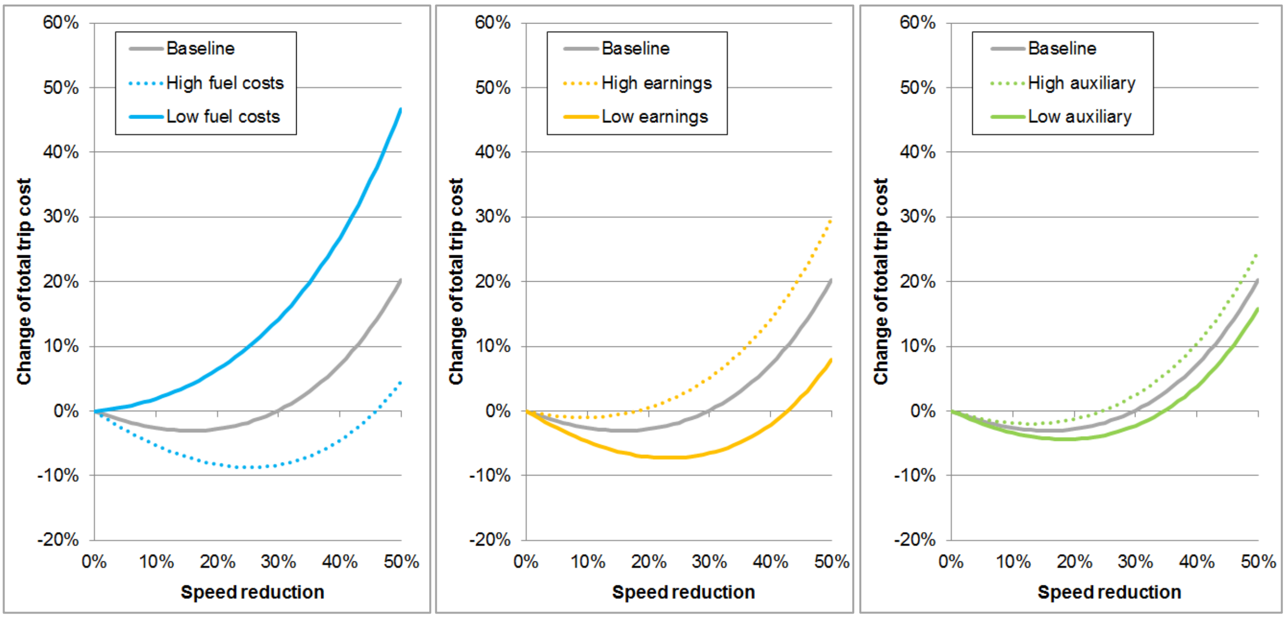
Under the baseline scenario for a panamax bulk carrier fuel costs are estimated at $500/ton, earnings are estimated at an average of $10 000/day and it is assumed that the auxiliary fuel consumption is equivalent to 10 % of the main engine; Figure 2 shows that the break-even point beyond which additional speed reductions are not economically viable is 29 % (i.e. refer to the grey line).

Figure 2 (left) shows that if the fuel cost is assumed to be at the higher cost of $750/ton then the economic viability of slow steaming increases considerably with the break-even point extending to speed reductions of up to 45 % (refer to the dotted blue line). Alternatively if the fuel cost is assumed to be at a lower cost of $250/ton then slow steaming is not economically viable at any speed reduction (i.e. refer to the blue line).

Figure 2 (middle) shows that the impact of varying the daily earnings may also result in a considerable difference in the economic viability of slow steaming. If the baseline scenario is adjusted to take into account a lower daily earning of $5 000 then the break-even point for slow steaming would be a speed reduction of 42 % (i.e. refer to the orange line). In contrast, if a higher daily earning of $15 000 is assumed, slow steaming would only be economically viable for a speed reduction of up to 17% (i.e. refer to the dotted orange line).

Figure 2 (right) shows that the relationship between the use of main power and auxiliary electric power is of relatively less significance deviating slightly from the baseline scenario (refer to the green (low auxiliary) and dotted green (high auxiliary) lines).

Figure 2 Impact of slow steaming on panamax bulk carriers



Source: Own calculations based on IMO (2014); Greiner (2017); Stopford (2009); Kemene (2018); German de Melo and Ignacio Echevarrieta

3.2.3. Capesize bulk carrier

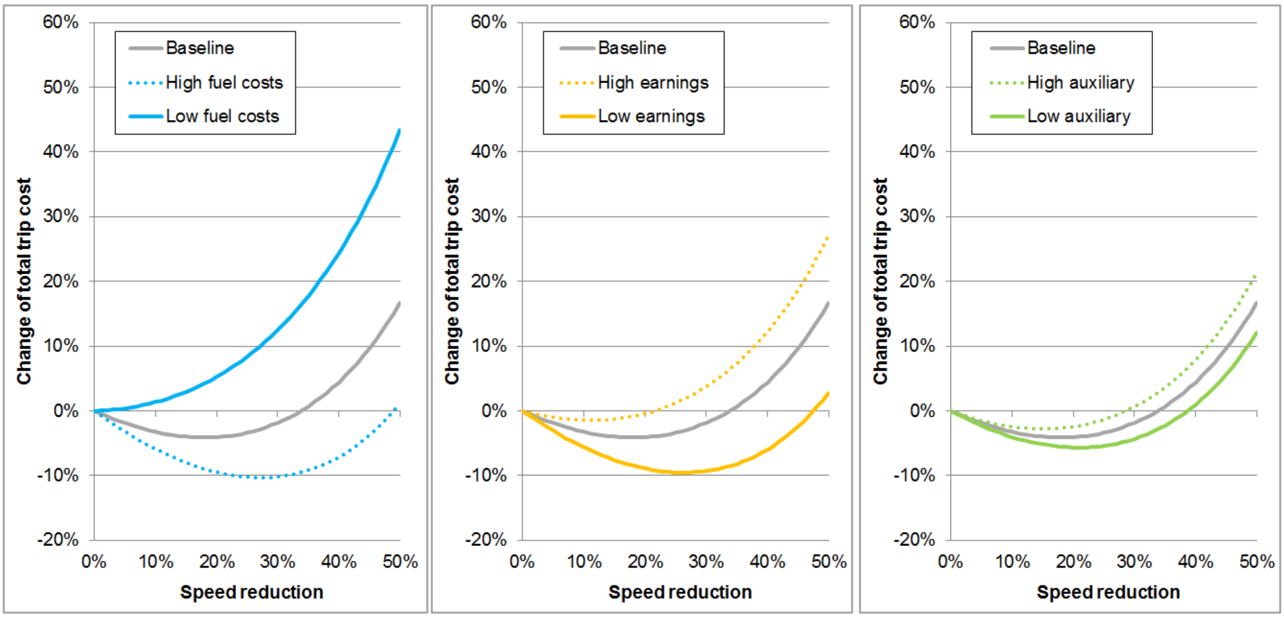
Under the baseline scenario for a capesize bulk carrier fuel costs are estimated at $500/ton, earnings are estimated at an average of $12 500/day and it is assumed that the auxiliary fuel consumption is equivalent to 10 % of the main engine; Figure 3 shows that the break-even point beyond which additional speed reductions are not economically viable is 33 % (i.e. refer to the grey line).

Figure 3 (left) shows that if the fuel cost is assumed to be at the higher cost of $750/ton then the economic viability of slow steaming increases considerably with the break-even point extending to speed reductions of up to 48 % (refer to the dotted blue line). Alternatively if the fuel cost is assumed to be at a lower cost of $250/ton then slow steaming is not economically viable at any speed reduction (i.e. refer to the blue line).

Figure 3 (middle) shows that the impact of varying the daily earnings may also result in a considerable difference in the economic viability of slow steaming. If the baseline scenario is adjusted to take into account a lower daily earning of $5 000 then the break-even point for slow steaming would be a speed reduction of 47 % (i.e. refer to the orange line). In contrast, if a higher daily earning of $20 000 is assumed, slow steaming would only be economically viable for a speed reduction of up to 21 % (i.e. refer to the dotted orange line).

Figure 3 (right) shows that the relationship between the use of main power and auxiliary electric power is of relatively less significance deviating slightly from the baseline scenario (refer to the green (low auxiliary) and dotted green (high auxiliary) lines).

Figure 3 Impact of slow steaming on capesize bulk carriers



Source: Own calculations based on IMO (2014); Greiner (2017); Stopford (2009); Kemene (2018); German de Melo and Ignacio Echevarrieta

4. Concluding remarks

In each of the scenarios, the adoption of progressively higher speed reductions extends the number of days at sea and this results in additional bulk freight costs (i.e. the longer voyages due to the introduction of speed reductions leads to an increase in operational, capital and revenue costs). However, based upon our analysis these additional bulk freight costs are offset by the lower fuel costs in the majority of the scenarios, unless the fuel price is very low or a ‘break-even point’ speed reduction is exceeded where the marginal fuel cost reductions no longer offset the marginal operational cost increases under slow steaming. The reason for this is that the extra time has a reciprocal relationship with the speed reduction whereas the marginal benefits of reducing speed on fuel consumption are highest at full speed and decrease the slower a ship is already going. Even in circumstances where slow steaming may result in an increase in bulk freight costs (i.e. under the assumption of low fuel costs or high daily earnings), it likely to only have a negligible impact on product prices in most cases as maritime transport only accounts for a minor share of the total transport costs of a product.

The results of the study also demonstrates that the impact of slow steaming on the total costs of smaller vessels, such as handysize bulk carriers, is considerably less than for larger vessels such as either panamax or capesize bulk carriers. This is due to the fact that the relative importance of time based costs (i.e. crew, insurance, capital costs etc) compared to fuel costs are higher for smaller ships than for larger vessels. The same relative fuel savings therefore have a lower impact on the total costs of the trip.

Finally, it is important to add that changes to the bulk freight costs of an individual vessel will not necessarily lead to a corresponding adjustment to freight rates. The extent to which changes to freight costs will be passed through to freight rates will ultimately depend on the market situation and this topic may warrant further research in the future.

5. Publication bibliography

Bialystocki, Nicolas; Konovessis, Dimitris (2016): On the estimation of ship's fuel consumption and speed curve. A statistical approach. In *Journal of Ocean Engineering and Science* 1 (2), pp. 157–166. DOI: 10.1016/j.joes.2016.02.001.

CE Delft (2017): Regulating speed: a short-term measure to reduce maritime GHG emissions. CE Delft, checked on 3/19/2019.

German de Melo; Ignacio Echevarrieta: Resizing study of main and auxiliary engines of the container vessels and their contribution to the reduction of fuel consumption and GHG. Faculty of Nautical Studies of Polytechnic University of Catalonia, checked on 4/17/2019.

Greiner, Richard (2017): Ship operating costs: Current and future trends. Moore Stephens LLP, checked on 3/20/2019.

Halim, Ronald; Kirstein, Lucie; Merk, Olaf; Martinez, Luis (2018): Decarbonization Pathways for International Maritime Transport. A Model-Based Policy Impact Assessment. In *Sustainability* 10 (7), p. 2243. DOI: 10.3390/su10072243.

IMO (2014): Third IMO Greenhouse Gas Study 2014. Executive Summary. IMO, checked on 3/21/2019.

Kemene, Angelica (2018): Newbuildings & Yards. Optima Shipping Services. Available online at https://www.marinemoney.com/system/files/media/2018-06/06202018_915_Kemene.pdf, checked on 3/22/2019.

Krammer (2016): The value of time in international trade. Harvard University.

Mallidis, I.; Iakovoub, E.; Dekkerc, R.; Vlachosa, D. (2018): The impact of slow steaming on the carriers' and shippers' costs: The case of a global logistics network. In *Transportation Research Part E* 111, pp. 18–39. Available online at https://doi.org/10.1016/j.tre.2017.12.008, checked on 19/03/19.

MEPC (2018): Resolution MEPC.304(72). Initial IMO strategy on reduction of GHG emissions from ships. IMO, checked on 3/19/2019.

Polo, Gerardo (2012): On maritime transport costs, evolution, and forecast. In *Ship Science & Technology* 5 (10), pp. 19–31, checked on 3/21/2019.

Rodrigue, Jean-Paul; Notteboom, Theo (2012): Dry ports in European and North American intermodal rail systems: Two of a kind? In *Research in Transportation Business & Management* 5, pp. 4–15, checked on 3/19/2019.

Stopford, Martin (2009): Maritime Economics, Third edition, checked on 3/20/2019.

UNCTAD (2017): Review of Maritime Transport 2017. UNCTAD, checked on 3/22/2019.

UNCTAD (2018): Review of Maritime Transport 2018. UNCTAD, checked on 3/20/2019.

6. Annex

Table 5 Estimation of bulk freight costs for a selection of illustrative routes based upon various assumptions

	Round trip	Speed reduction	Typical speed	Days at sea	Reduced fuel consumption (main engine)	Total daily fuel con-sumption	Main engine	Auxiliary engine	Fuel consumption costs		Operation costs (other than fuel consumption)		Capital cost		Earnings		Total cost	
	[nm]	[%]	[kn]	[d]	[%]	[t/d]	[t/d]	[t/d]	[t/trip]	[$/trip]	[$/d]	[$/trip]	[$/d]	[$/trip]	[$/d]	[$/trip]	[$/trip]	[change]
Bulk, Panamax (500 USD/t fuel)	20,000	0	13.8	60.5	--	37.7	33.9	3.8	2,282	1,140,765	5,700	344,953	2,700	163,399	10,000	605,180	2,254,297	--
		10	12.4	67.2	27	28.5	24.7		1,917	958,369		383,281		181,554		672,423	2,195,627	-2.6%
		20	11.0	75.6	49	21.1	17.4		1,599	799,676		431,191		204,248		756,475	2,191,591	-2.8%
		30	9.6	86.5	66	15.4	11.6		1,332	666,044		492,790		233,427		864,543	2,256,804	0.1%
Bulk, Panamax (250 USD/t fuel)	20,000	0	13.8	60.5	--	37.7	33.9	3.8	2,282	570,382	5,700	344,953	2,700	163,399	10,000	605,180	1,683,914	--
		10	12.4	67.2	27	28.5	24.7		1,917	479,185		383,281		181,554		672,423	1,716,442	1.9%
		20	11.0	75.6	49	21.1	17.4		1,599	399,838		431,191		204,248		756,475	1,791,753	6.4%
		30	9.6	86.5	66	15.4	11.6		1,332	333,022		492,790		233,427		864,543	1,923,782	14.2%
Bulk, Panamax (800 USD/t fuel)	20,000	0	13.8	60.5	--	37.7	33.9	3.8	2,282	1,825,224	5,700	344,953	2,700	163,399	10,000	605,180	2,938,756	--
		10	12.4	67.2	27	28.5	24.7		1,917	1,533,391		383,281		181,554		672,423	2,770,648	-5.7%
		20	11.0	75.6	49	21.1	17.4		1,599	1,279,482		431,191		204,248		756,475	2,671,397	-9.1%
		30	9.6	86.5	66	15.4	11.6		1,332	1,065,670		492,790		233,427		864,543	2,656,430	-9.6%
Bulk, Capesize (500 USD/t fuel)	30,000	0	13.6	91.8	--	55.5	50.0	5.6	5,095	2,547,367	6,700	615,040	5,500	504,884	12,500	1,147,463	4,814,754	--
		10	12.3	102.0	27	42.0	36.4		4,280	2,140,072		683,378		560,982		1,274,959	4,659,390	-3.2%
		20	10.9	114.7	49	31.1	25.6		3,571	1,785,704		768,800		631,105		1,434,328	4,619,937	-4.0%
		30	9.5	131.1	66	22.7	17.1		2,975	1,487,299		878,629		721,262		1,639,232	4,726,422	-1.8%
Bulk, Handysize (500 USD/t fuel)	6,000	0	12.7	19.6	--	22.2	20.0	2.2	436	218,023	5,000	98,209	2,200	43,212	7,500	147,313	506,757	--
		10	11.5	21.8	27	16.8	14.6		366	183,164		109,121		48,013		163,681	503,979	-0.5%
		20	10.2	24.6	49	12.4	10.2		306	152,834		122,761		54,015		184,141	513,751	1.4%
		30	8.9	28.1	66	9.1	6.9		255	127,294		140,298		61,731		210,447	539,771	6.5%

Source: Own calculation