Michelle Harris

From: Cariou Pierre [Pierre.Cariou@euromed-management.com]
Sent: Friday, April 01, 2011 8:48 AM
To: Secretary
Cc: Notteboom Theo
Subject: NOI - Impact slow steaming on ocean liner
Attachments: image001.png; Bio-Notteboom&Cariou.pdf; Cariou-Notteboom-ALRT2011.pdf; Cariou-TRD-2011.pdf; NotteboomCariou-IHME2011.pdf

Dear Karen V. Gregory

Following the publication of the Notice of Inquiry ("NOI") to solicit public comment on the impact of slow steaming on U.S. ocean liner, We would like) to make the following contributions based on former works on topics related to your subject matter:

- Notteboom, T. and P. Cariou (2011), Chapter 11. Bunker Adjustment Factor in Liner Shipping. In K. Cullinane (eds), *International Handbook of Maritime Economics (pp. 223-255)*, Edward Elgar, Cheltenham, UK, Northampton, MA, USA. (**NotteboomCariou-IHME2011.pdf**)

- Cariou P., (2011). Bunker costs in Container Liner Shipping: Are slow Steaming Practices Reflected in Maritime fuel Surcharges? In T. Notteboom (Ed.) *Current Issues in Shipping Ports and Logisitics (pp.69-82).* Antwerp: University Press Antwerp. (**Cariou-Notteboom-ALRT21011.pdf**)

- Cariou P., (2011). Is slow steaming a sustainable means of reducing CO2 emissions from container shipping, *Transportation Research Part D (16)*, 260-264. (**Cariou-TRD-2011.pdf**)

We hope that these contributions will be of interest to FMC. Please feel free to contact us if needed. For this purpose, I also attach a short bio with our contact information (**bio-Notteboom&Cariou.pdf**)

Your sincerely,

Pierre Cariou and Theo Notteboom

Pierre Cariou

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CHAPTER 4

Bunker costs in container liner shipping: Are slow steaming practices reflected in maritime fuel surcharges?

Pierre CARIOU and Theo NOTTEBOOM

Abstract

Slow steaming has been implemented by the main liner shipping companies since 2008. The reduction in vessel speed affects fuel consumption and should be reflected within the fuel surcharges paid by shippers. This article assesses if this was the case for the main outbound European container trades from the port of Antwerp. Through an extensive analysis of liner service characteristics, fuel costs and fuel surcharges this paper provides an answer to three research questions (a) How significant are slow steaming practices in container liner shipping?; (b) What is the impact of slow steaming on fuel consumption and liner service characteristics?; and (c) To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines?

1 | Introduction

Slow steaming, or the reduction in the sailing speed of maritime vessels, has become an increasingly common practice in container liner shipping as the amount and unit size of available vessel capacity rises and the price of fuel increases (Alphaliner 2010a). Slow steaming can help to absorb vessel overcapacity as a slower commercial speed will require more vessels to maintain the same service frequency per liner service. Slow steaming has also proven to be an effective way to save on fuel costs and to restore liner shipping company profitability. Slow steaming is also claimed to reduce environmental emissions by ships at sea (Kollamthodi et al., 2008; Buhaug et al., 2009; Corbett et al., 2009; Cariou, 2011; Faber et al., 2010). However, slow steaming practices added a new source of contention between shippers and ship-owners regarding fuel surcharges, known as Bunker Adjustment Factor or BAF implemented by shipping lines since 1974 (Menachof and Dicer, 2001:143). Shippers' organizations such as the European Shippers' Council have objected for years that the way BAFs are determined is opaque, without uniformity, and involves a significant element of revenue-making (ESC, 2003: 20, ESC, 2006:20). The anticompetitive effect of BAF was already subject to studies shedding light on a tendency of BAF of amplifying bunker prices rises (Cariou and Wolff, 2006; Meyrick and Associates, 2008) impacting negatively consumers prices (Karamychev and van Reeven, 2009), and on the fact that a combination of decreasing freight rates and fuel costs provide incentive to shipping lines to stall the downward correction of the BAFs (Cariou and Notteboom, 2011). Slow steaming added an additional dimension to the question whether fuel surcharges are a revenue-making instrument to shipping lines or only about cost recovery of incurred fuel costs.

This article adds to former studies in incorporating the impact from slow steaming. It investigates if slow steaming practices on major trade lanes are reflected within the BAFs charged to shippers by shipping lines. The paper addresses the follow research questions:

- How significant are slow steaming practices in container liner shipping?
- What is the impact of slow steaming on fuel consumption and liner service characteristics?
- To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines?

To answer these research questions, this paper presents first how fuel surcharges are set up by shipping lines. Section 3 presents a methodology for estimating the impact of slow steaming on the average fuel consumption of containerships, and consequently, on BAF. Section 4 applies the methodology to 618 vessels deployed in 104 services sailing from/to Europe in January 2010, and provides a comparison with 2008, the pre slow steaming era. Section 5 presents the results of a BAF vs. fuel costs analysis for 90 O/D relations using Antwerp as port of departure. Section 6 provides the conclusions and explores avenues for further research.

2 | Fuel surcharge practices since 2008

The application of fuel surcharges in liner shipping dates back to the liner conference era (Notteboom and Cariou, 2011). In principle, carriers cover basic bunker costs, while fuel surcharges only apply to changes above a certain level. Fuel surcharge practices have considerably evolved since the withdrawal in October 2008 of the European liner conferences block exemption (Regulation 4056/86). Their dismantling meant that container shipping lines calling at European ports were banned from collectively setting freight rates and other additional surcharges such as bunker and currency surcharges, and from publishing common tariffs. In doing so, this reduced the commonality amongst pricing structures and surcharges that existed before, with freight rates and surcharges being negotiated directly between shippers and ship-owners and with container lines using sometimes diverging calculation methods for determining fuel surcharges.

Despite these changes, guidelines still exist and are geared mostly for small shippers. For instance, *Maersk Line* published in early 2008 a formula for determining its BAFs, with the aim of creating more transparency (Maersk Line BAF calculator, 2010). The formula known as 'Maersk Line BAF Calculator' builds on two components: Bunker price changes in t x Trade specific constant so that:

$$BAF_t=(Bunker\ Price_t\text{-}Base)x(Consumption_{TEU/day})x(Transit\ Time_{day})x(Imbalance\ Factor_t)$$

Bunker price change is extracted from the difference in t between a representative basket of prevailing bunker prices in a specific trade (BP_t) and a predefined Bunker base element for a trade (Base) or "normal" bunker cost already included in the freight rate. The trade specific component is function of the consumption in metric tons/TEU/day of a representative vessel, a transit time in days and an imbalance factor. To provide an example from Maersk Line BAF calculator, for a 20 foot dry container exported from Belgium to China (outbound) in November 2010, the reported BP_t was 435 USD/ton, the Bunker base element equaled 65 USD/ton, the vessel consumption is 0.0256 mt/TEU/day, the transit time 35.6 days and the trade imbalance equal to 0.5. It led to a BAF of 2x[435-65]x[0.0256x36.5x0.5]= 345 USD to be paid for each FEU, a value close to the one retrieved from CMA-CGM on-line BAF calculator (370 USD/FEU).

Delmas/OTAL (part of CMA-CGM group) indeed also developed since September 2008 its own BAF formula, following the dismantling of the Europe West Africa Trade Agreement (EWATA). Similarly, an average reference fuel oil price, fuel oil consumption per full TEU carried and an average fuel oil price in t-1 are used for calculation of the BAF applicable in month t+1. Another example relates to *OOCL*. Its fuel surcharge policy is based on specifics on trade lane, service loop, vessel size and round voyage capacity on a monthly basis. OOCL uses a neutral third party provider of bunker price information (Platts) for the major locations around the world and selected a number of representative vessels for calculating fuel consumption, a more manageable way than taking into account the actual consumption of all their operating vessels. In general terms, the formula is similar to *Maersk Line* or *Delmas/OTAL*. As for many other shipping lines, OOCL made a policy decision not to disclose the values for each component in the formula. If the bunker price in a month moves beyond the agreed band of USD 25 (either up or down), then it will trigger a recalculation of the total BAF payable in the following month (see Notteboom and Cariou, 2011). The new calculation method led to a BAF that is lower compared to the previous liner shipping conference environment.

The new fuel surcharge calculators have not wiped out potential sources of contention between shippers and ship-owners. Shippers express concerns about the confidentiality of some inputs used in calculating the BAF. Examples include the projected cargo load for *OOCL* or imbalance factor for *Maersk Line*. The representative fuel consumption of vessels deployed on a specific trade is another major source of contention in the fuel surcharge calculations. Shippers face difficulties in verifying vessel consumption figures, which leads to some doubts in shippers' circles about whether the fuel savings caused by slow steaming practices are fully reflected in fuel surcharges.

Using the former example of a container shipped from Belgium to China, if the decision to slow steam a service reduces by 10% the vessel fuel consumption and is not factored in, this generates *ceteris paribus* around 34.5 additional USD per FEU (10% of $345) which for a typical service with 10 x 4,000 TEU vessels sums up USD 690,000 additional revenues per trip. However, these revenues are not without a cost (Kollamthodi et al., 2008; Corbett et al., 2009; Faber et al., 2010) as: (a) vessels are spending more time at sea reducing the annual payload; (b) in case of significant speed reduction, additional vessels are required to keep a weekly frequency in the ports of call (Notteboom et Vernimmen, 2008; Psaraftis et al., 2010) and (c) for shippers, in-transit inventory costs increase with transit time (Efsen et al., 2010; Bergh, 2010; Cariou, 2011). Next section presents a methodology to assess the first two effects.

3 | The overall impact of slow steaming

Using an extended version of *Maersk Line* BAF calculator, the BAF to be charged per FEU for a service *s* with *n* vessels can be estimated as follows:

$$BAF_{FEU} = 2.(BP_t - Base)\sum_{k=1}^{n} \frac{\left[(\alpha_s FC_{k,sea} + (1-\alpha_s)FC_{k,port})\right]}{\left[TEU_s\right]}.Transit\,time_s.IF_s \quad (1)$$

With $FC_{k,sea} = SFC_k EL_k kWh_k$ (2)

And:

$FC_{k,sea}$	the fuel consumption at sea per day for a vessel k
$FC_{k,port}$	the fuel consumption in port per day
Rot_s	the transit time in days with $\alpha_s.Rot_s$ days at sea and $(1-\alpha_s).Rot_s$ in ports
IFs	the imbalance factor for service s
TEU_s	the total capacity in teu deployed in a service s
SFC_k	the Specific Fuel oil Consumption in g/kWh
EL_k	the Engine Load in %
kWh_k	the engine power in kWh

Slow steaming impacts both on the fuel consumption of each individual vessel *k* ($FC_{k,sea}$) and on the characteristics of a service *s*. Focusing on the first component, for containerships carrying more than 1,000 TEU which are using two stroke marine diesel engines, slow steaming reduces the main engine fuel consumption at sea ($FC_{k,sea}$), with a limited effect for the auxiliary engine and consumption in port. Under normal condition, vessels were built for sailing at a speed close to design speed or an Engine Load between 70-90% of maximum continuous rate (MCR), a level at which the SFC is optimal - around 170-195 g/kW (MAN B&W Diesel A/S, 2008; Buhaug et al., 2009; Psaraftis et al., 2010; Faber et al., 2010). This value varies with the engine type and with weather conditions on route. The impact of slow steaming on fuel consumption depends on the magnitude of the speed reduction (MAN B&W Diesel A/S, 2008; Buhaug et al., 2009; Psaraftis et al., 2010; Faber et al., 2010). As long as the speed is reduced in small amounts up to a 10-15% reduction, the SFC remains fairly constant. As a rule of thumb, engine power is related to ship speed by a third power. When speed is reduced by more than 10% the SFC increases by up to 10%. This latter figure varies on the basis of engine characteristics, vessel type and engine age as engine retrofitting can limit the increase in SFC.[1]

The second impact from slow steaming is on the transit time and on the number of vessels to be deployed within a service (Notteboom and Vernimmen, 2008; Psaraftis et al., 2010; Cariou, 2011). The number *n* of vessels to add remains difficult to estimate as this primarily depends on what the shippers can bear in terms of increase in inventory costs (Bergh, 2010), and on the initial service characteristics in terms of the round voyage distance, the number and order of port calls, the frequency, the time buffers in the liner service, the fleet mix and the imbalance factor. As an alternative, some ports of call can also be dropped. Hence, a decision to opt for slow steaming requires a careful analysis of the trade-off between a positive impact resulting from the reduction in fuel consumption at sea and two negative effects: the need for additional vessels in case of significant reductions in speed; the increase in the time spent at sea, and therefore, in transit time. The final impact on BAF is then to be multiplied by differences in bunker prices, transit time and by the imbalance factor for a service or trade.

4 | The impact of slow steaming on fuel consumption at sea

Two sets of information are required to assess the impact of slow steaming on fuel consumption for a specific trade: (a) the number of services for which this strategy was implemented and how these services were affected, and (b) the vessel characteristics, in particular the reduction of the average fuel consumption as a consequence of slow steaming. To assess the extent of slow steaming per trade and the impact on fuel consumption, information was first gathered from three sources: from Alphaliner database (Alphaliner, 2010b) in January 2010 that was merged with data from the Lloyd's Register Fairplay database (2009); and data on 90 outbound port-to-port relations with Antwerp as the port of loading in July 2008 and November 2010. The names of the shipping lines included in the dataset are not disclosed for confidentiality reasons.

The initial data contains in Alphaliner database is for 174 liner shipping services and a total of 825 vessels deployed. The status of a service with respect to slow steaming was retrieved from comments in the database on liner service history. Services were then selected for 6 representative European container trades reducing the sample to 104 services with 618 vessels (table 1). For each trade, the mean age, design speed and engine power in kWh was then retrieved from LRF (2009).

Europe/Far East is the first trade with 39 services - 37% of the 104 services - and with 273 vessels deployed - 44% of the 618 vessels. An interesting feature is disparities on the extent of slow steaming from one trade to another. For instance, 79.5% of Far

[1] According to one-year data gathered from a private operator for a 4,300 TEU containership with a modern engine, the SFC would only increase from 195 to 198 g/kWh and the fuel consumption at sea would fall by around 60%.

Europe/Far East services are reported under slow steaming, contrary to services to Africa (6.3% of services). These results are roughly proportional, to the exception of services to Oceania, to vessel size and sailing distances. Regarding fleet structure, Far East is the trade on which the mean size of vessels is the largest, and North America, Oceania and Africa are trades for which vessels are the oldest. This later result is likely to influence the power needed, as age can be seen as a proxy of technology. Another important element to consider is differences in the structure of trade, and in particular, the number of reefers. Information gathered from private sources stresses for instance that the consumption of the auxiliary engine for a typical 4000 TEU vessel increases from 4 to 20 tons due to the number of reefers carried.

Table 1. Main characteristics of 174 European liner services in January 2010

	Number				Mean			
	Services	% SS	Vessels	% SS	TEU	Age	Design Speed	Engine kWh
Africa	16	6.3	68	5.9	2662	9	21	23,570
Far East	39	79.5	273	79.5	7970	5	25	58,778
India/Pakistan	11	72.7	63	74.6	4509	7	23	39,202
Latin /South America	21	28.6	131	28.2	3251	7	22	27,639
North America	14	14.3	74	25.7	3983	11	23	32,971
Oceania	3	33.3	9	33.3	2940	10	22	24,427

SS = slow steaming

Source: Authors from Alphaliner database (January 2010) and LRF (2009)

Table 2 provides additional information. It is based on a selection of 90 outbound services with Antwerp as a port of loading in July 2008 and October 2010. The port pairs considered are all connected via direct line-bundling services, meaning that no sea-sea transhipment takes place at intermediate hubs along the route. We distinguish two periods of analysis. The first period is June-July 2008, when the liner conference system still existed. As such, the case-study for the first period provides a snapshot of fuel surcharge practices in the liner conference era at a time when fuel costs reached unprecedented heights and when slow steaming was not yet implemented. The second period is October 2010 and is a time when slow steaming has been implemented. Indeed, if slow steaming practices already started in the summer of 2008, particularly on the Europe-Far East trade, to cope with the high bunker costs (as reported by Notteboom and Vernimmen, 2008), however, the full impact became visible in late 2009 and 2010. Indeed, more and more shipping lines decided to opt for slow steaming, not only to save on fuel costs but also to absorb the vessel surplus capacity created by the economic crisis. Information on the average one-way distance relates to the distance from Antwerp to the port of discharge, including the diversion distance to call at en-route ports of call is also estimated. The nautical distances were calculated using the Dataloy distance tables. In a few cases, up to seven ports of call are positioned between the loading port Antwerp and the port of discharge. At the other extreme, Antwerp sometimes acts as the last port of call in Europe while the port of discharge is positioned as the first port of call in the overseas service area.

Table 2 also depicts the average transit times between Antwerp and the overseas destinations and the average vessel size per trade route. Both elements are key variables in determining the fuel consumption per container carried together with commercial speed of services. The commercial speed of the vessels was determined using shipping lines' information on total transit times and port time. We decomposed the real transit time on a port-to-port basis into total sailing time, average port time per intermediate port of call and canal transit time. Differences in vessel size with values reported in table 1 are explained by differences in the characteristics of vessels deployed from Antwerp with those of services from Europe.

Table 2. Main characteristics of services in July 2008 and October 2010 of the set of O/D relations considered with port of loading Antwerp

	Services	**Distances**	**Size in TEU**		**Transit time in days**		**Commercial speed in kt**	
	Observation	**In nm**	**2008**	**2010**	**2008**	**2010**	**2008**	**2010**
Africa	15	4731	2525	3903	17.5	17.8	20.1	19.6
Far East	24	11183	7563	9308	25.6	29.1	22	18.4
India/Pakistan	9	7165	3963	4505	20.9	24.8	21.3	19.1
Latin/South America	23	5765	3700	4180	17.3	18.1	20.7	19.8
North America	12	5096	4102	4283	16.6	17	20.3	19.5
Oceania	7	13136	2922	2653	42.9	40.4	20	20.1

Notes:
(a) Including the diversion distance to call at en-route ports of call on liner service
(b) Including total sailing time, total port time at intermediate ports of call on liner service and canal transits

Two markets experienced a decrease in commercial sailing speed. Europe/Far East with a significant reduction on average of 16% in speed and India/Pakistan with a mean decrease of 10%. Furthermore, a decrease in speed does not automatically increase proportionally the transit time as some ports are dropped for some services. Indeed, on most trade routes the average transit time, together with the average vessel size have increased between July 2008 and October 2010, indicating a trend towards the use of larger unit capacities sailing at slower speeds compared to their design speed. The high transit time is not only caused by slow steaming: the use of ever larger container vessels implies a longer total port time on the route since more and more containers need to be handled when the vessel calls at a port. The cargo volume increase is typically not offset by a higher terminal productivity, in net terms leading to more time spent in ports during a round voyage. Also a change in the order of port calls can have an impact on the total transit time between Antwerp and the overseas port of destination. Only Europe-Oceania has seen a decrease in transit time and vessel size.

To estimate the ship's average fuel consumption per trade in 2008 and in 2010, we retrieved information on the design speed and engine power of containerships from LRF database (2009). For the design speed, we considered the average value by vessel categories. For instance, containerships sailing from Antwerp to Africa in 2008 are on average of 2,525 TEU, and the 107 vessels with a carrying capacity between 2,000 and 3,000 TEU reported in LRF (2009) have an average design speed of 22.3 knots. To determine the engine kWh[2], we approximated a log-linear relationship between engine kWh and TEU, with Engine $kWh=exp^{2.97}.TEU^{0.89}$ and $R^2=0.86$. In our former case, it leads to an engine power of 21,444 kWh.

We then estimated the fuel consumption per day using the design speed (22.3), the commercial speed (20.1 in 2008) and equation 2 for a SFC assumed to remain constant at 190 g/kWh. Fuel consumption is then due to engine power required and speed which is assumed to be related to ship speed by a third power. For our typical vessel sailing to Africa in 2008 at a commercial speed of 91% of design speed, (20.1/22.3), the mean fuel consumption per day at sea is $24x0.91^3x190x21,444/1000000$= 74 tons of fuel burned by day at sea in 2008 (at design speed, the ratio is 1 instead of 0.91). Table 3 presents results on fuel consumption per day for all trades in 2008 and 2010. It also presents similar results using the fuel consumption per day/TEU reported in Maersk Line BAF calculator in November 2010.

Table 3. Fuel consumption at sea of the main engine in July 2008 and October 2010 in tons/day

	2008 at design speed	**2008 at commercial speed**	**2010 at commercial speed**	**Maersk Line***
Africa	98	74	95	191
Far East	261	178	131	238
India/Pakistan	146	124	83	160
Latin/South America	138	107	86	218
North America	151	91	84	156
Oceania	111	83	77	106

** Reported value in November 2010 x by estimated size of containerships in Table 2*

Differences between estimated values and reported value by Maersk Line can be explained by the characteristics of services for this company compared to services originated from Antwerp. However, several general conclusions can be drawn. Firstly, values reported by Maersk Line are closer to the fuel consumption at design speed, rather than on fuel consumption at commercial speed. Secondly, for some trades, namely Africa and Latin/South America a huge gap exists between estimated and reported values.

[2] We also considered age but without significant results. A likely explanation is that vessel size already captures the influence of age.

5 | Comparison between fuel costs, BAF and freight rates

So far, the analysis focused only on one part of the equation: the impact of slow steaming on the average fuel consumption in metric tons per day. The analysis of the impact on BAF and its share within the total price to be paid by the line's customers is more difficult to assess. For the former, to the base freight rate, a series of surcharges such as the BAF, the CAF (currency adjustment factor), the THC (Terminal Handling Charges), piracy surcharge (Gulf of Aden/Suez transit), port congestion surcharges (if any) and often also container-equipment related surcharges (e.g. demurrage charges, detention charges, equipment handover charges, equipment imbalance surcharge, special equipment additional for an open top container or heavy container, etc.) need to be considered. This section focuses first on the impact on BAF while the base freight rate emerges later in the analysis.

Table 4. Estimated fuel costs and reported BAF in July 2008 and October 2010

July 2008 (IFO380 = US$ 585 per ton, MDO = US$ 1,125 per ton)

Port of loading = Antwerp Region of port of discharge	Average fuel costs per FEU carried (a)	Average BAF per FEU 1 Oct 10	Difference BAF - fuel cost per FEU carried	Standard Deviation	Minimum difference BAF - fuel costs	Maximum difference BAF - fuel costs	Ratio BAF versus fuel cost per FEU carried	Base freight rate per FEU 1 Oct 10	Ratio BAF versus base freight rate per FEU carried
	US$	US$	US$	US$	US$	US$	Ratio	US$	Ratio
Africa	1112	1329	217	134	-42	286	1.20	1798	0.74
Far East	374	1003	629	185	426	846	2.68	93	10.82
India / Pakistan	913	847	-66	25	-83	-33	0.93	592	1.43
Latin and South-America	789	1308	519	352	11	1119	1.66	1628	0.80
North America	662	1195	533	75	296	562	1.81	371	3.22
Oceania	1691	1453	-238	58	-285	-176	0.86	1628	0.89

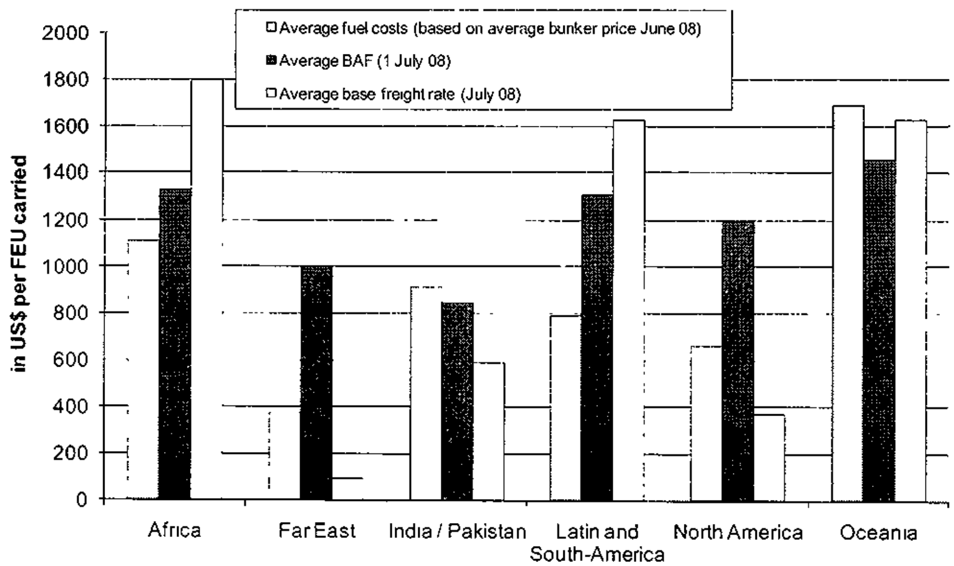
October 2010 (IFO380 = US$ 435 per ton, MDO = US$ 680 per ton)

Port of loading = Antwerp Region of port of discharge	Average fuel costs per FEU carried (a)	Average BAF per FEU 1 Oct 10	Difference BAF - fuel cost per FEU carried	Standard Deviation	Minimum difference BAF - fuel costs	Maximum difference BAF - fuel costs	Ratio BAF versus fuel cost per FEU carried	Base freight rate per FEU 1 Oct 10	Ratio BAF versus base freight rate per FEU carried
	US$	US$	US$	US$	US$	US$	Ratio	US$	Ratio
Africa	684	1077	393	163	110	531	1.57	1501	0.72
Far East	184	238	54	96	-84	116	1.29	702	0.34
India / Pakistan	458	738	280	74	192	362	1.61	669	1.10
Latin and South-America	464	1186	722	535	-162	1258	2.56	1828	0.65
North America	431	389	-42	61	-129	-1	0.90	1854	0.21
Oceania	1178	1407	229	156	104	396	1.19	1841	0.76

The comparison between our estimates on BAFs and those observed in 2008 uses a bunker price of US$ 585 per ton for the fuel grade IFO 380, to which a US$ 1,125 for marine diesel oil (MDO) was added. These figures relate to the average bunker price in Rotterdam in the month of June 2008. Average bunker prices in September 2010 reached US$ 435 per ton for IFO 380 and US$ 680 per ton for MDO. For each port-to-port relation we included an imbalance factor retrieved as the mean value reported in Maersk Line BAF and similar values retrieved from the ratio between outbound-to-inbound BAF charged by CMA-CGM in October 2010. The mean value is 1.56 for services from Europe to Africa, 0.44 to Far East and 0.98 to Latin/South America, 1.28 to North America the remaining two trades being with a factor of 1. We assumed that the same imbalance factors applied in July 2008. The fuel consumption by the auxiliary engine is assumed to be equal to 10% of the consumption of the main engine (EPA, 2000), to which 10 tons per day at sea were added in order to account for reefers for services to Latin/South America. Table 4 reports final estimates for the BAF values.

Figure 1. BAF, fuel costs and base freight rate per FEU – port-to-port relations with loading port Antwerp

July 2008 (IFO380 = US$ 585 per ton, MDO = US$ 1,125 per ton)



October 2010 (IFO380 = US$ 435 per ton, MDO = US$ 680 per ton)

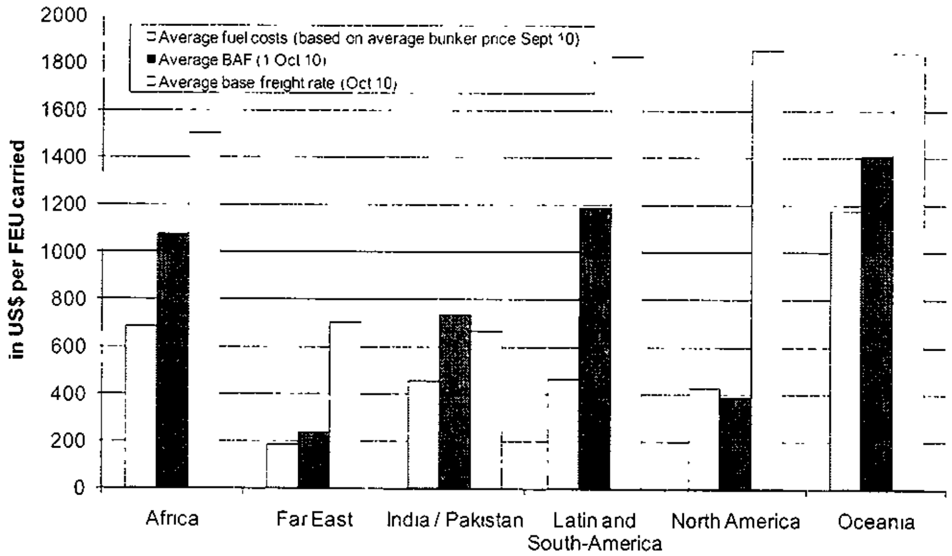


Table 4 and figure 1 bring together the main results of the analysis. Data relates to the transport of one FEU. The figures for BAF and the base freight rate were collected from freight forwarding companies and liner agencies in Antwerp. The following conclusions can be draw. First of all, the BAF per FEU carried is typically (much) higher than the average fuel costs per FEU that we estimated. These results confirm the earlier findings of Meyrick et al (2008) and Notteboom and Cariou (2011) who concluded that the BAF would involve an element of revenue-making for some trades. For June/July 2008, the BAF turned out to be slightly lower than the fuel costs in only 19 of the 90 cases. In October 2010 this figure amounted to 14 cases, most of these on the Europe-North America trade. The results underline that the revenue-making character of BAF has not disappeared after the abolition of liner conferences and the wider adoption of slow steaming. On the contrary, four of the six trade routes considered see an even larger gap between BAF and actual fuel costs. The revenue-making characteristic of the BAF became more significant on the shipping routes from Antwerp to Africa (from a BAF/fuel costs ratio of 1.2 in July 2008 to a ratio of 1.57 in October 2010; mainly caused by high fuel surcharges to West African ports), Latin and South-America (from 1.66 to 2.56; mainly caused by BAF practices to destinations in Mexico and the Caribbean), India/Pakistan (from 0.93 to 1.61) and Oceania (from 0.86 to 1.19). Except for Indian/Pakistan, these trade lanes have not been subjected intensively to a shift towards slow steaming. The widening gap between the fuel surcharges and the actual fuel costs on the India/Pakistan route demonstrates shipping lines clearly have not passed on the fuel savings resulting from slow steaming practices on this trade to customers. Part of the explanation might relate to the increasing risks of delays in Indian ports as a result of increased concerns over port congestion. However, if such were the case then congestion surcharges should be used as a means to compensate for delays, not the fuel surcharges. As also a number of West-African container terminals are plagued by severe port congestion, a similar point can be made on the high BAF/fuel costs ratio on the Europe-Africa trade. The fuel savings resulting from significant scale increases in vessel size on the African route (see table 2) have not resulted in a proportional decrease in fuel surcharges.

The Europe-Far East and Europe-North America routes are the only trade routes that have seen a relative narrowing of the gap between BAF and actual fuel costs. Fuel surcharges on the Europe-North America trade are on average no longer sufficient to cover the fuel costs, meaning that part of the fuel costs must be absorbed in the base freight rate. The Europe-Far East route provides the most interesting results, particularly in light of evaluating the impact of slow steaming on fuel surcharge practices. In the summer of 2008 shipping lines were still strongly overcharging customers for the incurred fuel costs (ratio of 2.08). Bunker cost per ton peaked in the summer of 2008 and shipping lines seized this opportunity to charge disproportionately high fuel surcharges. The situation eased somewhat in 2010 with most shipping lines now overcharging customers for the incurred fuel costs with BAFs typically at 10% to 50% above fuel costs (average ratio of BAF/fuel costs of 1.29). The increased adoption of slow steaming on this trade combined with the deployment of larger vessels has reduced the fuel costs per unit carried. This development did not lead to a widening of the gap between BAF and these fuel costs. While fuel overcharging is still common practice, more of the fuel cost savings are passed on to customers than in July 2008. The broader adoption of all-in rates and the use of relatively moderate fuel surcharges suggest that the Europe-Far East trade is becoming a trade route where shipping lines seem to have tempered BAF revenue-making strategies. Shipping lines' pricing practices on this trade route combined with a limited possibility for shippers to verify base data make it harder for shippers to prove that the savings generated by slow steaming are not passed on to them in an adequate way.

Variations exist in the difference between BAF and the estimated fuel costs per FEU (see minimum and maximum values in table 4). The spread in observations is particularly high for Latin and South America. A further investigation of the data stresses that the observed spread is mainly the result of differences in shipping lines' BAF policy for specific ports of discharge. The BAF strategy of shipping lines with respect to destinations in India/Pakistan, North-America and Oceania is more aligned.

6 | Conclusions

This paper aimed at incorporating the impact of slow steaming in the ongoing discussion on fuel surcharge practices of shipping lines. We analyzed the relation between slow steaming practices and BAFs by focusing on three distinct research questions: (a) How significant are slow steaming practices in container liner shipping?, (b) What is the impact of slow steaming on fuel consumption and liner service characteristics?, (c) To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines? Table 1 showed that slow steaming has become a common practice on the Europe-Far East trade while it also gained in importance on a number of other trade routes. Slow steaming practices were initiated in the summer of 2008, particularly on the Europe-Far East trade, as a response of shipping lines to fast rising bunker costs. However, the full impact became visible in late 2009 and 2010 as more and more shipping lines decided to opt for slow steaming, not only to save on fuel costs but also to absorb the vessel surplus capacity created by the economic crisis. This paper showed that slow steaming leads to longer transit times and more vessels per liner service, and significantly reduces fuel consumption of vessels deployed.

A case-study including 90 port-to-port relations with the port of Antwerp as the base loading port demonstrated slow steaming has had some impact on the differential between fuel costs and the fuel surcharges imposed on shippers by shipping lines. The results underline that the revenue-making character of BAF has not disappeared after the wider adoption of slow steaming, but the results tend to differ according to trade route considered. The BAF revenue-making strategies of shipping lines have become weaker on the Europe-Far East trade, the main slow steaming trade, but stronger on the Europe-India/Pakistan trade, another major slow steaming liner route. On trade routes with a low slow steaming impact, the BAF typically outstrips the actual fuel costs by a factor of 0.5 to 1.5. The only noticeable exception is the Europe-North America trade with most shipping lines now no longer covering the fuel costs via BAF.

11 Are Bunker Adjustment Factors aimed at revenue-making or cost recovery? Empirical evidence on the pricing strategies of shipping lines

Theo Notteboom and Pierre Cariou

11.1 Introduction

For liner shipping activities, not least container shipping, bunker oil is a considerable expense. According to Germanischer Lloyd (*Lloyd's Shipping Economist*, 2008a) or the World Shipping Council (*Lloyd's Shipping Economist*, 2008b), the fuel bill for an 8000 TEU (twenty-foot equivalent unit) ship accounts for around 50–60 per cent of its operating costs, a 33 per cent increase compared to three years previously. This impressive growth has led shipping lines to adapt their operating practices on bunker management (Notteboom and Vernimmen, 2009), using cheaper fuel grade alternatives, improving vessel design, reducing vessels' speed and adding capacity or dropping the number of ports of call in order to keep a weekly frequency in services, and hedging against future bunker price variations.

This chapter focuses on another traditional approach used by shipping lines to hedge against the risks of sharp and temporary fluctuations in bunker costs and to mitigate their impact on the overall freight rate: levying a specific surcharge on shippers known as the Bunker Adjustment Factor or BAF. BAF aims at passing the fuel costs on to the customer through variable charges, and is controversial. Shipping lines have more than once argued that the increase in bunker prices, especially in the short term, is only partially compensated for through surcharges to the freight rates and that it still affects their earnings negatively. In contrast, shippers' organizations such as the European Shippers' Council have always objected that the way BAFs are determined is opaque, without uniformity, and involves a significant element of revenue-making.

If the issue regarding BAF and its relevancy is not new (Menachof and Dicer, 2001), the concomitance of two events has made it even more salient today. On the one hand, the sharp increase in bunker costs between late 2005 and the summer of 2008 combined with the decrease in freight rates has led BAFs to reach unprecedented levels, where they have become a significant component in the overall costs to ship goods. For the second quarter of 2008, the base freight rate for a forty-foot container from Shanghai to Antwerp had reached around US$1400 to which a BAF of US$1242 was added. On the other hand, the recent repeal of European-related liner conferences in the wake of EU legislation has forced many shipping lines to develop new methods for calculating fuel surcharges, leading shippers to scrutinize the new practices regarding BAF and developed by individual carriers.

This chapter contributes to this issue in focusing on the relationship between fuel cost fluctuations and fuel surcharging practices as part of carriers' pricing strategies. The central research questions put forward are as follows. How have shipping lines changed their practices regarding BAF, considering the end of the liner conference era in Europe? How can bunker costs be estimated for a specific service? Can it be concluded, as stated by shippers, that BAFs are used by shipping lines to generate additional revenue, or are they only, as stated by shipowners, used to recover bunker costs and to cope with their unexpected fluctuations?

To answer these questions, this chapter is organized as follows. The next two sections discuss the viewpoints of shippers and shipping lines and zoom in on past (section 11.2) and current (section 11.3) practices of fuel surcharges. Section 11.4 presents a model aiming at calculating the bunker cost for a specific service that takes into account vessels (size, speed, engine type . . .) and service (days at sea, at port) as the main characteristics. Section 11.5 applies the model to various routes and compares our estimates of fuel costs with the observed BAFs on a set of port-to-port liner services out of the port of Antwerp. Section 11.6 provides the conclusions and explores avenues for further research.

11.2 Fuel surcharges in the liner conference era

In order to understand the factors considered by shipping lines in determining BAFs, a distinction must be made between practices before (collective pricing) and after the liner conference era (individual pricing). Liner conferences have always played an important role in pricing issues linked to fuel costs. The system of collective rate-setting dates back to the first conference, the Calcutta Steam Traffic Conference, set up by British cargo lines in 1875. However, BAF was only introduced in 1974 following the first oil crisis when bunker prices rose from US$20 per ton to over US$100 per ton in three months (Menachof and Dicer, 2001).

In principle, carriers cover basic bunker costs, while BAFs only apply to changes above a certain level. Liner conferences came up with their own way of dealing with BAF in applying a surcharge adjusted on the first day of each month and based on the closing IFO 380 bunker price in

Table 11.1 *BAF surcharge percentage for bunker price classes*

IFO 380 price level (euro per ton)	BAF surcharge (%)	IFO 380 price level (euro per ton)	BAF surcharge (%)
140 (Base level)	2.00	216–220	6.50
141–155	2.50	221–230	7.50
156–165	3.00	231–240	8.00
166–180	3.50	241–250	8.50
181–190	4.50	251–255	9.00
191–200	5.00	256–265	9.50
201–205	5.50	266–279	10.50
206–215	6.00	271–280	11.00

Rotterdam on the last weekday of the previous month (Table 11.1). The dollar price was then converted to euros at the closing rate of exchange in London on the same day (last weekday). If the bunker price went below 140 euros per ton, the surcharge was withdrawn.

Surcharges were jointly fixed by conference members and conformed with outside operators as well. The approach taken by the Far Eastern Freight Conference (FEFC), a liner conference for the Europe–Far East trade which ceased to exist in October 2008, represent a good illustration of such practices. When the FEFC introduced a BAF system in the aftermath of the oil crises of the 1970s, the underlying justification was that carriers operating within liner conferences could not otherwise adjust their prices promptly enough to counteract the effect of bunker price increases. When first introduced, the basis of the FEFC BAF calculation was the prices paid by the member lines and reported by them to third-party chartered accountants.

However, because the prices reported remained confidential, the system was felt to be too opaque by customers. Lines accordingly changed the system in order to base the BAF calculation on independent indices shown in the *Marine Oil Bunker Market Report* – published to subscribers and in the shipping press by Cockett Marine Oil Ltd. The BAF system as applied by the FEFC changed over the years from a percentage of the freight on a 90-day average to a lump sum based on a monthly calculation. This new system aimed at reflecting more closely the changes, both upwards and downwards, that occur in the volatile bunker market, with a lag effect in the application of the BAF. For instance, the February figures, after a month's notice period, were only applicable in April and the BAF calculation was monitored twice per week, to coincide with the publication of the Cockett report. It used a weighted average for fuel loaded in Asia, the

Middle East and Europe throughout the month, and then was averaged to provide the monthly BAF. An example of the calculation of the BAF per TEU is presented below:

$$BAF = \frac{I_t - I_b}{I_b} \cdot C_b$$

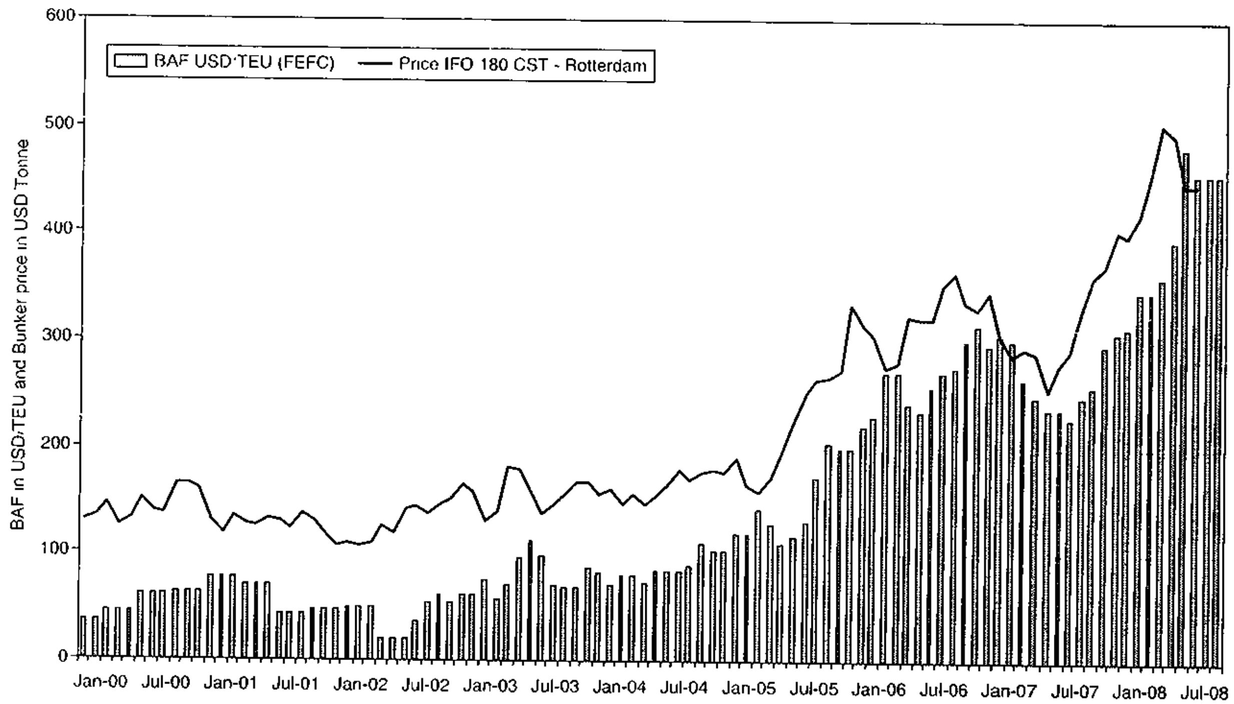
with:

I_t Average weighted index (bi-weekly);
I_b Base index;
C_b Base bunker cost per TEU.

The fixing of BAFs by liner conferences has always been a source of contention in shipping circles, particularly in times of high fuel prices. Research commissioned by the European Shippers' Council (ESC) into bunker surcharges applied by liner conferences more than once created a growing disquiet, as BAFs were found to be higher than actual fuel costs in some cases. Meyrick and Associates (2008) concluded, for instance, that the level of the BAF applied by the FEFC and Trans-Atlantic Conference Agreement (TACA) in early 2008 would involve a significant element of revenue-making. The model estimated that the 'true' cost-recovery BAF per TEU for March 2008 was US$67 lower than the real FEFC BAF of US$456 per TEU. For the TACA, the difference was even more emphatic: an estimated 'true' cost-recovery BAF of US$185 per TEU versus an actual TACA BAF of US$607 per TEU (a difference of some US$422 per TEU in March 2008). These studies strengthened the belief of the ESC that shippers are being overcharged when it comes to fuel surcharges set by liner conferences. Cariou and Wolff (2006) reached a similar conclusion. Investigating if a Granger causal relationship exists between the Bunker Adjustment Factor charged by members of the FEFC and bunker prices on the Europe–Far East container trade (Figure 11.1), the authors conclude that from 2000 to 2004, a causality can be established but that an increase in fuel price by 1 would lead to an increase in BAF by 1.5.

A survey commissioned by the European Liner Affairs Association (ELAA) went even further by stating: 'The general perception, especially from non-forwarder accounts, is that there is hardly any correlation with the underlying costs and that the surcharges are meant as an additional money maker for the lines' (MEL, 2005: 5). The growing disquiet among shippers fuelled the demand for more transparency in the calculation of fuel surcharges.

The position of shippers in relation to the BAF was made very explicit in a document submitted by the European Shippers' Council to the DG



Source: authors based on data from *Drewry Shipping Insight*, ISL (various years) and FEFC website.

Figure 11.1 Bunker price in Rotterdam (US$ per ton) and FEFC's BAF (US$ per TEU)

Competition of the European Commission on the review of Council Regulation 4056/86:

> Shippers do not accept the ocean carriers' claim that they operate in a unique environment and they are a special case deserving special protection from market forces. Shippers face similar business risk when trading in global markets; they are unable to pass on additional costs incurred through the use of surcharges . . . Bunker Adjustment Factors (BAFs) are being assessed as a collective surcharge by all members of a liner shipping conference whereas each carrier has its individual policy for fuel buying and consequently the prices vary accordingly. Moreover, it has never been demonstrated that the BAF increases reflect the true additional fuel costs . . . The absence of transparency in the imposition of surcharges has led shippers to call for their abolition. The method by which surcharges are calculated is complex and because of averaging of surcharges within a conference, surcharges are unrelated to the actual costs experienced by individual shipowners. Surcharges are used as a means of obtaining additional revenues. (ESC, 2003: 20)

In its response to a later information note published by the European Commission's DG Competition on 'Issues raised in discussions with the carrier industry in relation to the forthcoming Commission Guidelines on the application of competition rules to maritime transport services', the ESC further argued that: 'The fuel element of a contract with the shipper should solely be the decision of each individual carrier, based on their own individual costs, their own pricing strategy, and consideration of and with their individual customers' (ESC, 2006: 20).

11.3 Fuel surcharges after the liner conference era

Liner shipping conferences were outlawed in Europe on 18 October 2008. Liner shipping companies have lost their privileged status under EU competition law due to the withdrawal of the liner conference block exemption, which basically authorized horizontal price-fixing and similar agreements between liner shipping companies through Regulation 4056/86 of 1986. Where the liner consortia block exemption does not apply, all cooperative activity should be carefully and individually assessed under the competition provisions of the EC Treaty. The dismantling of liner conferences meant that container shipping lines calling at European ports were banned from discussing freight rates and other additional surcharges such as bunker and currency surcharges and from publishing common tariffs. The same applies for conference business plans and the exchange of confidential information on market shares, volumes or prices between lines. Carriers are now negotiating rates individually with shippers. The loss of the conference structure has thus resulted in the disappearance of commonality in pricing structures and surcharges amongst conference lines.

On 31 July 2008, the FEFC operating on the Asia–Europe trade, the world's second-largest liner conference after the Trans-Pacific, issued its last notice on BAF ahead of the European ban on shipping conference activities. The 17 member lines of the FEFC advised shippers of a 13.5 per cent increase in their BAFs on shipments to Europe with effect from 1 September to 17 October, 2008. The FEFC ceased to exist along with other rate-setting groups in trades with Africa, South America, the Indian subcontinent, the Middle East and Australasia. Some, including the Trans-Atlantic Conference Agreement, had already ceased operations earlier than October 2008.

In the European post-conference era, carriers will still be allowed to exchange trade data, a task that will be handled by the European Liner Affairs Association (ELAA), an industry lobby group that is transforming itself into a trade association to manage the exchange of information. The ELAA is planning to publish regularly the price of fuel over time in the most common locations for bunkering, as well as publicly available information on average fuel consumption for different standard vessel types so that an average cost per TEU can be calculated. This would increase transparency as to the cost of fuel, and would facilitate individual negotiations on compensation for fluctuating bunker costs

Now that Europe has brought an end to the conference system, the question arises as to how long it will survive in other parts of the world, especially in Asia where conferences are still an accepted way of doing business. A number of shipping lines have already taken steps to end their membership in non-European liner conferences. For example, at the end of November 2008, MOL resigned from the Transpacific Stabilization Agreement (TSA) and the Canada Transpacific Stabilization Agreement (CTSA). The reason is directly linked to the changing pricing and commercial practices following the end of liner conferences in Europe:

> With the European Union's abolition of liner anti-trust immunity, it has become extremely difficult to align the business processes of our entire organization when its regional divisions must operate to differing standards . . . We concluded MOL and its customers would be better served by conducting business independently from transpacific liner agreements (press statement by Masakazu Yakushiji, Executive Vice President, MOL Liner Division, MOL website, 28 October 2008)

Also, other shipping lines are redesigning business processes to make them applicable throughout their worldwide network.

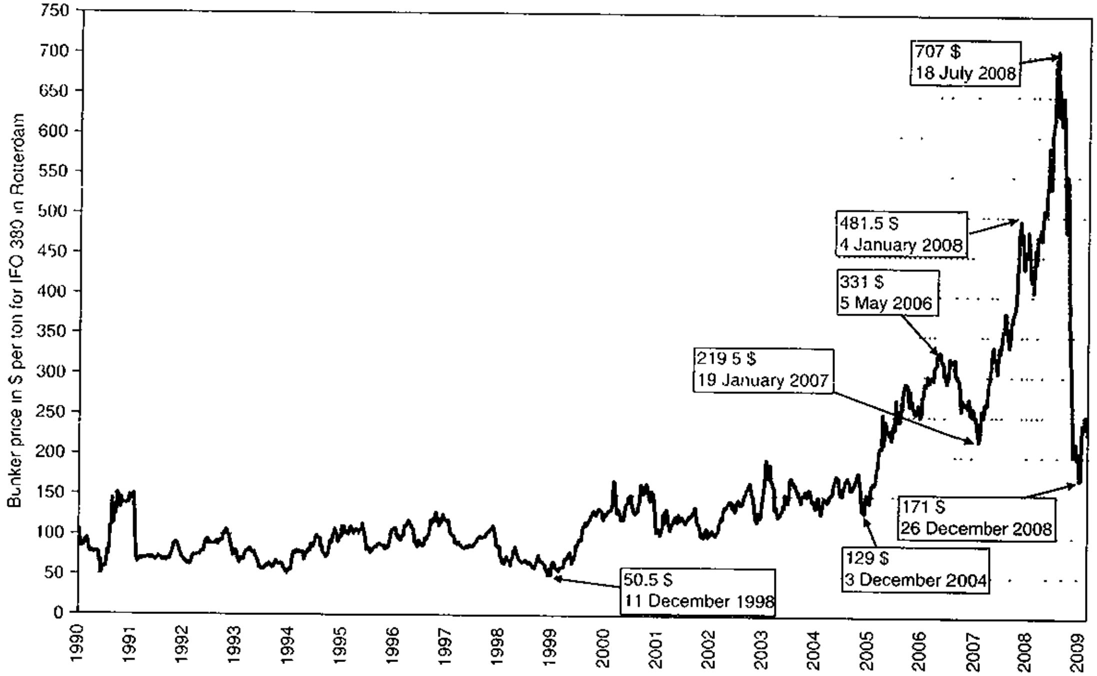
The leading ocean carriers prepared for the abolition of shipping conferences in Europe well in advance. After the European Union voted in 2006 to end liner shipping's block exemption from the EU competition rules, many shipping lines took action to become increasingly independent operators. This was further stimulated by the weakening of liner conferences as a result of carrier defections and, more recently, by slowing trade growth, overcapacity and competition from independent carriers. On top of this, liner conferences faced major difficulties in attaining internal consensus on rate adjustments. The FEFC even failed to implement two general rate rises in early 2008, as well as a peak-season surcharge scheduled for August 2008.

The disappearance of liner conferences took place in a period when ocean carriers were facing slowing traffic growth and tumbling freight rates due to the credit crisis and the economic downturn. Westbound rates from Asia to Europe decreased significantly to an average US$350 per TEU in October 2008 from US$1400 in October 2007. Some carriers accepted even lower rates in an effort to fill their ships, to improve capacity utilization and to reverse the downward trend of the base freight rates. A number of shipping lines even took actions to suspend loops mainly on the Europe-Far East and Trans-Pacific trades. For instance, NOL/APL cut 25 per cent of its liner service capacity on the Asia-Europe trade. At the same time, however, fuel costs soared to unprecedented heights in the summer of 2008 after decades of manageable price volatility and, soon after, plummeted from US$700 per ton in July 2008 to about US$200 per ton at the end of November 2008 (see Figure 11.2).

Shipping lines are challenged to charge customers for fluctuating fuel costs. In turn, customers are asked to absorb a sizable increase in their freight costs, and carriers recognize that this requires an easily justifiable, transparent process. The combination of strong fluctuations in fuel costs and downward pressure on freight rates has resulted in a reversal of the significance of the base freight rate versus fuel surcharges, as illustrated in Table 11.2

One of the concrete outcomes of this trend is the introduction of a new formula to charge customers for the fuel costs incurred. The fact that the conference system was disbanded means that those individual carriers who choose to still charge a BAF need their own independent method of calculating the charge. Each carrier made its own decisions on whether or not to charge a BAF and if so, on what basis the method of calculation and resulting quantum would be worked.

Maersk Line introduced, for instance, a new formula for BAF in early 2008, with the aim of creating more transparency. The formula used in the web-based 'Maersk Line BAF Calculator' builds on factors such as fuel consumption, transit time and imbalances in container flows (press communication, Maersk Line, 21 January 2008) as follows:



Source: authors based on data Clarksons Research Services Ltd.

Figure 11.2 *Bunker price for IFO 380 in Rotterdam (US$ per ton)*

Table 11.2 Base freight rate and BAF for the maritime transport of one forty-foot equivalent unit container (FEU) from Shanghai to Antwerp (excluding CAF, THC and other surcharges)

	Typical freight rate	Typical BAF
Q1 2007	US$ 2100	US$ 235
Q2 2008	US$ 1400	US$ 1242
Sept 2008	US$ 700	US$ 1440
Feb 2009	US$ 250 (all-in)	
April 2009	US$ 550 (all-in)	

Source: Authors based on market figures.

$$BAF = \frac{TS_t \; (P_t - P_{t-1})}{(F_t \cdot TI_t)}$$

With:

F_t Average fuel consumption per FEU;
P_t Bunker prices per ton in t (monthly or quarterly);
TS_t Trade-specific constant;
TI_t Trade imbalance factor

In preparation for the end of the European Conferences, Delmas/OTAL (part of CMA-CGM group) also developed its BAF calculation formula. The BAF levels used by the shipping line are announced at the beginning of each month and applied for the following month. The new BAF replaced the one previously issued by the Europe West Africa Trade Agreement (EWATA) since September 2008 and considers various elements such as:

- The average reference fuel oil price.
- The average fuel oil consumption of the line's ships per full TEU carried.
- The average fuel oil price for the month $t - 1$ is the basis for the calculation of the BAF applicable for the month $t + 1$.

A final example relates to OOCL. This shipping line has also ensured legal compliance by developing its own independent pricing and surcharge structure based on its own costs and operational requirements. OOCL constructed its own BAF formula to reflect market conditions and is unique to OOCL. It is based on trade, trade lane and service loop and also considers vessel size and round voyage capacity. In general terms, the formula is as follows:

Table 11.3 Illustration of upside and downside risks of fuel price changes – Transatlantic to/from US West Coast

Transatlantic US West Coast	Bunker price	BAF	
+ ↑	US$ per ton	US$ per TEU	
	613	590	
	588	555	
	563	521	
	538	486	
	513	452	Band of US$50
Current level (assumption)	488	417	Band of US$50
–	463	383	Band of US$50
	438	348	
	413	314	
	388	279	
↓	363	244	

Source: data from the OOCL shipping company

$$BAF = \frac{F_t \cdot (P_t - P_b)}{T_t}$$

With:

F_t Total fuel consumption;
P_t Current bunker price per ton;
P_b Base bunker price per ton;
T_t Projected cargo loaded onboard.

OOCL made a policy decision not to disclose the actual values for each component in the formula, calculating it on a monthly basis and taking the average bunker price during that period. If the bunker price has moved beyond the agreed band of US$25 (either up or down), then it will trigger a recalculation of the total BAF payable in the following month. OOCL uses a neutral third-party provider of bunker price information (Platts) for all the major locations around the world. OOCL selected a number of representative vessels for the purposes of calculating fuel consumption, a more manageable way than taking into account the actual consumption data of all its operating vessels.

The introduction of the new formula had an impact on the level of the base freight rates and of the BAF. The new calculation led to a BAF that is lower compared to the liner conference environment; whilst conferences used base bunker prices from around 1990, OOCL now started to use a base price from 2005. This resulted in a doubling of the base bunker price in the new formula and a reduction of the bunker price for OOCL's customers. OOCL shifted the difference into the ocean freight to maintain a revenue neutral position, whilst BAF is now more reflective of the prevailing fuel price conditions.

The disappearance of European-related liner conferences has also had an impact on liner conferences that still operate on non-European routes. These liner conferences have also responded to the demand for transparency by changing the way BAF is calculated. For example, in September 2008 the Westbound Transpacific Stabilization Agreement (WTSA) changed how it calculates bunker fuel surcharges in the US-Asia freight market. The new formula went into effect for dry cargo in October 2008. WTSA began the process of modifying its surcharge formula by eliminating steps to arrive at a complete 'average of averages' that reflects the cost impacts of rising fuel prices on multiple, different container services. The new bunker surcharge formula tracks a single marine fuel (that is, IFO 380). It also eliminates the weighted average of weekly prices at 11 load ports and, instead, uses a straight average of Hong Kong and Los Angeles prices for the West Coast; and Hong Kong and New York prices for the East Coast surcharge. The fuel price data for the three ports are obtained from the publicly available website Bunkerworld. A second set of changes involved components for constructing fuel cost impacts from changes in fuel prices. These include:

- Vessel effective capacity.
- Westbound allocation of deadweight capacity after east-bound empty repositions.
- Maximum capacity for loaded containers before reaching a ship's weight limit.
- Daily fuel consumption.
- One-way steaming time (excluding time in port).

Averages for the above components vary for West Coast and East Coast services, but are constant for each service. The formula also adjusts effective capacity to allow for the deadweight impact of empty returns. The new calculation method thus makes separate calculations for West Coast and East Coast services

As can be seen from former discussions, if most shipping lines had implemented a more transparent system regarding BAF, one of the main issues for shippers would be related to the absence of transparent information on some specific elements considered within the BAF calculation. If the level of current bunker fuel price is not an issue since data can be easily found, information on the selection of the base bunker price, on the vessel utilization rate and on the fuel consumption per vessel are more problematic. The next section presents a methodology focusing on the latter element, namely the estimation of the total fuel cost for a specific service.

11.4 Estimation of the fuel costs on a specific service[1]

A first step when analysing the relationship between fuel surcharges and actual fuel costs consists in determining the fuel consumption per TEU carried. Earlier work on this issue has been presented by Buxton (1985) and Cullinane and Khanna (1999) who introduced formula for the estimation of the daily fuel costs per TEU or ton based on parameters such as engine power and the specific fuel consumption (S_{FOC}). In this chapter, we add to these previous works by explicitly taking into account the characteristics of liner services (number of ports of call, roundtrip distance, and so on). The Total Fuel Consumption (TFC_j) in USS for a specific route/service j of T days (round trip) by i (i = 1. . . n) vessels is the sum of the fuel costs for main and auxiliary engines when the vessels are at sea (t_1), maneuvering in port or transiting through canals (t_2) and hotelling (t_3):

$$TFC_j = \sum_{i=1}^{n} \sum_{t=1}^{3} (P_m \cdot FC_{mit} + P_a \cdot FC_{ait}) \qquad (11.1)$$

with:

- TFC_j Total fuel cost for a specific service j in USD;
- t_1 Time when the vessel is at sea;
- t_2 Time when the vessel is maneuvering or transiting through canals;
- t_3 Time when the vessel is hotelling (waiting and when at berth);
- P_m Bunker price for the main engine (m);
- P_a Bunker price for the auxiliary engine (a);
- FC_{mit} Fuel consumption for main engine (m) per day for vessel i under status t.
- FC_{ait} Fuel consumption for auxiliary engine (a) per day for vessel i under status t.

When the vessel is at sea (t_1), the fuel consumption for the main engine (m) and vessel i (in grams/mile) can be estimated as.

$$FC_{m,i,t=1} = \frac{m_s \cdot L_f \cdot S_{FOC} \cdot P_e}{V_0} \qquad (11.2)$$

with.

- m_s Sea-margin to consider weather conditions and expressed as a percentage;
- L_f Load factor expressed as a percentage of the maximum continuous rate;

S_{FOC} Specific fuel oil consumption in g/kW-hr;
P_e Installed engine power in kW given for a TEU size and design speed v_0;
v_0 Design speed in nautical mile (nm).

We assume a sea-margin of 15 per cent (MAN B&W Diesel A/S, 2008) and a load factor of 80 per cent (Endersen et al., 2003; EPA, 2000; Corbett and Koehler, 2003). Furthermore, and whatever the vessel's status (t_1, t_2, t_3), the fuel consumption for the auxiliary engine (FC_{aux}) is considered as 10 per cent of the consumption of the main engine (Endersen et al., 2003; EPA, 2000; Corbett and Koehler, 2003). To estimate S_{FOC} and P_e for a vessel i at a given design speed v_0, we used information on container ships extracted from the Lloyd's Fairplay Ship Database (Lloyd's Maritime information Services, October 2008). The initial sample is made of 4834 container ships that were rearranged to consider only fully cellular containerships delivered, on order or pending[2] and more than 2000 TEU.[3] The final sample is made up of 2259 container ships whose main characteristics are presented in Table 11.4.

Out of the 2259 container ships, 33.8 per cent are between 2000 and 3000 TEU and 70.1 per cent are less than 5000 TEU. The mean vessel size is 4332 TEU, the mean age around eight years and the mean speed 23.04 knots. Out of the 2259 container ships, 97 per cent are using two-stroke slow-speed engines for which a value of 171 g-kW-hr is used as a proxy of S_{FOC} (MAN B&W Diesel A/S, 2008). In order to consider the impact of a change in the vessel's size on fuel consumption, we estimated (ordinary least squares – OLS) the relationship between installed engine power (P_e) and vessel size (in TEU).

$$Log(P_e) = 1.996 - 1.013.Log(teu) \qquad R^2 = 0.83 \qquad (11.3)$$

Combining equation (11.2) in (11.3) and assuming as stated previously, a sea-margin of 15 per cent, a load factor of 80 per cent, a S_{FOC} of 171 g-kW-hr so that $C = m_s \cdot L_f \cdot S_{FOC} = 1.15 \times 0.8 \times 171 = 157.3$, the total fuel consumption at sea for the main engine in grams/day and at a given speed v_0 can then be estimated as,

$$\frac{FC_{m,1}}{\text{at } v_0} = 24 \cdot C \cdot e^{1.996} \cdot teu^{1.013} = 3775 \cdot e^{1.996} \cdot teu^{1.013} \qquad (11.4)$$

Results from our estimations on $FC_{m,1}$ are presented in tons/day in Table 11.4. Figure 11.3 compares our estimates (equation 4) with the initial data from Lloyd's Fairplay Ship Database (in logarithm), the correlation coefficient being equal to 0.88 (based on 595 observations for which information on the fuel consumption for the main engine is given).

Table 11.4 Main characteristics of the sample and results from estimations (by TEU range)

	2000 3000	3000 4000	4000 5000	5000 6000	6000 7000	7000– 8000	8000– 9000	9000– 10000	10000+	Total #
Number of vessels #	764	350	469	285	146	60	122	46	17	2259
Mean size (TEU)	2530	3432	4385	5491	6505	7372	8293	9307	11660	4332
Mean design speed (nm) - v_0	21.2	22.4	23.9	24.5	25.3	25.1	24.9	25.1	23.6	23.04
Mean age (year)	10.1	11.6	6.5	5.2	4.4	4.7	1.9	1.4	0.6	7.8
Mean main engine (kW)	20699	26741	38616	49243	57764	61436	64353	67259	66580	36084
Engine type										
Two Stroke/Slow speed (%)	93	98	99	97	99	98	99	100	100	2184
Other[a] (%)	7	2	1	3	1	2	1	0	0	75
Fuel consumption in tonnes/ day[b]	80	102	142	199	229	233	255	N/A	N/A	121
Fuel consumption in grams// TEU/mile	62	55	56	62	58	52	51	N/A	N/A	0.000051
Estimations on fuel consumption at sea for various speeds										
$FC_{m,t}$ in tonnes/day[c]	78.1	106.4	136.4	171.3	203.4	230	260	292	367[d]	134.8
Vessel speed (knots)										
18	47.0	54.9	52.8	57.9	68.8	77.8	87.9	98.8	124.1	66.0
19	56.1	65.6	63.1	69.3	82.2	93.0	105.1	118.1	148.4	78.9
20	66.5	77.7	74.7	82.0	97.4	110.1	124.5	139.8	175.7	93.5
21	78.1	91.3	87.8	96.4	114.4	129.4	146.2	164.2	206.4	109.8
22	–	106.4	102.4	112.3	133.4	150.8	170.5	191.5	240.7	128.0

Table 11.4 (continued)

	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000	9000–10000	10000+	Total #
23			118.5	130.1	154.5	174.7	197.5	221.8	278.7	148.3
24			136.4	149.7	177.8	201.0	227.2	255.2	320.7	–
25	–	–	–	171.3	203.4	230.0	260.0	292.0	367.0	–

Notes
a Not specified.
b HFO consumption is only available for the main engine and for 594 observations.
c Estimation from equation (11.4) for main engine and at the mean size in TEU and design speed v_0 of the category.
d Due to the limited number of observations for vessels more than 10000 TEU (17 vessels), we assume that the design speed for this category is 25 knots (Man B&W Diesel A/s, 2008).

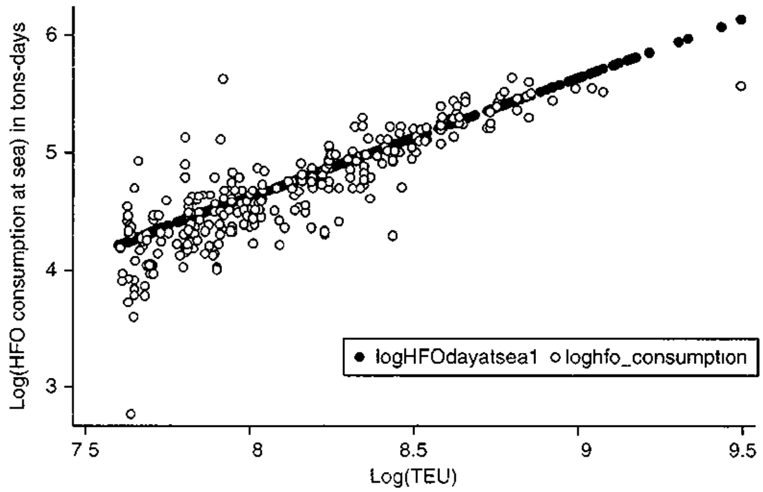


Figure 11.3 Fuel consumption with vessel size

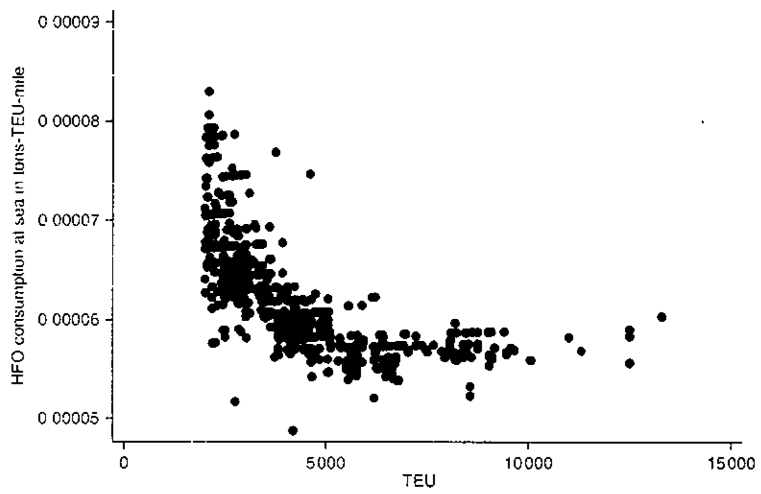


Figure 11.4 Economies of scale on fuel consumption

Figure 11.4 presents estimates on economies of scale on fuel consumption at sea expressed in tons per mile (equation 11.4/($24.v_n \cdot teu$)). It appears from Figure 11.4 that if economies of scale on fuel consumption exist, their effect is mainly visible for vessels increasing from 4000 to 6000 TEU.[4]

Above 6000 TEU, the additional marginal reduction in fuel consumption in tons per TEU-mile is rather limited. This result is mainly due to the reduction in the mean design speed for bigger vessels (23.6 kt for 10 000+ compared with 25.1 for 9000–10 000 for instance) that counterbalances the impact of the increase in number of TEU. This result would be, of course, different if 25 knots is taken as the initial design speed such as in MAN B&W Diesel A/S (2008). Considering the limited number of vessels more than 10 000 TEU in our sample (17 containerships only), we will assume an initial design speed of 25 knots for this category in the remainder of this chapter.

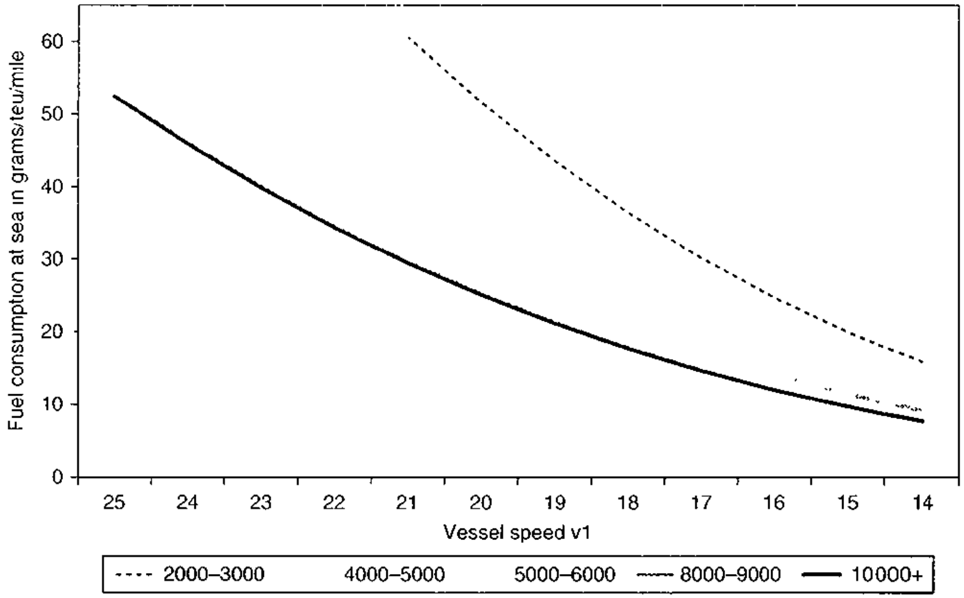
To estimate the fuel consumption when a vessel is maneuvering or transiting through canals ($FC_{me2} + FC_{ae2}$), we use equation (11.4) but without considering a sea-margin (equal to 1) and for a load factor of 15 per cent (EPA, 2000; Corbett and Koehler, 2003). The fuel consumption per day when the vessel is maneuvering or transiting through canals (t_2) can then be estimated at 16.3 per cent[5] of the fuel consumption when the vessel is at sea (t_1). As previously, 10 per cent is added for the auxiliary engine's consumption. When it comes to fuel consumption during port operations ($FC_{me3} + FC_{ae3}$)[6] we used a proxy of 5 per cent of the fuel consumption at sea for the main engine and (10% x 5%) for the auxiliary engine as previously.

As stated above, former estimates on fuel consumption at sea (FC_{me1}) only hold considering an installed power engine (P_e) for a given design speed v_0. In order to analyse the impact of a reduction in the commercial speed from a design speed v_0 to an actual speed of v_1, we investigated the relationship between P_e and v_0. The results (on 2245 observations for which v_0 and P_e were given, $Log(P_e) = 3.311 \cdot Log(teu)$ with $R^2 = 0.99$) are close to the traditional assumption of a cubic relationship between these two variables. We assumed that the variance in load factor of the engine does not affect fuel consumption and used former estimates so that for a commercial speed v_c, the fuel consumption is:

$$\frac{FC_{me1}}{at\ v_c} = \frac{FC_{me1}}{at\ v_0} \left(\frac{v_0}{v_1}\right)^{3} \qquad (11.5)$$

Estimations are reported in Table 11.4 for various vessel categories and for speeds varying from $v_1 = 18$ knots to the design speed v_0. Figure 11.5 illustrates the impact of a speed reduction on fuel consumption at sea in grams per TEU-mile for four vessel categories.

It appears that vessels in the range between 5000 and 10 000+ TEU give similar and better results in terms of fuel cost per TEU-mile. Table 11.5 compares our estimates on fuel cost at sea for the main engine (FC_{me1}) with



Source: authors calculations

Figure 11.5 Example of the impact of the decrease in vessel speed from the initial design speed v0 to v1

Table 11.5 Comparison of our estimates with Germanischer Lloyd (GL) figures on fuel costs per day at sea, end of July 2006

Speed (knt)	5000 TEU		8000 TEU		12000 TEU	
	Estimates	GL	Estimates	GL	Estimates	GL
14	8848	12200	13430	16000	18956	20700
16	13747	16800	20866	21600	29453	27500
18	20278	23100	30778	29000	43444	36500
20	28709	31800	43575	39400	61508	48700
22	39320	43700	59681	52200	84242	64400
24	52399	59300	79531	69400	112261	83600
26	68239	82800	103574	96100	146199	114700

Source: Our figures and Germanischer Lloyd (2010).

a study by Germanisher Lloyd for 5000, 8000 and 12000 TEU container ships (Notteboom and Vernimmen, 2009). These estimates were obtained for a bunker price (P_m) of US$350 per tonne (IFO 380 Singapore) in July 2006.

11.5 Estimation of the fuel costs for specific O/D relations and comparison with BAF

The case study developed in this section focuses on the estimation of BAF for containers exported via the port of Antwerp to a specific overseas port of discharge. The total price to be paid by the line's customers consists of a base freight rate and a series of surcharges such as the BAF, the CAF (currency adjustment factor), the THC (terminal handling charges), port congestion surcharges (if any) and often also container-equipment related surcharges (for example demurrage charges, detention charges, equipment handover charges, equipment imbalance surcharge, special equipment additional for an open-top container or heavy container, and so on). The case study focuses on the BAF, while the base freight rate emerges later in the analysis. We distinguish two periods of analysis.

The first period is June July 2008, corresponding to a period when the bunker price per ton reached its peak (see Figure 11.2) and the liner conference system still existed. As such, the case study for the first period provides a snapshot of fuel surcharge practices in the liner conference era at a time when fuel costs reached unprecedented heights. The BAFs observed in this case study relate to the fuel surcharges applicable on the first of July 2008. The bunker price applied throughout the analysis is US$585 per ton for the fuel grade IFO 380 and US$1125 for marine diesel oil (MDO). These figures relate to the average bunker price in Rotterdam in the month of June 2008. The choice of Rotterdam is mainly based on its proximity to the loading port Antwerp, although the authors are aware of the fact that Rotterdam is among the cheaper bunker ports worldwide. Using the bunker price in Rotterdam as a basis might therefore slightly underestimate the actual bunker costs for shipping lines.

The second period considered in this study is December 2008, corresponding to a post-liner conference period when the bunker price per ton reached around US$200 after a few months of price erosion. As such, we are able to analyse the changes in the fuel surcharge practices after the abolition of (European) liner conferences and at a time when fuel costs were much lower compared to the first case. The average bunker price in Rotterdam throughout November 2008 was US$220 per ton for IFO 380 and US$535 for MDO. These prices underline the sharp decline in fuel prices between the first period of observation and the last.

We collected data on 117 port-to-port relations with Antwerp as the port of loading. The names of the shipping lines included in the data set are not disclosed, for confidentiality reasons. The port pairs considered are all connected via direct line-bundling services, meaning that no transhipment takes place at intermediate hubs along the route. The port bundles have been aggregated to eight service areas of the port of Antwerp: Africa, the Baltic and Iberian feeder markets, the Far East, India/Pakistan, Latin and South America, the Near East and the East Mediterranean, North America and Oceania.

Table 11.6 summarizes the main characteristics of the dataset. The average one-way distance relates to the distance from Antwerp to the port of discharge, including the diversion distance to call at en route ports of call. The nautical distances were calculated using the Dataloy (2010) distance tables. In a few cases, up to seven ports of call are positioned between the loading port Antwerp and the port of discharge. At the other extreme, Antwerp sometimes acts as the last port of call in Europe, while the port of discharge is positioned as the first port of call in the overseas service area. The average number of ports of call between Antwerp and the ports of discharge on the respective line-bundling services equals 3.05 with a standard deviation of 1.85. Table 11.6 also depicts the average transit times between Antwerp and the overseas destinations (including the sailing time, port time at intermediate ports of call on the liner service and canal transit time) and the average vessel size per trade route. Both elements are key variables in determining the fuel consumption per container carried (see previous sections).

The commercial speed of the vessels was determined using shipping lines' information on total transit times and port time. We decomposed

Table 11.6 Main characteristics of the set of O/D relations considered in the case study (port of loading is Antwerp)

Region of port of discharge	Observations (no.)	Average one-way distance[a] (nm)	Average transit time (in days)[b] (days)	Average vessel size (TEU)
Africa	15	4731	17	2525
Baltic Iberian Atlantic feeder	10	1314	5	1350
Far East	24	11 183	28	7563
India / Pakistan	9	7165	21	3963
Latin and South America	23	5765	17	3700
Near East / East Med	17	3468	13	3535
North America	12	5096	17	3242
Oceania	7	13 136	43	2922
	117			

Notes

a Including the deviation distance to call at en route ports of call on liner service.

b Including total sailing time total port time at intermediate ports of call on liner service and canal transits

the real transit time on a port-to-port basis into total sailing time, average port time per intermediate port of call and canal transit time. After applying different values for the commercial speed of the vessel, the simulation exercise revealed that the following aggregated commercial speeds gave the best results:

- Vessels larger than 4000 TEU: 22 knots.
- Vessels between 2000 and 4000 TEU: 20 knots.
- Vessels smaller than 2000 TEU: 19 knots.

The total vessel consumption for each port-to-port relation was calculated by combining the sailing time, the vessel speed and the vessel size with the figures provided earlier in Table 11.4 and by adding the fuel consumption linked to the total port time (also in intermediate ports of call) and the canal transit time. The fuel cost for the auxiliary engine was also taken into account as suggested in the previous section, that is, consumption of MDO fuel on the basis of 10 per cent of main engine consumption. For each port-to-port relation we estimated the degree of utilization of the vessel's slot capacity (slots used excluding empty containers) based on industry information. The average degree of utilization for all observed liner services out of Antwerp equals 75 per cent in June July 2008 and

71 per cent in December 2008. By combining vessel size and degree of utilization, it is possible to determine the TEU loaded with pay cargo per port-to-port relation.

Tables 11.7 and 11.8 bring together the main results of the analysis, while Figures 11.6 to 11.9 present various comparisons. All data relates to the transport of one FEU. The figures for BAF and the base freight rate were collected from freight forwarding companies and liner agencies in Antwerp. Unfortunately, we were not able to collect BAF-data for December 2008 on the Europe-Far East trade as shipping lines massively used all-in rates without imposing a separate BAF.

Based on Tables 11.7 and 11.8 and Figures 11.6 to 11.9 the following conclusions on liner service relations with loading port Antwerp can be drawn. First of all, the BAF per FEU (forty-foot equivalent unit) carried is typically (much) higher than the average fuel costs per FEU that we estimated. For June-July 2008, the BAF turned out to be slightly lower than the fuel costs in only ten of the 117 cases. The difference between BAF and the actual fuel costs ranges from 9 per cent for Oceania to an elevated 147 per cent for Latin and South America. These results confirm the earlier findings of Meyrick & Associates (2008) who concluded that the BAF involves an element of revenue-making. The case study for June–July 2008 demonstrates that the revenue-making characteristic of the BAF is significant on the shipping routes from Antwerp to Latin and South America, Africa and North America. The revenue-making characteristic of the BAF is far less significant on intra-European feeder routes and on traffic relations with the Far East, India/Pakistan and Oceania.

Second, variations exist in the difference between BAF and the estimated fuel costs per FEU. The spread in observations is particularly high for Latin and South America, the Far East and Africa. A further investigation of the data stresses that the observed spread is mainly the result of differences in shipping lines' BAF policy for specific ports of discharge. The BAF strategy of shipping lines with respect to destinations in India/Pakistan, North America and Oceania is revealed to be more aligned.

Third, the results for December 2008 stress that the revenue-making character of BAF has not disappeared after the abolition of liner conferences. On the contrary, most trade routes see an even larger gap between BAF and actual fuel costs. The difference between BAF and the actual fuel costs ranges from 106 per cent for Oceania to an elevated 426 per cent for Latin and South America. A closer investigation of the figures reveals that shipping lines held on to high BAFs while the actual fuel costs plummeted due to a sharp decrease in the bunker price. This coincided with falling base freight rates. In other words, the results demonstrate that a combination of decreasing freight rates and decreasing fuel costs seems to

Table 11.7 Case study results, June–July 2008 (port of loading is Antwerp)

Region of port of discharge	Average fuel FEU carried FEU carried[a] (US$)	Average BAF per FEU 1 July 08 (US$)	Difference BAF fuel cost per FEU carried (US$)	Standard Deviation (US$)	Minimum difference BAF fuel costs (US$)	Maximum difference BAF fuel costs (US$)	Ratio BAF versus fuel cost per FEU carried (Ratio)	Base freight rate per FEU 1 July 08 (US$)	Ratio BAF versus base freight rate per FEU carried (Ratio)
Africa	562	1329	767	168	512	1087	2.36	1798	0.74
Baltic Iberian Atlantic feeder	194	217	22	96	−61	210	1.12	829	0.26
Far East	825	1003	179	202	−187	550	1.22	93	10.82
India/Pakistan	610	847	236	58	135	319	1.39	592	1.43
Latin and South America	529	1308	778	340	144	1337	2.47	1628	0.80
Near East / East Med	341	611	270	118	0	401	1.79	1184	0.52
North America	491	1195	705	118	462	882	2.44	371	3.22
Oceania	1336	1453	116	122	91	302	1.09	1628	0.89

Note: a based on bunker price of US$ 585 per ton of IFO 380 for main engine and US$1125 per ton of MDO for auxiliary engine (average bunker prices for June 2008 in Rotterdam).

Table 11.8 Case study results, December 2008 (port of loading Antwerp)

Region of port of discharge	Average fuel FEU carried FEU carried	Average BAF per FEU 1 Dec 08	Difference BAF fuel cost per FEU carried	Standard Deviation	Minimum difference BAF fuel costs	Maximum difference BAF fuel costs	Ratio BAF versus fuel cost per FEU[a] carried	Base freight rate per FEU 1 Dec 08	Ratio BAF versus base freight rate per FEU carried
	(US$)	(US$)	(US$)	(US$)	(US$)	(US$)	(Ratio)	(US$)	(Ratio)
Africa	233	484	251	78	141	404	2.08	1582	0.31
Baltic – Iberian Atlantic feeder	80	200	101	98	45	307	2.49	718	0.28
Far East	342	N.A							
India/Pakistan	253	645	86	142	292	649	2.55	558	1.16
Latin and South America	219	1154	54	594	−272	1630	5.26	1194	0.97
Near East / East Med	141	527	117	91	259	573	3.73	1024	0.51
North America	203	586	52	261	−197	672	2.69	511	1.15
Oceania	554	1139	64	91	458	717	2.06	1675	0.68

Note: a based on bunker price of US$220 per ton of IFO 380 for main engine and US$535 per ton of MDO for auxiliary engine (average bunker prices for November 2008 in Rotterdam).

Direct Taxation of Ship-based CO2 Emissions

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1 Introduction

CTX has argued at length that the only effective, efficient, and safe alternative for reducing CO2 emissions from ocean shipping is a tax on CO2 emissions [2] In particular we have argued that EEDI is just about the worst of all possible regulatory possibilities, wasteful in resources, unsafe, and in the sectors where slow-steaming is practiced including tankers, bulk carriers, and large containerships, totally ineffective.[1][3] In these sectors, EEDI will result in little, if any, reduction in CO2 emissions, over the market cycle. These arguments will not be repeated here.

But it is not enough to say that a tax is the only way to go. It is incumbent on any tax proposal to lay out in some detail exactly what the regulation will look like, and how it wll be implemented and enforced. That is the purpose of this paper.

2 Taxing Bunkers

Up to now, all the proposals for taxing CO2 emissions of which CTX is aware do not tax CO2 directly. They are a tax on the CO2 content of bunker fuel oil (BFO). This focus on fuel is based on two assumptions:

1. A carbon content based bunkers tax is a near-perfect proxy for CO2 emissions, since removing and sequestering carbon on-board is not only not economic, it is next to impossible.
2. A tax on fuel will be much easier to implement and enforce than a tax on the actual emissions.

(1) is certainly true, now and for the foreseeable future. But it turns out that (2) is just flat wrong.

The current BFO tax proposals envision either

a) collecting the tax at the ship level, or

b) collecting the tax at the bunker supplier level.

But so far no one to the CTX's knowledge has said exactly how this will be done. (The same thing is true of a bunkers based cap-and-trade which also needs to monitor fuel consumption by ship.) The reason that this has not been done is that it can't be done.

Either system ends of being dependent on the Delivery Ticket, that is, the paperwork that documents the transfer of bunkers from the bunker supplier to the ship. Under either system, both buyer and seller have an immense incentive to produce paperwork that understates the amount of bunkers transferred. Assuming a \$50 per CO2 ton bunkers tax, the tax bill on a single 5000 ton VLCC bunkering will be about \$750,000. The opportunity for collusion is inescapable. To prevent this would require incorruptible, fearless third party inspectors at every bunkering. And their bosses and bosses bosses would have to be equally incorruptible and fearless. Even if one deployed such an army of saints, the system would easily be evaded by clandestine bunkerings.

This saintly army would have to have the strong support of the local legal system despite the fact that the bunkering country has nothing to gain from collecting the tax. Finally, if a bunkering country made such strenuous and valiant efforts to prevent collusion that it was successful, it would simply move bunkering to a less vigilant nation.[1] Gresham's Law would quickly force any honest owners and any honest BFO suppliers out of business. The amounts of money at stake are so large that the corruption will extend to the highest levels in all but the wealthiest countries. The IMO estimates that international shipping emitted 870 million tons of CO2 in 2007.[4] A \$50 per ton CO2 tax represents over 40 billion dollars a year of economic rent, just waiting to be pounced on.

One can imagine attempting a layer or two of multi-national checks on top of such a system, but such checks will be too far removed from the actual transactions to have any impact; and, if they did, they would become stranded on the reef of national sovereignty.

Given the ability of bunkering to move to the most "attractive" jurisdiction, — or no jurisdiction at all by going far enough offshore — ***enforcing a bunker tax on international shipping is simply not feasible. The same thing is true a fortiori of a bunkers based ETS.***

[1] Which raises the obvious question of why would even the most honest country enforce a tax which it is not going to receive only to push its bunkering business elsewhere.

3 Monitoring Stack Gas Emissions

Mark Twain is supposed to have said "It's not what we don't know that's the problem. It's what we know that ain't so."[2] The entire ship-owning community has assumed that monitoring ship stack CO2 emissions in not feasible, or at least not economically feasible.

In fact, CO2 stack emissions can be monitored to an accuracy of better than +/-2% in a reliable, tamper-proof, difficult to spoof manner for about $50,000 per ship. And as a bonus, we can throw in a direct, encrypted transfer of the data via satellite to a central processing entity.

Stack gas flows and composition are being measured all over the world. It is multi-hundred million dollar business. Beginning January, 2010, the USA EPA required 4,671 American installations to continuously monitor CO2 emissions.[3] This GHG program builds on the Acid Rain Program (ARP) which has required continuous monitoring of stack SO2 since 2000 or earlier.

There are several highly competitive technologies for doing this. I will mention just one as an example. We need both total gas volume and the CO2 concentration of the gas.

1. Measure volumetric flow by ultra-sonic pulses. This works by measuring the difference in travel time of sound pulses sent downstream and upstream in the stack. These systems cost about $10,000. The system is actually measuring gas flow velocity along the path of the beam and is accurate to 0.1 m/s. A typical ship stack velocity is 30 m/s, so we are talking +/-0.3%.
2. Measure CO2 concentration via absorption spectroscopy. This system uses a laser to project a beam across the stack. The frequency of the beam is tuned to an absorption line of the gas of interest. The received signal is analyzed for strength and line shape. Since the bandwidth of the beam is very narrow, only the gas of interest is picked up. Accuracy is better than 2% of reading. These systems cost about $35,000. One analysis box can support multiple beams (typically four). (Sulfur and NOx control regimes could piggyback on the CO2 system by simply adding two more laser modules to the analyzer.
3. The data would be collected in a sealed computer, and periodically (say once a day) transmitted directly to a central processing entity, presumably IMO, via satellite. Cost of the data storage and communication device, less than $5000, assuming we use the ship's Satcom system. There is no reason not to as long as the message is properly encrypted and electronically signed.[4]

All this equipment is off-the-shelf. They are type approved not by a compliant, vendor-paid, Classification Society, but by real regulatory bodies such as the USA's EPA, Germany's TUV, and the British MCERTS. All that's required is a bit of application specific software, most of which is already available.

There are several points to be made about such a system:

No by-pass First and foremost, the system is extremely difficult to by-pass. By-passing an engine fuel flow meter or a bunkers transfer gage is child's play. And the evidence of such by-passing can be cleaned up in less than a hour. But a VLCC will generate up to 300,000 m3/h of stack gas. By-passing even a modest portion of this flow will require major modifications of the ship's exhaust system, which would be very difficult to hide from port state inspectors. The modifications would require the connivance of a large part of the crew, exposing the owner to whistle-blower risks. Right now it is the whistle-blowers that the owners fear most. This system involves the crew in a way that playing paper-work games does not.

No paperwork The data goes direct to the IMO. There is no dependence on the ship or the bunker supplier or any third party inspector or a contra-motivated bunkering nation. There will be no forgery, for there is no paper to forge.[5]

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[2] Actually Twain probably never said this. The quote is more properly attributed to a competitor, Josh Billings, demonstrating the accuracy of the aphorism.

[3] Regulatory Impact Analysis for the Mandatory Reporting of GHG Emissions Final Rule. These plants extend down to 25 MW thermal *input*, about the size of a Aframax tanker power plant. The EPA estimates the cost of the hardware to do this at $44,403 plus about $8,000 for installation (Table 4.2a)

[4] A dedicated satcom would add less than $10,000 to the cost of the system.

[5] At least not before the data gets to the IMO. IMO will have to enforce the honesty of the data collection staff in much the same way a national mint enforces honesty on the people who print the money. But we are talking about a handful of people in a tightly controlled environment.

Nearly tamper-proof Once the data is collected it is nearly impossible for the ship to change it. The data would not only be in a sealed black-box, but it would be immediately check-summed and encrypted. If someone were able to break into the emissions computer, no one other than the software designers would know how to take advantage of the break-in. And any attempt to break into this box would send an alarm to IMO and expose the ship to special inspections and fines.[6]

Difficult to spoof There are no moving parts, no sample extraction system whose tubes might be "re-directed". Whatever the would be spoofer attempts to do, it has to be done in the middle of a hot stack. The crew would have to be involved. It has to affect the whole beam.[7] And it can't interfere with the beams in a manner the system can detect. Furthermore, both the ultrasonic sensors and the laser are set up to send an alarm if someone attempts to fiddle with them, or even generates a clearly anomalous signal. The probes themselves would be sealed to the stack, both physically and electronically, so any attempt to remove them would set up off alarms, and result in broken seals.[8]

The cost of enforcement is almost in the noise. Assuming a $50 per ton CO2 tax, a $50,000 package would be paid for with 300 tons of fuel burn, three full-power steaming days for a VLCC.[9] If a system alarmed, we will need inspectors to go on-board and find out what happened, but this will be an exceptional case. If a system stopped reading or the readings are anomalous, the ship would be charged an amount that is a generous upper bound on what she could have emitted during the period the system is down or malfunctioning, as the ARP program does now. Thus, the owner will be strongly motivated to keep the system well maintained.

In short, ***monitoring of ship-based CO2 emissions is not only feasible, it is cheap.***[10] Most importantly, there is no opportunity for collusion between the people that are supposed to be collecting the tax, and those that are supposed to be paying it.

4 Using the Data

The next question is: how should the emissions data we have collected at IMO be used? CTX thinks the answer is obvious: charge the polluter for his pollution. Send the shipowner a bill for his emissions. This is discussed in some detail in the next section. However, this is not the only possible use. The emissions data could be used.

As a check on a bunkers tax based system If we stubbornly stick with a bunkers based tax, stack gas monitoring could make the system work. If the stack emissions did not match the Delivery Ticket claims, then an investigation and presumably fines, etc would follow. CTX think this is a needless, inefficient, costly, messy complication of a direct emissions tax. But it could be done

To enforce a cap-and-trade system CTX has argued strongly in favor of a tax over a emissions permit trading system. But if we were to impose an ETS rather than a tax, it should be done via stack gas data not bunkers purchases. And an ETS, for all its faults, is vastly superior to command and control legislation, especially FEDI

To enforce mandated standards Last and least, the system could be used to enforce arbitrary standards. Such regulation is bound to be inefficient, full of loop holes, biases, and unintended consequences, and prone to all kinds of political influences.[11]

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[6] By the same token anyone who attempted to switch out the emissions computer for another designed to send false signals to the IMO would need to know the code

[7] One could imagine for example some kind of barrier or deflector just upstream from the sonic beam path which would slow the gas flow along the path But such a barrier would have to be large robust piece of structure easily detected in a number of ways

[8] The data would be automatically audited upon receipt at the IMO for alarms malfunctions and simply suspicious numbers. Once again the program can learn from the successful ARP procedures

[9] In fact, the system could be given to the owners

[10] The system could be economically installed on ships that burn as little as 2 TPD of fuel (400 kW) At $50/t CO2, the payback on such a ship (boat?) would be about a half a year. Since the data collection is fully automated, the marginal administration cost of adding another ship to the database is negligible.

[11] The most basic unintended consequence of EEDI is that it won't reduce CO2 emissions at least not from sectors where slow-steaming is practiced, which includes tankers, bulk carriers, and big containerships.[3]

It flies in the face of all we know about intelligent regulation. It is the wrong thing to do. But it could be done.

5 A Direct Emissions Tax

For all the reasons discussed in [2] not to mention 100 years of economics literature, CTX believes that the obvious use of the emissions data is a direct tax. Once a month the central data processing entity, which for now I will assume is IMO, would send the owner a bill for his emissions.

This raises a number of implementation issues, which must be addressed:

Price What should the level of the tax be? Economic theory tells us that the price of a ton of CO2 injected into the atmosphere (regardless of source) should be the marginal social cost of that ton of CO2.[12] Unfortunately, no one knows what that is. Current prices range from about \$15 per ton (EU ETS permit price) to about \$150 per ton (Swedish carbon tax) IMO will have to make a guess. CTX recommends starting out on the low side, say \$25 to \$50 per ton CO2, with the intention of probably increasing the tax in the future.

What's important in CTX's view is that, whatever the tax is, it be fixed for at least 4 years. This is required to give the owners the certainty they need to make long-term investments in CO2 reducing technology. Every 4 years IMO would meet to discuss adjusting the price. Ideally, over time the international shipping tax would follow similar CO2 taxes prices in other sectors.

Getting Paid Sending out an invoice is not the same as actually collecting the tax. Very large sums will be at stake. Owners have the ability to magically disappear and re-appear in another corporate guise; and IMO has no police power. To control this the tax must be levied on the ship. In the event of non-payment, IMO would send out an alert to the flag state and the port states who are party to the Convention. If the money is not forthcoming in a reasonable amount of time (with interest), the port states would be empowered to detain the ship, until the monies are paid. Failing such payments, the ship would be auctioned off to pay the claims.[13] ***As long as the bulk of the major port states detained ships for non-payment***, any non-paying owner would either lose his ship or be forced off all the world's major trade routes. The key is the port states.

However, the flag states should have an obligation as well. Flag states which tolerated non-paying ship owners would be black-listed by the port states supporting the legislation. This would force flag states to either enforce the tax, or be relegated to ships that could trade only in the back-waters.

Term Charters There is a potential problem associated with taxing the ship. When a ship is term chartered, the term charterer becomes the effective owner. He has control over what bunkers are purchased, where the ship goes and how fast, in other words, how much CO2 the ship produces. For the system to work, the term charterer, not the owner, must end up being charged the cost of his pollution. This will require reasonably minor changes in the term charter contracts (known as charter parties). All that is needed is a charter party clause that makes the term charterer explicitly responsible for the ship's CO2 emissions as billed by IMO during the duration of the charter.[14] IMO will still bill the ship, but the owner becomes a pass-through. The owner will still have to collect from the charterer but this is an age old problem, and the owner has a number of weapons at his disposal, including withholding discharge in the event of non-payment.

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[12] Once we have internalized the cost to society of emitting a ton of CO2 by imposing a tax equal to the social cost of the most expensive ton of pollution, ***our job is to do nothing else***. Just sit back and let the market go to work. Mandatory requirements that happen to be efficient given this tax will have no effect since the shipowners will adopt them automatically. Any inefficient requirement won't be adopted which is exactly what we want. In other words, once the proper tax is in place, any mandated requirement is either unnecessary or bad for society. EEDI falls into the latter category.[1]

[13] At any given time, at most three or four months of the tax will be at risk. Any ship that is worth less than four months of her CO2 tax should be pulled off the water and scrapped.

[14] Net of any penalties due to system malfunction.

The whole concept of a pass-through is not new. Some port charges and canal tolls are currently handled this way. In fact, a whole body of law called a maritime lien has developed around the concept of making the ship responsible for non-payment of charterer expenses. Nonetheless the enabling legislation must make explicit the owner's right to require repayment of the CO2 tax from a term charterer (and sub-charterers). It's little different that asking a landlord to collect an electricity bill from a tenant.

6 The Scramble for the Rent

The final 40 billion dollar a year question is: where should the money go? This is a political issue faced by any system that puts a value on a public good. And it is an issue into which CTX will not venture. We will say only that the proceeds should be divied up in a way that:

Makes the tax politically feasible Unless the tax is enacted, the whole exercise is pointless. This probably means that a portion of the proceeds has to go to the flag states.

Does not compromise the price mechanism This would occur, for example, if the flag states, competing for owners, rebated a portion of the tax revenues to their owners. This would seem obvious, but apparently it was not to the designers of the EU ETS system, which gives away valuable permits on the basis of past pollution, thereby destroying a portion of the incentive to reduce emissions which reduction would cost the polluter some of next year's allocation.[15]

7 Conclusions

1. A carbon tax for international shipping based on tracking bunker fuel purchases cannot be feasibly implemented and enforced. This conclusion hold a fortiori for a bunkers based cap-and-trade.
2. A carbon tax based on direct stack measurement of CO2 emissions is not only feasible, it is cheap, and it would be far, far more difficult to evade than a bunkers based scheme.

References

[1] J. Devanney. Eedi, a case study in indirect regulation of co2 pollution. Technical report, Center for Tankship Excellence, 2010.

[2] J. Devanney. Efficient, safe reduction of co2 emissions from shipping. Technical report, Center for Tankship Excellence, 2010.

[3] J. Devanney. The impact of eedi on vlcc design and co2 emissions. Technical report, Center for Tankship Excellence, 2010.

[4] Marintek et al. Second imo ghg study 2009. Technical report, IMO, 2009. MEPC 59/24/Add. 1.

[15] The shows up most vividly in the new entrant and closure context. New CO2 emitting plants are given valuable permits for free, but a new nuclear plant that produces nil CO2 is not. Similarly an old, inefficient CO2 belcher has a strong inducement not to shut down and lose its permits. The perverse incentives are obvious.

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CHAPTER 4

Bunker costs in container liner shipping: Are slow steaming practices reflected in maritime fuel surcharges?

Pierre CARIOU and Theo NOTTEBOOM

Abstract

Slow steaming has been implemented by the main liner shipping companies since 2008. The reduction in vessel speed affects fuel consumption and should be reflected within the fuel surcharges paid by shippers. This article assesses if this was the case for the main outbound European container trades from the port of Antwerp. Through an extensive analysis of liner service characteristics, fuel costs and fuel surcharges this paper provides an answer to three research questions (a) How significant are slow steaming practices in container liner shipping?; (b) What is the impact of slow steaming on fuel consumption and liner service characteristics?; and (c) To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines?

1 | Introduction

Slow steaming, or the reduction in the sailing speed of maritime vessels, has become an increasingly common practice in container liner shipping as the amount and unit size of available vessel capacity rises and the price of fuel increases (Alphaliner 2010a). Slow steaming can help to absorb vessel overcapacity as a slower commercial speed will require more vessels to maintain the same service frequency per liner service. Slow steaming has also proven to be an effective way to save on fuel costs and to restore liner shipping company profitability. Slow steaming is also claimed to reduce environmental emissions by ships at sea (Kollamthodi et al., 2008; Buhaug et al., 2009; Corbett et al., 2009; Cariou, 2011; Faber et al., 2010). However, slow steaming practices added a new source of contention between shippers and ship-owners regarding fuel surcharges, known as Bunker Adjustment Factor or BAF implemented by shipping lines since 1974 (Menachof and Dicer, 2001:143). Shippers' organizations such as the European Shippers' Council have objected for years that the way BAFs are determined is opaque, without uniformity, and involves a significant element of revenue-making (ESC, 2003: 20, ESC, 2006:20). The anticompetitive effect of BAF was already subject to studies shedding light on a tendency of BAF of amplifying bunker prices rises (Cariou and Wolff, 2006; Meyrick and Associates, 2008) impacting negatively consumers prices (Karamychev and van Reeven, 2009), and on the fact that a combination of decreasing freight rates and fuel costs provide incentive to shipping lines to stall the downward correction of the BAFs (Cariou and Notteboom, 2011). Slow steaming added an additional dimension to the question whether fuel surcharges are a revenue-making instrument to shipping lines or only about cost recovery of incurred fuel costs.

This article adds to former studies in incorporating the impact from slow steaming. It investigates if slow steaming practices on major trade lanes are reflected within the BAFs charged to shippers by shipping lines. The paper addresses the follow research questions:

- How significant are slow steaming practices in container liner shipping?
- What is the impact of slow steaming on fuel consumption and liner service characteristics?
- To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines?

To answer these research questions, this paper presents first how fuel surcharges are set up by shipping lines. Section 3 presents a methodology for estimating the impact of slow steaming on the average fuel consumption of containerships, and consequently, on BAF. Section 4 applies the methodology to 618 vessels deployed in 104 services sailing from/to Europe in January 2010, and provides a comparison with 2008, the pre slow steaming era. Section 5 presents the results of a BAF vs. fuel costs analysis for 90 O/D relations using Antwerp as port of departure. Section 6 provides the conclusions and explores avenues for further research.

2 | Fuel surcharge practices since 2008

The application of fuel surcharges in liner shipping dates back to the liner conference era (Notteboom and Cariou, 2011). In principle, carriers cover basic bunker costs, while fuel surcharges only apply to changes above a certain level. Fuel surcharge practices have considerably evolved since the withdrawal in October 2008 of the European liner conferences block exemption (Regulation 4056/86). Their dismantling meant that container shipping lines calling at European ports were banned from collectively setting freight rates and other additional surcharges such as bunker and currency surcharges, and from publishing common tariffs. In doing so, this reduced the commonality amongst pricing structures and surcharges that existed before, with freight rates and surcharges being negotiated directly between shippers and ship-owners and with container lines using sometimes diverging calculation methods for determining fuel surcharges.

Despite these changes, guidelines still exist and are geared mostly for small shippers. For instance, *Maersk Line* published in early 2008 a formula for determining its BAFs, with the aim of creating more transparency (Maersk Line BAF calculator, 2010). The formula known as 'Maersk Line BAF Calculator' builds on two components: Bunker price changes in t x Trade specific constant so that:

$$BAF_t\text{=(Bunker Price}_t\text{-Base)x(Consumption}_{TEU/day}\text{)x(Transit Time}_{day}\text{)x(Imbalance Factor}_t\text{)}$$

Bunker price change is extracted from the difference in t between a representative basket of prevailing bunker prices in a specific trade (BP_t) and a predefined Bunker base element for a trade (Base) or "normal" bunker cost already included in the freight rate. The trade specific component is function of the consumption in metric tons/TEU/day of a representative vessel, a transit time in days and an imbalance factor. To provide an example from Maersk Line BAF calculator, for a 20 foot dry container exported from Belgium to China (outbound) in November 2010, the reported BP_t was 435 USD/ton, the Bunker base element equaled 65 USD/ton, the vessel consumption is 0.0256 mt/TEU/day, the transit time 35.6 days and the trade imbalance equal to 0.5. It led to a BAF of 2x[435-65]x[0.0256x36.5x0.5]= 345 USD to be paid for each FEU, a value close to the one retrieved from CMA-CGM on-line BAF calculator (370 USD/FEU).

Delmas/OTAL (part of CMA-CGM group) indeed also developed since September 2008 its own BAF formula, following the dismantling of the Europe West Africa Trade Agreement (EWATA). Similarly, an average reference fuel oil price, fuel oil consumption per full TEU carried and an average fuel oil price in t-1 are used for calculation of the BAF applicable in month t+1. Another example relates to *OOCL*. Its fuel surcharge policy is based on specifics on trade lane, service loop, vessel size and round voyage capacity on a monthly basis. OOCL uses a neutral third party provider of bunker price information (Platts) for the major locations around the world and selected a number of representative vessels for calculating fuel consumption, a more manageable way than taking into account the actual consumption of all their operating vessels. In general terms, the formula is similar to *Maersk Line* or *Delmas/OTAL*. As for many other shipping lines, OOCL made a policy decision not to disclose the values for each component in the formula. If the bunker price in a month moves beyond the agreed band of USD 25 (either up or down), then it will trigger a recalculation of the total BAF payable in the following month (see Notteboom and Cariou, 2011). The new calculation method led to a BAF that is lower compared to the previous liner shipping conference environment.

The new fuel surcharge calculators have not wiped out potential sources of contention between shippers and ship-owners. Shippers express concerns about the confidentiality of some inputs used in calculating the BAF. Examples include the projected cargo load for *OOCL* or imbalance factor for *Maersk Line*. The representative fuel consumption of vessels deployed on a specific trade is another major source of contention in the fuel surcharge calculations. Shippers face difficulties in verifying vessel consumption figures, which leads to some doubts in shippers' circles about whether the fuel savings caused by slow steaming practices are fully reflected in fuel surcharges.

Using the former example of a container shipped from Belgium to China, if the decision to slow steam a service reduces by 10% the vessel fuel consumption and is not factored in, this generates *ceteris paribus* around 34.5 additional USD per FEU (10% of $345) which for a typical service with 10 x 4,000 TEU vessels sums up USD 690,000 additional revenues per trip. However, these revenues are not without a cost (Kollamthodi et al., 2008; Corbett et al., 2009; Faber et al., 2010) as: (a) vessels are spending more time at sea reducing the annual payload; (b) in case of significant speed reduction, additional vessels are required to keep a weekly frequency in the ports of call (Notteboom et Vernimmen, 2008; Psaraftis et al., 2010) and (c) for shippers, in-transit inventory costs increase with transit time (Efsen et al., 2010; Bergh, 2010; Cariou, 2011). Next section presents a methodology to assess the first two effects.

3 | The overall impact of slow steaming

Using an extended version of *Maersk Line* BAF calculator, the BAF to be charged per FEU for a service *s* with *n* vessels can be estimated as follows:

$$BAF_{FEU} = 2.(BP_t - Base)\sum_{k=1}^{n}\frac{[(\alpha_s FC_{k,sea} + (1-\alpha_s)FC_{k,port})]}{[TEU_s]}.Transit\,time_s.IF_s \quad (1)$$

With $FC_{k,sea} = SFC_k.EL_k.kWh_k$ (2)

And:

$FC_{k,sea}$	the fuel consumption at sea per day for a vessel k
$FC_{k,port}$	the fuel consumption in port per day
Rot_s	the transit time in days with $\alpha_s.Rot_s$ days at sea and $(1-\alpha_s).Rot_s$ in ports
IFs	the imbalance factor for service s
TEU_s	the total capacity in teu deployed in a service s
SFC_k	the Specific Fuel oil Consumption in g/kWh
EL_k	the Engine Load in %
kWh_k	the engine power in kWh

Slow steaming impacts both on the fuel consumption of each individual vessel *k* ($FC_{k,sea}$) and on the characteristics of a service *s*. Focusing on the first component, for containerships carrying more than 1,000 TEU which are using two stroke marine diesel engines, slow steaming reduces the main engine fuel consumption at sea ($FC_{k,sea}$), with a limited effect for the auxiliary engine and consumption in port. Under normal condition, vessels were built for sailing at a speed close to design speed or an Engine Load between 70-90% of maximum continuous rate (MCR), a level at which the SFC is optimal - around 170-195 g/kW (MAN B&W Diesel A/S, 2008; Buhaug et al., 2009; Psaraftis et al., 2010; Faber et al., 2010). This value varies with the engine type and with weather conditions on route. The impact of slow steaming on fuel consumption depends on the magnitude of the speed reduction (MAN B&W Diesel A/S, 2008; Buhaug et al., 2009; Psaraftis et al., 2010; Faber et al., 2010). As long as the speed is reduced in small amounts up to a 10-15% reduction, the SFC remains fairly constant. As a rule of thumb, engine power is related to ship speed by a third power. When speed is reduced by more than 10% the SFC increases by up to 10%. This latter figure varies on the basis of engine characteristics, vessel type and engine age as engine retrofitting can limit the increase in SFC.[1]

The second impact from slow steaming is on the transit time and on the number of vessels to be deployed within a service (Notteboom and Vernimmen, 2008; Psaraftis et al., 2010; Cariou, 2011). The number *n* of vessels to add remains difficult to estimate as this primarily depends on what the shippers can bear in terms of increase in inventory costs (Bergh, 2010), and on the initial service characteristics in terms of the round voyage distance, the number and order of port calls, the frequency, the time buffers in the liner service, the fleet mix and the imbalance factor. As an alternative, some ports of call can also be dropped. Hence, a decision to opt for slow steaming requires a careful analysis of the trade-off between a positive impact resulting from the reduction in fuel consumption at sea and two negative effects: the need for additional vessels in case of significant reductions in speed; the increase in the time spent at sea, and therefore, in transit time. The final impact on BAF is then to be multiplied by differences in bunker prices, transit time and by the imbalance factor for a service or trade.

4 | The impact of slow steaming on fuel consumption at sea

Two sets of information are required to assess the impact of slow steaming on fuel consumption for a specific trade: (a) the number of services for which this strategy was implemented and how these services were affected, and (b) the vessel characteristics, in particular the reduction of the average fuel consumption as a consequence of slow steaming. To assess the extent of slow steaming per trade and the impact on fuel consumption, information was first gathered from three sources: from Alphaliner database (Alphaliner, 2010b) in January 2010 that was merged with data from the Lloyd's Register Fairplay database (2009); and data on 90 outbound port-to-port relations with Antwerp as the port of loading in July 2008 and November 2010. The names of the shipping lines included in the dataset are not disclosed for confidentiality reasons.

The initial data contains in Alphaliner database is for 174 liner shipping services and a total of 825 vessels deployed. The status of a service with respect to slow steaming was retrieved from comments in the database on liner service history. Services were then selected for 6 representative European container trades reducing the sample to 104 services with 618 vessels (table 1). For each trade, the mean age, design speed and engine power in kWh was then retrieved from LRF (2009).

Europe/Far East is the first trade with 39 services - 37% of the 104 services - and with 273 vessels deployed - 44% of the 618 vessels. An interesting feature is disparities on the extent of slow steaming from one trade to another. For instance, 79.5% of Far

[1] According to one-year data gathered from a private operator for a 4,300 TEU containership with a modern engine, the SFC would only increase from 195 to 198 g/kWh and the fuel consumption at sea would fall by around 60%.

Europe/Far East services are reported under slow steaming, contrary to services to Africa (6.3% of services). These results are roughly proportional, to the exception of services to Oceania, to vessel size and sailing distances. Regarding fleet structure, Far East is the trade on which the mean size of vessels is the largest, and North America, Oceania and Africa are trades for which vessels are the oldest. This later result is likely to influence the power needed, as age can be seen as a proxy of technology. Another important element to consider is differences in the structure of trade, and in particular, the number of reefers. Information gathered from private sources stresses for instance that the consumption of the auxiliary engine for a typical 4000 TEU vessel increases from 4 to 20 tons due to the number of reefers carried.

Table 1. Main characteristics of 174 European liner services in January 2010

	Number				Mean			
	Services	% SS	Vessels	% SS	TEU	Age	Design Speed	Engine kWh
Africa	16	6.3	68	5.9	2662	9	21	23,570
Far East	39	79.5	273	79.5	7970	5	25	58,778
India/Pakistan	11	72.7	63	74.6	4509	7	23	39,202
Latin /South America	21	28.6	131	28.2	3251	7	22	27,639
North America	14	14.3	74	25.7	3983	11	23	32,971
Oceania	3	33.3	9	33.3	2940	10	22	24,427

SS = slow steaming

Source: Authors from Alphaliner database (January 2010) and LRF (2009)

Table 2 provides additional information. It is based on a selection of 90 outbound services with Antwerp as a port of loading in July 2008 and October 2010. The port pairs considered are all connected via direct line-bundling services, meaning that no sea-sea transhipment takes place at intermediate hubs along the route. We distinguish two periods of analysis. The first period is June-July 2008, when the liner conference system still existed. As such, the case-study for the first period provides a snapshot of fuel surcharge practices in the liner conference era at a time when fuel costs reached unprecedented heights and when slow steaming was not yet implemented. The second period is October 2010 and is a time when slow steaming has been implemented. Indeed, if slow steaming practices already started in the summer of 2008, particularly on the Europe-Far East trade, to cope with the high bunker costs (as reported by Notteboom and Vernimmen, 2008), however, the full impact became visible in late 2009 and 2010. Indeed, more and more shipping lines decided to opt for slow steaming, not only to save on fuel costs but also to absorb the vessel surplus capacity created by the economic crisis. Information on the average one-way distance relates to the distance from Antwerp to the port of discharge, including the diversion distance to call at en-route ports of call is also estimated. The nautical distances were calculated using the Dataloy distance tables. In a few cases, up to seven ports of call are positioned between the loading port Antwerp and the port of discharge. At the other extreme, Antwerp sometimes acts as the last port of call in Europe while the port of discharge is positioned as the first port of call in the overseas service area.

Table 2 also depicts the average transit times between Antwerp and the overseas destinations and the average vessel size per trade route. Both elements are key variables in determining the fuel consumption per container carried together with commercial speed of services. The commercial speed of the vessels was determined using shipping lines' information on total transit times and port time. We decomposed the real transit time on a port-to-port basis into total sailing time, average port time per intermediate port of call and canal transit time. Differences in vessel size with values reported in table 1 are explained by differences in the characteristics of vessels deployed from Antwerp with those of services from Europe.

Table 2. Main characteristics of services in July 2008 and October 2010 of the set of O/D relations considered with port of loading Antwerp

	Services	Distances	Size in TEU		Transit time in days		Commercial speed in kt	
	Observation	In nm	2008	2010	2008	2010	2008	2010
Africa	15	4731	2525	3903	17.5	17.8	20.1	19.6
Far East	24	11183	7563	9308	25.6	29.1	22	18.4
India/Pakistan	9	7165	3963	4505	20.9	24.8	21.3	19.1
Latin/South America	23	5765	3700	4180	17.3	18.1	20.7	19.8
North America	12	5096	4102	4283	16.6	17	20.3	19.5
Oceania	7	13136	2922	2653	42.9	40.4	20	20.1

Notes:
(a) Including the diversion distance to call at en-route ports of call on liner service
(b) Including total sailing time, total port time at intermediate ports of call on liner service and canal transits

Two markets experienced a decrease in commercial sailing speed. Europe/Far East with a significant reduction on average of 16% in speed and India/Pakistan with a mean decrease of 10%. Furthermore, a decrease in speed does not automatically increase proportionally the transit time as some ports are dropped for some services. Indeed, on most trade routes the average transit time, together with the average vessel size have increased between July 2008 and October 2010, indicating a trend towards the use of larger unit capacities sailing at slower speeds compared to their design speed. The high transit time is not only caused by slow steaming: the use of ever larger container vessels implies a longer total port time on the route since more and more containers need to be handled when the vessel calls at a port. The cargo volume increase is typically not offset by a higher terminal productivity, in net terms leading to more time spent in ports during a round voyage. Also a change in the order of port calls can have an impact on the total transit time between Antwerp and the overseas port of destination. Only Europe-Oceania has seen a decrease in transit time and vessel size.

To estimate the ship's average fuel consumption per trade in 2008 and in 2010, we retrieved information on the design speed and engine power of containerships from LRF database (2009). For the design speed, we considered the average value by vessel categories. For instance, containerships sailing from Antwerp to Africa in 2008 are on average of 2,525 TEU, and the 107 vessels with a carrying capacity between 2,000 and 3,000 TEU reported in LRF (2009) have an average design speed of 22.3 knots. To determine the engine kWh[2], we approximated a log-linear relationship between engine kWh and TEU, with Engine $kWh=exp^{2.97}.TEU^{0.89}$ and $R^2=0.86$. In our former case, it leads to an engine power of 21,444 kWh.

We then estimated the fuel consumption per day using the design speed (22.3), the commercial speed (20.1 in 2008) and equation 2 for a SFC assumed to remain constant at 190 g/kWh. Fuel consumption is then due to engine power required and speed which is assumed to be related to ship speed by a third power. For our typical vessel sailing to Africa in 2008 at a commercial speed of 91% of design speed, (20.1/22.3), the mean fuel consumption per day at sea is $24x0.91^3x190x21,444/1000000=$ 74 tons of fuel burned by day at sea in 2008 (at design speed, the ratio is 1 instead of 0.91). Table 3 presents results on fuel consumption per day for all trades in 2008 and 2010. It also presents similar results using the fuel consumption per day/TEU reported in Maersk Line BAF calculator in November 2010.

Table 3. Fuel consumption at sea of the main engine in July 2008 and October 2010 in tons/day

	2008 at design speed	**2008 at commercial speed**	**2010 at commercial speed**	**Maersk Line***
Africa	98	74	95	191
Far East	261	178	131	238
India/Pakistan	146	124	83	160
Latin/South America	138	107	86	218
North America	151	91	84	156
Oceania	111	83	77	106

** Reported value in November 2010 x by estimated size of containerships in Table 2*

Differences between estimated values and reported value by Maersk Line can be explained by the characteristics of services for this company compared to services originated from Antwerp. However, several general conclusions can be drawn. Firstly, values reported by Maersk Line are closer to the fuel consumption at design speed, rather than on fuel consumption at commercial speed. Secondly, for some trades, namely Africa and Latin/South America a huge gap exists between estimated and reported values.

[2] We also considered age but without significant results. A likely explanation is that vessel size already captures the influence of age.

5 | Comparison between fuel costs, BAF and freight rates

So far, the analysis focused only on one part of the equation: the impact of slow steaming on the average fuel consumption in metric tons per day. The analysis of the impact on BAF and its share within the total price to be paid by the line's customers is more difficult to assess. For the former, to the base freight rate, a series of surcharges such as the BAF, the CAF (currency adjustment factor), the THC (Terminal Handling Charges), piracy surcharge (Gulf of Aden/Suez transit), port congestion surcharges (if any) and often also container-equipment related surcharges (e.g. demurrage charges, detention charges, equipment handover charges, equipment imbalance surcharge, special equipment additional for an open top container or heavy container, etc.) need to be considered. This section focuses first on the impact on BAF while the base freight rate emerges later in the analysis.

Table 4. Estimated fuel costs and reported BAF in July 2008 and October 2010

July 2008 (IFO380 = US$ 585 per ton, MDO = US$ 1,125 per ton)

Port of loading = Antwerp Region of port of discharge	Average fuel costs per FEU carried (a)	Average BAF per FEU 1 Oct 10	Difference BAF - fuel cost per FEU carried	Standard Deviation	Minimum difference BAF - fuel costs	Maximum difference BAF - fuel costs	Ratio BAF versus fuel cost per FEU carried	Base freight rate per FEU 1 Oct 10	Ratio BAF versus base freight rate per FEU carried
	US$	US$	US$	US$	US$	US$	Ratio	US$	Ratio
Africa	1112	1329	217	134	-42	286	1 20	1798	0.74
Far East	374	1003	629	165	426	846	2.68	93	10.82
India / Pakistan	913	847	-66	25	83	-33	0 93	592	1.43
Latin and South-America	789	1308	519	352	11	1119	1 66	1628	0.80
North America	662	1195	533	75	296	562	1 81	371	3 22
Oceania	1691	1453	-238	58	-285	-176	0 86	1628	0 89

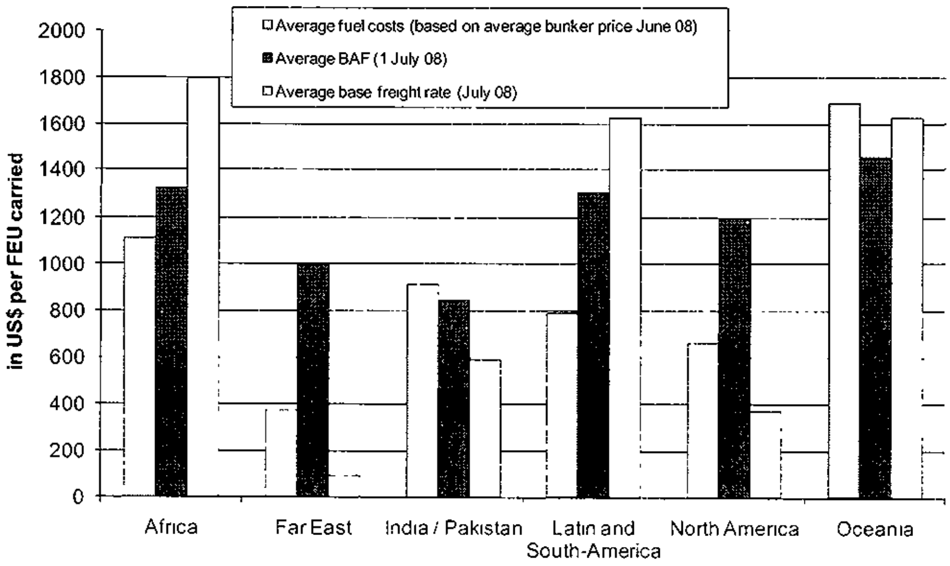
October 2010 (IFO380 = US$ 435 per ton, MDO = US$ 680 per ton)

Port of loading = Antwerp Region of port of discharge	Average fuel costs per FEU carried (a)	Average BAF per FEU 1 Oct 10	Difference BAF - fuel cost per FEU carried	Standard Deviation	Minimum difference BAF - fuel costs	Maximum difference BAF - fuel costs	Ratio BAF versus fuel cost per FEU carried	Base freight rate per FEU 1 Oct 10	Ratio BAF versus base freight rate per FEU carried
	US$	US$	US$	US$	US$	US$	Ratio	US$	Ratio
Africa	684	1077	393	163	110	531	1 57	1501	0.72
Far East	184	238	54	96	-84	116	1 29	702	0 34
India / Pakistan	458	733	280	74	192	362	1 61	669	1.10
Latin and South-America	464	1186	722	535	-162	1258	2 56	1828	0 65
North America	431	389	-42	61	-129	-1	0 90	1854	0 21
Oceania	1178	14.7	229	156	104	396	1 19	1841	0 76

The comparison between our estimates on BAFs and those observed in 2008 uses a bunker price of US$ 585 per ton for the fuel grade IFO 380, to which a US$ 1,125 for marine diesel oil (MDO) was added. These figures relate to the average bunker price in Rotterdam in the month of June 2008. Average bunker prices in September 2010 reached US$ 435 per ton for IFO 380 and US$ 680 per ton for MDO. For each port-to-port relation we included an imbalance factor retrieved as the mean value reported in Maersk Line BAF and similar values retrieved from the ratio between outbound-to-inbound BAF charged by CMA-CGM in October 2010. The mean value is 1.56 for services from Europe to Africa, 0.44 to Far East and 0.98 to Latin/South America, 1.28 to North America the remaining two trades being with a factor of 1. We assumed that the same imbalance factors applied in July 2008. The fuel consumption by the auxiliary engine is assumed to be equal to 10% of the consumption of the main engine (EPA, 2000), to which 10 tons per day at sea were added in order to account for reefers for services to Latin/South America. Table 4 reports final estimates for the BAF values.

Figure 1. BAF, fuel costs and base freight rate per FEU – port-to-port relations with loading port Antwerp

July 2008 (IFO380 = US$ 585 per ton, MDO = US$ 1,125 per ton)



October 2010 (IFO380 = US$ 435 per ton, MDO = US$ 680 per ton)

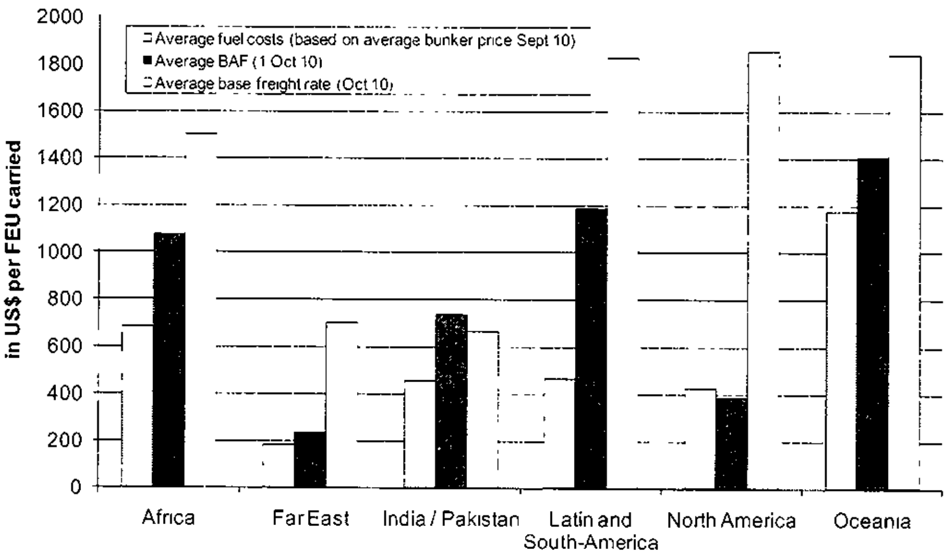


Table 4 and figure 1 bring together the main results of the analysis. Data relates to the transport of one FEU. The figures for BAF and the base freight rate were collected from freight forwarding companies and liner agencies in Antwerp. The following conclusions can be draw. First of all, the BAF per FEU carried is typically (much) higher than the average fuel costs per FEU that we estimated. These results confirm the earlier findings of Meyrick et al (2008) and Notteboom and Cariou (2011) who concluded that the BAF would involve an element of revenue-making for some trades. For June/July 2008, the BAF turned out to be slightly lower than the fuel costs in only 19 of the 90 cases. In October 2010 this figure amounted to 14 cases, most of these on the Europe-North America trade. The results underline that the revenue-making character of BAF has not disappeared after the abolition of liner conferences and the wider adoption of slow steaming. On the contrary, four of the six trade routes considered see an even larger gap between BAF and actual fuel costs. The revenue-making characteristic of the BAF became more significant on the shipping routes from Antwerp to Africa (from a BAF/fuel costs ratio of 1.2 in July 2008 to a ratio of 1.57 in October 2010; mainly caused by high fuel surcharges to West African ports), Latin and South-America (from 1.66 to 2.56; mainly caused by BAF practices to destinations in Mexico and the Caribbean), India/Pakistan (from 0.93 to 1.61) and Oceania (from 0.86 to 1.19). Except for Indian/Pakistan, these trade lanes have not been subjected intensively to a shift towards slow steaming. The widening gap between the fuel surcharges and the actual fuel costs on the India/Pakistan route demonstrates shipping lines clearly have not passed on the fuel savings resulting from slow steaming practices on this trade to customers. Part of the explanation might relate to the increasing risks of delays in Indian ports as a result of increased concerns over port congestion. However, if such were the case then congestion surcharges should be used as a means to compensate for delays, not the fuel surcharges. As also a number of West-African container terminals are plagued by severe port congestion, a similar point can be made on the high BAF/fuel costs ratio on the Europe-Africa trade. The fuel savings resulting from significant scale increases in vessel size on the African route (see table 2) have not resulted in a proportional decrease in fuel surcharges.

The Europe-Far East and Europe-North America routes are the only trade routes that have seen a relative narrowing of the gap between BAF and actual fuel costs. Fuel surcharges on the Europe-North America trade are on average no longer sufficient to cover the fuel costs, meaning that part of the fuel costs must be absorbed in the base freight rate. The Europe-Far East route provides the most interesting results, particularly in light of evaluating the impact of slow steaming on fuel surcharge practices. In the summer of 2008 shipping lines were still strongly overcharging customers for the incurred fuel costs (ratio of 2.08). Bunker cost per ton peaked in the summer of 2008 and shipping lines seized this opportunity to charge disproportionately high fuel surcharges. The situation eased somewhat in 2010 with most shipping lines now overcharging customers for the incurred fuel costs with BAFs typically at 10% to 50% above fuel costs (average ratio of BAF/fuel costs of 1.29). The increased adoption of slow steaming on this trade combined with the deployment of larger vessels has reduced the fuel costs per unit carried. This development did not lead to a widening of the gap between BAF and these fuel costs. While fuel overcharging is still common practice, more of the fuel cost savings are passed on to customers than in July 2008. The broader adoption of all-in rates and the use of relatively moderate fuel surcharges suggest that the Europe-Far East trade is becoming a trade route where shipping lines seem to have tempered BAF revenue-making strategies. Shipping lines' pricing practices on this trade route combined with a limited possibility for shippers to verify base data make it harder for shippers to prove that the savings generated by slow steaming are not passed on to them in an adequate way.

Variations exist in the difference between BAF and the estimated fuel costs per FEU (see minimum and maximum values in table 4). The spread in observations is particularly high for Latin and South America. A further investigation of the data stresses that the observed spread is mainly the result of differences in shipping lines' BAF policy for specific ports of discharge. The BAF strategy of shipping lines with respect to destinations in India/Pakistan, North-America and Oceania is more aligned.

6 | Conclusions

This paper aimed at incorporating the impact of slow steaming in the ongoing discussion on fuel surcharge practices of shipping lines. We analyzed the relation between slow steaming practices and BAFs by focusing on three distinct research questions: (a) How significant are slow steaming practices in container liner shipping?, (b) What is the impact of slow steaming on fuel consumption and liner service characteristics?, (c) To what extent has slow steaming changed the relation between fuel costs and fuel surcharges imposed on shippers by shipping lines? Table 1 showed that slow steaming has become a common practice on the Europe-Far East trade while it also gained in importance on a number of other trade routes. Slow steaming practices were initiated in the summer of 2008, particularly on the Europe-Far East trade, as a response of shipping lines to fast rising bunker costs. However, the full impact became visible in late 2009 and 2010 as more and more shipping lines decided to opt for slow steaming, not only to save on fuel costs but also to absorb the vessel surplus capacity created by the economic crisis. This paper showed that slow steaming leads to longer transit times and more vessels per liner service, and significantly reduces fuel consumption of vessels deployed.

A case-study including 90 port-to-port relations with the port of Antwerp as the base loading port demonstrated slow steaming has had some impact on the differential between fuel costs and the fuel surcharges imposed on shippers by shipping lines. The results underline that the revenue-making character of BAF has not disappeared after the wider adoption of slow steaming, but the results tend to differ according to trade route considered. The BAF revenue-making strategies of shipping lines have become weaker on the Europe-Far East trade, the main slow steaming trade, but stronger on the Europe-India/Pakistan trade, another major slow steaming liner route. On trade routes with a low slow steaming impact, the BAF typically outstrips the actual fuel costs by a factor of 0.5 to 1.5. The only noticeable exception is the Europe-North America trade with most shipping lines now no longer covering the fuel costs via BAF.

One recurrent explanation for the fact that slow steaming has not lead to a closing of the gap between BAF and actual fuel costs is that slow steaming generated additional costs. Indeed, shipping lines had to incorporate more vessels within services in order to keep the weekly frequency. However, this seems not a valid reason to shippers as they are typically paying more BAF for a liner service that shows a poorer performance in terms of transit time.

This paper does not pretend to provide a full answer to all pending issues in this area. While we could present a set of clear conclusions, there is room for further in-depth and comparative research on the relationship between BAF, slow steaming and the actual fuel costs. One obvious extension lies in broadening the scope of the case study to other regions, other shipping lines and other base ports. Such comparative research would reveal whether BAF policies are to some extent port-specific, carrier-specific or route-specific. Another field of further research lies in the analysis of the relationship between BAF, slow steaming and fuel costs on port pairs that are not linked to each other via direct services, but for which sea-sea transhipment in another port is needed before reaching the port of discharge (i.e. interlining, relay or hub-feeder systems). In our case-study, we have only considered direct liner services.

References

Alphaliner (2010a), Extra Slow Steaming to absorb over 2 percent of ship capacity, *Alphaliner Weekly Newsletter* 2: 1-2

Alphaliner (2010b), Retrieved (January 2010) from http://www.alphaliner.com/

Bergh, I. (2010), Optimum speed – from a shipper's perspective, *Container ship up-date DNV*, No 2 2010: 10-13.

Buhaug, Ø., Corbett J., Endresen, O., Eyring, V., Faber J., Hanayama, S., Lee, D., Lindstad, H., Mjelde, A., Palsson, C., Wanquing, W., Winebrake, J., Yoshida, K., (2009), *Second IMO greenhouse gas study*. International Maritime Organization, London.

Cariou P., Wolff F-C. (2006), An analysis of Bunker Adjustment Factor and freight rates in the Europe/Far East market 2000-2004, *Maritime Economics and Logistics* 8(2): 187-201

Cariou, P. (2011), Is slow steaming a sustainable means of reducing CO_2 emissions from container shipping? *Transportation Research Part D,* Forthcoming.

CMA – CGM (2010), http://www.cma-cgm.com/eBusiness/BAFFinder/Default.aspx.

Corbett, J., Wang, H., Winebrake, J. (2009), The effectiveness and costs of speed reductions on emissions from international shipping. *Transportation Research Part D* 14: 539-598.

ESC (2003), *The European Shippers' Council's submission to DG Competition of the European Commission on the review of Council Regulation 4056/86*, European Shippers' Council, Brussels

ESC (2006), *Response from the European Shippers' Council to the information note on 'Issues raised in discussions with the carrier industry in relation to the forthcoming*

Commission Guidelines on the application of competition rules to maritime transport services' published by the Directorate General for Competition, European Shippers' Council, Brussels, October.

Eefsen T., Cerup-Simonsen B. (2010), Speed, carbon emissions and supply chain in container shipping, *Proceedings of the International Association of Maritime Economists Conference*, Lisbon, 7-9 July.

EPA (2000), *Analysis of commercial marine vessels emissions and fuel consumption data*, United States Environmental Protection Agency, February.

Faber, J., Freund, M., Köpke, M., Nelissen, D. (2010), *Going slow to reduce emissions. Can the current surplus of maritime transport capacity be turned into an opportunity to reduce GHG emissions?* Sea at Risk publishing, Retrieved (August 2010) from http://www.seas-at-risk.org/1mages/speed%20study_Final%20version_SS.pdf.

Karamychev V., van Reeven P. (2009), Why Fuel Surcharges may be Anticompetitive, *Journal of Transport Economics and Policy (JTEP)* 43(2): 141-155

Kollamthodi, S., Brannigan, C., Harfoot, M., Skinner, I., Whall, C., Lavric, L., Noden, R., Lee, D., Buhaug, Ø., Maritnussen, K., Skejic, R., Valberg, I., Brembo J., Eyring, V., Faber J. (2008), *Greenhouse gas emissions from shipping: trends, projections and abatement potential*. Final Report to the Shadow Committee on Climate Change. AEA Energy, September.

Lloyd' Register Fairplay (2010). *World shipping encyclopedia*.

Maersk Line BAF calculator (2010), Retrieved (June 2010) from http://baf.maerskline.com/

MAN B&W Diesel A/S (2008), Propulsion Trends in Container Vessels, Copenhagen, Denmark.

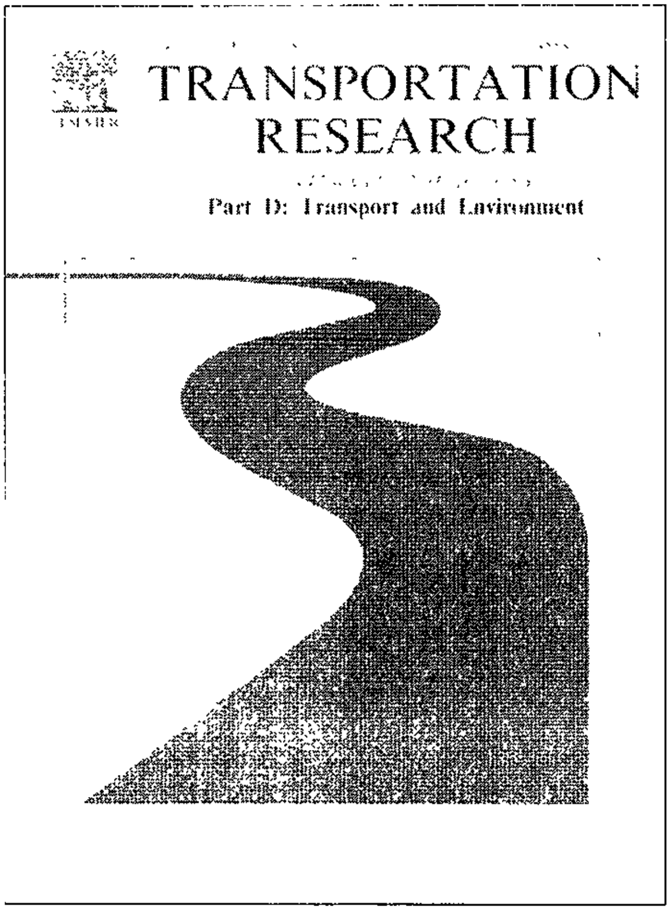
Menachof D.A., Dicer G.N. (2001), Risk Management methods for the liner shipping industry: the case of the Bunker Adjustment Factor, *Maritime Policy and Management* 28(2): 141-155.

Meyrick and Associates (2008), *Review of BAFs - Transatlantic and Europe/Far East trades*, Report prepared for the European Shippers' Council, Melbourne, May.

Notteboom, T., Cariou, P. (2011), Are Bunker Adjustment Factors aimed at revenue-making or cost recovery? Empirical evidence on pricing strategies of shipping lines, in: Cullinane, K., *International Handbook of Maritime Economics*, Edward Elgar: Cheltenham, forthcoming (April 2011)

Notteboom, T.E., Vernimmen, B. (2008), The effect of high fuel costs on liner service configuration in container shipping, *Journal of Transport Geography* 17(5), 325-337

Psaraftis, H., Kontovas, C. (2010), Balancing the economic and environmental performance of maritime transportation, *Transportation Research Part D 15: 458-462.*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Notes and comments

Is slow steaming a sustainable means of reducing CO_2 emissions from container shipping?

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ABSTRACT

Slow steaming strategies have been implemented by most shipping lines and significantly reduce CO_2 emissions from international shipping. This article measures the rate at which CO_2 emissions have been reduced for various container trades and estimates the bunker break-even price at which this strategy is sustainable in the long run. It is found that shows such reductions can only be sustained given a bunker price of at least $350–$400 for the main container trades.

1. Introduction

Slow steaming has become increasingly common in liner shipping as the amount of available capacity rises and the price of fuel increases. One positive effect of slow steaming is that it lowers CO_2 emissions that are proportional to the amount of fuel burned. This effect is worth studying, especially for container vessels, which represented 4% of all maritime vessels but generated 20% of emissions from international shipping in 2007 (Psaraftis Kontovas, 2009). Reducing a vessel's speed by 10% decreases emissions by at least 10–15% but also creates substantial losses in revenues (Psaraftis and Kontovas, 2010). This paper uses secondary data to provide a more accurate view of the impact of slow steaming on liner shipping CO_2 emissions since 2008, not on the global level but for specific trades subject to different rates of slow steaming.

2. Methodology

For containerships with a capacity of more than 1000 TEU using two-stroke marine diesel engines, a speed reduction from design speed (V_{ds}) to slow steaming (V_{ss}) for a vessel k impacts the main engine fuel consumption at sea ($ME_{k,sea}$), with a limited effect on the auxiliary engine[1] (Faber et al., 2010). Accordingly, the effect of a speed reduction on CO_2 emissions for a service with n vessels can be approximated as:

$$\Delta CO_{2\,V_{ds}-V_{ss}} = 3.17 \times \sum_{k=1}^{n} (ME_{k,sea} \times D_{k,sea} + ME_{k,port} \times D_{k,port}) = 3.17 \times \Delta FC_{V_{ds}-V_{ss}} \quad (1)$$

with

$$ME_{k,sea} = SFOC_k x EL_k x \text{ kW h}_k \quad (2)$$

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[1] We omit periods during which vessels are hotelling or transiting through canals. We also ignore the fact that the use of bow thrusters and the number of reefer containers affect fuel consumption.

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Table 1
Main engine consumption at sea in tons/day at design speed.

Vessel size (TEU)	LRF database[a]			This paper[b]		
	Number of vessels	Design speed V_{ds}	ME_k at V_{ds}	Number of vessels	Design speed V_{ds}	ME_k at V_{ds}
1000–2000	94	19.4	53	249	19.6	53
2000–3000	100	20.9	81	368	21.8	89
3000–5000	152	22.9	128	644	23.6	143
5000–8000	93	24.8	209	420	24.9	220
8000+	12	24.4	258	249	24.6	272

[a] Four hundred and fifty-one vessels for which consumption at sea is provided.
[b] Thousand nine hundred and thirty vessels for which the engine kW h is known.

where the emission factor in kilograms of CO_2 emitted per ton of fuel burned by the main engine is 3.17; $D_{k,sea}$ is the number of days at sea; and $D_{k,port}$ is the number of days in ports. The main engine's daily fuel consumption at sea ($ME_{k,sea}$) is the product of specific fuel oil consumption ($SFOC_k$), engine load (EL_k) and engine power (kW h_k). Vessels are built for sailing close to design speed, which is 70–90% of the maximum continuous rate (MCR), a level at which the SFOC is optimal and at around 180–195 g/kW h. This value varies by engine type and can change in different weather conditions. We assume that fuel consumption in port ($ME_{k,port}$) is 5% of the main engine consumption at design speed (US Environmental Protection Agency, 2000).

The impact of slow steaming on fuel consumption depends on the speed reduction As long as the speed is reduced in small amounts up to a 10–15%, the SFOC remains fairly constant, a rule of thumb is that engine power is related to ship speed by a third power. When speed is reduced by more than 10%, perhaps to 30%, as assumed here, the engine load decreases to around 40% of MCR and the SFOC increases by up to 10%; a figure that varies according to engine characteristics, vessel type and engine age.[2]

We assume that when a vessel is sailing at close to that is the pre-slow steaming era, the SFOC is 195 g/kW h and the engine load is 90% of MCR. When the speed is reduced by 30%, the SFOC increases to 205 g/kW h. For a typical 4000 TEU containership with a 43,000 kW h engine and a design speed of 24 kn, this implies that fuel consumption at sea is 182 tons per day at design speed. When sailing 30% slower, at 17–18 kn, the fuel consumption is 85 tons per day; a 55% reduction. This reduction in fuel consumption is applied to slow steaming vessels, although differences exist in terms of vessels and trades.[3]

With slow steaming, however, the rotation is stretched by ΔRot, the average number of miles travelled in a year per vessel falls, although the time required in port for a particular service remains similar, as more vessels are deployed. In fact, additional vessels are required to maintain a weekly frequency at each port of call (Notteboom and Vernimmen, 2008). This implies that the long-term sustainability of slow steaming depends on the additional operational costs for the n vessels added (OC) and on changes in inventory costs (IC_{teu}), as containers spend more time at sea. The bunker price break-even point (BP^*) for which the reduction is sustainable is:

$$BP^* \geqslant \frac{\Delta OC_{ds,ss} + \Delta Rot_{ds,ss} x IC_{teu}}{\Delta FC_{ds,ss}} \tag{3}$$

As long as the current bunker price is significantly more than BP^*, slow steaming is viable and one can expect that the reductions achieved in CO_2 emissions will be maintained.

3. CO_2 reductions from slow steaming, 2008–2010

An estimation of the impact of slow steaming on CO_2 emissions on the trade level requires information on the initial vessel's fuel consumption at sea at design speed ($ME_{k,sea}$), to which a 55% reduction will apply when that vessel is slow steaming, and on service characteristics, including the number of services and vessels under slow steaming, the days at sea and in port and the number of vessels deployed.

To determine $ME_{k,sea}$, information from *Lloyd's Register-Fairplay* (LRF, January 2010) was used. Table 1, provides details on the daily fuel consumption for 451 container vessels grouped into five categories. We compared these figures with our estimates based on a load factor of 90% and an SFOC of 195 g/kW h, which is multiplied by the engine's kW h. The latter information is available for 1930 vessels in LRF.

To assess the impact of slow steaming by trade, information was gathered from the Alphaliner (2010) database in January 2010. These identify the service in which a vessel is deployed for 2051 containerships with carrying capacity of more than 1000 TEU.[4] Furthermore, for each of the 387 services, the route, frequency, rotation in number of days and ports of call are gi-

[2] According to 1-year data gathered from a private operator for a 4300 TEU containership with a modern engine, the SFOC would only increase from 195 to 198 g/kW h and the fuel consumption at sea would fall by around 60% when speed is reduced by 30%.
[3] Even for the 4300 TEU vessel considered here, it runs at 10–20% of MCR, equivalent to 12–14 kn, 10% of the rotation.
[4] For the (2051–1930) vessels for which the engine kW h is not known, we assume that their consumption is equal to the mean of the category to which they belong (Table 1).

Table 2
Impact of slow steaming on annual fuel consumption per vessel (2008, 2010).

Vessel size (TEU)	Characteristics (2051 vessels)[a]				Days at sea		Average fuel oil consumption per ship (in '000 tons per year)		
	Number of vessels	% Vessels slow steaming	Mean size (TEU)	Design speed V_{dv}	2007[b] and 2008	2010	2007[b]	This paper (2008)	This paper (2010)
1000–2000	278	19.4	1481	19.5	241	244	9700	8997	8759
2000–3000	398	22.6	2542	21.7	247	250	15,600	15,409	14,666
3000–5000	677	37.2	4087	23.6	250	255	25,200	24,698	22,789
5000–8000	432	65.7	5948	24.9	251	260	37,500	36,695	31,541
8000+	266	75.5	9175	24.6	259	270	46,400	46,727	38,777

[a] Based on Alphaliner (2010)
[b] From Buhaug et al. (2009).

Table 3
Impact of slow steaming on CO_2 emissions by trade (2008, 2010)[a].

	Number of services	% services slow steaming	Number of vessels	% vessels slow steaming	Mean size in TEU	CO_2 emissions in 000 tons	% 2010/ 2008
Multi-trade	63	57.1	539	64.2	5994	47,500	-16.5
Europe/Far East	28	78.6	115	74.8	7720	12,900	16.4
Asia/North America	52	42.3	323	47.1	5142	29,400	9.7
North Atlantic	22	22.7	98	30.6	3469	5778	6.7
Australasia/ Oceania	17	23.5	96	27.1	3490	6275	4.1
Latin America/ Caribbean	73	20.5	314	24.2	2823	16,200	-4.8
Middle East/South Asia	87	23.0	342	25.7	3802	22,900	-6.7
South/East Africa	16	31.3	97	29.9	3007	5460	5.9
West Africa	29	20.7	127	37.8	2106	4510	–9.1
Total	387	35.4	2051	42.9	4485	**150,921**	**11.2**

[a] Calculations based on Alphaliner (2010).

ven. We retrieved information on the status of a service with regard to slow steaming from comments in the database on service history. Table 2 provides descriptive statistics for vessel size; 42.9% of vessels were slow steaming in January 2010 with the proportion of ships slow steaming rising with vessel size.

The number of days spent at sea in 2008 is assumed similar to Buhaug et al. (2009), and as a result of the slow steaming, the average time at sea rose in 2010 from an average of 259–270 days. This increase is (Table 3) and is obtained by adding 2 weeks, one in each direction, to services reported to be slow steaming in 2010. For vessels deployed in a service under slow steaming, 35.4% of services in 2010), a 55% reduction in fuel consumption at sea is assumed. In 2008, the bunker consumption for the 2051 container vessels was 53.6 million tons. Even though 137 more vessels were used, bunker consumption and CO_2 emissions decreased by an estimated 11.1% in 2010 as a consequence of slow steaming.

Turning to trade differences, Table 3 shows the characteristics of 387 services aggregated into eight trades, with an additional category for multi-trades, services covering more than two trade routes, such as around-the-world and pendulum services. The largest number vessels are deployed in multi-trades (35.1% of capacity), followed by the Asia/North America (18.1% of capacity) and the Middle East/South Asia (14.1% of capacity) trades. The under-representation of the Europe/Far East trade is because most multi-trade services cover this leg. In January 2008, 78.6% of Europe/Far East services were under slow steaming, compared with 57.1% of multi-trades.

The decrease in emissions is 11.1% due to reductions in fuel consumption represents a fall from 170 million tons of CO_2 in 2008 to 151 million in 2010, with the greatest reduction is for vessels on the multi-trade and Europe/Far East services. This contrasts with smaller trades such as Australia/Oceania related trades which are subject to less slow steaming.

4. The sustainability of slow steaming

To determine the sustainability of slow steaming (Eq. (3)), the cost of adding vessels to a service under slow steaming as well as the increase in inventory costs for shippers must be considered. Operational costs vary according to the number of vessels added and their characteristics. We assume the former is proportional to the number of services under slow steaming, with one vessel added for each service. For these vessels, the average daily operational costs (OC_k) were retrieved from HSH Nordbank (2008). This figure was $7000 per day for 1000–2000 TEU vessels, $8000 per day for 2000–3000 TEU vessels,

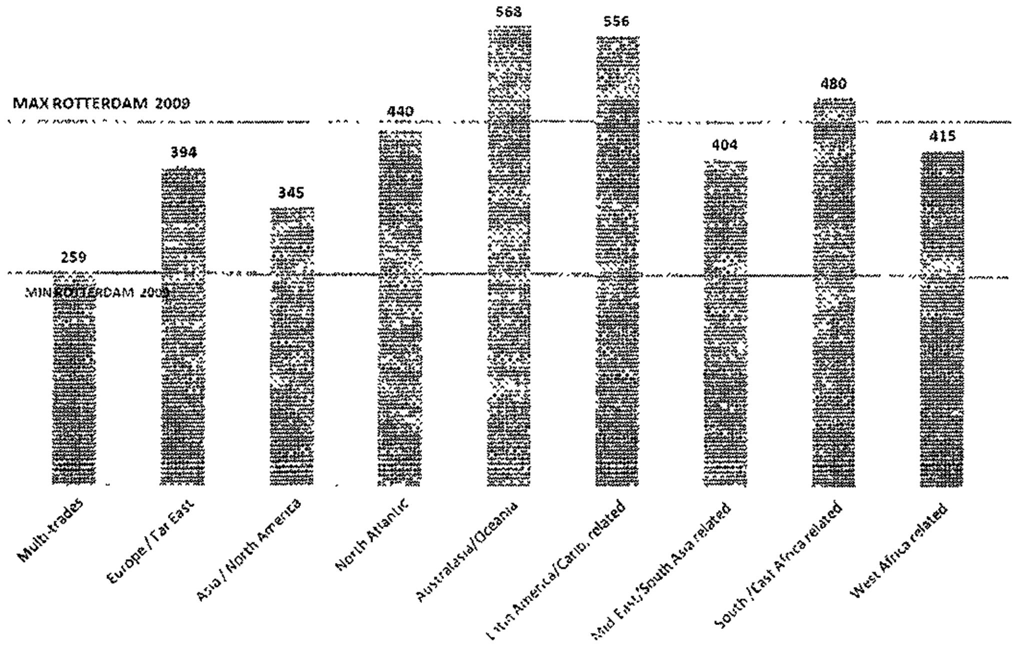

Fig. 1. Bunker price break-even point in $/ton

and $9000 for 3000 TEU plus capacity vessels. To determine inventory costs, we rely on the estimate provided by Eefsen and Cerup-Simonsen (2010) of an average value of $27,331 per TEU, an annual interest rate of 35%, with 70% of full containers.

For instance, for multi-trades services in January 2010, we assume that 36 vessels (57.1% × 63) have been added to this trade since 2008. Given the characteristics of vessels on that trade, the average daily operating cost is $8833 and the break-even bunker price point is a function of:

- Annual savings on consumption, derived from Table 3, which are equal to (56,900,000–47,500,000)/(2 × 3.17) = $1482,000 tons of fuel
- Additional operational costs, which are equal to $116 million for the 36 additional vessels.
- In-transit inventory costs equal to $266 million for 70% of the 64.2% × 3.2 million TEU that are spending one additional week at sea.

The bunker break-even price for multi-trade services at which slow steaming would be viable is then equal to $259 per ton of IFO. Given current bunker prices, suggesting that vessels are unlikely to return to normal speeds and companies are unlikely to remove the additional capacity in multi-trade services in the near future. Fig. 1 presents the results for all trades.

The findings have a number of implications. In the Australia/Oceania, Latin America/Caribbean trades, the percentage of services under slow steaming are relatively low and the bunker break-even point is relatively high as a result of the low ratio between time at sea, when savings occur, and time in port. For these services, BP^* is more than $550. For the sake of comparison, the IFO bunker price in Rotterdam fluctuated between $260 and $470 per ton in 2009. For many trades, the break-even point is close to the average value observed in Rotterdam. For these markets, the implementation of a tax levy (Marine Environment Protection Committee, 2009a) of around $50 could be enough to pass the break-even point.

5. Conclusions

This paper shows that slow steaming has reduced emissions by around 11% over the past 2 years; close to the target of a 15% reduction by 2018 that was proposed by the International Maritime Organisation's Marine Environment Protection Committee, 2009b). Furthermore, the reduction is achieved without the adoption of any new technology in the short run but remains fragile in the long run. Indeed, if bunker prices fall while freight rates and inventory costs rise, the profit motives for operating a vessel at full speed are likely to rise. Since this is likely to cause freight rates to rise, slow steaming can only remain sustainable if bunker prices remain high or if powerful market-based solutions, such as tax levies and/or cap-and-trade systems, are implemented to sustain bunker prices. However, a variety of technical elements were not considered. At very slow speeds, additional consumption occurs, the quality of the exhaust is altered and such slow speeds can give rise to design and safety issues.

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References

Alphaliner, 2010 <http://www.alphaliner.com/> (retrieved January 2010).

Buhaug, Ø., Corbett, J., Endresen, O., Eyring, V., Faber, J., Hanayama, S., Lee, D., Lindstad, H., Mjelde, A., Palsson, C., Wanquing, W., Winebrake, J., Yoshida, K., 2009. Second IMO Greenhouse Gas Study. International Maritime Organization, London.

Eefsen, T., Cerup-Simonsen, B., 2010. Speed, carbon emissions and supply chain in container shipping. In: Proceedings of the International Association of Maritime Economists Conference, Lisbon.

Faber, J., Freund, M., Köpke, M., Nelissen, D., 2010. Going slow to reduce emissions. Can the Current Surplus of Maritime Transport Capacity be Turned into an Opportunity to Reduce GHG Emissions? Sea at Risk Publishing. <http://www.seas-at-risk.org/1images/speed%20study_Final%20version_SS.pdf> (retrieved August 2010).

HSH Nordbank, 2008. Operating Costs 2008. A Study on the Operating Costs of German Ships. <http://www.hsh-nordbank.com/media/pdf/kundenbereiche/schifffahrt/research/betriebskosten_studie08/betr_kosten_studie_kurz_engl.pdf?> (retrieved August 2010)

Lloyd' Register Fairplay, 2010. World Shipping Encyclopedia

Marine Environment Protection Committee, 2009a. Prevention of Air Pollution from Ships; an International Fund for Greenhouse Gas Emissions from Ships. 59/4/5 Submitted by Denmark, 9 April

Marine Environment Protection Committee, 2009b. Analysis on the Appropriate Values of the Reduction Rates of the Required EDDI. 60/4/36 Submitted by Japan, 15 January 2010.

Notteboom, T., Vernimmen, B., 2008. The effect of high fuel costs on liner service configuration in container shipping. Journal of Transport Geography 17, 325–337.

Psaraftis, H., Kontovas, C., 2009. CO_2 emission statistics for the world commercial fleet. WMU Journal of Maritime Affairs 8, 1–25.

Psaraftis, H., Kontovas, C., 2010. Balancing the economic and environmental performance of maritime transportation. Transportation Research Part D 15, 458–462.

US Environmental Protection Agency, 2000. Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data. United States Environmental Protection Agency, Washington, DC.