Impact analysis on shipping lines and European ports of a cap-and-trade system on CO$_2$ emissions in maritime transport

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Abstract

The maritime transport sector still falls outside the scope of the mechanisms for the reduction of greenhouse gas emissions established by the Kyoto Protocol. However, given the prospect of an increase in CO₂ emissions caused by shipping, the debate surrounding regulations relating to emissions in this sector is intensifying in several international fora. The International Maritime Organisation (IMO) and the European Union are discussing the introduction of a market-based measure for maritime transport. This article focuses on the principle of a cap-and-trade system and explores the potential impacts of the implementation of such a measure on the organisation of containerised shipping lines and European ports. In order to respond to these questions, different scenarios varying the scope for application and the degree of connection with other existing cap-and-trade markets have been constructed. The results demonstrate significant and differentiated effects between the various scenarios.
Introduction

The international maritime transport sector is not subject yet to the mechanisms for the reduction of greenhouse gas emissions established by the Kyoto Protocol, although its emissions represented 3% of global emissions in 2007. In a ‘business as usual’ scenario, the total number of tonne-miles for the shipping sector in 2050 will be approximately four times higher compared to 2007 and the emissions level is set to increase two or three-fold in the same period (IMO, 2009). Such a situation may change rapidly as the debate about regulations relating to emissions in this sector is intensifying in several international fora: the International Maritime Organisation (IMO), the United Nations Framework Convention on Climate Change (UNFCCC) and within the European Union. In addition, the European Commission has already decided in its new Transport White Paper of 28 March 2011, that “EU CO\textsubscript{2} emissions from maritime transport should be cut by 40% (if feasible by 50%) by 2050 compared to 2005 levels”.

Technical and operational improvements realised by the industry in a “business as usual scenario” will not allow to achieve sustainable levels of CO\textsubscript{2} reductions. An awareness of the need for regulatory intervention has led the IMO to task the Maritime Environment Protection Committee (MEPC) with identifying and developing a market-based instrument applicable to the maritime sector on a global scale. Work and negotiations have been under way since 2008 and a final decision is anticipated at the IMO General Assembly in late 2011. However, the European Commission has decided that in the event that no international agreement has been reached by the end of 2011, a regulatory instrument on a European scale will be implemented to include maritime transport emissions in the Europe 2020 emissions reduction strategy.

This article aims to analyse the economic repercussions for containerised maritime transport companies, in terms of operating shipping lines and shipowners’ strategies, as well as for the European port system, of introducing a market instrument to bring maritime emissions into line with the 2030 scenario in the IPCC report (2007) for stabilising atmospheric CO\textsubscript{2} concentration at 450 parts per million.

In order to achieve this, after reviewing the options for market instruments currently under discussion and explaining why this article focuses on a cap-and-trade system (1), four scenarios for the price of emissions allowances for a 2030 horizon will be constructed (2). The effects of these scenarios on operating costs for containerised maritime shipping companies serving Europe will be assessed (3). A prospective analysis of shipowners’ strategy for adapting to change will then be carried out (4). This will feed into analysis of the potential repercussions of the implementation of the Maritime Emissions Trading Scheme (METS) on the organisation of shipping networks and services to ports, in the overall light of the different scenarios established (5).

1. Market instruments: the options discussed within the framework of international negotiations

Since 2008, IMO member states have made many submissions concerning the definition and architecture of a market-based measure for maritime transport.

The United States and Japan have proposed a system based on the energy efficiency of ships. This system, combining mandatory efficiency standards and credit or penalty mechanisms for ships according to their level of compliance with standards, aims to maximise improvements within the sector, whilst avoiding setting global emissions caps. It is internal to the maritime sector and does not release any funding for developing nations.
European states, for their part, have proposed instruments which fall into two broad categories: an environmental tax on the one hand, a principle made famous by Pigou in 1920, and a cap-and-trade system developed by Montgomery (1972).

From a theoretical point of view, taxes and cap-and-trade systems follow two different logics: with a tax, the regulator sets a price for CO2 and lets market determine the reduction of emissions; with trading schemes, the government sets a reduction target and lets the prices of CO2 adjust on the market.

Under these conditions, the key element to consider is, as shown by Weitzman (1974), the uncertainty of both damage and abatement costs. Weitzman has shown that, under uncertainty, the tax is preferable when the marginal damage curve is relatively flat compared with the marginal abatement cost curve. In contrast, cap-and-trade mechanisms are preferable when marginal benefits of further reductions are greater than the costs of delivering these reductions. Emission permits can also avoid errors in assessing costs (Baumol and Oates, 1988).

In the case of climate change, Stern (2007) explains that, in the short-term, the marginal damage curve is likely to be fairly flat. But over the long term, as the stock of GHGs grows, marginal damages are likely to rise and marginal damages may rise sharply. Moreover, as new lower-carbon technologies become available, the marginal abatement costs are likely to be flat over the long term. Thus cap-and-trade systems are more efficient in the case of long term policies, such as climate policy.

Moreover, from a practical point of view, CE Delft (2010) considers that such a system is the most cost-effective for reducing emissions because of its openness to other carbon markets and its potential to establish a connection between different sectors, in addition to its capacity to release funding for developing countries. Instead, bunker levy systems do not envisage any potential for interaction with other sectors, even though they are able to contribute to a fund for developing countries. Furthermore, the METS is contra-cyclical in nature: when the world economy and the demand for maritime transport are growing the price of CO2 emissions allowances increases and this limits demand. In the event of a financial crisis, the drop in maritime transport causes the price of CO2 plummet, thus reducing the negative impact for the shipping sector of the crisis for economic stakeholders. In addition, the METS is less complex to implement than a tax, because imposing an international levy raises constitutional issues, in particular for certain countries such as Norway or the United States where a new tax would need constitutional adaptations. Finally, if the European Union were to implement a market instrument for maritime transport, it would be likely to be based on a cap-and-trade system linked to the ETS, as is the case for air transport.

For these several reasons, this article focuses on a cap-and-trade system (METS with full auctioning), in order to analyse potential impacts of its implementation.

2. Definition of scenarios for allowances prices for a 2030 horizon

When the growth in demand for maritime transport and associated CO2 emissions in 2030 have been estimated and the targets for emission reductions for this same horizon have been specified, it is possible to construct four scenarios for emissions allowances prices in 2030.

2.1. CO2 emissions for a 2030 horizon without cap-and-trade system

In 2007, emissions from ships solely on the voyages connecting the last non-European port visited and the first European port, and the voyages between European ports, reached 208 Mt CO2
(henceforth referred to as “European” emissions), and global maritime transport emissions, including fisheries, reached 1,050 Mt CO$_2$ (IMO, 2009).

In order to make projections for a 2030 horizon on the hypothesis that no climate policy is implemented, IMO took as its basis one of the six IPCC development scenarios, namely scenario A1B, the closest to the International Energy Agency (AIE) forecasts for 2050. IMO (2009) indicates that according to this scenario the demand for maritime transport will be multiplied by 2.05 between 2007 and 2030. This implies that without technological or organisational efficiency gains European and global maritime emissions in 2030 would be 426 and 2,152 Mt CO$_2$ respectively.

However, compared to these projections, IMO (2009) considers that in the absence of a carbon market, the increase in environmental efficiency connected to progress in technology and in the operation of ships for a 2030 horizon would be 21.5%. This implies that the expected European and global emissions for 2030 in a ‘business as usual’ scenario would be 335 and 1,689 Mt CO$_2$ respectively.

2.2. Targets for reduction for a 2030 horizon

By creating a cap-and-trade system, the authorities set the amount of emissions at a level which results from a choice between several political options. The hypothesis adopted in this article is for a reduction target of 20% by 2030 compared to emissions recorded in 2007, whether the scope of the cap-and-trade be European or global.

This choice is based on the fact that the new Transport White Paper sets a -40% emissions reductions target for the shipping sector by 2050 (and if feasible -50%) compared to 2005. Assuming a linear progression, this would mean a -20% reduction by 2030. This means that in 2030, the regulator would auction a quantity of allowances to the maritime sector corresponding to an emissions level which would be 20% lower than in 2007.

2.3. Potential scenarios for the implementation of a METS

Two variables were used to construct four scenarios: the geographic scope of the METS and the degree of connection between the METS and other carbon markets existing in 2030.

Two hypotheses for scope of application were considered for the METS:
- a European METS based on emissions from journeys between the last non-European port visited and European ports$^1$;
- a world METS based on an assumed IMO agreement covering all maritime exchanges.

It seems likely that negotiations within IMO or the European Union will culminate in the first instance in an agreement limiting in practice the geographic scope of the METS.

Two hypotheses on the level of connection of the METS market with other markets were selected:
- total connection: this assumes that shipowners are free to buy as many allowances as they wish on other markets;
- limited connection: in this instance, the regulator imposes a fixed limit on the number of allowances that shipowners can buy on other markets, for instance 2/3 of the number of

$^1$ For the example of a containerised service between Europe and Asia with Singapore as the last Asian port and with Le Havre and Hamburg as the first and last European ports respectively, the overall emissions on the voyage between these two ports will be taken into account, as will the journey between Le Havre and Hamburg. However if the shipowner decides to add a stopover in Tangiers on this same service between Singapore and Le Havre, only the emissions between Tangiers and Le Havre are subject to carbon trading.
allowances available to them on the METS market within the framework of this study. This limit may be affected by the actual availability of allowances on the other markets.

By combining these hypotheses, four scenarios are obtained:
- scenario 1: European scope and total connection
- scenario 2: European scope and limited connection
- scenario 3: World scope and total connection
- scenario 4: World scope and limited connection

2.4. Allowance prices and potential for emissions reductions in the sector

The price of allowances varies according to the degree of connection between the METS market and the other carbon markets. In the case of unlimited access to other markets (scenarios 1 and 3), the price of a METS allowance for one tonne of CO$_2$ for a 2030 horizon will be aligned with the price on the other markets. By contrast, if the connection is limited (scenarios 2 and 4), the price of allowances on the maritime markets (METS) will differ from the other markets.

For scenarios 1 and 3

On the basis of European commitments to reduce CO$_2$ emissions by 20% by 2020, the price of an ETS allowance which was set at €14.1 per tonne of CO$_2$ in 2009 would need to be set at €38 in 2020 (Perthuis and Delbosc, 2010). If the rate of growth between 2009 and 2020 is assumed to remain constant until 2030, then this yields an allowance price of €94 in 2030, i.e. 66 €$_{2007}$ or 90 $$_{2007}$.\footnote{Based on a rate of inflation of 1.6% per annum and an exchange rate of 1.4 $/€ (source: OFCE).}

The methodology for calculating emissions avoided by 2030 is based on comparative analysis of the allowance price per tonne of CO$_2$ and the marginal CO$_2$ abatement costs for the maritime transport sector in 2030 as proposed by CE Delft (2009). In the absence of a carbon market (the price of a tonne of CO$_2$ = €0), shipowners would spontaneously implement strategies enabling them to reduce emissions per tonne-km by 33% compared to 2007.

In reality, as shown above, anticipated efficiency gains in the absence of a cap-and-trade mechanism would only reach 21.5% because of the existence of barriers to the implementation of emissions mitigation measures (Franc, 2010).

By considering a new axis added to the abscissas (shown as a dotted line on Figure 1) which cuts the central estimate curve at 21.5% on the axis (point A on Figure 1), when the price of a tonne of CO$_2$ reaches 65 €$_{2007}$ i.e. 90 $$_{2007}$, efficiency gains per tonne-km would be 28% (point B on Figure 1) compared to emissions in 2007. CO$_2$ emissions from the maritime sector for 2030 can therefore be estimated:
- for scenario 1 (Europe), 307 Mt of CO$_2$ (28% reduction compared to 426 Mt of CO$_2$);
- for scenario 3 (world), 1,556 Mt of CO$_2$ (28% reduction compared to 2,152 Mt of CO$_2$).
Scenarios 2 and 4

If it is assumed that there is a limited connection between markets, so that shipowners can only buy on other markets up to 2/3 of the number of allowances which are available to them under the METS, then they can buy:

- in scenario 2, the equivalent in allowances of 166 Mt of CO$_2$ under the METS, to which can be added allowances corresponding to 111 Mt of CO$_2$ through other forms of carbon market-based mechanisms. They can therefore emit 277 Mt of CO$_2$;
- in scenario 4, the equivalent in allowances of 840 Mt of CO$_2$ under the METS, to which can be added allowances corresponding to 540 Mt of CO$_2$ through other forms of carbon markets. They can therefore emit 1,400 Mt of CO$_2$.

Efficiency gains per tonne-km therefore reach 35% compared to 2007. This level corresponds to point C in Figure 2, and thus to a METS allowance price of 147.5 €$_{2007}$ i.e. 205 $_{2007}$. The price of allowances which can be bought on other markets is still 90 $_{2007}$. This implies that the average price for buying allowances (3/5 at 205 $_{2007}$ and 2/5 at 90 $_{2007}$) would be 159 $_{2007}$.
- scenario 1: 90 \$_{2007} on emissions from journeys between the last non-European port visited and European ports;
- scenario 2: 159 \$_{2007} on emissions from journeys between the last non-European port visited and European ports;
- scenario 3: 90 \$_{2007} on emissions covering all maritime exchanges;
- scenario 4: 159 \$_{2007} on emissions covering all maritime exchanges.

3. The effects of introducing a cap-and-trade system on the cost structure of regular containerised maritime lines serving Europe

In order to assess the effect of the introduction of a cap-and-trade system based on the four scenarios identified above, the operating accounts of the main shipping lines serving European ports were recreated. A distinction has been made between lines serving Northern Europe and those serving the Mediterranean area.

3.1. Construction of operating accounts for lines serving Europe

The operating accounts of various lines have been constructed on a ‘business as usual’ basis, i.e. based on the expected development of containerised maritime transport for a 2030 horizon in the absence of a carbon marked-based instrument. The set of hypotheses was constructed as follows:
- hypotheses relating to the capacity of ships were established on the basis of a projection for a 2030 horizon for the steady growth observed in the size of the most recent ships and of those on order;
- in the absence of consensus in the literature on evolutions for a 2030 horizon concerning the speed of ships on a line by line basis, the ports served by each line and the load factor of ships, the hypotheses used have been constructed on the basis of data for existing services;
- the IMO report (2009) estimates that efficiency gains for ships could be of the order of 2% in 2020 and 25% for a 2050 horizon; this study assumes that, in the absence of a cap-and-trade system, shipping will reduce its emissions by 10% per tonne-km by 2030 thanks to technological improvements;
- the hypotheses selected for bunker fuel charges – 700 US\$_{2007} for the price per tonne of IFO 380 and 1,150 US\$_{2007} per tonne of marine diesel oil – are based on estimates by the EIA (Energy Information Agency) and IAE (International Energy Agency) for the price of oil per barrel in 2030. The implementation, on 1 January 2015, of the new standards in Annex VI of the Marpol Convention for sulphur content in marine fuel oils in the Channel, North Sea and Baltic could lead to an increase in the cost of fuel of approximately 40% for ships sailing in these waters; however these elements have not been included in the model;
- in the absence of any indications in the literature on the increase in operating cost structures for container ships for a 2030 horizon, data produced by Drewry (2010) has been used. Terminal handling costs (THC) are based on THC published by Maersk.

Table 1 shows the hypotheses selected for the various lines serving Northern Europe. A similar process was applied to construct the operating accounts for lines serving European ports in the Mediterranean.

\[\text{Table 1} \]

3 The Barry Rogliano Sales (BRS) shipbrokers’ database was used.
4 With the addition of reductions relating to the implementation of organisational measures, a total reduction of 21.5% is achieved.
Table 1: Hypotheses for calculating the operating accounts of various shipping lines serving Northern Europe for a 2030 horizon

<table>
<thead>
<tr>
<th></th>
<th>Feeder</th>
<th>Regional</th>
<th>Feeder N.Af</th>
<th>Africa</th>
<th>North Am</th>
<th>W. Indies</th>
<th>South Am</th>
<th>South Asia</th>
<th>SE Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel capacity (TEU 10t)</td>
<td>1,600</td>
<td>1,600</td>
<td>3,000</td>
<td>3,000</td>
<td>8,500</td>
<td>3,000</td>
<td>5,500</td>
<td>8,500</td>
<td>12,500</td>
</tr>
<tr>
<td>Distance (nautical miles)</td>
<td>1,200</td>
<td>7,450</td>
<td>3,500</td>
<td>9,000</td>
<td>9,500</td>
<td>8,340</td>
<td>13,000</td>
<td>14,500</td>
<td>23,000</td>
</tr>
<tr>
<td>Speed of the ships (knots)</td>
<td>19.4</td>
<td>19.4</td>
<td>21.7</td>
<td>21.7</td>
<td>24.6</td>
<td>21.7</td>
<td>24.6</td>
<td>24.6</td>
<td>25</td>
</tr>
<tr>
<td>Load factor from Europe</td>
<td>85%</td>
<td>90%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>63%</td>
<td>90%</td>
<td>48%</td>
</tr>
<tr>
<td>Load factor to Europe</td>
<td>85%</td>
<td>72%</td>
<td>85%</td>
<td>51%</td>
<td>77%</td>
<td>60%</td>
<td>90%</td>
<td>63%</td>
<td>95%</td>
</tr>
<tr>
<td>Sets of containers (quantity)</td>
<td>1.7</td>
<td>1.7</td>
<td>1.7</td>
<td>2.5</td>
<td>1.7</td>
<td>2.0</td>
<td>2.5</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>20’/40’ containers’ share</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
<td>40%/60%</td>
</tr>
<tr>
<td>Number of calls in Europe</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Number of calls out of Europe</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Average length of a call (day)</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>1.5</td>
<td>1</td>
<td>1.3</td>
<td>1.5</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>IFO 380 consumption at sea (t/day)</td>
<td>47.4</td>
<td>47.4</td>
<td>84.2</td>
<td>84.2</td>
<td>225.9</td>
<td>84.2</td>
<td>171.9</td>
<td>225.9</td>
<td>234.5</td>
</tr>
<tr>
<td>MDO consumption in/near ports (t/day)</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>4</td>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Number of days at sea by rotation</td>
<td>3</td>
<td>16</td>
<td>7</td>
<td>17</td>
<td>16</td>
<td>16</td>
<td>22</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td>Number of days in/near ports by rotation</td>
<td>4</td>
<td>12</td>
<td>8</td>
<td>18</td>
<td>12</td>
<td>12</td>
<td>20</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>Number of ships in service</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Capital per vessel ($/day)</td>
<td>6,098</td>
<td>6,098</td>
<td>8,321</td>
<td>8,321</td>
<td>21,068</td>
<td>8,321</td>
<td>14,476</td>
<td>21,068</td>
<td>31,459</td>
</tr>
<tr>
<td>Crew ($/day/ship)</td>
<td>2,022</td>
<td>2,022</td>
<td>2,129</td>
<td>2,129</td>
<td>2,937</td>
<td>2,129</td>
<td>2,469</td>
<td>2,937</td>
<td>3,137</td>
</tr>
<tr>
<td>Repair and maintenance ($/day/ship)</td>
<td>2,454</td>
<td>2,454</td>
<td>4,320</td>
<td>4,320</td>
<td>7,290</td>
<td>4,320</td>
<td>6,523</td>
<td>7,290</td>
<td>8,244</td>
</tr>
<tr>
<td>Fuel IFO 380 ($/t)</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>Fuel MDO ($/t)</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
<td>1,150</td>
</tr>
<tr>
<td>Capital per 20’ container ($/jour)</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Capital per 40’ container ($/jour)</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Port charges ($/call)</td>
<td>38,426</td>
<td>38,426</td>
<td>46,682</td>
<td>46,682</td>
<td>89,660</td>
<td>46,682</td>
<td>64,134</td>
<td>89,660</td>
<td>137,320</td>
</tr>
<tr>
<td>Maintenance Europe ($/container)</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td>Maintenance out of Europe ($/container)</td>
<td>135</td>
<td>210</td>
<td>135</td>
<td>260</td>
<td>392</td>
<td>185</td>
<td>165</td>
<td>165</td>
<td>200</td>
</tr>
<tr>
<td>Empty containers maintenance refund</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Management and Administration ($)</td>
<td>510</td>
<td>510</td>
<td>510</td>
<td>510</td>
<td>635</td>
<td>510</td>
<td>615</td>
<td>635</td>
<td>665</td>
</tr>
<tr>
<td>Agency commissions rate</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Duty channel ($)</td>
<td>392,000</td>
<td>392,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nb: all costs are in US$2007
Source: authors’ own table based on MEDDTL data (to be published).
3.2. Impact of scenarios introducing a cap-and-trade system on the operating costs of containerised lines

Table 2 summarises the cost variations for the transport per twenty-foot equivalent unit (TEU)\(^5\), line by line, potentially caused by the implementation of each of the four scenarios for introducing a cap-and-trade system.

Table 2: Impact of a cap-and-trade system on the cost per TEU of lines serving Northern Europe

<table>
<thead>
<tr>
<th>Service</th>
<th>Without allowances</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost/TEU</td>
<td>Cost/TEU</td>
<td>Additional cost</td>
<td>Cost/TEU</td>
<td>Additional cost</td>
</tr>
<tr>
<td>Feeder</td>
<td>$361</td>
<td>$376</td>
<td>4.0%</td>
<td>$387</td>
<td>7.1%</td>
</tr>
<tr>
<td>Regional</td>
<td>$832</td>
<td>$907</td>
<td>9.0%</td>
<td>$964</td>
<td>15.9%</td>
</tr>
<tr>
<td>Feeder N.Africa</td>
<td>$438</td>
<td>$461</td>
<td>5.1%</td>
<td>$478</td>
<td>9.1%</td>
</tr>
<tr>
<td>Africa</td>
<td>$1,001</td>
<td>$1,042</td>
<td>4.0%</td>
<td>$1,073</td>
<td>7.7%</td>
</tr>
<tr>
<td>North Am.</td>
<td>$797</td>
<td>$832</td>
<td>4.4%</td>
<td>$859</td>
<td>7.8%</td>
</tr>
<tr>
<td>W. Indies</td>
<td>$780</td>
<td>$875</td>
<td>12.1%</td>
<td>$947</td>
<td>21.4%</td>
</tr>
<tr>
<td>South Am.</td>
<td>$976</td>
<td>$1,038</td>
<td>6.3%</td>
<td>$1,085</td>
<td>11.1%</td>
</tr>
<tr>
<td>South Asia</td>
<td>$1,031</td>
<td>$1,078</td>
<td>4.5%</td>
<td>$1,114</td>
<td>8.1%</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>$1,143</td>
<td>$1,204</td>
<td>5.4%</td>
<td>$1,251</td>
<td>9.4%</td>
</tr>
</tbody>
</table>

NB: all costs are in US$\text{2007}

Source: authors’ own table based on MEDDTL data (to be published).

Firstly, the impact on the cost per TEU transported fluctuates between the different scenarios for the same line:
- when the scope of the cap-and-trade system is global, routes to which the market instrument is applied are much longer than when the scope is European;
- when the connection with other carbon markets is limited, the average price of allowances is higher than when the connection is total.

The impact on the cost per TEU transported also fluctuates between lines within the same scenario. In scenario 4, for example, a feeder service linking several Northern European ports has an additional cost of 7.1%, compared to 25.4% for a service between South America and Northern Europe. Variations of this kind can be explained by the duration of the service and the type of ship used:
- services for which the time spent at sea exceeds the time in ports (all things being equal) are the most heavily penalised. The service to South-East Asia is at a particular disadvantage compared to a feeder service;
- the largest ships, that are also the most economical per TEU transported, operate on the longest lines (which partially offsets the first point) but not all long distance services are operated by large ships, as is the case for services to South America.

Similar results can be seen for the Mediterranean area.

\[^5\] Twenty-foot Equivalent Unit. One twenty-foot container equals 1 TEU. A forty-foot container equals 2 TEU.
4. Shipping companies’ adaptation strategies

Although shipping companies can always pass on part of the cost of allowances to their clients in the form of surcharges such as Bunker Adjustment Factors, they should strive, like any economic stakeholder faced with an increase in cost structures, to adapt their business operations in order to minimise their costs. Shipping companies have four levers for action at their disposal in order to achieve this: investment in technological improvements for ships, reductions in ship speeds (slow steaming), using larger ships and modifying the routes of their regular lines.

4.1. Technological measures

Numerous studies have attempted to highlight the potential for CO₂ emissions reductions linked to the introduction of technical improvements to ships. One of the practical measures frequently cited by experts is the use of LNG fuel for ships. However, great uncertainty surrounds estimates for the timetable for its introduction and the reduction in associated emissions.

The hypothesis used here to calculate the operating accounts of lines is that technological improvements in ships in a ‘business as usual’ scenario for a 2030 horizon will lead to an efficiency gain per tonne-km of 10% compared to 2007.

This is a cautious hypothesis compared to the literature on the subject. The IEA (2009) estimates that the potential in terms of efficiency gains for new ships would be 30% for a 2030 horizon compared to 2005, and 20% compared to the existing fleet.

In general terms, there are three reasons for advocating caution when assessing the potential for the spread of technological innovations:
- the way in which the shipbuilding market is organised does not provide stakeholders with incentives to innovate. Shipowners place the bulk of their order with shipyards who then offer a series of off-the-shelf ships. These shipyards have optimised their production based on a series of models and are not especially inclined to take the industrial risk of introducing innovative systems which they have not fully mastered to their production;
- most shipping companies remain cautious because, even if certain sunk costs are trivial compared with the potential gains, they are afraid that the maintenance and repair costs for these innovative systems may be prohibitive, especially if the technology is not yet widespread in the maritime industry;
- the main technological improvements are amortised more easily on large ships than on smaller ships. They will not therefore be implemented in the same way on all ships and on all lines.

Under these circumstances, it would seem reasonable to consider that the efficiency gains linked to technological improvements to container ships for a 2030 horizon would struggle to exceed 20%. Although it is difficult to assess the implementation costs of various underlying measures in the current state of knowledge (Miola et al., 2010), this potential 20% would not be achieved in all scenarios. It would be more profitable to invest in technological improvements in scenarios 3 and 4, where the scope is global, than in scenarios 1 and 2, where the scope is European. Efficiency gains would then be close to 10% (without allowances) for scenarios 1 and 2, and 20% for scenarios 3 and 4.
4.2. Reductions in ship speeds

Since a ship’s fuel consumption is approximately proportional to the square of its speed, slow steaming is a particularly effective way of reducing fuel costs and is especially appropriate when there is overcapacity of provision as was the case at the height of the recent economic crisis (Notteboom and Cariou, 2009). In fact, if a shipping company slows down the speed of ships on a given line and wishes to retain the frequency of stopovers in ports served by the line, it must add one or more ships per line, which may pose problems in periods of undercapacity of provision, but which, conversely, enables it to use ships at a lower price in periods of overcapacity of provision.

Could slow steaming, which until now was used to deal with a specific event, become a permanent solution in the event of the introduction of a cap-and-trade system? Figure 3 shows the gains per TEU transported achieved by reducing the speed of ships and increasing the length of rotations by 50%.

**Figure 3: Reduction in cost per TEU by increasing the duration of the rotation of ships by 50%**

![Graph showing reduction in cost per TEU by increasing the duration of the rotation of ships by 50%](image)

**Source: the authors**

Even without allowances, increasing the duration of the rotation of ships by 50% can cut the cost per TEU transported by more than 10% on certain lines when bunker costs reach 700 US$2007 per tonne of fuel. Recourse to slow steaming becomes increasingly profitable as speed rises and the distance covered at sea in relation to the number of ports visited by the line increases. This is the case for lines connecting Europe with the West Indies, South America, South Asia, and South-East Asia. This measure is less profitable for services to North America and North Africa or on regional services. The situation for feeders is similar to regional services.

Moreover, the higher the price of emissions allowances and the broader the scope of their application, the more profitable slow steaming becomes. With the exception of regional lines and the West Indies which remain European in scope, the benefits of the measure increase for scenarios 1, 2, 3 and 4.
4.3. Increased ship capacity

Shipowners’ preoccupation with achieving economies of scale has led to sustained growth in the size of ships since the introduction of containerisation (Cullinane and Khanna, 1999). The question arises as to whether this trend will continue and whether the introduction of a cap-and-trade system will contribute to it.

The change in the cost per TEU when the ships are increased by one class in comparison to the current situation for each line (assuming that load factor remains unchanged) in a ‘business as usual’ situation without allowances and in the four different scenarios has been analysed.

It appears that if economies of scale are not yet exhausted, especially in the absence of cap and trade system, the introduction of a METS should in theory provide some small encouragement to use larger ships on lines linking Northern Europe with South America, South Asia and South-East Asia. However the conclusions for lines serving North America are more qualified as many ports on the Eastern seaboard of the United States have a limited draught. On other lines, the introduction of a METS should not cause shipowners to switch to higher capacity ships, whatever the scenario. Analogous results were obtained for ships serving the Mediterranean.

4.4. Changes in the spatial organisation of shipping networks

Modifying the spatial organisation of regular lines is an alternative solution for shipowners seeking to reduce their costs after the introduction of a METS. Is there any particular benefit associated with changing ship stopover plans in order to limit the distance of voyages concerned by the METS? Are stopovers in ports located on the boundaries of Europe likely to increase?

This latter question arises in particular when the scope of the METS is European, as there are benefits to shortening the voyage between the last non-European port visited and the first European port visited. When the scope is global, this benefit does not exist.

In order to understand this issue, simulations of the spatial organisation of the major shipping lines serving Northern Europe and the Mediterranean were run, in particular for scenarios 1 and 2 relating to the European METS:
- For lines linking Europe to North Africa, North America and South America, a stopover in Northern Europe has been replaced by calling at Tangiers in Morocco. For lines linking Northern Europe with South Asia and South-East Asia, a call at the Algeciras hub has been replaced by the Tangiers hub.
- For lines linking the Mediterranean to Africa, North America and South America, calling at the Algeciras hub is replaced by the Tangiers hub; for lines connecting the Mediterranean to South Asia and South-East Asia, a call at the Malta hub is replaced by Enfidha in Tunisia.

The line serving the West Indies has not been considered in this analysis as the 3000 TEU ships used on this line do not have a sufficiently high capacity to make a transhipment hub relevant, be that Tangiers or elsewhere.

Figure 4 shows the changes in costs per TEU when the schedule of stopovers of a line is modified to include a North African port for a ‘business as usual’ scenario, or scenarios 1 and 2.
On the basis of hypotheses supported by simulations, with a METS the major transoceanic lines serving Northern Europe would all benefit from serving a North African port first, with the exception of the North American line. In the latter case, savings on allowances do not compensate for the cost of a detour to make a call in Tangiers.

According to the same hypotheses, rerouting ships to North African ports would seem to be a profitable option for all transoceanic lines serving the Mediterranean.

In general terms, the higher the price of allowances, the more profitable calls in North African ports become.

4.5. Assessment of shipowners’ adaptation strategies

The main CO\textsubscript{2} emissions reductions in maritime transport are supposed to be brought about by operational changes rather than technological improvements to ships.

If the scope of the METS were European (scenarios 1 and 2), shipowners could on the one hand slow down the speed of their ships and on the other hand prioritise the spatial reorganisation of their main transoceanic routes serving Europe to carry out transhipment operations in North African ports. The effects of these two measures would be even more significant if the price of allowances were high, which might potentially stem from a low connection between the METS and other carbon markets. Although slow steaming should significantly reduce maritime transport emissions, this does not apply to calling in at North African ports, which in fact causes carbon leakage. However, the difficulty of reversing the installation of new transhipment hubs should restrict their spread.

If the scope of the METS were global (scenarios 3 and 4), shipowners would have to make widespread use of the practice of slow steaming on their main lines and use more economical ships or even larger ships on certain lines. The METS would therefore bear significant fruit.

5. Effects on services to European ports

On the basis of a quantitative analysis of the operating accounts shown above combined with a qualitative analysis to specify certain conditions, it would appear that the implementation of a METS
would have repercussions on European port activity. In general, ports which are less able to respond to changes in maritime services could be marginalised (LNG infrastructures, land-connections…). The results vary according to the scenario studied and the shipping lines considered.

A European METS (scenarios 1 and 2) favouring the development of hubs in the Maghreb would penalise hubs situated on the Mediterranean coast, such as Malta, Gioia Tauro, Algeciras or Valencia and, conversely, promote the growth of North African ports.

A high allowance price (corresponding to scenario 2) could also penalise feeding between feeding ports on the Atlantic coast (Vigo, Bordeaux, Nantes, Saint-Nazaire) and the large European ports, in favour of land transport, in particular by road.

If the scope of the METS were global (scenarios 3 and 4), shipping companies should be encouraged to reduce the speed of their intercontinental lines significantly, especially when the price of allowances is high. Thus, when demand for transport is steady, the price of allowances could rise significantly if the connection between the maritime market and other markets is limited (scenario 4).

At the same time, if the demand for transport were high, shipowners could be inclined to avoid extending the duration of their ships’ rotations unduly. The calculations carried out based on the model presented demonstrate that if the cost of allowance is high (scenario 4), then it is in shipowners’ interest to prioritise slow steaming on their main lines (average speed of 16 knots), to cut out two port calls in the Northern area by adding a feeder ship to serve these two ports rather than to maintain these two calls directly, and to speed up ships to avoid extending ship rotation times. In these circumstances, the ports of Le Havre and Dunkirk, which generate relatively little freight compared to Northern European ports such as Antwerp, Rotterdam and Hamburg, could be bypassed by some lines and be serviced by feeding, or even see this traffic disappear, with connections to the hinterland being provided by the large ports by road, rail or barge.

Moreover, if allowance prices were high (scenario 4), ports which already have petrochemical and gas installations could obtain a competitive advantage if LNG were to develop as a shipping fuel. This would be the case for example in Zeebrugge, Barcelona, Marseille-Fos and Valencia.

For feeding ports on the Atlantic coast, the impact of a global METS in terms of transferring feeding traffic onto the roads would be the same as for a European METS.

6. Conclusions

First and foremost, a cap-and-trade system which is restricted to Europe runs the risk of causing carbon leakage and loss of competitiveness in European ports. This supports the case that the authorities should strive to promote the extension of the scope of the METS rapidly to a global scale.

Secondly, if the price of allowances were to rise steeply, secondary ports on the Atlantic coast could be penalised by the shift of feeding traffic to roads, which would run counter to the targets for the modal shift policy. This constitutes an incentive to give the highest priority to studies relating to harmonisation of externalities assessment between the different modes of transport.

In addition, ports which could be skipped by certain transoceanic lines using slow steaming would be faced with the urgent need to explore the methods available to them to improve their competitiveness. It would seem particularly appropriate to consider the levers that these ports would have to use in order to increase their capacity to receive and supply the ships of the future, in
particular if the introduction of a market-based instrument in the maritime sector encouraged the spread of new propulsion technologies for ships.

Finally, the implementation of a METS could discriminate against smaller carriers, the majority of whom have smaller and older ships than the large shipping companies, and who are at risk moreover of being penalised in gaining access to allowance markets.

These conclusions demonstrate the benefit of pursuing this type of analysis by extending its scope to explore the impacts of implementing a METS to other sectors of maritime transport such as bulk and Ro-Ro carriers.

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