

Impacts of short-term measures to decarbonize maritime transport on perishable cargoes

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Abstract The International Maritime Organization (IMO) has adopted a strategy to reduce emissions from international shipping that sets very ambitious targets. The first set of actions, so-called short-term measures are expected to be implemented by 2023 and result in a reduction of emissions' intensity by at least 40% by 2030 compared to 2008 levels. Compliance may be achieved through a reduction in sailing speeds, but certain countries have raised concerns on the ramifications of longer transit times on their exports, particularly for perishable products. In this paper, we present a methodology to assess the impacts of various short-term measures on perishable products. We use an extension of a nested modal split model to examine shifts towards other modes of transport. We demonstrate our methodology with a transpacific case study carrying perishable products from South America to China. We compare the short-term measures currently under discussion, in one of the first academic studies to explore these issues. These include a speed limit approach, a power limit, and a goal-based measure. Our results show that a power limit or a goal-based measure would offer some advantages to liner shipping operators using more efficient vessels, unlike a speed limit. Using 2008 as the benchmark year has resulted in small speed reductions required by the liner shipping sector to reach its targets. For perishable cargoes, small speed reductions can be tolerated by the shippers without significant modal shift. Choosing the right short-term strategy is of utmost importance in order to promote clean shipping practices in the next years.

Keywords: decarbonization of shipping, emissions intensity, perishable cargoes, modal shift, transpacific trade.

1. Introduction

Globally there is a significant effort to curb anthropogenic greenhouse gas (GHG) emissions in order to tackle climate change. During the annual conference of parties (COP21) in 2015 in Paris, a climate change agreement was reached that aims to keep the increase of the global average temperature to a maximum of 1.5°C compared to pre-industrial levels by the end of the 21st century. In order to do this, all sectors will need to participate in this effort and improve their environmental performance. Transportation accounts for 24% of global CO₂ emissions from fossil fuel combustion according to the “Tracking Transport” report by the International Energy Agency (IEA, 2019).

International shipping contributed approximately 2.2% of the global anthropogenic emissions in 2012, or about 796 million tonnes, and this figure was expected to grow between 50 and 250% by 2050 due to the growth of the world maritime trade. (IMO, 2014). At the same time, shipping moves an estimated 80-90% of world trade, and it is expected to continue increasing its transportation volume. The IEA estimates that international shipping emitted 693 million tonnes of CO₂ in 2018, whereas the whole transportation sector accounted for 8,000 million tonnes. While these numbers suggest that shipping is more efficient than other modes, it still has to reduce its environmental impacts if we are to reach the goals set out by COP21.

To this end, the International Maritime Organization (IMO) has set ambitious targets in its so-called Initial Strategy, calling for the decarbonization of international shipping. The strategy has a threefold objective, whereby an at least 40% reduction in the carbon intensity of emissions¹ is sought after by 2030 (aiming for 70% by 2050) compared to the benchmark year of 2008, an at least 50% reduction in absolute greenhouse gas (GHG) emissions by 2050 (also baseline year 2008), and to peak shipping emissions as soon as possible. Even though the USA along with Saudi Arabia were the only two countries that did not endorse the Initial IMO Strategy in April 2018, in April 2021 the US special presidential envoy for climate announced that the USA wants the IMO to push for a zero emissions target by 2050². However, how the latter could be realized remains to be seen.

The strategy classifies emissions abatement measures into three groups based on time: short-term measures, medium-term measures, and long-term measures. In the short-term, measures are expected to be agreed upon and start implementation by 2023, medium-term measures are expected between 2023 and 2030, while the long-term measures refer to the period 2030-2050. The first category is expected to revolve around speed reduction and optimization of operations, while for the medium-term it is envisaged that market-based measures (MBMs) will be deployed. In the long-term, the focus will be on alternative fuels (low-carbon, ammonia, hydrogen, bio-fuel blends, wind propulsion, or others). This paper focuses on the short-term measures and their impacts on trade, and on certain countries that have raised concerns about their exports. It is important to note that currently several proposals are under discussion at the IMO level for the short-term measures, and a combined technical/operational measure was approved in November 2020, set out for eventual adoption in June 2021. In addition, the ongoing discussion has been postponed due to the COVID-19 global outbreak.

¹ the IMO has not specified how the emissions intensity is to be quantified. Carbon intensity is generally expressed as grams of CO₂ per transport work, with transport work expressed in tonne-miles. We consider the emissions intensity as grams of CO₂ emissions per nautical mile (NM) – TEU, as for liner shipping TEUs are more appropriate.

² <https://lloydlist.maritimeintelligence.informa.com/LL1136527/US-will-push-IMO-to-adopt-target-of-absolute-zero-emissions-by-2050>

The rest of the paper is organized as follows: Section 2 presents a brief literature review on slow steaming, the maritime transportation of perishable products, and on modal shift models for freight transportation. Section 3 presents the methodology we use to examine the measures, and how these are translated into shifts in transportation demand. Section 4 presents a case study for the transportation of cherries from Chile to China, and the impacts of emissions from the four measures. Section 5 concludes the paper with a discussion on the main findings and on ways forward to ensure that negative impacts on trade are minimal.

2. Literature review

This section reviews relevant literature on slow steaming in recent years, perishable assets, and relevant studies that have dealt with modal shifts in freight transportation.

2.1 Slow steaming

Slow steaming refers to the common practice of ship operators to slow down their cruising speeds as a means to reduce fuel costs during either increased fuel prices, or when the market is down and excess ship capacity is available. Benford (1981) conducted one of the first studies on the subject, in the aftermath of the oil price crisis in the late 1970's. The practice found a renewed interest following the financial crisis of 2008 and the relatively high fuel prices observed until 2013. Numerous researchers focused on the effectiveness of slow steaming, also considering the environmental benefits in carbon emissions reductions. The paper of Corbett et al. (2009) showed a potential reduction of up to 70% in carbon emissions if slow steaming was applied in containership routes. The authors noted the potential of further pursuing slow steaming, should maritime transport be included in carbon-pricing schemes. This is particularly important as, currently, the European Commission intends to include shipping in the European Emissions Trading System (ETS), regardless of any short-term measures decided at the IMO level. Koesler et al. (2015) supported that an ETS could be successful in reducing emissions from shipping, however in their research they did not consider a regional ETS as the one currently envisioned by the EU. A regional ETS could create market distortions and affect the competitiveness of ports near the borders where ETS applied³. Recently Greece and Sweden supported the inclusion of shipping into the EU ETS, however it is early to tell if the conditions they required (for instance price stability) would be taken on-board. On the subject of slow steaming and its environmental benefits, this can lead to reduced emissions even when emissions from added ships to the service are included. Essentially, in order to satisfy transport demand, operators would need to deploy more ships in their services to make up for the increased voyage times. However, the fuel consumption per voyage is decreased sufficiently to counter the effect of the higher number of voyages (Cariou, 2011). Finally, the contribution of Maloni et al, (2013) is notable, as the authors examined the wider implications of slow steaming, and considered the impacts of the longer transit times on the inventory costs of shippers, along with a conceivable reduction in freight rates. The authors also suggested the further investigation of the potential of financially-based incentive programs for environmental improvements in maritime transport. These could include carbon taxes, emissions trading (carbon cap and trade), or reimbursements for ship operators that improve their fuel efficiency. Other works are summarized in the taxonomy of speed models and literature review presented by Psaraftis and Kontovas (2013) to which we refer readers for a more in-depth presentation of slow steaming in academic research.

³ For example, consider a ship requiring emissions credits for its voyages from/to EU ports. Now suppose a ship normally comes from Virginia (USA) to Rotterdam. It might be cheaper for the ship operator to call at an adjacent non-EU port (for example Felixstowe), and then use a feeder vessel to connect to Rotterdam, thus paying only for emissions in the Felixstowe-Rotterdam leg.

2.2 Inventory costs and possible modal shifts

Apart from the requirement to add more vessels in a service in order to satisfy demand when sailing speeds are lowered, another repercussion is the deterioration of the service offered to shippers. The added voyage time translates into a potential cargo value loss during transportation, as well as additional insurance costs and propagation of delays in pickup and subsequent transportation legs. As a result, shippers may opt to send time-dependent cargoes via faster transportation modes leading to modal shifts. The mode choice of a shipper depends on several factors that include some easy to measure, such as the monetary cost of service and the total travel time, and other more elusive factors pertaining to the reliability of service, the total number of transshipments, client loyalty to a particular mode and others. The decision-making process of the shipper is usually modelled after calculating the utility (or rather disutility) of each of the available shipping options.

Having calculated the relative disutility of all available options, it is possible to model potential shifts to other transportation modes if something changes. These changes could consist of a new transport cost for one or more of the options (for example via a toll), an alteration in the total voyage time (a lengthier service as a result of a speed reduction), or a drop in the reliability of service (less frequent calls). In literature, most modal shift models have been using logistic regression (logit) models. These methodologies come in handy when modeling discrete choices, and have been very popular in passenger transportation models. In these cases, there are many more explanatory variables that can include comfort, waiting times, number of changes in case of intermodal transport, and others. For freight transport, the logit models are simpler and typically only consider reliability, cost, and travel time. In recent years there has been a resurgence of modal shift models applied in maritime transport, but the majority has focused on short sea shipping (SSS) routes that compete with rail or road alternatives, following the stricter sulphur limits affecting these services (Zis and Psaraftis, 2017; Lemper et al., 2015; Odgaard et al., 2013).

In liner shipping, the seminal paper of Notteboom (2006) discussed the impacts of time, and in particular potential delays, on the depreciation of cargo. The author uses a simplified example where a TEU of a value of €40,000 could lose between €3 and €4.5 per day in opportunity costs, and €10 to €30 in cargo value loss per day of delay. Bell et al. (2013) used a similar approach to estimate the inventory cost of a full container as the depreciation of its cargo content at \$20 per TEU per day. Wang et al. (2015) discussed the difficulty of estimating the value of transit time (VOTT) from the ship operators' perspective. Their VOTT included inventory costs, and the authors estimated values between \$5 and \$30 per TEU per day for transpacific services. On the other hand, in short-sea shipping, most relevant work was examining changes in the total voyage time of just a few hours and used annual depreciation rates between 3 and 10% (Zis and Psaraftis, 2018); the authors noted that for more time-sensitive cargoes higher rates should be used. Other papers consider only the depreciation cost of the container itself and not the deterioration of the cargo it carries. For example, Cheaitou and Cariou (2012) optimized a liner shipping service considering the quantity of reefers and included the depreciation costs of standard and refrigerated containers. They note that perishable cargoes tend to have higher revenues, but do not consider the impact of changing a speed on the quality and value of the cargo carried.

2.3 Perishables

The depreciation rates shown in the previous papers mainly assumed an annual rate ranging between 10 and 30%. These values are low in the case of perishable products. Essentially, an annual depreciation rate of 100% would mean that after one year the asset has completely lost its value. Perishable goods can be defined as

products whose quality deteriorates quickly with time, due to their exposure to environmental conditions⁴. Historically perishable items tend not to be shipped over long distances (Sandberg et al., 2006). The importance of monitoring the quality of highly perishable products through intelligent packaging is noted by Heising et al. (2014). In terms of freight, perishable goods usually include food, fruits and vegetables, dairy, and seafood and meat products. Traditionally, these products are transported refrigerated or chilled and fast transportation is vital to ensure sufficient shelf life. Lin et al. (2015) note that 90% of perishables are transported in reefer containers. Bogataj et al. (2005) develop a theoretical model for cold supply chains and illustrate the importance of temperature variations as well as of lead time for deliveries on the quality of cargoes.

Soysal et al. (2018) presented an interesting inventory routing problem (IRP) of perishable products with a fixed expiration date that cannot be exceeded. Other studies incorporated the perishability of a product by increasing the deterioration rate of the transported commodity. Research on perishable assets has also looked into incorporating the harvest and distribution of products in the decision-making process of the producers. For example, Ahumada and Villalobos (2011) considered the case of tomatoes and peppers, noting the importance of delivery time for the quality of the products, and the trade-offs between storage and transportation. In their optimization model, the authors included constraints on the maximum delivery time that the client could allow, noting also that it may be difficult to simply send large quantities at once. Interestingly, sea-transport is not one of the available transportation options due to the limited time before the products reach their ripe status. Adachi et al. (1999) presented a theoretical model on the optimal inventory policy for perishable products whose value is dropping as these are closing in on their expiration date. However, the authors did not consider changes in the delivery time of their supply chains.

We can observe that the majority of academic research on perishable products was focusing on inventory management from the producers' side. Transportation time is included in the models but mostly as a fixed time. Most of these problems assumed fast supply chains and transport modes for these cargoes. In maritime logistics research, work on perishable goods is relatively scarce, arguably due to the much lower transportation volumes of such products by sea transport. This is evident in the paper of Bjørnal (2002) that assessed the competitiveness of Chile as a salmon exporting country, noting a disadvantage compared to Norway which can export salmon using the much faster road options. There is some work looking at SSS that utilizes faster sailing speeds and shorter legs. Pérez-Mesa et al. (2010) focused on perishable products in Europe and on the feasibility of using Ro-Pax vessels for shipments in the context of the Motorways of the Seas initiative. The authors used a modal split model to estimate transportation demand. They note that, for certain perishables, it is better to utilize smaller vessels in order to maintain a constant level of supply (instead of using larger shipments at longer intervals). However, they did not explicitly define the deterioration rate or value of time for the perishable cargoes. Russo and Chilà (2010) also used a modal split model for freight transport and note that high-speed passenger vessels could be utilized also for perishables and high value cargoes in certain European countries that have geographical advantages (e.g., being on the Mediterranean or Baltic Sea). They included a dummy variable for perishable products but do not specify how this affects the utility of the transport option.

Outside the realm of SSS, Dulebenets and Ozguven (2016) attempted to incorporate perishable goods in vessel scheduling problems in liner shipping, and consider the decay of assets using an exponential formula. They assumed a decay rate of 0.67% per hour for meat products, and 0.216% per hour for fresh vegetable products,

⁴ In the literature, occasionally the term depreciation is used for both perishables and non-perishable goods. To avoid misconceptions, we will be using the term deterioration to refer to the loss of cargo value over time in the case of perishable products.

which is exponential and taken from Wang and Li (2012). However, Wang and Li (2012) suggested these rates for products ‘on shelf’ so it seems that these rates, applied to liner shipping (for transportation of refrigerated cargoes), are taken out of context. Using the 0.216%, as taken by Dulebenets and Ozguven (2016), is equivalent to a daily deterioration rate of 5.05%, or almost 80% per month. Using these values, the authors concluded that it is better for the ship operator to increase their sailing speed, leading to a higher bunker consumption by up to 42%. However, the authors did not specify what proportion of transported cargoes have a perishable nature. It is therefore important not to simply use results that are applicable in other stages of a product’s lifetime. This insight is particularly important for the case study we are examining in section 4, as a transpacific leg on a liner shipping service usually ranges between 21 and 30 days. Using the deterioration rates of the papers cited above, this would mean that all products would arrive practically rotten.

3. Understanding the wider impacts of short-term measures for the decarbonization of transport

IMO’s initial strategy focuses on CO₂ emissions intensity, which should be reduced by 40% by 2030 compared to the 2008 levels. Several proponents of short-term measures have emerged in the last two years. The proposed measures can be classified into two main streams: the prescriptive track and the goal-based approaches. In the former case, the proposed measure will specify the manner in which the desirable reductions will be achieved. For instance, the implementation of a speed limit in certain shipping sectors and waters would be a prescriptive measure. In the latter case, the ship owner is free to choose in what way they will reduce their emissions to comply with a specified goal. For example, they could choose to reduce their speed, use cleaner fuels, or invest in technological equipment that would reduce their fuel consumption. Whichever measure prevails in the future discussion at the IMO, it is evident that it will affect current shipping operations.

3.1 An overview of current proposals on short-term measures

The procedure at the IMO is that any member state can propose a measure that will achieve the required emissions intensity reduction until an agreement has been reached. There are several measures currently under consideration, and we will not go into detail in each of the submissions. Instead, below we examine the impacts of the following generic measures:

- A speed limit
- A power limit
- A goal-based measure in the form of a carbon intensity indicator (CII)
- The existing operational energy efficiency ship index (EEXI)

Speed limit proponents have included the Clean Shipping Coalition (CSC), a non-governmental organization (NGO), and they proposed an elaborate scheme in which the speed limit is a function of ship type and size bracket. Such a scheme would be very difficult to monitor and enforce. Power limits were initially proposed by Japan, Norway, Greece, and BIMCO. The limit would be based on the assumed performance of an average ship sailing at the current average speeds of each sector, and in theory it could be reversed at times of need. Denmark, France, and Germany have proposed a goal-based measure where each ship would have its own CII, and it would need to follow a prescribed schedule of reductions each year. Finally, the EEXI would require ships to meet a set of energy efficiency requirements after the measure has taken effect. In practical terms, EEXI would likely be implemented via a limit to the output of the ship’s main engine.

For each proposal under discussion at the IMO, the corresponding authors are required to submit an impact assessment of the measure and its impacts on other IMO member states. This impact assessment must also address concerns voiced by member states, and more specifically by the Least Developed States (LDCs) as well as the Small Islands Developing States (SIDS)⁵. For more information on how such states can be negatively affected, we refer to the work of Guillaumont (2010) that thoroughly explains how LDCs and some SIDS are vulnerable to external economic shocks. The author stresses the need for the development of an economic vulnerability index to help identify states at higher risk.

3.2 Background on South American countries and concerns on speed reductions

Regarding South American countries, some concerns have been officially raised on the impacts of speed on their exports. In IMO (2018), a document submitted to the IMO just before its Initial Strategy was adopted, Chile and Peru expressed serious concerns on the potential negative impacts that reducing speed might have on exports of various agricultural products, including cherries and avocados. In fact, a study conducted by Starcrest at the request of the Asia-Pacific Economic Cooperation (APEC, 2019) examined the impacts of slow steaming on trade for distant economies. In their analysis, they consider the added costs from a potential delay in days, as a result of slow steaming, taking into account deterioration, interest rate, and insurance costs. For perishables, they suggest the use of a 30% deterioration rate, and for Chilean cherries in particular a range of 30 to 75% deterioration rate. In their analysis, they considered this as an annual deterioration rate, applicable on the current market value of the product for additional days of transport in case of slow steaming (as compared to the normal speed). For the face value Starcrest uses a value of \$2.25 per kg. The overall conclusion of the report is that for dry bulk and containerized cargoes the impact of slow steaming would be rather small, however, for perishables and fast-moving consumer goods the APEC economies may be adversely impacted. A possible question might be what is the impact of speed reduction on the in-transit inventory cost of cargoes exported from South America to Asia. Depending on export elasticities, such cost could conceivably increase cost, insurance and freight (CIF) prices and/or reduce free on board (FOB) prices, thus hurting export competitiveness. According to Imb and Mejean (2017), Chile is a country with a low export elasticity, among a set of 28 developing and developed countries. Sea transport is not the only export mode for Chilean cherries. Trucks account for typically less than 5% of cherry exports and aviation accounts for about 15%. These numbers fluctuate slightly over time (IMO, 2018). It is clear that the only alternative mode to Asia is aviation, so if ship speed is reduced considerably, some of the cherry exports may be shifted to aviation initially. In the longer term this may lead to a reduction of exports to China, and either the production of cherries would be reduced, or alternative markets would have to be found (unless the shelf life of the cherries can be improved).

3.3 Generalized cost of transport and modal choice

The term “generalized cost of transport” is frequently used as a proxy of the utility/disutility of a transportation option. The generalized cost is a function that allows linking factors of different units (for example monetary units and time) into one composite measure of the utility/disutility of each option. Total travel time can be converted into a monetary cost by considering the depreciation rate of the transported cargoes, which is itself a function of the value of cargo and its type. This is essentially the value of time. We use the following equation (adapted from Zis and Psaraftis (2017)) to calculate the generalized cost of transport GC_i that links travel time with monetary costs for travel option i .

⁵ We undertook the impact assessment of the proposal of Denmark et al. on a mandatory operational goal-based short-term measure (IMO, 2020c).

$$GC_i = TC_i + \frac{CV \cdot r}{365} TT_i \quad (1)$$

Where TC_i is the monetary transport cost of mode i , r is the annual depreciation rate (%) of the transported cargo that has a monetary value CV , and TT_i is the total transit time (days). The fraction in equation 1 is representing the value of time for the transportation of the cargo. Regarding the depreciation rate (%), as explained in section 2.3, when it comes to perishable assets different approaches have been used. The model considers the general case where there are three main transportation modes (maritime fast- M_F , maritime regular M_R or air - A) available to a shipper. It is possible to estimate shifts caused by a distortion in the market (for example a change in the total freight cost, or transit time) by using modal split models for the transportation of cargoes. These models are effectively trying to capture the decision-making process of a shipper when two or more alternatives are available. We assume that there is a correlation between the two maritime modes, and that is depicted in the use of a nested logit model, where the decision-maker (shipper) first chooses the main transportation mode (maritime – M , or air - A), and subsequently any option within the selected nest. The probability of choosing nest $i \in \{M, A\}$ is given by equation 2.

$$P_i = \frac{e^{-\lambda_1 \cdot GC_i}}{e^{-\lambda_1 \cdot GC_A} + e^{-\lambda_1 \cdot GC_M}} \quad (2)$$

Where λ_j is a dispersion parameter that acts as a weight attached in the choice to the generalized cost. At larger values for λ_j , the implication of a change in the cost of one option to the decision has a graver consequence on the probability of choosing that mode. The terms GC_A and GC_M represent the composite generalized costs of each nest. Following the initial selection of a nest, the next step is to decide which particular mode within the nest to select (regular or fast for the maritime nest, we only consider one air mode). The probability of selecting maritime mode $j \in \{M_F, M_R\}$ is:

$$P_j = \frac{e^{-\lambda_M \cdot GC_j}}{e^{-\lambda_M \cdot GC_{M_R}} + e^{-\lambda_M \cdot GC_{M_F}}} \quad (3)$$

Where λ_M is the dispersion parameter for the second split. Finally, the composite maritime cost GCM is given by equation 4.

$$GC_M = \frac{-1}{\lambda_M} \log(e^{-\lambda_M \cdot GC_{M_R}} + e^{-\lambda_M \cdot GC_{M_F}}) \quad (4)$$

4. A numerical case study on transpacific trade

Before proceeding with our analysis, it is important to present some key figures regarding fresh cherry exports from Chile. The export of these products to markets in Asia and Europe takes place in narrow time intervals during the year, for instance from October to February for Chilean cherries, with a peak in December as seen in Figure 1.

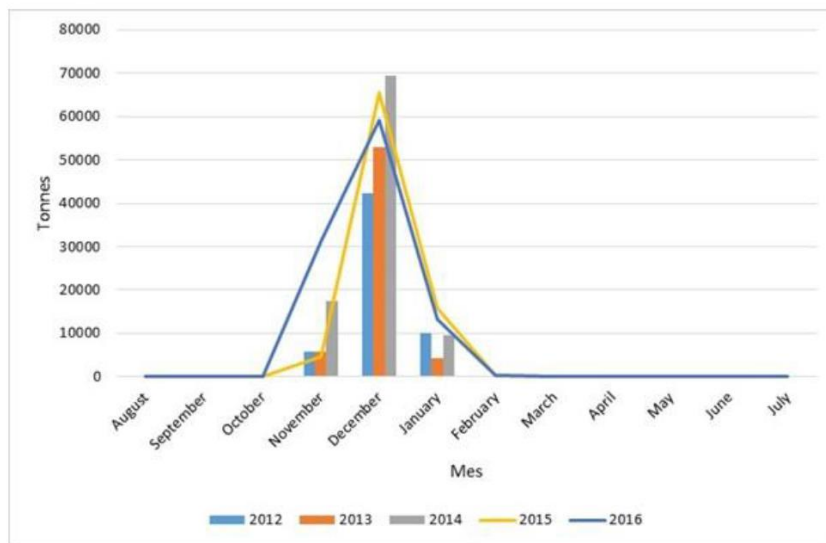


Figure 1: Chilean cherry exports. Source: IMO (2018)

South American countries claim that if transit times from South America to China exceed 40 days (which corresponds to a ship speed of about 15 knots), then their products are likely to be damaged. Instead, they calculate that if a ship speed of 20 knots is used, transit time will be 33 days and damage would be averted. It has to be noted that these numbers were calculated presumably overestimating the sailing distances. The submission (IMO, 2018) clearly stated the case for Chile and Peru, although it probably overstated the case for perishable product exports of these two countries.

We should note that in several transpacific liner shipping services there are significant differences in sailing speeds on the eastbound vs westbound legs. In the spring of 2018, the time Chile and Peru voiced these concerns to the IMO, an average eastbound (Asia to S. America) speed of 17.5 knots and an average westbound speed as low as 12.5 knots were observed in a relevant transpacific service (Psaraftis, 2019). The difference in speed is attributed to commercial reasons, and to the difference in the values and quantities of cargo transported at each leg. This implies significant slow steaming, especially in the direction from Chile/Peru to China.

The situation in the fall of 2018 did not improve much in terms of speed. A Maersk Line service from Chile to Hong Kong in the peak of the cherry export season in mid-December 2018 would sail the 10,195NM in 34 days, implying a speed of 12.5 knots; still rather slow.

In 2019, there were certain services that sailed at higher speeds. For example, Maersk offers a service from San Antonio (Chile's largest port) to Yangshan (Shanghai, China), a sailing distance of 10134NM, and a transit time of 28 days. This would require an average sailing speed of 15.2 knots. We note that in the ensuing analysis we consider only the transportation of cherries in reefer containers on conventional containerships deployed in either a regular or fast (express) service. We do not consider the option of transporting these cherries in reefer ships.

4.1 Cherry exports from Chile to China

Cherry exports are one of the most important products of Chile that has seen a steady growth in recent years. Chile is considered as the second largest fresh cherry exporter in the world, while China is the largest market, accounting for roughly one third of all Chilean exports, despite the typical 30 to 45 days sea voyage (Bamber and Fernandez-Stark, 2016). Chilean cherries have several advantages including their disease-free quality due

to the geographic isolation of Chile, as well as the counter-seasonal benefit of supplying fresh fruits to export markets in the northern hemisphere (Valdivieso et al., 2012).

According to the Chilean Fruit Exporters Association (ASOEX), the main season for cherries is between mid-October and late February (depending on the variety), with the peak season being December. Figure 2 shows the growth in cherry exports over recent years and the main export destinations for the product.

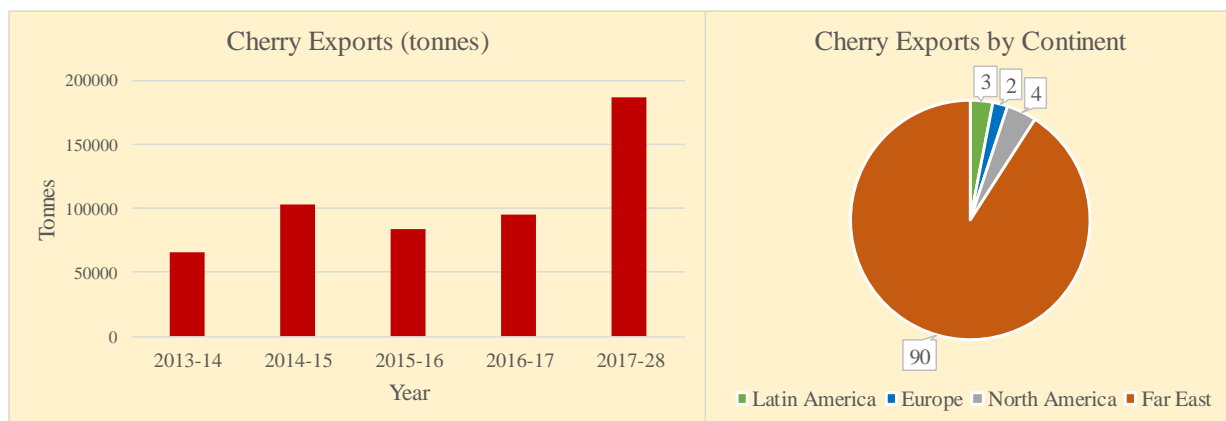


Figure 2: Cherry exports by year and destination. Data source: ASOEX

This significant growth in exports is projected to continue in the coming years. For 2019/20 ASOEX released a projection for 209,000 tonnes of cherries⁶ (41.8 million boxes of 5kg per box). Bamber and Fernandez-Stark (2016) note that early season cherries are sent via air to China and tend to have very high prices (up to \$20 per kg), while mid-season produce is sent via sea.

Chile raised its concerns that a potential speed reduction (as a short-term measure under discussion then) “could generate a distortion or a barrier to trade, because the exporter may not be able to arrive at its destination with its products in optimum condition and this would have repercussions on the competitiveness of the State” (IMO, 2018).

A potential reduction in speed could in our opinion have two effects. The first obvious effect is that it would make sea transport less attractive and thus it could potentially lead to certain shipments being switched from water to air, with significant negative environmental consequences. The second effect, which would be more important, has to do with the very short season for demand for cherries in the Far East. As shown earlier, the peak production of cherries in Chile is between October and February, with the majority of the volumes in December. Following that period, other producers would also be competitive in the markets of China.

4.2 Constructing a baseline case

In this section we are presenting a what-if analysis to see potential negative impacts of decarbonization measures, taking the example of cherry exports as our case study. A numerical example may facilitate readers on potential modal shifts. We consider shipments from Chile to China with two available transportation options: waterborne, and airborne. To use modal shift models, the first step is the identification of all transport options and gathering information on the market share of each option. We consider the generalized cost of transporting cherries from Chile to China. According to ASOEX, approximately 84% of exports to China are

⁶ <https://www.freshplaza.com/article/9154177/chilean-cherry-exports-will-amount-to-209-000-tons-in-the-2019-20-season/>

seaborne with the remainder being transported by air. The cost of transporting cherries via airfreight is estimated to be 4.5 times higher than maritime⁷. Given the state of the market as of December 2019, one refrigerated forty-foot equivalent unit (FEU) would cost around \$5600 for transportation from Chile (San Antonio) to Yangshan. As a baseline, we consider a total transit time of 30 days (based on the existing service from Maersk that required 28 days) versus a total transit time of 50 hours using air. The complete data for the baseline case are shown in Table 1.

Table 1: Baseline Scenario – Shipper Options

Transport Mode					
Maritime			Air		
Market Share (%)	Transit Time (Days)	Transport Cost ⁷ (\$/FEU)	Market Share (%)	Transit Time (Days)	Transport Cost (\$/ton)
84	28.2	5500	16	2.1	833

Table 2 shows the technical specifications of two ships actually deployed on transpacific services that are also used for the transportation of cherries from Chile to China. These are a regular containership (ship A) serving the route at the same period, and the technical specifications of a containership (ship B) deployed in the faster service (“Cherry Express”) during the cherry season. Some interesting observations can be made from the data of Table 2 for the two ships that are relatively similar in size. Ship B, which is 17 years younger, has noticeably more efficient engines in terms of specific fuel oil consumption (SFOC) as it would be expected. It was also constructed to have a maximum speed slightly lower than Ship A. In general, larger vessels tend to be equipped with more powerful engines and also to have a higher maximum speed. Considering that Ship B is newer and bigger, its maximum speed is actually lower than Ship A, which could be an indication of the trend to build vessels that are offering slower services than in the past. Both vessels travel on much lower sailing speeds than their design speeds (where the SFOC has its optimum value), and in fact if we do not take into consideration the effects of weather on power demand, the main engines are operated at very low loads (16% of the Maximum Continuous Rating - MCR for ship A, 33% of MCR for ship B). We provide the fuel consumption at design speed (tonnes per day) as retrieved from Clarksons Research *world fleet register* data for the two vessels, noting that these figures refer to sea-trials data (sailing in calm waters). The fuel consumption at different sailing speeds in Table 2 were calculated using a generic activity based model adapted from Zis et al. (2014), with the following equation for each engine e (main or auxiliary) during activity a (sailing, hoteling at port):

$$FC_{e,a}(\text{tonnes}) = 10^{-6} \cdot SFOC_{e,a} \cdot EL_{e,a} \cdot EP_{e,a} \cdot t_a \quad (5)$$

Where EP is the nominal installed power (kW), SFOC is expressed in grams of fuel per kWh, and t (hours) is the time of activity. For cruising, the time of activity is the fraction of sailing distance over sailing speed. The loads of the main engine at different sailing speeds are calculated, assuming a cubic relationship between engine load EL (% of MCR) and sailing speed. This is shown in equation 6 for two different sailing speeds V_{S1} and V_{S2} , and their respective engine loads.

⁷ These estimates were taken from online sources including www.worldfreightrates.com and www.sea-rates.com. Data were collected during December 2019 to March 2020, and we use average values from that period

$$\frac{EL_{m1}}{EL_{m2}} = \left(\frac{VS_1}{VS_2}\right)^n \quad (6)$$

In reality, this exponential relationship may utilize higher n values than 3, depending on the environmental conditions (winds, waves, currents). Finally, we consider that both vessels have a capacity utilization rate of 75% in order to be able to make some comparisons. The amount of cargo loaded also exhibits an exponential relationship with fuel consumption, and typically an exponent of 2/3 is used. In our work we do not consider the impacts of different loading levels as we do not have data on the weight of containers.

Table 2: The technical specifications of the two ships (regular and fast service) and fuel consumption estimations

Ship	Capacity (TEU)	Reefer capacity (TEU)	Year	Design Speed	Main Engine Power (kW)	SFOC at 85%MCR (g/kWh)	Main engine Fuel Consumption at-sea (tpd)**	Aux. Engine Power (kW)	SFOC Aux (at*sea)*	EL Aux (at-sea)	SFOC Aux (port)
A	9640	1600	1999	24	69900	172.8	240	15000	220	15%	220
B	10100	2000	2016	23	72198	166	179.2	13500	210	17%	210
Fuel Consumption at different speeds											
Ship	Design Speed	Main Engine FC (tons/NM)	Aux Engine FC (tons/NM)	Ports FC (tons)	Total Voyage FC	Carbon Intensity (g CO ₂ per TEU-NM)	Service Speed	Main Engine FC	Aux Engine FC	Ports FC	Total Voyage FC
A	24	0.4196	0.021	11.88	4549.15	1.9	15.2	0.1712	0.033	11.88	2112.33
B	23	0.3257	0.019	11.23	3567.79	1.42	18.67	0.2173	0.024	11.23	2496.36

* Authors' estimate based on relevant literature. All other fields are based on data from Clarskons Research World Fleet Register

** Sea-trial data

The emissions intensity (grams of CO₂ per TEU-NM) is considerably lower for both vessels at their service speed, vis à vis their design speed. The next sections attempt to discuss the impacts of different decarbonization measures using the two vessels, and considering also the potential modal shifts towards air freight.

4.3 Reaching the IMO ambitions

The first goal of the IMO initial strategy has a target date of 2030, with an emissions reduction intensity of at least 40% compared to 2008 levels. As presented earlier, *emissions intensity* has not been explicitly defined yet, and there is no exact information on the baseline case for 2008. Therefore, what follows in this subsection is subject to some assumptions. As emissions intensity we consider the grams of CO₂ per TEU/NM. According to Notteboom and Vernimmen (2009), at the time of writing their article (submitted in 2008), container vessels were sailing at 24 knots, which was actually at a time of increasing bunker prices, since the authors used values of around \$500 per ton for HFO, much earlier to the requirements of using low sulphur fuel. The sailing speed reported by the authors was not area-specific, so we will use that speed as a baseline on transpacific routes such as the one examined here. We show the resulting fuel consumption and emissions for ship A (which would have been relatively new in 2008), and compare it with the emissions intensity target for 2030. We are still assuming a conservative 75% capacity utilization for the ship due to lack of data (for example Notteboom and Vernimmen used a 95% utilization on westbound and 80% on eastbound services for the North European –Asian trade). We assume that emissions in port are included in the calculation, and that the total fuel consumption in port is not changing. In reality, container terminals are becoming faster at handling the same volumes, so it can be anticipated that the berthing time would be reduced for the same number of container moves.

Table 3: Emissions intensity breakdown and target according to IMO

Emissions	Baseline (2008) of ship A at 24 knots	Emissions intensity target (2030)
CO ₂ at-sea per voyage (tonnes)	13756.7	NA
CO ₂ in port (tonnes)	36.61	
Total CO ₂ per TEU (tonnes/trip) including ports	1.9	
CO ₂ intensity (g/TEU-NM)	184.61	110.76

Finally, the case study we are looking at is for the transportation of cherries in reefer containers. Most vessels have a limited amount of reefer plugs they can use, notably the Cherry Express service uses vessels that have a higher reefer capacity. It is also certain that carrying more reefers per trip would require higher fuel consumption from the auxiliary engines. The emissions intensity we derive is per TEU (regardless of whether it is a reefer or not), and perhaps this is unfair compared to other cargoes that might be heavier in the same transported volume. It is also unfair as some containers may carry heavier cargoes (and thus their emissions intensity per mass transported would be lower), or may not be fully loaded themselves. The latter double load factor problem shows why narrowing everything down to a single KPI has several weaknesses.

4.4 Impacts of a speed limit

We start with the examination of a potential speed limit, noting that what that speed limit should be is a very difficult question as the limit would depend on the specific shipping sector, and trade lanes. In addition, currently there is significant difference in sailing speeds on westbound and eastbound routes (see Psaraftis 201 for more info), which could be attributed to commercial factors and also the impact of ocean currents. Therefore, issuing one speed limit for both directions may be counterproductive.

In the previous submissions to the IMO, a speed limit was not suggested, so in this section we will consider different levels to see their efficacy in reducing emissions. In Table 4 we show the emissions breakdown and intensity at different sailing speeds (design, current and limits), as well as the actual sailing speed that would result in the 40% reduction target. We also note that these calculations are not considering the effects of weather. These, in general, increase fuel consumption disproportionately at higher sailing speeds, so if the baseline is taken at 2008, when ships were sailing much faster, the required speed reduction to achieve 40% less emissions would be lower.

Table 4: Emissions intensity breakdown for various speed limits

Emissions	Baseline (2008) of ship A at 24 knots	Speed to reach 40% reduction target		Speed limit of 15 Knots		Speed limit of 12 knots		Speed limit 10 knots	
		Ship A (17.83 knots)	Ship B (20.13 knots)	Ship A	Ship B	Ship A	Ship B	Ship A	Ship B
Total voyage duration (days)	17.9	24.1	21.3	28.6		35.8		42.95	
Tonnes CO ₂ at- sea per voyage	13756.7	8254.5	8648.4	6276.97	5369.63	4669.9	4024.53	3916.63	3401.6
Tonnes CO ₂ in port	36.61	36.61	34.6	36.61	34.6	36.61	34.6	36.61	34.6
Tonnes CO ₂ per TEU per trip	1.9	1.14	1.14	0.87	0.71	0.65	0.53	0.54	0.45
CO ₂ intensity (g/TEU- NM)	184.61	110.76		84.23	68.77	62.67	51.55	52.55	43.56

Interesting observations can be made based on the findings of Table 4. We considered three different speed limits (10, 12, and 15 knots). If a higher speed limit was used, Ship A would be basically unaffected (as it now sails at 15.2 knots), but ship B would no longer be able to offer a faster service as in the “Cherry Express”. For the lower speed limits, we can see that the newer ship B has also a lower emissions intensity (and overall emissions) than ship A, but through the speed limit the advantages of using a cleaner vessel are lost, since both vessels would arrive at the same time.

4.5 Impacts of a power limit

Using a power limit to achieve emissions reductions has been proposed in a submission (IMO, 2020a) cosponsored by Greece, Japan, Norway, Panama, United Arab Emirates, ICS, BIMCO, INTERTANKO and RINA. The underlying idea is that there will be a power limitation system to comply with the EEXI requirements. We are not going to go into detail on that submission, but instead we will present the effects of different levels of limits on output power for the two ships in our examined case study. Instead of using a percentage of the MCR that would be the higher limit, we will have a maximum power output of the propulsion engines, which will be the same for both ships, considering that they are practically containerships of the same class. Table 5 shows the potential emissions reductions for each ship through main engine power limitations, and what would be the maximum attainable speed without exceeding this power limit (assuming calm weather). Table 5 also shows the necessary sailing speed required for each vessel, so that their emissions intensity is the IMO target.

Table 5: Emissions intensity breakdown for various power limits

Emissions	Baseline (2008) of ship A at 24 knots	Power limit at 50000 kW		Power limit at 30000 kW		Power limit at 20000 kW		Emissions intensity target Required Power (kW)	
		Ship A	Ship B	Ship A	Ship B	Ship A	Ship B	Ship A 23891	Ship B 30260
Sailing Speed (knots)	24	22.8	23.8	19.2	20.1	16.8	17.5	17.83	20.13
Voyage duration (days)	17.9	18.8	18	22.3	21.4	25.5	24.5	24.08	21.33
Tonnes CO ₂ at-sea per voyage	13757	12523	11488	9246	8465	7377	6737	8254	8648
Tonnes CO ₂ in port	36.61	36.61	34.6	36.61	34.6	36.61	34.6	36.61	34.6
Tonnes CO ₂ per TEU per trip	1.9	1.73	1.52	1.28	1.12	1.02	0.89	1.14	
CO ₂ intensity	184.61	168.05	154.17	124.07	113.58	98.99	90.4	110.76	

(g/TEU- NM)								
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We can see that, in all scenarios, the more efficient ship B would be able to sail faster, saving approximately one day of voyage, and at the same time emit less per transport work. This shows that, in contrast to a speed limit, a power limit would offer some advantages to the ship operators using more efficient vessels. The last column of Table 5 shows that if the objective were to achieve the target emissions intensity, the more efficient ship B could do so with a higher power limit, compared to the older ship A. Finally, the sailing speeds that would achieve this goal are quite high, as the benchmark was 2008 when ships were actually sailing much faster than during the last decade.

4.6 Impacts of a goal-based measure

A goal-based measure has been suggested as a possible way forward in a submission by Denmark, France and Germany (IMO, 2020b). The measure suggests that an individual target of carbon intensity reduction is to be assigned at each ship, and it is up to the shipowner and crew how to achieve this reduction. We are not going to present the measure in detail in our illustrative example, but it is worth mentioning that the proposal suggests a gradual reduction each year starting in 2023, finishing when the goal is achieved in 2030. For containerships specifically, a final reduction of 45% by 2030 is proposed, starting at 27% by 2023, while for refrigerated cargo carriers (reefer ships) the range is 26 to 40%. It should be noted that the measure calls for an average reduction across the year, so a ship operator could opt to have some faster journeys and offset these with much slower voyages at other times of the year. Table 6 shows what the goal-based measure would require for the two ships, assuming that initially the ship operators would only use slow steaming to achieve the goal-based measure reductions. The goal-based measure would set targets for individual ships, but the exact mechanism by which individual ships would be assigned targets is still under discussion. Therefore, in our example, we simply use the baseline of ship A, and set the same goals in emissions intensity for both ships.

Table 6: Emissions intensity breakdown for a goal-based measure with stricter progression each year

Emissions	Baseline (2008) of ship A at 24 knots	2023		2025		2028		2030	
		27% reduction		32% reduction		41% reduction		45% reduction	
		Ship A	Ship B	Ship A	Ship B	Ship A	Ship B	Ship A	Ship B
Speed (knots)	24	19.98	22.47	19.19	21.61	17.65	19.94	16.9	19.1
Voyage duration (days)	17.9	21.5	19.1	22.4	19.9	24.3	21.5	25.4	22.4
Tonnes CO ₂ at-sea per voyage	13757	10006	10488	9318	9766	8080	8469	7530	7893
Tonnes CO ₂ in port	36.61	36.61	34.6	36.61	34.6	36.61	34.6	36.61	34.6

Tonnes CO ₂ per TEU per trip	1.9	1.39	1.29	1.12	1.05
CO ₂ intensity (g/TEU- NM)	184.61	134.77	125.53	108.92	101.54

We see that under this type of measure, a more efficient ship enjoys a greater advantage, as it can sail much faster and its emissions intensity remains the same., but presumably it would be linked to its Energy Efficiency Design Index (EEDI) (particularly for vessels built after 2008), and the percentage reduction requirements each year (2023 to 2030) would be the same for each ship. We can also observe that for all target levels, both ships would actually be allowed to sail faster than their current service speeds (even the Cherry Express currently (2021) sails at 19.3 knots, a slight increase from 18.67 knots in 2020). This measure seems better in the sense that it is more flexible, and rewards current “greener” ships compared to older and less efficient ones. Finally, in the cherry case, it seems that there would be no issue as the existing services could still be using their current speeds even by 2030. If for other products higher sailing speeds would be necessary for certain voyages, the ship operators could still sail at higher speeds on these journeys, and slow down on others while still maintaining the average goal each year.

4.7 Modal shifts

In previous case studies, it has been shown that, in the different approaches to achieve emissions reduction, a speed reduction would suffice in all cases. It was also shown that using the baseline case of 2008, with the very high sailing speeds at the time, current sailing speeds are already compliant with the emissions intensity reductions. However, we must stress that previous calculations have assumed fuel consumption at calm weather, also disregarding the (positive or negative) effects of ocean currents. The results therefore show that the main concerns of Chile, i.e., that speed reduction would be detrimental on their exports to the Far East are not going to be realized. However, eventually, speed reductions will be necessary in order to achieve also a net reduction in emissions (and not only emissions intensity). We also stress that speed reduction would not be the only means of ship operators, as they could also reduce their emissions intensity via technological improvements, or using low carbon fuel (and biofuels). Even more effective would be a strategy that increases the utilization capacity of their vessels. In our case study we assumed a capacity utilization of 75%; should this increase, the required sailing speed would be higher.

In this section we focus on the impacts of a change in sailing speed in the regular service (ship A), on a possible modal shift to competing airfreight. The ensuing analysis considers lowering the sailing speed from 15.2 (ship A) to 14 and 12.5 knots, and different speed reductions for the faster service. We list our assumptions due to limitations regarding data:

- We do not have explicit information on the freight rate charged for the faster service, so we assume that this is more expensive than the regular service.
- A hierarchical (nested) logit model is used. This means that the shippers first decide on the main transportation mode (maritime vs. air), and then decide on which particular service (which maritime; fast or regular).
- We had information that 84% of cherries use maritime modes, and the remaining use air freight.
- We consider the quantity of 209,000 tonnes of cherries as the total amount to be transported (data from ASOEX) over the export season from late October to early April.

- The frequency of service for the maritime modes is weekly.
- We do not know the market share for the faster service vs. the regular service, so we used an assumption on the baseline shares in Table 7.

The resulting modal shifts are summarized in Table 7, which also shows total chain CO₂ emissions. These are seen to increase as cargo shifts to the airfreight. We show the emission intensity per ton of product in order to facilitate comparisons with airfreight.

Table 7: Modal shifts due to speed reduction for the regular service

Scenario	Maritime Regular				Maritime Fast				Air				Total Chain		
	Market Share (%)	Days	Cost/FEU ⁸ (\$)	CO ₂ per ton	Market Share (%)	Days	Cost/FEU ⁷ (\$)	CO ₂ per ton	Market Share (%)	Days	Cost per ton (\$)	CO ₂ per ton	CO ₂ (tons)		
Baseline Regular: 15.2 Fast: 18.76	58.8	28.2	5500	0.022	25.2	22.9	8000	0.027	16	2.1	833	12	405465		
Regular: 14 Fast: 18.76	47.67	30.6		0.019	35.05				17.27				437250		
Regular: 12.5 Fast: 18.76	30.41	34.4		0.017	50.78				18.81				475716		
Regular: 14 Fast: 17	56.78	30.6		0.019	25.23				25.3				0.023	17.98	454649
Regular: 12.5 Fast: 16	46.38	34.4		0.017	32.93				26.8				0.021	20.69	522001

^{8 8} These estimates were taken from online sources including www.worldfreighrates.com and www.sea-rates.com. Data were collected during December 2019 to March 2020, and we use average values from that period

Table 7 shows that changes in the sailing speed will not have a significant effect in terms of causing modal shifts to airfreight, but there will be some changes between the two maritime alternatives. In fact, at a scenario where the regular service slows down to 12.5 knots while the fast service maintains its current speed, the modal shift towards the faster service is considerable. However, in all scenarios compared to the current speeds, the total emissions are actually increasing, as more cargoes are shifting to air transport. So, while maritime emissions are reduced because of the lower sailing speeds, unless actual demand for cargo is dropping the net effect on the environment will be worse.

4.8 Limitation of season due to speed reduction

The previous section showed that significant modal shifts should not be expected as a consequence of a small reduction in sailing speeds. In addition, recent years have seen the emergence of dedicated faster shipping services for cherries (the so-called Cherry Express services from Hapag Lloyd) that offer transit times of only 22 days from Chile to Hong Kong, and 27 days to Shanghai⁹. This shows that there is significant demand for this product to generate additional services offering competitive advantages in terms of transit times. We therefore believe that if due to the short-term measures certain shipping routes would reduce sailing speeds, the existing capacity and a greater demand for such products may result in a differentiation of services. In addition, even with low speed limits, total voyage time does not increase past 36 days, and producers had been vocal about exceeding 35-40 days (IMO, 2018).

However, a more important concern, due to a significantly lower sailing speed, is that a slower speed would reduce the “consumption” period of the product in China. Currently, the first batches of cherries arrive in mid-October using air transport, and the first ships are scheduled to arrive by mid-December, after leaving Chilean ports in mid-November. In a worst-case scenario, of sailing speeds dropping to 12.5 knots (minimum acceptable speed), the total transit time of the first and last shipment would increase by 6 days respectively. Assuming that the consumption pattern in import markets is unchanged throughout the season (there is actually a peak during holiday seasons and in the Chinese New Year), we could consider a worst case scenario of shortening the cherry selling season by 12 days, in a total period of 120 days. This would lead to a 10% reduction of transport throughput that could be replaced by the faster maritime service or, worse, by air transport. If a speed limit was enforced, then there would not be the option of speed differentiation in the maritime modes, and the lost cargo volumes would have to be shipped via air transport.

In 2018/19, exports of cherries increased and smaller shipments were sent on more vessels, something that was hailed by importers due to the reduction in risk. We expect that if the season is actually reduced due to lower sailing speeds, one possible reaction would be to increase lot sizes, or shift more exports to airfreight, with a significantly higher environmental footprint. However, there is not enough information to perform a thorough analysis on how these modal shifts would play out (e.g., we have information for the total volumes by mode, but not broken-down by week).

5. Concluding remarks

Considering that the implementation of most of the suggested short-term measures will start in 2023, there should be sufficient time for adapting to the new situation. Measures under discussion are currently considering a progressive emissions reduction to reach the 2030 levels, and therefore the situation should be manageable for the affected stakeholders.

5.1 Comparing short term measures

⁹ <https://www.hapag-lloyd.com/zh/news-insights/news/2019/10/chile---asia---an1-cherry-express-service.html>

It is clear that some volumes of perishable cargoes will actually move to airfreight. In addition, depending on which kind of measure moves forward, older, less efficient, vessels may have to be moved to other trades (where cargo is not expensive or perishable) and faster vessels can be used in peak demand seasons. We show that using a speed limit as a means of reducing emissions intensity would be effective, but it would be counterproductive, as it would not provide any incentive to shipowners to invest in more energy efficient vessels. Using a power limit instead, would allow more efficient vessels to sail faster on the same routes, compared to older and more fuel consuming vessels, while also ensuring that emissions intensity targets are achieved. Finally, a goal-based measure has the advantage of offering a smoother transition period to reach the emissions intensity levels of 2030. As a result, older vessels would be slowly phased out in the major trade lanes, and ship operators could have more time to decide how to reach their goal-based targets each year. It would also make it easier for the operators to choose having certain faster services at peak demand periods, and offset these with a slower service in other voyages.

5.2 Mitigating strategies

It should be noted that, in goal-based measures, annual emissions reductions are considered. It would therefore be possible to maintain existing sailing speeds for short periods when perishables are transported, and reduce speeds at other periods when non time sensitive cargoes are moved. This would not be possible through a speed limit (assuming that this is lower than the current sailing speeds), or through the EEXI approach if the deployed vessels have a poor environmental performance. Exceptions have been advocated by several affected member states as a potential mitigation measure. We believe that these should not be the norm for the short-term measures, as it does not seem likely that a speed limit will be instituted that could have detrimental impacts on these services. If a goal-based measure or an operational measure (EEXI or power limits) is adopted, then shippers would require a more environmentally friendly ship to move their cargoes. Particularly for the goal-based measure, and considering the seasonality of these products, it would be possible that shipments are moving on higher than average sailing speeds when carrying perishables on a limited season, and then these vessels are deployed on lower sailing speeds in other seasons in a year. Finally, the importance of a high utilization rate of each ship's capacity will also be very important in ensuring low carbon intensity levels.

5.3 Other contributing factors

In reality, there are additional factors that could distort this market which cannot be modelled. For example, recent unrest in Chile and riots in Santiago led to some ports temporarily halting their activities¹⁰. There were concerns that certain shipments planned for November 11th, 18th, and 25th 2019 would be cancelled. In 2018, the first maritime shipment was sent on November 22 for a 35-day journey to China¹¹. We can therefore observe that the market would have increased the season for exporting cherries, and at the same time offer faster services. Air transport of cherries is more expensive but has a longer season due to the smaller transit times. According to online sources, the first shipment¹² (141 containers via air) of 2019 arrived in China on October 18. Other unexpected factors and disruptions could severely influence both the production of such products, as well as the consumption at the end markets. Another important issue has to do with the impacts of the global sulphur cap that affects the costs of sea transport. According to current BAF surcharges, an increase in fuel price by \$100/ton could translate in an increase of \$64/TEU. Interestingly, certain countries are now suspending port checks of sulphur compliance due to the COVID-19 pandemic. Estimating the impacts of the global cap is beyond the scope of this paper and certainly cannot be attributed to the goal-based measure. It can be easily understood however that freight rates for cherries could increase by up to 7% using a simplified conservative estimate. Finally, it should also be noted that the 2030 reduction goals are comparing with 2008 levels, when sailing speeds in the liner shipping sector were much higher than they are today. Therefore, it is

¹⁰ <https://www.freshplaza.com/article/9162949/unrest-in-chile-affects-cherry-export-to-china/>

¹¹ http://www.xinhuanet.com/english/2018-11/23/c_137626431.htm

¹² <https://www.freshplaza.com/article/9154946/the-first-batch-of-chilean-cherries-arrives-in-shanghai/>

much easier for this sector to live up to these targets without significantly reducing its sailing speeds. Several ships are currently already satisfying the required emissions reduction targets, assuming a high level of capacity utilization. However, when it comes to perishable goods transport, reducing speed is more challenging as we attempted to show in this paper.

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