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Three potential benefits of the EU and IMO's landmark efforts to monitor carbon dioxide emissions from shipping

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International shipping accounts for around 2.2% of global carbon dioxide (CO₂) emissions (Smith et al., 2014). Emissions from international shipping are expected to increase by 50%–250% by 2050, mainly due to the growth of the world maritime trade (Smith et al., 2014). However, efforts to control CO₂ emissions from the global shipping industry are absent from the Kyoto Protocol and Paris Agreement. Therefore, the International Maritime Organization (IMO) has released an ambitious strategy to cut the total annual greenhouse gas emissions of shipping by at least 50% by 2050, compared with 2008 (IMO, 2018).

To promote the reduction of CO₂ emissions from maritime transport in a cost-effective manner, the European Union (EU) and IMO have introduced two similar albeit separate regimes. The EU has laid down rules for the accurate monitoring, reporting, and verification (MRV) of CO₂ emissions from ships with a gross tonnage above 5000 arriving at, within, or departing from ports under the jurisdiction of a Member State (EU, 2015). The fuel consumption and CO₂ emission data per ship for the 2018 reporting period of the MRV regime have already been published. The IMO has implemented a data collection system (DCS) that requires ships with a gross tonnage of

5000 and above to report verified fuel consumption data via their flag states (IMO, 2016). The first reporting period of the IMO DCS is from January 1 to December 31, 2019. In contrast with the MRV regime, which publishes the CO₂ emissions of each ship, the IMO DCS will anonymize ships' names and IMO numbers in its publications.

We argue that, using the verified fuel consumption data on individual ships published by the EU, relevant parties, such as regulatory bodies, ship owners, and ship charterers, will be able to assess the fuel efficiency of each ship, taking into account the effects of the speed, cargo load, and sea and weather conditions under which the ship has sailed. In particular, the speed and cargo load information can be obtained from ships' automatic identification system (AIS) data, which are commercially available (Yang et al., 2019); the global sea and weather conditions are accessible from government agencies such as the European Center for Medium-Range Weather Forecast (ECMWF, 2019); machine learning models, such as regression models (Meng et al., 2016) and artificial neural network (ANN) models (Du et al., 2019), have been developed to predict the fuel efficiency of ships based on features of speed, cargo load, and sea and weather conditions. Although the IMO DCS will publish aggregate fuel consumption data, ship owners or operators can, and probably will, authorize the IMO to publicize a ship's fuel consumption data if the ship is more fuel-efficient than similar ships in the industry.

Therefore, although the main purpose of the data collection regimes instated by the EU and the IMO is to identify measures to reduce CO₂ emissions from ships, we propose that there will be three potential benefits even without further measures taken.

Benefit 1: Efficient ships will carry cargos and inefficient ships will be idle

Fuel cost is a significant component of the operating costs of ships and sometimes constitutes over half of the operating costs. As charterers¹⁾ pay the fuel cost, they favor

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1) We use the word "charterer" to refer to time charterer; the time charterer, instead of the ship owner, pays the fuel costs of the chartered ship.

fuel-efficient ships. In reality, however, charterers cannot know with uncertainty the fuel-consumption performance of ships in the chartering market. This situation can be understood if we consider the case of buying a second-hand car from a private owner: The owner shall say that the car is his/her love and is well maintained, but we do not know whether it is true or not. As a consequence, some inefficient ships can still be chartered (sometimes even at higher rates (Adland et al., 2017)) and used to carry cargos. With the availability of fuel consumption data from the two schemes, charterers will be able to assess the fuel-efficiency of different ships, and thus will be less likely to charter inefficient ships. This will reduce the overall fuel consumption of the shipping industry.

Benefit 2: Ship owners will maintain their ships in excellent fuel-efficiency conditions

Ship owners and charterers form a principal-agent problem: Ship owners can invest in improving the fuel efficiency of ships, but the benefit of fuel consumption reduction accrues to charterers; a market failure occurs if the ship owners' investment is not fully recovered by higher charter rate. Empirical studies show that a very small proportion of the fuel cost savings go to ship owners as reflected by higher time charter rates, e.g., 40% reported by Agnolucci et al. (2014) and only 14% during normal freight market conditions reported by Adland et al. (2017) for Panama ships. Though these studies use coarse data (e.g., amount of cargos transported, average speed) instead of more granular data such as instantaneous speed and sailing conditions (sea and weather conditions), the results certainly imply that more fuel-efficient ships do not earn higher time charter rates they deserve. The main reason is that ship owners know the information of the fuel efficiency of the ships, but the charterers do not. Nevertheless, ships owner cannot guarantee a certain fuel efficiency of their ships because the actual sailing conditions of the ships are very complex. This dilemma can be best understood if we consider the case of buying a second-hand car from a private owner again: Even if the car is indeed the owner's love and is well maintained, the owner still refuses to promise, e.g., a three-year guarantee, because the buyer may be a driver who does not take good care of cars and who often has to drive cars in rough conditions; as a consequence, the buyer is willing to offer a price that matches only the verifiable conditions of the car such as age and mileage, but not one that matches the unverifiable conditions such as wear of engine and fuel efficiency; then, the owner has no motivation to spend money maintaining the car before selling it. With the availability of fuel consumption data from the two schemes, charterers will be able to assess the fuel-efficiency of ships and hence would be willing to pay significantly higher rates for more fuel-efficient ships. This will motivate ship owners to maintain their ships in excellent conditions (e.g., through regular hull cleaning).

As a result, the average fuel-efficiency of the ships in the market will be higher and this will reduce the overall fuel consumption of the shipping industry.

Benefit 3: Charters can operate ships more efficiently based on historical data

In the absence of historical ship operating data, charterers have to collect data from scratch to establish operational modes (e.g., dynamic sailing speed optimization and weather routing) that minimize fuel consumption. With the availability of fuel consumption data from the two schemes, charterers will be able to near optimally operate the chartered ships from the beginning of the charter period without spending much time on data collection. This will reduce the fuel consumption of the ship and thereby carbon emissions.

In sum, we believe that the EU and the IMO's landmark efforts to monitor CO₂ emissions from shipping will prompt the shipping industry to voluntarily improve its fuel efficiency, thus reducing fuel consumption and CO₂ emissions.

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