Organisation for Economic Co-operation and Development

SDD/DOC(2024)2

Unclassified English - Or. English

6 March 2024

STATISTICS AND DATA DIRECTORATE

An ocean of data: The potential of data on vessel traffic

SDD Working Paper No. 121

Contact: stat.contact@oecd.org.

JT03538759

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Abstract / Résumé

Rising uncertainties and geo-political tensions, together with increasingly complex trade relations have increased the demand for monitoring global trade in a timely manner. Although it was primarily designed to ensure vessel safety, information from the Automatic Information System, which allows for the tracking of vessels across the globe, is particularly well suited for providing insights on port activity and maritime trade developments, which accounts for a large share of global trade. Data are available in quasi real time but need to be pre-processed and validated. This paper contributes to existing research in this field in two major ways. First, it proposes a new methodology to identify ports, at a higher level of granularity than in past research. Second, it builds indicators to monitor port congestion and trends in maritime trade flows and provides more granular information to better understand those flows. Those indicators will still need to be refined, by complementing the AIS database with additional data sources, but already provide a useful source of information to monitor trade, at the country and global levels.

Keywords: maritime trade, big data, port activity, port congestion.

JEL codes: F17, C55, C81.

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Les incertitudes croissantes et les tensions géopolitiques, ainsi que les relations commerciales de plus en plus complexes, ont accru la demande de suivi du commerce mondial en temps opportun. Bien qu'elle ait été initialement conçue pour garantir la sécurité des navires, l'information contenue dans le Système Automatique d'Information (en Anglais, AIS), qui permet de suivre les navires à travers le monde, est particulièrement bien adaptée pour fournir des informations sur l'activité portuaire et l'évolution du commerce maritime, qui représente une large part du commerce mondial. Les données sont disponibles quasiment en temps réel mais doivent être prétraitées et validées. Cet article contribue aux recherches existantes dans ce domaine de deux manières principales. Premièrement, il propose une nouvelle méthodologie pour identifier les ports, à un niveau de détail plus élevé que dans les recherches précédentes. Deuxièmement, il crée des indicateurs pour suivre la congestion portuaire et les tendances des flux commerciaux maritimes et fournit une information plus granulaire afin de mieux comprendre ces flux. Ces indicateurs devront encore être affinés, en complétant la base de données AIS avec des sources de données supplémentaires, mais ils constituent déjà une source d'information utile pour suivre le commerce, aux niveaux national et mondial.

Mots clés : commerce maritime, big data, activité portuaire, congestion portuaire.

Codes JEL : F17, C55, C81.

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An ocean of data: The potential of data on vessel traffic

By Graham Pilgrim, Emmanuelle Guidetti and Annabelle Mourougane[1]

1. Introduction

1. Rising uncertainties and geo-political tensions, together with increasingly complex trade relations have increased the demand for monitoring global trade in a timely manner. At the same time, advances in Big Data Analytics and access to a huge quantity of alternative data – outside the realm of official statistics - have opened new avenues to monitor trade. They can help identify bottlenecks and disruptions in real time but need to be pre-processed and validated.

2. One such alternative data source is the Automatic Identification System (AIS) which was developed by the International Maritime Organisation and allows for the tracking of vessels across the globe. The system includes messages transmitted by ships to land or satellite receivers. Messages are available in quasi real time. Although it was primarily designed to ensure vessel safety, this data is particularly well suited for providing insights on trade developments, as over 80% in volume and 70% in value terms of international merchandise trade are being carried by sea (UNCTAD, 2022). Furthermore, AIS data holds granular vessel information and detailed location data, which when combined with other data sources can enable the identification of activity at a port (or even berth) level, by vessel type or by the jurisdiction of vessel ownership.

3. For a number of years, the UN Global Platform has made AIS data available to those compiling official statistics, such as National Statistics Offices (NSOs) or International Organisations. It applies a number of techniques to address some of the shortcomings of the dataset. More recently, the UN AIS Task Team has provided a platform for sharing experiences within the official statistics community and facilitated the development of the new methodologies required for the analysis of this data, such as the automated identification of port locations (CSO Ireland, 2022). The data has also been exploited by data scientists and research centres to monitor trade in specific commodities such as Liquefied Natural Gas (QuantCube Technology, 2022) or to analyse port and shipping operations in a specific country (Tsalamanis et al., 2018). Beyond trade, the dataset has been used to track emissions from the maritime sector (Clarke et al., 2023).

[1] The compilation of this work benefitted greatly from the contributions of Polina Knutsson and Enrico Wegner. Valuable comments were received from Alexander Banquet, Daniel Clarke, Bram Edens, Asa Johansson, Matthew de Queljoe, Antonella Liberatore, Catherine MacLeod, Paul Schreyer and Frank Van Tongeren. Many thanks to Virginie Elgrably for excellent technical assistance.

4. This paper contributes to existing research in this field in two major ways. First, it proposes a new methodology to identify ports, at a higher level of precision than in past research. Second, it builds indicators to monitor port congestion and trends in maritime trade flows and provides a tool to get detailed information and better understand those flows. Those indicators will still need to be refined, by complementing the AIS database with additional data sources, but already provide a useful source of information to monitor trade, at the country and global levels.

5. The AIS was initially not intended for statistical purposes, and it is key to be aware and attempt to resolve some of its shortcomings. The paper applies a number of techniques, to address some of those. However additional research, suggested within the conclusion will be needed to improve further the exploitation of this rich source of information.

6. The main insights from the analysis are as follows:

- The AIS dataset appears to be a very promising source of data, which provides timely – close to real time data - and very granular data but needs to be treated adequately to get reliable information to be used in policy advice.
- A new methodology includes information on the main characteristics of ships from the AIS dataset and results in a more precise approach to identify ports, constituting an improvement compared to existing approaches.
- Indicators derived from AIS can help monitor port activity, in the event of strike, natural disasters or after port extension. Proxies can also be derived of maritime trade volumes. Although the indicator levels cannot be interpreted as levels of trade flows, an increase is likely to coincide with a rise in maritime activity, which in turn is positively correlated with global trade. As such, those data can provide timely indicators of sudden changes in global trade.
- Preliminary proxies of maritime trade point to a sizeable drop in activity of some specific port areas and traffic of some categories of vessels during the COVID-19 pandemic. They suggest a drop in port activity and trade disruptions at the start of the war in Ukraine, although data need to be interpreted with caution in this specific case, as there are also indications of AIS emitters being switched off by ships. Most recent data suggested little maritime trade growth in 2023 in many countries in Europe and North America, but a rebound of exports in Asia. There is also evidence of a rerouting of cargos from the Suez Canal to the Cape of Good Hope since the start of the Houthi attacks in October 2023.
- A new OECD AIS Tracking Dashboard allows visualisation of key indicators of ports and maritime trade, and is available here.

7. The paper is structured as follows. The next section presents AIS data including its design and limitations. Section 3 reviews the literature and current methods which have been applied in the analysis of AIS data to date. Section 4 presents the methodology to detect port areas and to develop a number of port-level and maritime trade metrics, including some validation of findings against official data. Section 5 describes selected real-time indicators of port activity and Section 6 preliminary proxies of maritime trade in the aftermath of specific shocks such as the COVID-19 pandemic or the start of the war in Ukraine, and in the most recent period. Section 7 presents a user-friendly dashboard to visualise the data. A last section concludes and points to future areas of research to further improve the exploitation of this rich dataset.

2. AIS data

8. The Automatic Identification System (AIS) is used by vessels to transmit information to other vessels and coastal authorities. Its primary goal is to improve maritime safety. International Maritime Organisation (IMO) regulations require that AIS transmitters be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. However, in practice many more vessels than required have AIS installed as it aids in safety and has minimal installation cost.

9. The data used within this paper is obtained from Spire Global Inc, which operates one of the largest AIS monitoring networks, with billions of AIS messages spanning from January 2019 to date. The UN Global Platform makes these data available to the public and provides the opportunity to process the data using the large-scale data processing engine Apache Spark.

10. A transmitter on each vessel emits a "ping" or radio message at a regular frequency. The messages are received and stored by receivers located on land or satellites. There are 64 types of messages but overall, the information transmitted can be broken down into two categories: static and dynamic.

11. Static data include information on the characteristics of the vessel and variables such as navigational status, destination and draught (Table 1). Some of the static data is manually inputted and is in general transmitted every 6 minutes, or when the information has been updated. It should be noted that the accuracy of static data is reliant on the vessel's crew to correctly input this information and is therefore prone to errors.

Table 1. Key fields from static AIS messages

Field	Description	Example Value
IMO	Identification Code, the vessel name code (main ID used in the paper)	8919221
MMSI	Maritime Mobile Service Identity (used to improve the coverage of the database, when IMO is not available)	211100000
Vessel Name	The name of the vessel	ANTONIA B
Vessel Type	Type of vessel e.g. Cargo, Cruise	Cargo
Time	Time when the signal was emitted	31-03-2023 11:55:18 PM
Length	Length of the vessel in meters	81
Width	Width of the vessel in meters	11
Draught	Depth of the water, in meters	4
Destination	Name of the Port and Country	DKNAK (Denmark, Nakskov)
Estimated time of arrival (ETA)	Estimated time of arrival of ship voyage (In format MMDDHHmm)	04040200 (4th April 2023 at 2:00am)
Navigation status	The navigation state of the vessel e.g. At anchor, Moored, Underway using engine	Underway using engine

Source: AIS database.

12. Dynamic data relates to the position and movement of vessels and is collected automatically from GPS sensors aboard. It includes variables such as speed over ground, vessel heading and positional data (Table 2). In general, dynamic data is updated in accordance with the rate of change of the underlying data. The frequency of updates can vary from two seconds for fast moving vessels changing course to three minutes for vessels which are anchored and therefore relatively static.

13. While the vast majority of information is well transmitted and received, inaccurate, noisy or corrupted data are possible. Issues can be introduced on the transmission side if, for instance, the transmitter is deliberately turned off. While there are legitimate reasons for doing this, such as cases were making your location available would put the vessel at risk (e.g. in locations of known piracy), there are also illegitimate reasons such as when performing illegal activities.

14. Transmission is only half of the story: these signals also need to be received and stored. To achieve this, commercial data providers maintain a network of satellite and land-based receivers. However, many transmitted messages are not received by those receivers. The latter also suffer from shortfalls. For example, the revisit frequency of satellite-based systems tends to be longer than land-based systems. Commercial data providers operate large satellite arrays to mitigate this issue. Land-based systems also have their shortcomings. With coverage being limited by the location of the receiver, signal clashes in locations which are densely populated, system outages and atmospheric conditions affect the quality of the messages.

Table 2. Key fields from dynamic AIS messages

Field	Description	Example Value
Message Type	AIS includes 64 types of messages. Each provides different information. For example, message type 1 is a scheduled position report, whereas message type 3 is a position report which has been requested of the vessel.	3
Time	Time when the message was sent	01-04-2023 12:03:52 AM
Longitude	The longitude position of the ship	9.54548833
Latitude	The latitude position of the ship	55.70625167
Speed over ground	Speed of the vessel measured in knots	9.2
Course over ground	The direction the vessel is moving in measured in degrees	125.4
Rate of Turn	How quickly the vessel is turning measured in degrees per minute	0
Heading	The direction the ship is pointing measured in degrees	120

Source: AIS database.

3. Past research using AIS data

15. AIS data has been used to extract information on vessel behaviour and maritime traffic for a number of years. Previous studies mainly focussed on vessel anomaly detection and risk assessment of ship collision (see Spiliopoulos et al. (2018) for references of related work). They extract shipping routes using the Origin-Destination method (by counting departure ports and destinations), grid-based methods (by dividing a study area into grids and counting the frequency of ships in each grid) combined with cluster analysis to group vessels by group and a density-based approach (the denser the ship distribution, the higher the possibility that a major route exists at that location). However, those methods suffer from a number of limitations when applied on a large scale and may lead to significant differences between extracted and actual shipping routes (Cheng et al., 2018).

16. More recently, uses and applications of AIS data have expanded beyond maritime safety. The broadening in the scope into the domain of monitoring international trade was facilitated by the set-up of the UN Global Platform, which makes this data available to those compiling official statistics, such as National Statistics Offices (NSOs) or International Organisations.

17. At the country level, the Irish Central Statistics Office (2022) estimates port areas via a Stationary Marine Broadcast Method (SMBM), using stationary vessels localisation, partitioning the world into hexagons and developing rules to identify port areas. While the approach is effective for the vast majority of cases it can cause issues in cases of transiting vessels. Tsalamanis et al. (2018) combine AIS with the Consolidated European Reporting System (CERS), which records details such as destination port and expected time of arrival for the voyage of each ship, to explore the relationships between the largest ports in the United Kingdom at a macro level and the behaviour and operational characteristics of ships at a micro level.

18. Moving beyond precompiled port call data from external data providers, Cerdeiro et al. (2020) use a machine-learning approach based on a spatial clustering algorithm (DBSCAN) to determine port boundaries and apply these boundaries to compute trade indicators. They also handle cases of ships traversing ports without stopping at port facilities by training a classifier on vessel data available from US Customs and applying this classifier at a global level, with mixed results. Bai et al. (2024) apply a machine-learning algorithm on AIS data to identify ports and anchorage and calculate port congestion rates of the world top 10 container ports. QuantCube Technology (2022) derives a trade monitor for LNG from AIS information on vessels carrying this commodity.

19. Recent applications have moved one step further and derived proxies of trade from the information contained in the AIS. In one of the first applications for monitoring trade Arslanalp et al. (2019) precompiled port calls from MarineTraffic, which at the time of writing operated one of the largest global AIS networks and calculated a “cargo-load” factor (which proxies the weight of the cargo) by monitoring the change in draught of vessels, and reckoned this indicator was providing useful information to monitor trade in Malta. Subsequently, Arslanalp et al. (2021) improved the cargo load factor calculation by applying the method from Jia et al. (2019), which includes vessel information such as length, width, draught, capacity and block coefficient (which accounts for the shape of the vessel) for Pacific Island countries. The IMF derives estimates of trade volume following a similar logic in the IMF PortWatch project and builds on this research further to monitor disruptions to maritime trade flows at a global level.

20. Beyond trade, Clark et al. (2023) estimate CO_2 emissions from shipping using the AIS, the Information Handling Services (IHS) ship register, the European Union’s monitoring, reporting and verification data system and machine-learning techniques to predict an emissions efficiency ratio for each ship. The ratio is then multiplied by the distance travelled by the ship, derived from AIS data, to obtain each ship’s emissions.

4. Methodology

21. Understanding the global trading system in greater details requires a knowledge of where vessels unload and load goods. In general, this activity occurs in ports and this paper focusses primarily on monitoring this activity. Whilst AIS data contains information surrounding the location of the vessel, it does not specifically determine whether this location is within port and in turn under the authority of which jurisdiction the port resides. A five-step methodology is developed here to achieve this:

1. Data cleaning and preparation
2. Identification of areas which are likely to be ports
3. Building a database of vessel arrivals and departures at a port level
4. Building a set of indicators to capture developments in maritime trade
5. A simple approach to monitor traffic in maritime choke points

Data cleaning and preparation

22. Using billions of AIS messages for analysis is not straightforward. It requires the use of distributed processing systems, such as Spark, and to pre-screen the data to those essential to limit the time to process this information.

23. Given the focus on international trade, only vessels which are engaging in global trade are retained. This is achieved by merging information contained in the IHS Shipping Registry (which incorporates Seaweb and Lloyd's Register of Ships), with AIS variables. More specifically, vessels engaging in global trade are identified using the IMO number for vessels of "Cargo Carrying" class from the IHS Shipping Registry. This includes containers, bulk dry, oil or liquefied gas or chemical tankers, cargo and some passenger vessels.

24. Additionally, AIS messages come in a number of formats (64 in total). Message types whose level of accuracy with regards to longitude and latitude is low (for instance message type 27) were removed from the sample.

25. Data were also treated to handle cases of duplicate data, anomalies and lack of suitability for analysis on international trade. Firstly, duplicate data for the same vessel and timestamp are handled by simply aggregating the data by IMO, MMSI and timestamp and taking only the first message, as in the vast majority of cases, duplicates exist due to multiple entries of identical data within the AIS database.

26. Secondly, infeasible movements can occur when an AIS message becomes corrupted and an incorrect location is received. These cases were compared with past occurrences of travels from the previous location to the current location. The message was removed when the average speed of the examined case was more than 60 kilometres per hour. Average speed is determined by applying the Great Circle Distance method, which measures the shortest distance between two points on the surface of a sphere and assuming a spherical Earth.

27. Thirdly, as the objective is to produce indicators on a very granular port level, cases where the level of rounding shows that the data transmitted (or received) did not have sufficient accuracy were removed. Thresholds were defined depending on the formats of longitude and latitude (Table 3). The level accuracy was aligned with typical boat dimensions. For example, cases of decimal degrees accuracy at the four decimal places level and degrees, minutes and seconds accuracy at the 1/10 minute accuracy level were removed.

Table 3. Format and accuracy levels of longitudes and latitudes

	Accuracy	Example	Approximate Error (m)
Decimal Degrees (DD)			
	4 decimal places	41.4033, 2.1740	55.57
	5 decimal places	41.40338, 2.17403	5.56
Degrees, Minutes and Seconds (DMS)			
	1/10 minute accuracy	41°24'N 2°12E	92.62
	1 second accuracy	41°24'12"N 2°10'27"E	15.44
	1/10 second accuracy	41°24'12.2"N 2°10'26.5"E	1.54

Note: Based on the assumption that the Approximate Error (m) = Minimum increment size * 111139 / 2 where 111,139 is an estimate of the distance of one degree of movement at the Equator in meters.
Source: Authors' computation.

Identification of ports

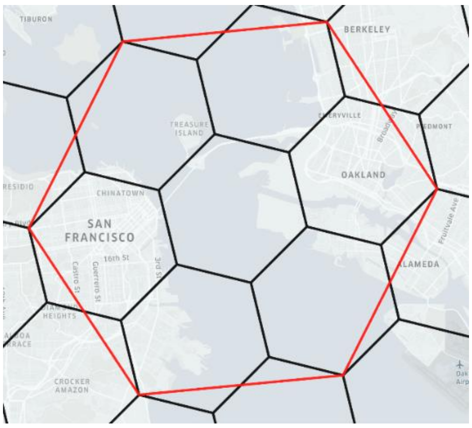
28. The most innovative part of the methodology is the endogenous identification of 'likely' port areas based on information on the vessels' position (e.g. longitude and latitude) contained in the AIS messages.

29. Aggregating positional data at a meaningful level is a non-trivial task. This can be done by partitioning the world into individual cells which are then used to determine areas, such as ports. The method used in this paper builds on and extends the Stationary Marine Broadcast Method (SMBM) developed by the Irish CSO (2022).

30. The SMBM firstly attempts to locate hexagons which contain stationary vessels. Approaches for grouping geospatial data vary, and a number of reference systems such as H3 (reference), S2 (reference) and Geohash (reference) have been developed. The SMBM methodology focusses on the use of the H3 referencing system, which breaks the world into hexagons for a number of levels of detail (Figure 1). Table 4 gives average edge widths of the corresponding hexagons, allowing users to appraise the level of detail. Once these hexagons have been determined the port area is defined as hexagons within three steps from this location. This contrasts with existing methods, such as the one underlying the IMF Portwatch, which identifies port polygons manually.

Figure 1. Visualising the H3 georeferencing system at multiple levels

H3 Level 5 (Red) and H3 Level 6 (Black)



Source: Uber (https://h3geo.org/docs/highlights/indexing).

31. As a first approximation, areas where a large number of vessels are identified as static could correspond to ports. However, searching simply for static vessels would generate a number of false positives, as there are a number of reasons why a vessel could be static, such as waiting at anchor outside a port or simply by chance. To address this issue, areas where only significant numbers of static vessels are present are included, which removes a great number of false positives. The range of area around each individual static vessel is then included using the vessel dimensions and heading information, which allows for analysis of ports at close to berth level.

32. Figure 2 summarises the set of rules to detect ports. The first stage determines which vessels show characteristics of being static. The second stage aggregates these vessels at a high level (H3 level 8) in order to determine which hexagon shows characteristics of corresponding to ports. The third stage filters data to only those which are both static and within determined port polygons. The fourth and final stage takes account of vessels‘ heading (direction which the vessel is facing) and dimension data to determine port areas at a greater granularity (H3 level 11) than in past research.

Table 4. Average edge lengths and areas for the H3 georeferencing system

Resolution	Average edge length (m)	Average Hexagon Area (m^2)
0	1281256.01	4,357,449,416,078.39
1	483056.84	609,788,441,794.13
2	182512.96	86,801,780,399.00
3	68979.22	12,393,434,655.09
4	26071.76	1,770,347,654.49
5	9854.09	252,903,858.18
6	3724.53	36,129,062.16
7	1406.48	5,161,293.36
8	531.41	737,327.60
9	200.79	105,332.51
10	75.86	15,047.50
11	28.66	2,149.64
12	10.83	307.09
13	4.09	43.87
14	1.55	6.27
15	0.58	0.90

Source: Uber (https://h3geo.org/docs/core-library/restable).

33. Stage 1: A vessel in port which is moored tends to be secured in place to a fixed structure. Fixing limits the movement of the vessel and means it should be static in both location and movement. This therefore means that AIS messages should show a speed of zero, limited heading change from the previous and following messages, and limited movement from the previous and following messages. This differs from ADB (2023) which defines a vessel as static when the speed is below one knot. Such a threshold would however not be sufficient in the methodology presented here to identify exact berth polygons and would lead to many false positives. Table 5 summarises the conditions required to define a vessel as static.

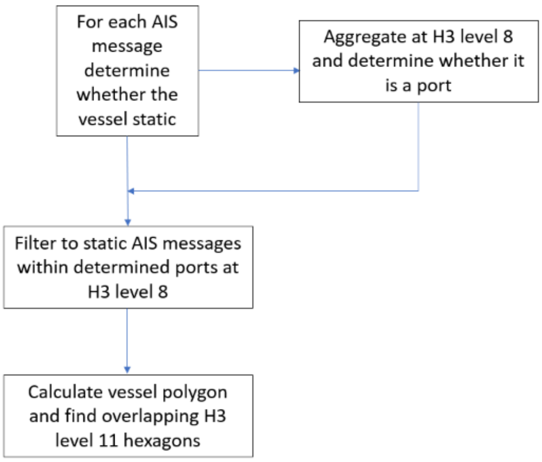
34. Stage 2: By aggregating and considering an H3 level 8 hexagon (with an edge length of approximately 500 meters), it is possible to set a number of rules that will determine whether the area corresponds to a port or not. A hexagon is classified as a port if:

- Over 20% of the AIS messages within the H3 level 8 hexagon are classified as static;
- There is at least one AIS message with the Navigation Status of “Moored”; and
- There are more AIS messages with the Navigation Status of “Moored” than “At anchor”.

35. Stage 3 identifies vessels which are both static and within H3 level 8 Port Hexagons.

36. In Stage 4 the polygon of potential space which the boat could occupy is determined by using the heading, length and width data (Figure 3 and Table 6). Overlaps with H3 level 11 Hexagons (with an edge length of roughly 30 meters) are determined for all matching AIS messages, which results in a database of over 1.2 million hexagons which are believed to belong to ports. An example of this method is shown for the area surrounding the Port of Rotterdam (Figure 4). Validation checks were undertaken in some case, where official data were available (Box 1).

Figure 2. Overview of the port detection methodology



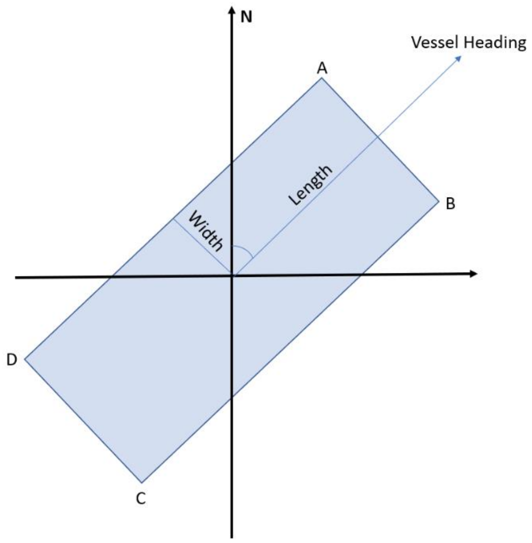
Source: Authors' representation.

Table 5. Requirements to be considered a static vessel

Description	Condition
Previous speed is nil	$SOG_{t-1} = 0$ where SOG stands for the vessel's speed over ground
Current speed is nil	$SOG_t = 0$
Following speed is nil	$SOG_{t+1} = 0$
Heading change from previous message is less than 1 degree	$\left\|180 - \|Heading_t - Heading_{t-1}\|\right\| \leq 1$
Heading change to following message is less than 1 degree	$\left\|180 - \|Heading_t - Heading_{t+1}\|\right\| \leq 1$
Movement from previous message is less than 10 meters	$63,710,088*cos-1*(sin(latitude_{t)})*sin(latitude_{t-1}) +cos(latitude_{t)})*cos(latitude_{t-1})*cos(longitude_t - longitude_{t-1}))) \leq 10$
Movement to following message is less than 10 meters	$63,710,088*cos-1(sin(latitude_t)*sin(latitude_{t+1)}) +cos(latitude_t)*cos(latitude_{t-1})*cos(longitude_t - longitude_{t+1}))) \leq 10$

Note: 63,710,088 is the radius of Earth in meters.
Source: Authors' representation.

Figure 3. Determining the space which a vessel could occupy



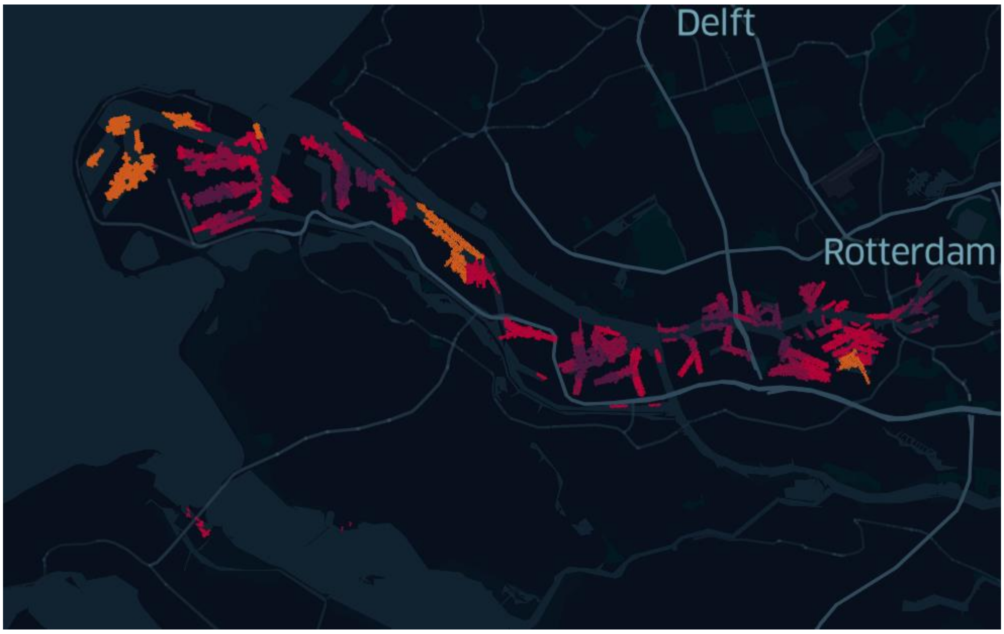
Note: The methodology assumes that the position of the transmitter on the vessel is not known.
Source: Authors' representation.

Table 6. Calculation of polygon coordinates

Point	Longitude	Latitude
A	Longitude + Length*sin(heading)/cos(latitude)/111139 + Width*cos(heading)/cos(latitude)/111139	Latitude + Length*cos(Heading)/111139 - Width*sin(Heading)/111139
B	Longitude + Length*sin(heading)/cos(latitude)/111139 - Width*cos(heading)/cos(latitude)/111139	Latitude + Length*cos(Heading)/111139 + Width*sin(Heading)/111139
C	Longitude - Length*sin(heading)/cos(latitude)/111139 - Width*cos(heading)/cos(latitude)/111139	Latitude - Length*cos(Heading)/111139 + Width*sin(Heading)/111139
D	Longitude - Length*sin(heading)/cos(latitude)/111139 + Width*cos(heading)/cos(latitude)/111139	Latitude - Length*cos(Heading)/111139 - Width*sin(Heading)/111139

Note: 111,139 is an estimate of the distance of 1 degree of movement at the Equator in meters.
Source: Authors' computation.

Figure 4. Visualisation of identified port hexagons at H3 Level 11 in the area surrounding Rotterdam



Source: Authors' representation using AIS.

Box 1. Validating methodology: Irish case

A number of countries, such as Ireland, make port visits available on a quarterly basis, allowing the comparison with both official data and a similar methodology. In the case of Ireland, it is also possible to compare those data with those derived by the CSO using a similar methodology.

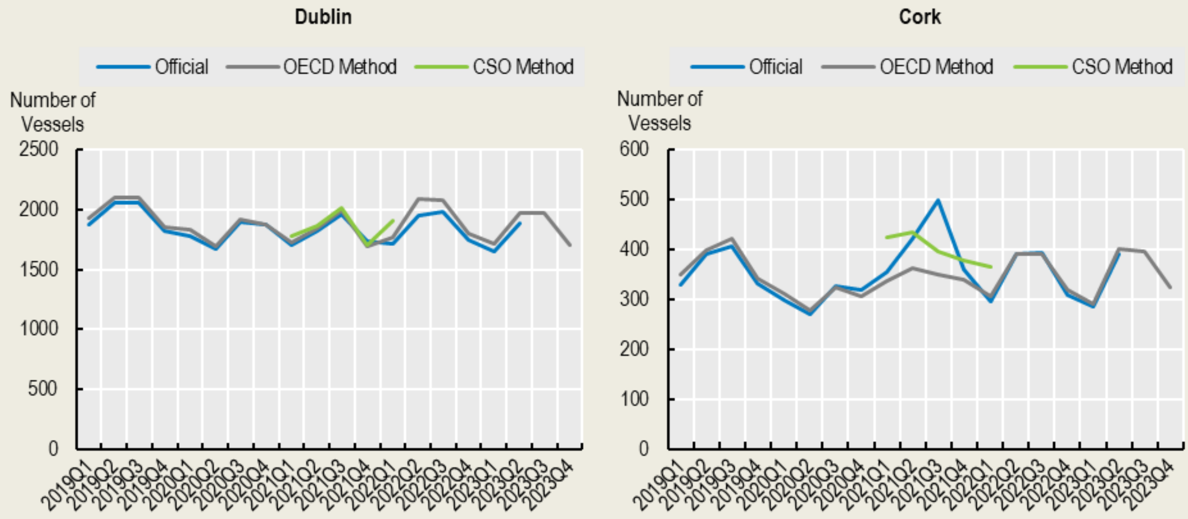
At a national level, the results of the OECD AIS method appear to closely track those of official statistics and show differences in a similar order of magnitude as the method proposed by the Irish CSO (Figure 6). The OECD AIS method has the benefit of timeliness and, at the time of writing, provides an additional two quarters of information – and more granular data, such as at a monthly or weekly basis.

Figure 5. Estimates of port visits for all Irish ports

Source: Authors' calculations using AIS data, CSO Estimates and CSO Official Data.

When analysing at an individual port level, results very closely match official statistics for Ireland's largest port, Dublin (Figure 7). When focussing on a smaller port, Cork, the OECD method appears to closely track official statistics for the majority of the time period, however, differences are notable in 2021 with a peak in official data, which remains to be explained and requires further investigation.

Figure 6. Estimates of port visits for selected Irish ports



Source: Authors' calculations using AIS data, CSO Estimates and CSO Official Data.

Overall, the comparisons show that the OECD method produces suitable estimates of port calls. However, as with any experimental Big Data, further refinements and improvement are necessary to further enhance the quality of the derived information.

37. The polygons derived to delineate ports are not linked to an underlying jurisdiction or port, which limits their analytic use. The purpose of this stage is to allocate these polygons to actual ports and to their corresponding jurisdictions. Once this has been achieved it is possible to derive vessel arrivals and departures from these ports.

38. Three data sources have been used to complement the AIS information, presented in order of use in this paper.

- The universe of potential ports is defined as ports identified within the United Nations Code for Trade and Transport Locations (UN/LOCODE) database, due to its completeness and wide adoption within industry. UN/LOCODE is a collaboration in the framework of the joint trade facilitation effort undertaken within the United Nations. It currently includes over 100 000 locations in almost 250 jurisdictions which are involved in the trade of goods and is widely used by major shipping companies, freight forwarders and in the manufacturing industry (UN/LOCODE | UNECE). In total this comprises roughly 17 400 potential ports. However, approximately 6 000 (or 35%) of these ports are not populated with co-ordinate information, and it is necessary to complement this source with additional information.
- The World Port Index is an online database of world-wide maritime port information, which provides information (including UN/LOCODE and co-ordinate information) for over 3 700 global ports. Therefore, in order to further enhance the coverage of our Port Dataset, co-ordinate information is used in cases where it is not available in the original UN/LOCODE database. This populates an additional 1 600 UN/LOCODE with co-ordinate information. The inclusion of this information means roughly 75% of ports within the UN/LOCODE database have associated port co-ordinate information.
- Geonames is a global geographical database containing over 11 million places names. For each UN/LOCODE which is missing co-ordinate information, the name is analysed and a potential matching name from the Geonames database is identified within the jurisdiction. A potential match is defined by having a Levenshtein Distance between the target UN/LOCODE and the Geonames location name of less than or equal to three. In case where multiple matches are found the closest match is taken. Levenshtein Distance is commonly used in text analysis to determine the difference between two strings and can be thought of as the minimum number of single-character edits (insertions, deletions or substitutions) required to change one word into another. Once applying this method 95% of ports within the UN/LOCODE database have co-ordinate information. The remaining unmapped ports are assumed to be minor and are therefore excluded.

39. Each hexagon within the database is linked to the closest port from the database of ports and in turn to a given jurisdiction. By combining this information with the cleaned AIS dataset, it is now possible to determine port visits from the detailed dataset.

Indicators to monitor maritime trade

40. Once ports have been identified, a number of indicators can be derived from the AIS messages on vessels and ports to provide insights on maritime trade.

41. A port arrival is determined by an AIS message received with a location which corresponds to the determined hexagons, and a port departure is determined when an AIS message is received from a hexagon which is outside the areas identified as port. A departure is valid when it corresponds to a movement of over ten kilometres to discount movement within the port (e.g. unloading in two separate berths). Vessels also need to be present for at least one hour, to avoid counting vessels passing through the port area. At the same time, imposing a very long duration would fail to capture roll-on roll-off (Ro-ro) passenger vessels, which usually pass by ports very rapidly. This would underestimate traffic in ports such

as Dover. Vessels which do not move or are in for repairs have not been excluded but their number is very small.

42. Several metrics for port visits matching these conditions are computed (Table 7). Port visits can be compiled at a country, port, berth or even vessel level basis. This degree of granularity is higher than existing databases on maritime transports or ports. This information, aggregated at port level, is made publicly available and is updated regularly as part of the OECD AIS Tracking Dashboard (Section 7).

43. Additional metrics can be used to monitor trade at the global and country level (Table 8). Vessel visits provide an idea of the density of traffic. Total capacity, which is the sum of the deadweight tonnage of all visiting vessels is an indicator of the port capacity, and when it increases significantly can point to port congestion. Entry and handling speeds also cast light on port capacity and how busy the port is.

Table 7. Information on vessels and ports from AIS messages

Metric	Description
Entry Time (Theoretical Minimum)	Time at which the last AIS message was received from outside of the port area before a port visit
Entry Time (First confirmed message)	Time at which the first AIS message was received within the port area
Exit Time (Last confirmed message)	Time at which the last AIS message was received within the port area
Exit Time (Theoretical Maximum)	Time at which the first AIS message was received from outside of the port area after a port visit
Vessel IMO	Identifier IMO corresponding to the vessel
Vessel MMSI	Identifier MMSI corresponding to the vessel
Number of Observations	Number of observations within the port area
Cumulative Distance travelled on Entry	Cumulative distance travelled by the vessel until arrival within the port area, in kilometers
Cumulative Distance travelled on Exit	Cumulative distance travelled by the vessel until departure from the port area, in kilometers
Draught Listed on Entry	Draught value transmitted in the last AIS message before arrival within the port area, in meters
Deadweight Tonnage (DWT)	Deadweight tonnage from the Shipping Registry for the given vessel. Sum of the maximum weight including the vessel, cargo and ballast, in tonnes
Gross Tonnage	Gross tonnage from the IHS Shipping Registry for the given vessel, in tonnes
Most Common H3 Level 11 Hexagon	Most common H3 Level 11 Hexagon of the vessel during the port call
Port Name	Port name corresponding to the most common H3 Level 11 Hexagon
Jurisdiction	Jurisdiction corresponding to the most common H3 Level 11 Hexagon

Source: Authors' compilation.

44. While AIS does not include information on the quality and the nature of what is transported in vessels, indications of changes in volumes at ports can be proxied by computing changes in the load factor for vessels entering and leaving the port. Load is derived by comparing the average draught to the maximal draught weighted by the deadweight tonnage. Changes in the load factor for vessels entering and leaving the port provide information on the volume of goods delivered or loaded.

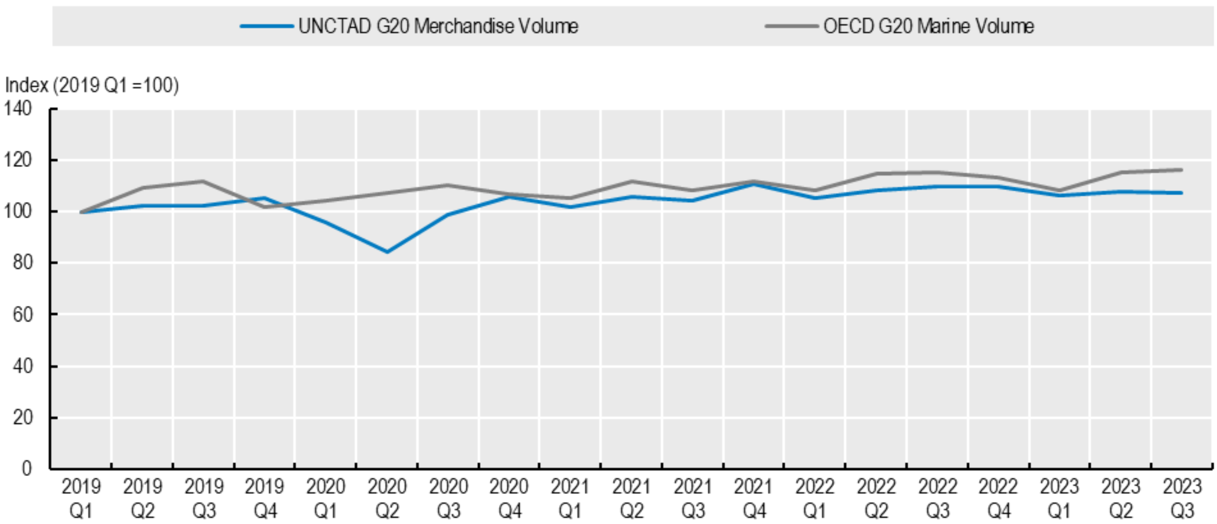
Table 8. Indicators to monitor port congestion and maritime trade

Measure	Description	Calculation method
Vessels	Count of number of visits	
Capacity	Summation of the deadweight tonnage of visiting vessels, tonnes	Sum of DWT
Entry Speed	Speed the vessel travelled from departure to the given port, kilometers per hour	Average of: "Distance travelled by vessel" to Port/ "Time taken to get to Port" weighted by DWT
Handling Speed	Time taken to handle a unit of deadweight within the port, tonnes per second	Sum of Deadweight handled / Sum of Total time in Port
Load	Loading factor for vessels entering the port	Average of Draught / Max draught weighted by DWT
Maritime import volume proxy	An estimate of the maritime import volume using draught changes and vessel characteristics in tonnes. The indicator can be computed for all types of vessels.	Sum of positive changes in draught / Max draught * Total capacity
Maritime export volume proxy	An estimate of the maritime export volume using draught changes and vessel characteristics in tonnes. The indicator can be computed for all types of vessels.	Sum of negative changes in draught / Max draught * Total capacity

Source: Authors' compilation.

45. Proxies of import (resp. export) merchandise volumes can be derived by summing the positive (resp. negative) changes in draughts over the maximum draught multiplied by the total capacity. To validate the procedure an index of the G20 maritime volumes derived from AIS messages is compared to the G20 merchandise trade volume measure, published by UNCTAD (Figure 7). The two series align well from 2021 onwards. Differences in 2020 could be explained by maritime trade being more resilient than other forms such as air, rail and road during the first year of the pandemic.

Figure 7. Validating AIS-based trade volume proxies, G20 economies



Source: Authors' calculations using AIS data and UNCTAD G20 merchandise estimates.

A simple approach to zoom into key maritime choke points

46. Waiting zones outside ports, for instance in key maritime passages, are also likely to signal bottlenecks and obstacles to trade. For instance, the Suez Canal is often closely watched as an indicator of possible disruption to trade. As the number of key maritime choke points is limited, a simpler approach than the methodology above can be used to monitor traffic in these areas.

47. The first stage is similar to the methodology used to identify ports and consists in data cleaning, removing duplicates and implausible or inaccurate observations. In addition, land-based signals can also be excluded, when there are indications those have been incorrectly emitted.

48. In the second stage, an arc is drawn to delineate the choke point of interest. For instance, for the Suez Canal, an arc is drawn between a first point of longitude 32.2 and latitude 31.05 and a second point of longitude 32.4 and latitude 31.05. To examine whether a vessel passes by the choke point, an arc is drawn between the two positions reported in two consecutive AIS messages. The arc associated with the vessel is then intersected with the arc previously drawn around the choke point. To simplify the procedure, only one transit of the choke point per vessel per day is considered. Although relatively simple, relying on arcs allows more accurate estimates of traffic passage in choke points than using a polygon-based method. The main drawback is to have to identify choke points one by one, although this is manageable given the limited number of key maritime choke points.

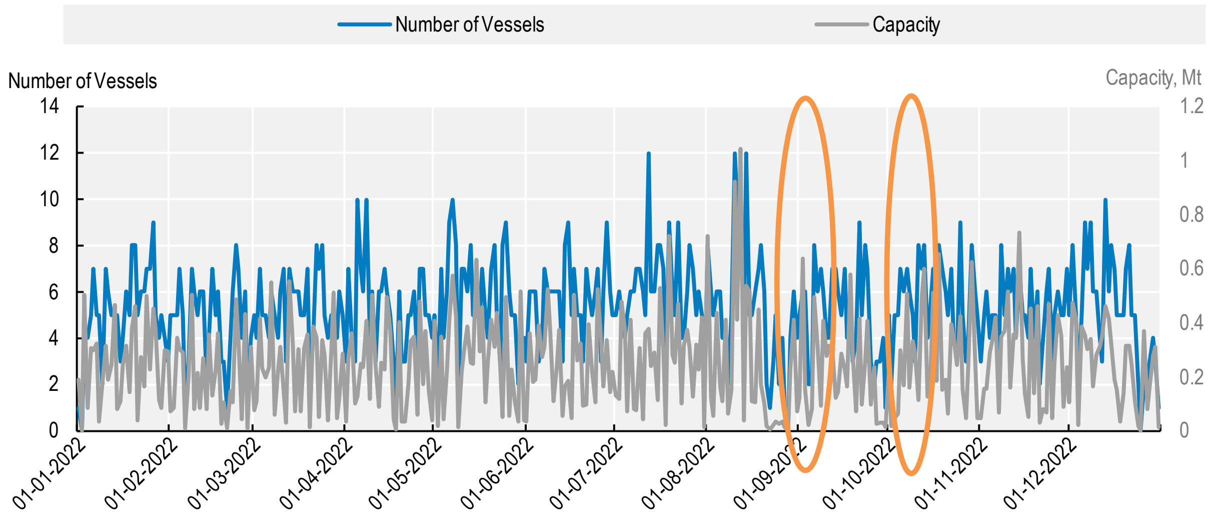
5. Monitoring port activity

49. A key use of the methodology developed in Section 4 is to identify port congestion in close to real time, following a strike, a natural disaster or the extension of a terminal. Some examples are provided below.

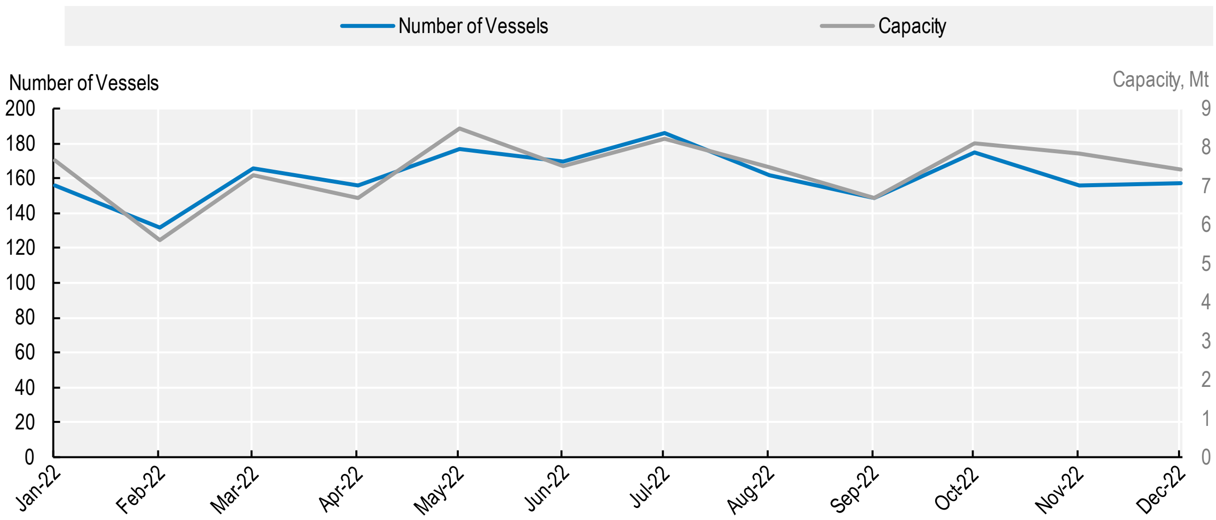
50. A first example examines the extent to which port activity dropped following the Felixstowe/Harwich strikes in the United Kingdom, which were announced for 21st August – 29th August 2022 and 27th September – 5th October 2022. Although activity was disrupted during the strikes, these do not seem to have resulted in a notable fall in total capacity on a monthly basis (Figure 8). The drop after the strike does not seem to be unusual compared to past fluctuations.

Figure 8. Felixstowe/Harwich port activity following the 2022 strikes

A – Daily observations



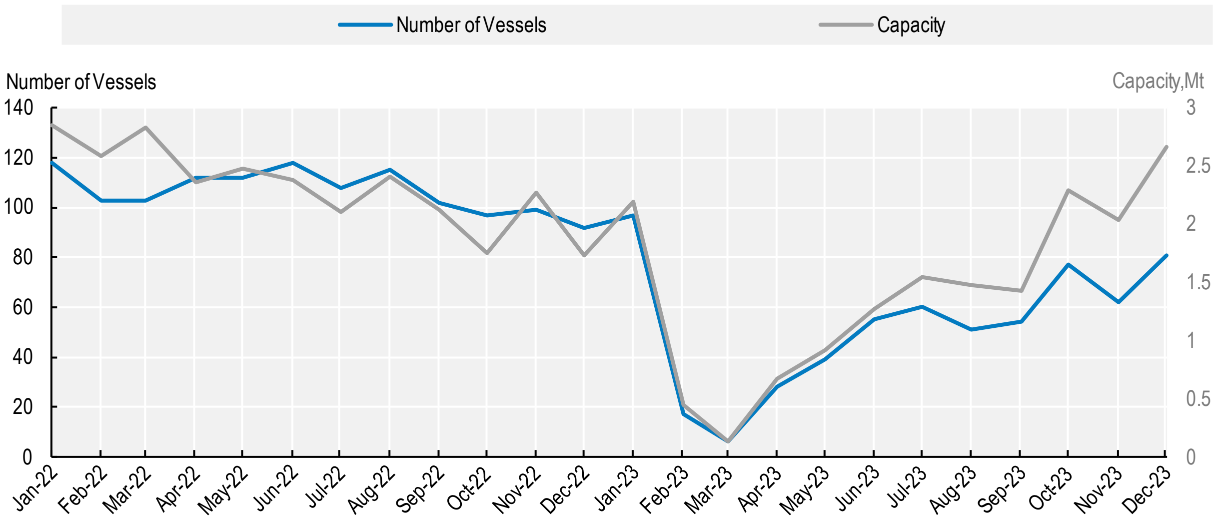
B – Monthly observations



Note: See Table 8 for definitions. Monthly are computed from the sum of daily data.
Source: Authors' calculations using AIS data.

51. A second example relates to the earthquakes in Turkey, which caused severe disruptions in the port of Iskenderun in February 2023. A magnitude 7.8 earthquake and numerous aftershocks resulted in widespread damage and tens of thousands of fatalities in the region. Fires engulfed shipping containers causing damage to the port and its infrastructure. The initial disruption can be seen with numbers decreasing in February immediately following the event. Port traffic in October 2023 appears to have returned to normal levels (Figure 9). This profile is consistent with past estimates of earthquakes, using synthetic control methods, for instance by Cavallo et al. (2013) and more recently Askoy et al. (2023). Indeed, the impact of natural disaster is usually short lived as substantial reconstruction efforts boost GDP, including through increases in government spending.

Figure 9. Activity in the port of Iskenderun in the aftermath of the 2022 earthquakes

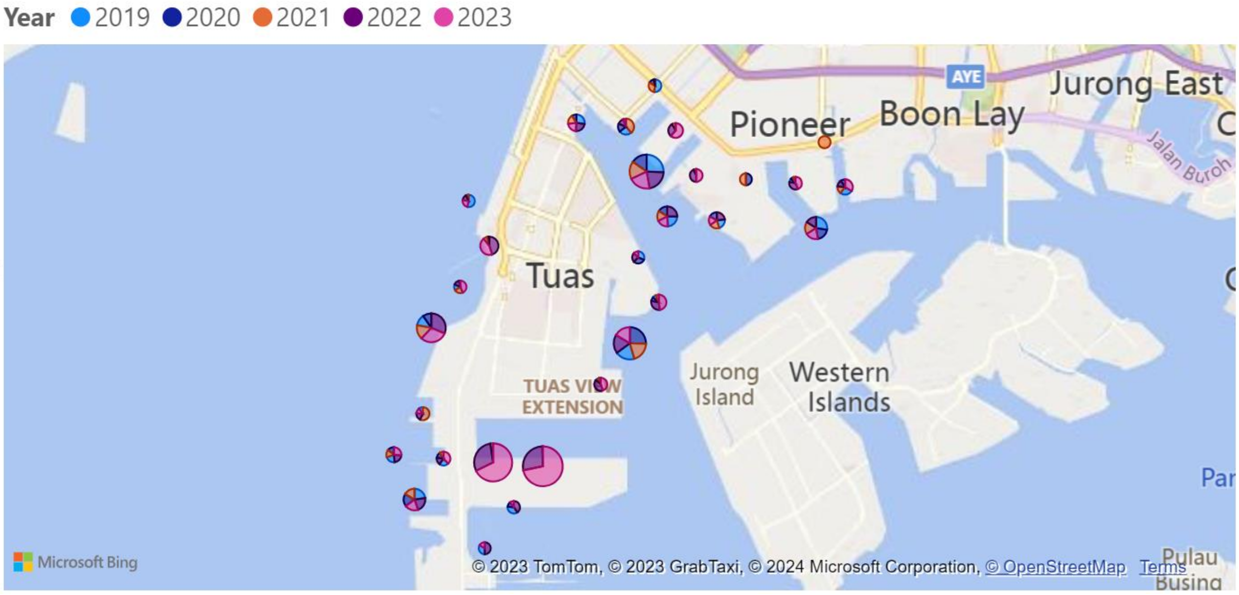


Note: See Table 8 for definitions
Source: Authors' calculations using AIS data.

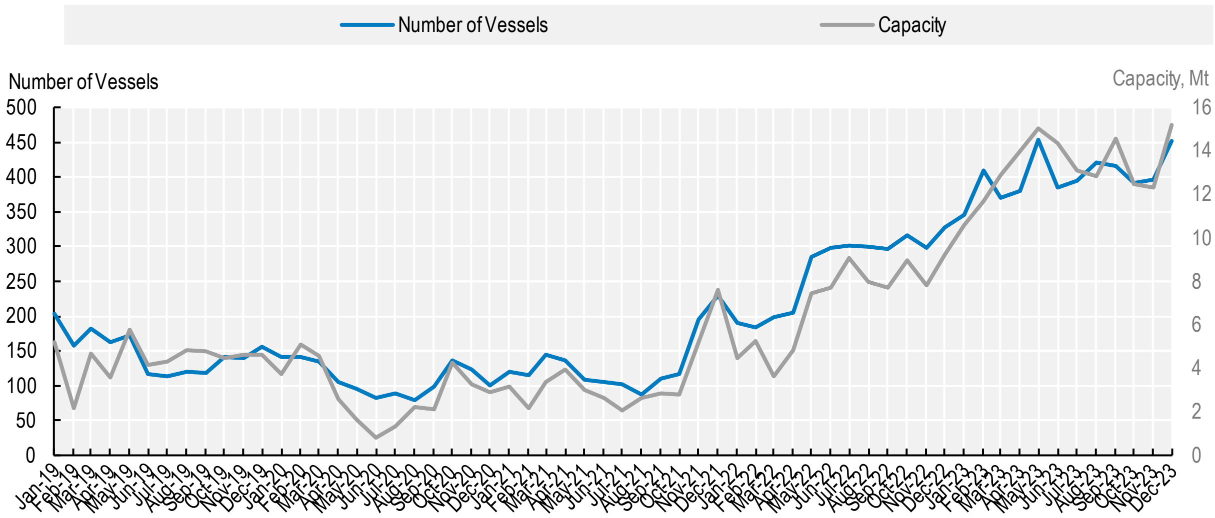
52. A third example illustrates that an extension of investments in port terminals, such as the 2021 expansion of the Tuas terminal in Singapore, can have widespread effects on trading patterns (Figure 10, Panel A). This contributed to a sustainable increase in the number of vessels visiting the port and to an increase in port capacity (Figure 10, Panel B).

Figure 10. Extension of Tuas terminal in Singapore

A – Localisation by time period



B- Volume measures of Tuas Port



Note: See Table 8 for definitions.
Source: Authors' calculations using AIS data.

6. First insights on maritime trade

53. The number of vessels and port capacity – the sum of Dead Weight Tonnage (DWT) of all the vessel visiting ports – provide some indication of trends in maritime trade. Although the indicator levels cannot be interpreted as levels of trade flows, an increase is likely to coincide with a rise in maritime activity, which in turn is positively correlated with global trade. As such, those data can provide timely indicators of sudden changes in global trade.

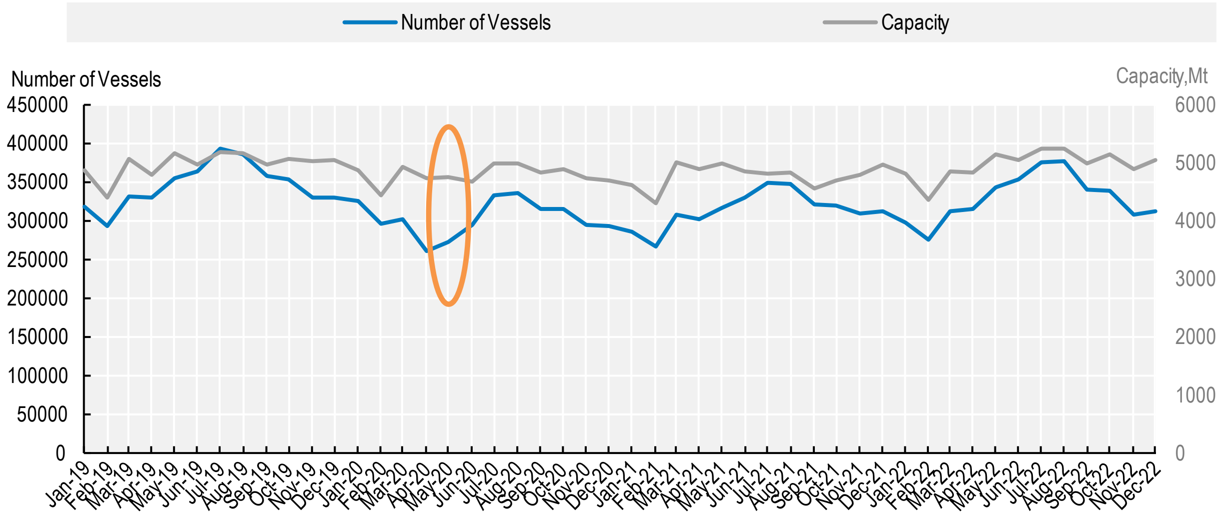
Maritime trade during the pandemic

54. Volume measures of maritime trade derived from AIS can be used to examine developments during specific episodes such as the COVID-19 pandemic. Looking at those indicators at the global level, it is difficult to disentangle a potential effect of the pandemic from normal seasonality and calendar effect in the data, including the Chinese New Year (Figure 11, Panel A). Given the limited historical data, it is not easy to correct the data from seasonality and calendar effects.

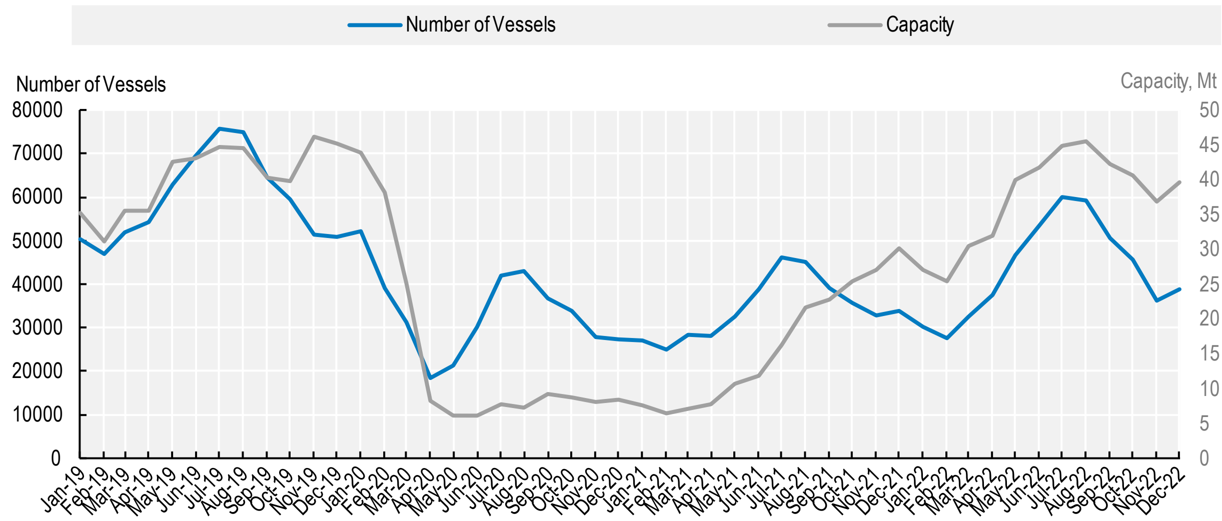
55. Results point to a decline by 13.5% in the number of vessels from March to April 2020, while this number was broadly stable in the same period in 2019 or in 2021. But the fall was short-lived and the number of vessels started to rise in May 2020 to almost reach December 2019 levels. This is in line with other assessments, which also concluded that the effect of the pandemic on trade was temporary. The magnitude of the estimates differs somewhat from previous assessments, even though they are often also derived from AIS information. However, many of those estimates focussed on the first months of the pandemic and/or on specific regions which were particularly affected. Verschuur et al. (2021) use AIS to estimate the global volume of imports and exports for selected countries in the first six months of the pandemic. Depellegrin et al. (2020) examined the Veneto region in Italy in March-April 2020. Zhu et al. (2020) and Shi and Weng (2021) study the impact of the pandemic on ship activities in China's ports using AIS in the first months of 2020.

Figure 11. Global measures of maritime transport

A – All vessels



B – Passenger (only) vessels



Note: See Table 8 for definitions.
Source: Authors' calculations using AIS data.

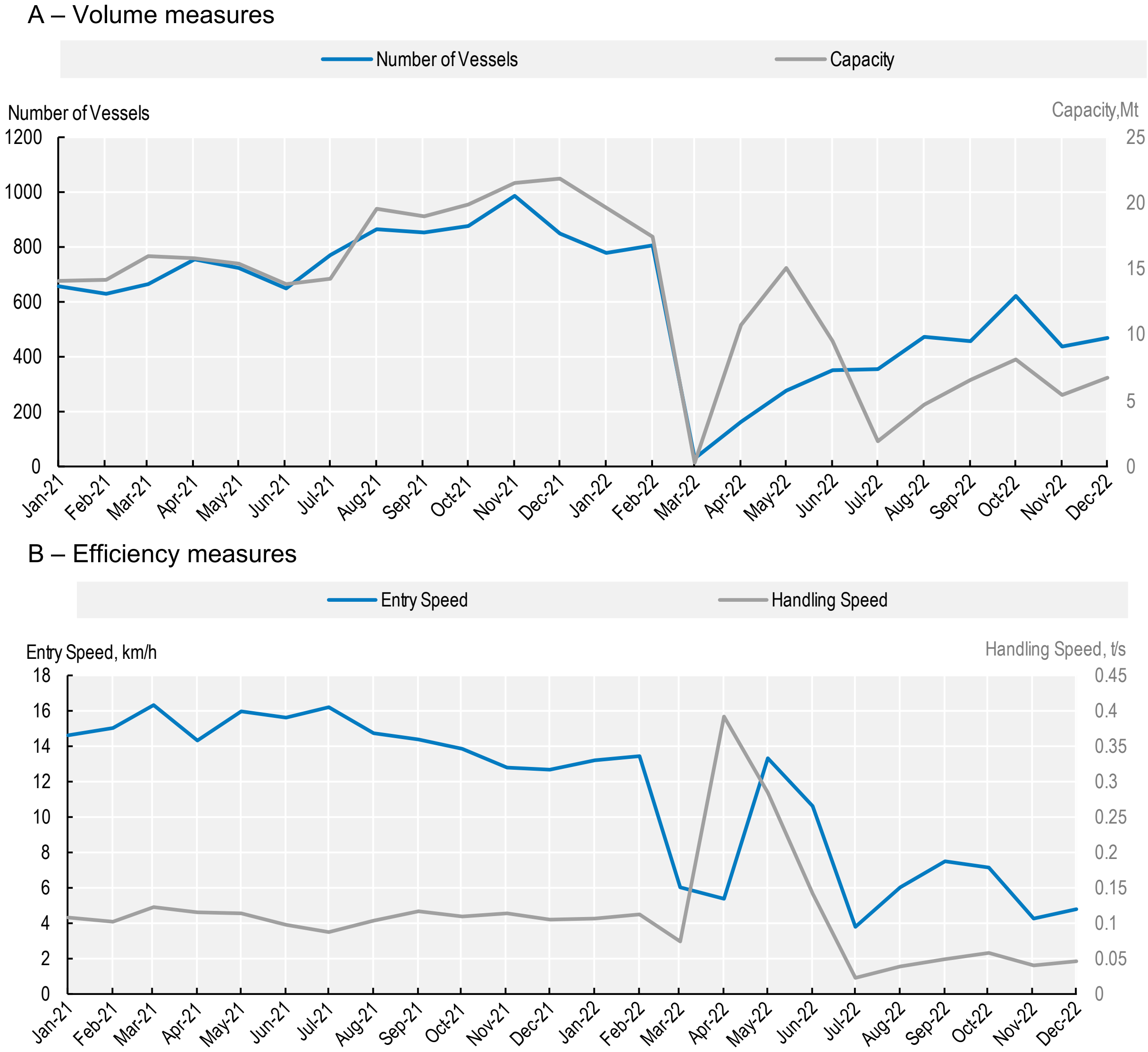
56. Aggregate developments mask significant movements at more granular levels. Indeed, traffic collapsed in some ports. The fall was sometimes very short-lived in touristic areas such as Papeete, but lasted the whole year in other ports (e.g. Daxie in China).

57. The collapse was also massive when looking exclusively at passenger vessels (Figure 11, Panel B), which were affected by passenger travel bans worldwide well into 2021 (Benz, Mourougane and Gonzales, 2020). Traffic resumed in the second quarter of 2021, but as the initial fall was massive, port capacity regained their pre-crisis levels only in the third quarter of 2022. Traffic in other types of vessels were less affected, resulting in small effects at the aggregate levels.

Maritime trade since the start of the war in Ukraine

58. Another example examines the traffic disruptions following the start of the war in Ukraine in March 2022. The war was followed by a marked drop in the number of vessels visiting the country and port capacity (Figure 12, Panel A). Entry speed in the ports also dropped, while handling speed recovered at a fast rate, as the quantity of traffic remained below pre-war levels (Figure 12, Panel B). Those data need however to be interpreted with caution. Indeed, there is evidence of a substantial increase in the frequency of ships switching off AIS since the outset of the military activity in Ukraine (Lloyd Intelligence, 2023).

Figure 12. Port activity in Ukraine



Note: See Table 8 for definitions.
Source: Authors' calculations using AIS data.

Signs of a stabilisation in maritime trade for 2023

59. Changes in estimated maritime export and import volumes in 2023 display some common features across most developed economies, suggesting little growth on average over the year in global trade. Those numbers need to be interpreted with caution. Although volume changes can reveal a trend, they do not account for what is traded and do not give a precise estimate of the value of those flows. However, additional information on the type of vessels is provided (Table 9), which can be further broken down by country.

60. In this section, the focus is on AIS messages originating from containers, which tend to carry higher values and a more diverse set of products than bulk carriers. In addition, smaller vessels that do not follow a repetitive pattern and may not be representative of global trade routes, have been excluded from the calculation.

61. Volume measures of containers point to a stabilisation, many countries in Europe and in America experienced a slowdown in imports in the latter part of the year while exports have remained broadly stable or slightly picked up during that period (Figure 13). Developments in Asia differed from what was observed for Europe and North America. In particular, there are indications that exports, via containers, have continued to expand and imports via bulk dry vessels have increased in China. Imports in Asia have stayed flat.

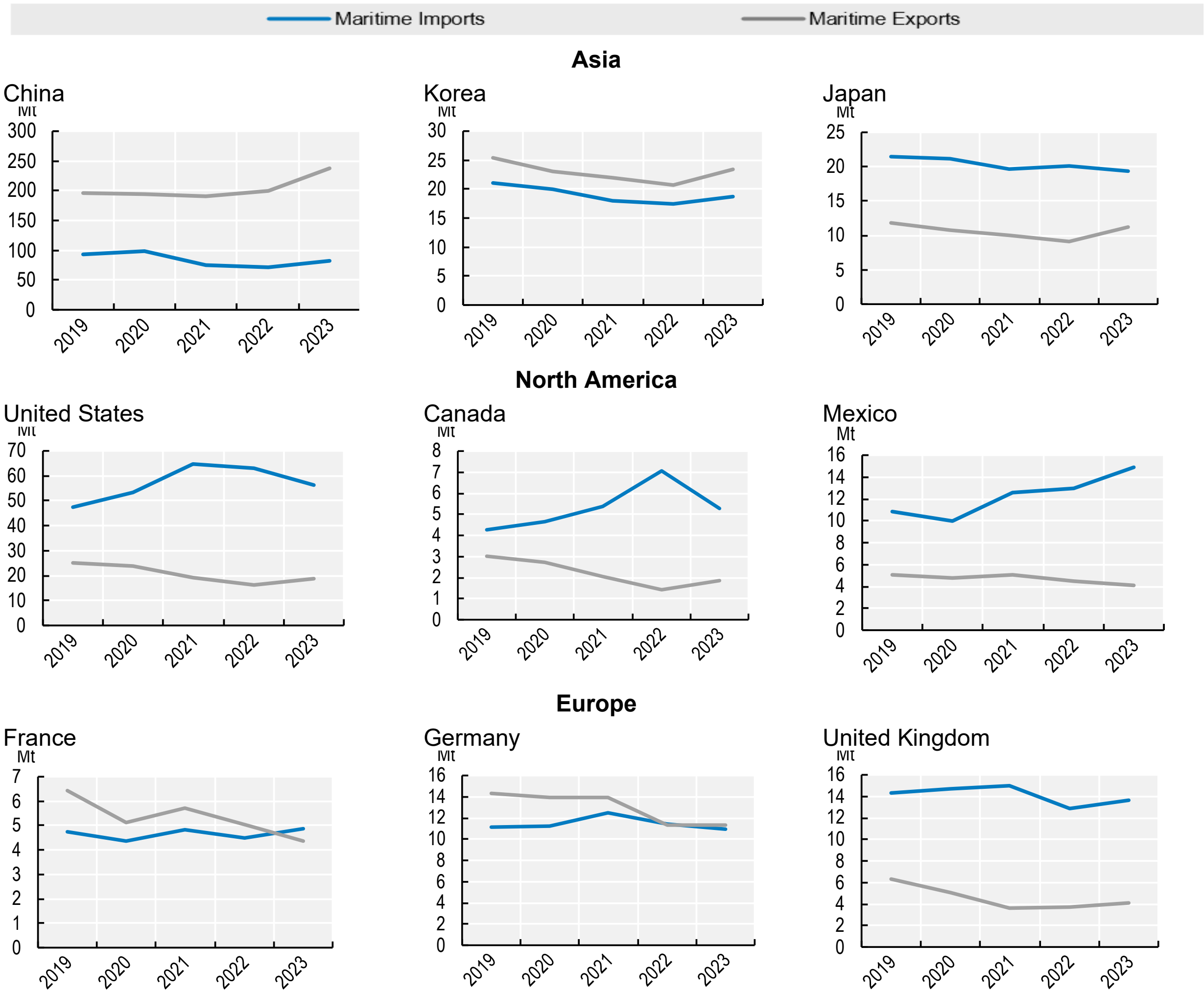
Table 9. Maritime import and export volumes by vessel types, all countries

	Maritime import volume, Mt		Maritime export volume, Mt	
	2022	2023	2022	2023
Bulk dry	1986.8	1977.1	2018.0	2003.4
Oil	676.8	700.1	687.1	693.5
Container	616.4	669.7	615.0	693.7
Chemical	312.5	315.9	316.0	317.1
General Cargo	201.3	197.0	202.3	198.9
Liquefied Gas	111.7	112.2	113.7	115.4
Other Bulk Dry	39.5	36.8	39.7	37.4
Ro-Ro Cargo	31.3	30.7	31.5	31.0
Self Discharging Bulk Dry	25.1	24.2	25.0	24.1
Passenger/Ro-Ro Cargo	13.3	13.7	13.4	13.8
Refrigerated Cargo	4.3	3.9	4.4	3.8
Bulk Dry / Oil	3.8	4.0	3.7	4.0
Other	3.3	3.6	3.7	9.1
Total	**4026.1**	**4088.8**	**4073.3**	**4145.2**

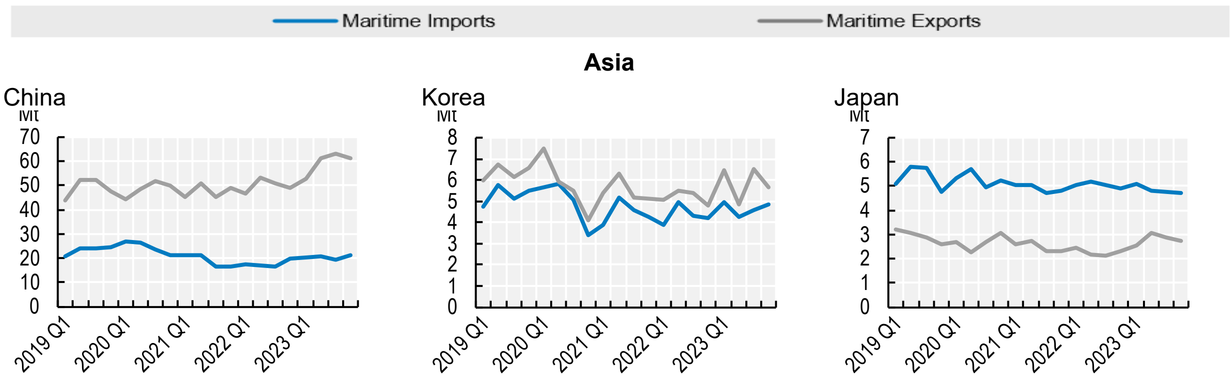
Source: Authors' calculations using AIS data.

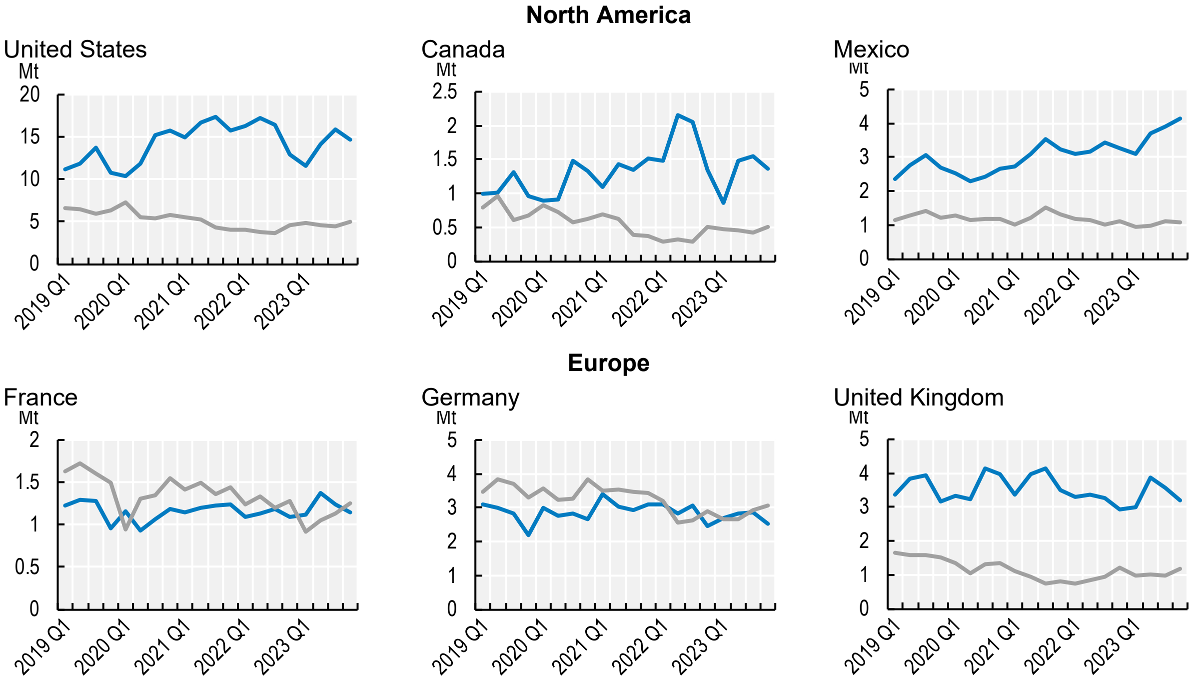
Figure 13. Maritime import and export volume of containers in selected countries

A – Annual patterns



B – Quarterly patterns





Source: Authors' calculations using AIS data.

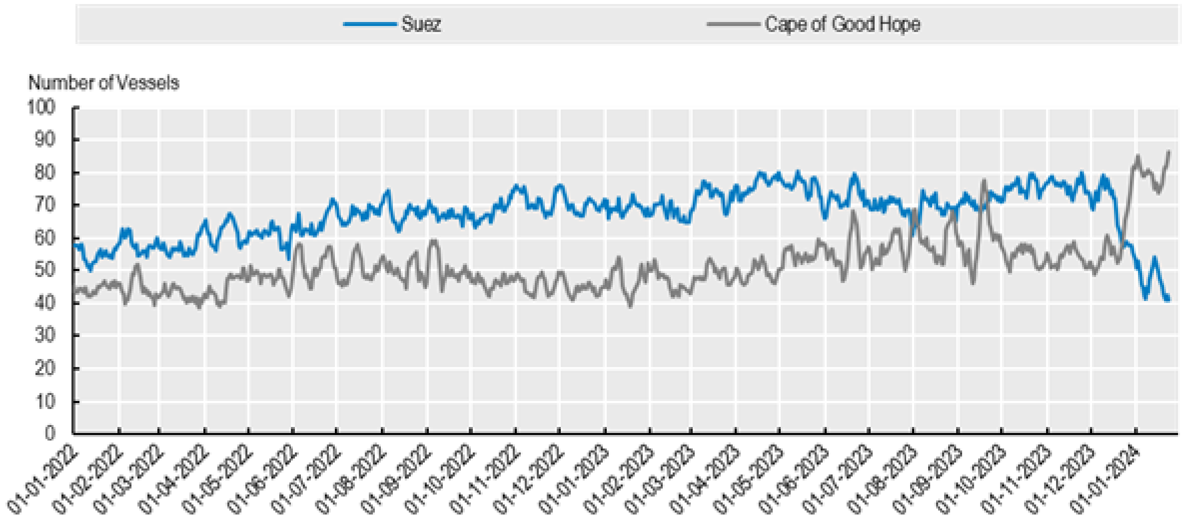
Vessels rerouting from the Suez Canal to the Cap of Good Hope following the Houthi attacks

62. AIS information can help cast light on topical issues in a very timely manner. For instance, the Houthi attacks on vessels since October 2023 have restricted containers ships heading to Europe via the Suez Canal to avoid passing the Bab el-Mandeb Strait and rather reroute via Southern Africa and the Cape of Good Hope. This has raised concerns of lengthening delivery times for supplies, increasing supply-chain bottlenecks and rising prices.

63. Tracking information from AIS, using the simple approach to estimate traffic at choke points, can help assess the magnitude of these effects, provide detailed information on the type of the vessels which would be most affected and monitor the situation in quasi real time. As for the preceding example on the Ukraine war, the caveat is that vessels may switch off their emitters for fear of being spotted, which can lower the reliability of AIS signals.

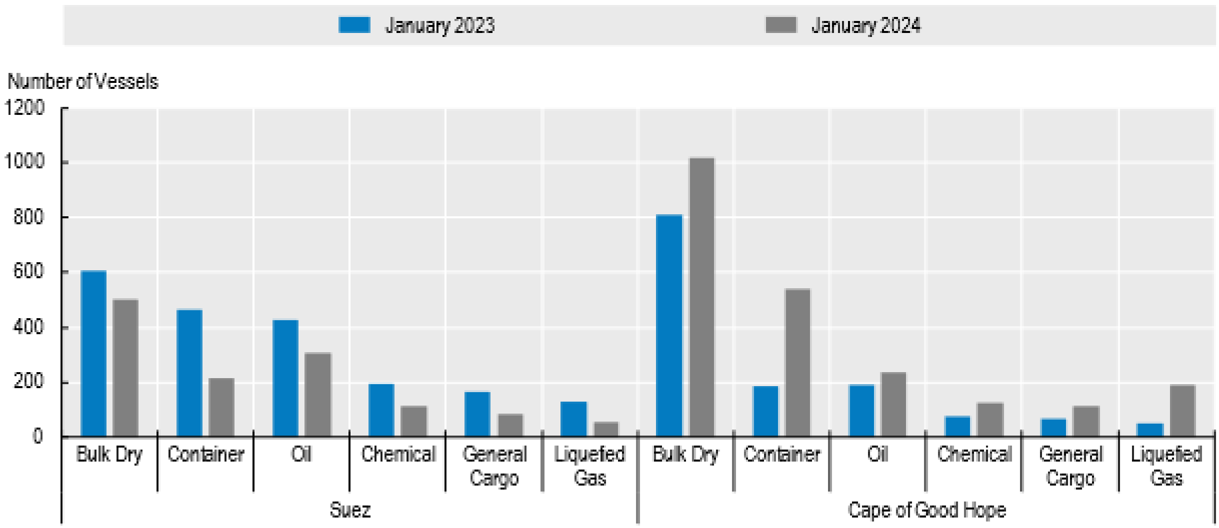
64. The switch in vessel routes since the first Houthi attack on 19th October is clearly visible, with a dramatic fall in daily traffic in the Red Sea and a mirrored rise in the Cape of Good Hope (Figure 14). All types of vessels altered their routes but comparing the number of vessels in January 2024 from the count in January 2023, the number of containers passing by the Suez Canal was halved (Figure 15).

Figure 14. Daily transits of the Suez Canal and the Cape of Good Hope



Note: 7-days moving average.
Source: Authors' calculation using AIS data.

Figure 15. January transits of the Suez Canal and the Cape of Good Hope, by vessel type



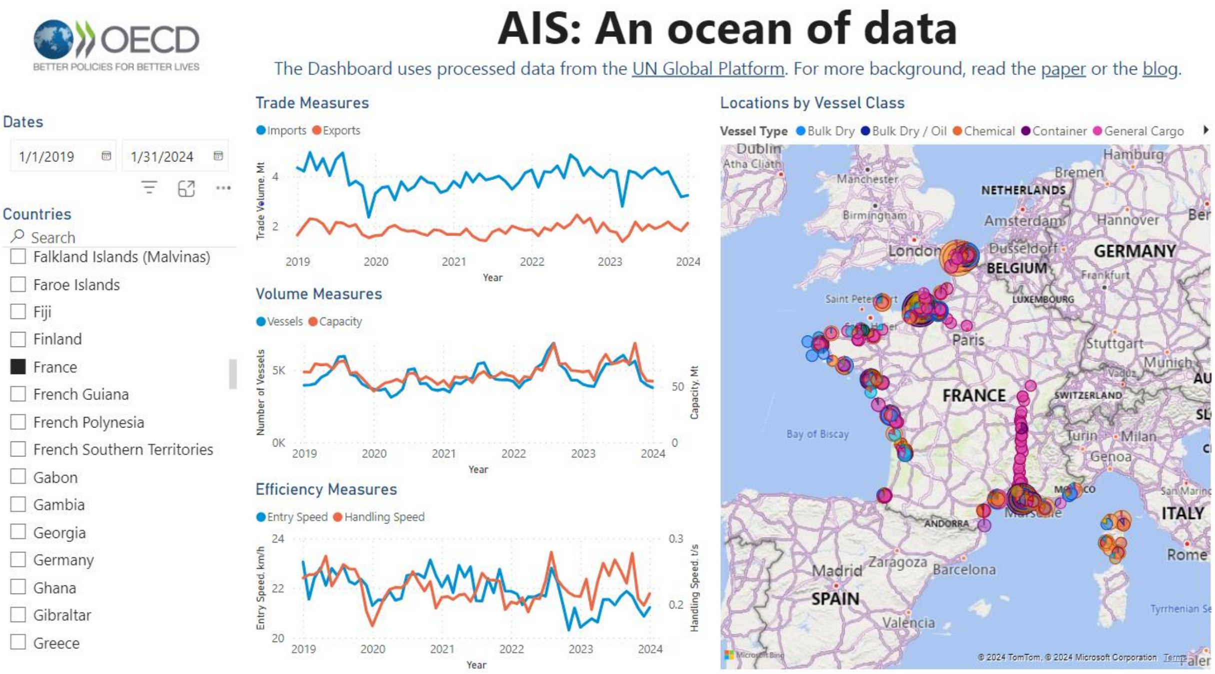
Source: Author s' calculation using AIS data.

7. A user-friendly dashboard

65. A user-friendly OECD AIS Tracking dashboard has been developed to visualise data and monitor activity of ports globally (Figure 16). The dashboard allows the user to select the country or port of interest, together with volumes and efficiency measures defined in Table 8. Data can be visualised at daily or lower frequencies. The dashboard is updated every month, and can be updated upon request, to monitor the fallout of particular events. Users can also choose the period they are interested in (from 2019 to the most recent period).

66. The dashboard provides details on ports but also on the types of vessels which are visiting those ports, together with basic statistics, allowing to identify unusual movements. Users wishing to explore the data further can find the dashboard here.

Figure 16. OECD AIS tracking dashboard



8. Conclusions

67. The AIS is a rich data source which can complement official statistics. Although the messages do not provide information on the products that are traded, they can be used to provide approximation of the direction of trade in quasi real time. Monitoring can be done at the global or country level and at a very disaggregated levels, such as port levels, or by types of vessels. This allows for undertaking up-to-date detailed analyses with less resources than in the past.

68. Some key limitations need to be underlined, suggesting that further work is required to be able to use the database fully for monitoring purpose.

- At the moment, data are not seasonally nor calendar adjusted. This can blur signals on most recent developments. As the data are available since 2019 only, it is however challenging to make such an adjustment. Methods are being developed to adjust alternative data for seasonality (Daniel et al., forthcoming).
- Given the data limitation, proxy indicators of trade volumes are calculated by trying to approximate the weight of the vessel. Complementing the information using customs data and bill of ladings would allow to get more precise estimates together with more information on the type of products which are traded. Managing the costs and cross-country availability of the data is a key challenge.

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