Big Data on Vessel Traffic: Nowcasting Trade Flows in Real Time IMF Working Paper Statistics Department Big Data on Vessel Traffic: Nowcasting Trade Flows in Real Time

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Big Data on Vessel Traffic:
Nowcasting Trade Flows in Real Time

by Serkan Arslanalp, Marco Marini, and Patrizia Tumbarello

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Big Data on Vessel Traffic: Nowcasting Trade Flows in Real Time

Prepared by Serkan Arslanalp, Marco Marini, and Patrizia Tumbarello[1]

Authorized for distribution by Gabriel Quirós-Romero

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Abstract

Vessel traffic data based on the Automatic Identification System (AIS) is a big data source for nowcasting trade activity in real time. Using Malta as a benchmark, we develop indicators of trade and maritime activity based on AIS-based port calls. We test the quality of these indicators by comparing them with official statistics on trade and maritime statistics. If the challenges associated with port call data are overcome through appropriate filtering techniques, we show that these emerging "big data" on vessel traffic could allow statistical agencies to complement existing data sources on trade and introduce new statistics that are more timely (real time), offering an innovative way to measure trade activity. That, in turn, could facilitate faster detection of turning points in economic activity. The approach could be extended to to create a real-time worldwide indicator of global trade activity.

JEL Classification Numbers: C53, C55, F17.

Keywords: Big Data, Trade Statistics, Automatic Identification System, Vessel Traffic.

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I. Motivation

Maritime trade has formed the backbone of economic prosperity from ancient times to the globalized 21st century (Spiliopoulos and others, 2017). Until recently, it was almost impossible to accurately track the plethora of shipping routes—new technologies allow us to do so now and to derive real-time information on the state of the global economy. In 2018, about 80 percent of global trade by volume (more than 70 percent by value) was shipped by sea, according to the United Nations Conference on Trade and Development (UNCTAD). In the same year, more than 10 billion tons of goods for international trade were loaded at the world's ports (UNCTAD, 2018).

Most of the international trade is carried by cargo vessels. Today, it is relatively easy to track these vessel voyages in real time. Modern technology allows us to monitor the global movements of these ships using the automatic identification system (AIS)—a maritime safety communication system for international vessels. This system was introduced by the International Maritime Organization (IMO) in 2004 as a requirement for major commercial ships. All major commercial ships (over 300 gross tons) are required to install a device that emits a radio signal, indicating the ship's identification number, position, speed, and other safety-related information about the ship's course. These devices transmit a signal every few seconds, generating a continuous flow of information about shipping traffic. This paper aims to showcase how this new big data source can be used to nowcast trade flows.

As discussed in the IMF Staff Discussion Note on Big Data (IMF, 2017), big data can provide innovative, real-time, and granular insights for economic and financial analysis. The IMF's new *Overarching Data and Statistics* Strategy *at the Fund in the Digital Age* gives strategic priority to supporting the use of big data for early detection of risks, closing data gaps, and improving the timeliness of official statistics (IMF, 2018).

Indeed, the benefits of big data for policymaking can be several. It can complement the timeliness, granularity, and, in some cases, possibly even the accuracy of official statistics based on traditional data sources and surveys. For example, use of mobile phone data on travel services may be more cost-effective than cross-border surveys for external sector statistics, a potentially valuable option for countries that rely heavily on tourism and remittances.

At the same time, the effective use of big data involves some challenges. In the absence of internationally agreed standards, exercising quality control and assurance is critical. Close collaboration among several institutions, including with the private sector, may be needed. Specific statistical techniques may be needed to extract signals from big data sources that are unstructured for policy analysis. In that context, and particularly relevant for high-frequency big data sources, statistics derived from real time data could pose a risk of mistakenly picking up erratic patterns that in turn determine responses that—building on noisy short-term developments—could lead to sub-optimal policy outcomes. In other words, high frequency data imply a trade-off between efficiency (i.e. timeliness) and robustness (i.e. reliability).

In this context, we use in this paper a benchmark case with high-quality official statistics (for Malta) to illustrate how a new big data source on vessel positions and movements can be used to extract usable signals for trade monitoring; we also emphasize the advantages and limitations of this approach. In particular, we note that vessel data can be used as a measure of (i) trade in goods (not services); (ii) trade volume (not value); (iii) gross trade (not re-exports); and (iv) trade by broad groups, rather than by specific goods (beyond homogenous goods such as oil or natural gas). Moreover, we highlight that vessel data could be a good proxy of trade volume in goods when (i) the share of seaborne trade in total merchandise trade is high (in volume terms); and (ii) shipments at each port tend to be in one direction or another (i.e. mainly export or import). Finally, we highlight that vessel traffic data should be used with caution when (i) the coverage of AIS-receiving stations (terrestrial or satellite) is poor near the country's ports; or (ii) trade sanction are in place that may cause vessels to switch off their AIS transponders during trade activity with country under sanctions.

In doing so, we propose a two-step approach to nowcast trade flows in real time. First, we develop a filter to identify cargo ships involved in trade activity in port calls data. Second, we produce two indicators based on the filtered ships: a "cargo number" indicator, which counts the number of ships visiting ports; and a "cargo load" indicator, which combines information in the AIS data about the size of the vessel (i.e., deadweight tonnage) and changes in its cargo load (i.e., draught) to derive a trade volume index.[2]

Malta is an excellent benchmark case for demonstrating the validity of this for several reasons. First, it is a small and open economy and is highly dependent on external trade. Second, it depends heavily on imports for its industries and consumers. About two-thirds of its imports are carried by ship. Third, as a member of the European Union, Malta complies with EU regulations by providing reliable and comparable port statistics. Such statistics are useful benchmarks to validate the feasibility of using this approach to nowcast trade flows.

For quality assurance, we compare the two indicators with benchmark official statistics. We find that the cargo number indicator tracks well the number of port visits in Malta's maritime statistics, although at a higher level. The higher level may indicate that AIS data—which are based on actual movements of ships detected through technology—offer a better coverage of vessel traffic in ports than traditional maritime data based on partial surveys and administrative data collected by port authorities.

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[2] Appendix 1 provides a glossary of maritime terms used in this paper. The Matlab code used to construct the cargo number and cargo load indicators is available from the authors upon request.

Our cargo load indicator tracks well Malta's official trade volume statistics. The strong correlation between official and AIS-based estimates is encouraging and suggests that the approach could be of real value to any country willing to capture its trade flows in a timely manner. At the same time, as expected, we do not find that the cargo load indicator by trading partner (i.e., using the last and next port information contained in AIS data) matches the geographical breakdown of trade in the IMF's *Direction of Trade Statistics* (*DOTS*). This result is expected given the country origin of goods transported by a cargo ship does not necessarily coincide with the country of last port (e.g., a container ship departing from Singapore may be transporting goods from Japan).

The policy implications of these results are as follows:

- The use of vessel traffic data could improve the timeliness of official trade statistics. This could sharpen policymakers' ability to detect emerging risks in trade flows and, possibly, help identify turning points in the business cycle, especially for small open economies that rely heavily on seaborne trade for either imports or exports.

- The more granular (ship-by-ship and port-by-port) data could reveal emerging patterns in international trade, including those associated with global trade tensions.

- The data could close data gaps, especially for countries where most international trade is seaborne and statistical capacity is weak (e.g., small island states).

Small states—which represent a quarter of the Fund's membership—could especially benefit from our proposed approach. First, most small states are island states and hence their trade is mostly seaborne. Second, given limited economies of scale, small states tend to import a significant portion of their consumption basket, which makes tracking trade activity at ports macro-critical for detecting turning points in the business cycle. Third, many small states have relatively weak statistical systems and hence can benefit from this alternative data.

The rest of the paper is organized as follows. Section II introduces the characteristics of the vessel data as an innovative source for trade. In Section III, we describe our proposed approach to extract high-frequency indicators of trade activity based on port call data. In Section IV, we show that these indicators track well official trade and maritime statistics for the benchmark case (Malta). Section V concludes with policy implications of our findings.

II. Automatic Identification System (AIS): An Innovative Data Source for Tracking Vessel Traffic in Real Time

Today, large-scale real-time data tracking major commercial vessels during their international voyages are increasingly available. This is due mainly to the AIS transponders that vessels are required to carry on board since 2004, after the International Maritime

Organization (IMO) required them for major commercial vessels. The IMO developed the AIS as a standard to help vessels avoid collisions while helping port authorities control maritime traffic more efficiently. It is mandatory for international commercial ships above a certain tonnage, including cargo ships and tankers.

The AIS is a self-reporting system that allows vessels to broadcast key information to other vessels, on-ground base stations, and satellite receivers in order to avoid collisions and enhance security (see Appendix 2 for details). Vessels equipped with AIS transponders periodically broadcast signals that include the vessel's identifying information, its characteristics, destination, and other on-board information, such as current location, speed, and heading.

This information has made it possible to get a global picture of trade patterns in real time and on a granular basis. Several commercial data providers aggregate AIS data to provide such a global picture, based on information from thousands of terrestrial and satellite receivers. These include MarineTraffic, VT explorer, IHS Global, exactEarth, Spire, ORBCOMM, and FleetMon (Tu and others, 2017). Separately, Bloomberg makes historical AIS data available on a limited basis, in partnership with IHS Global.

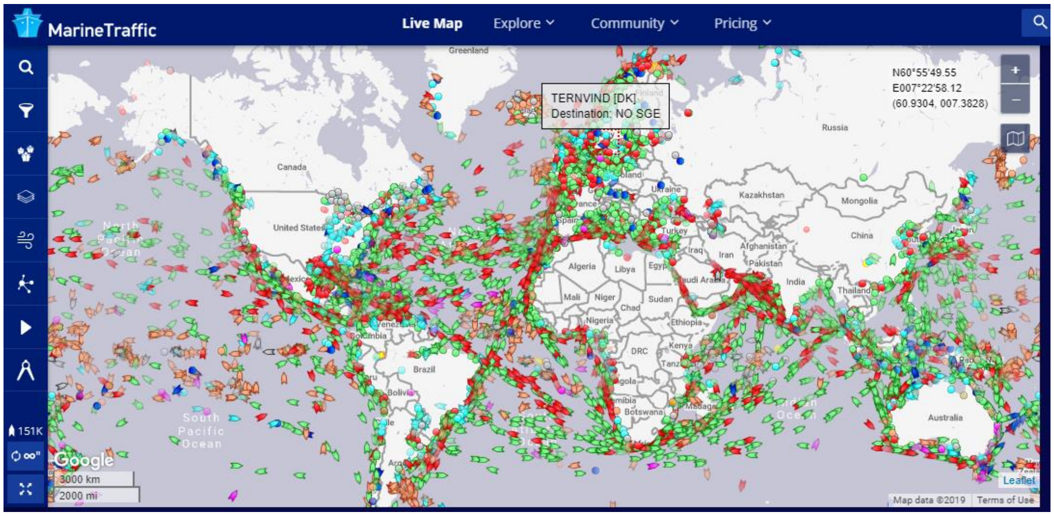
Among these commercial data providers, MarineTraffic is currently operating one of the most comprehensive networks; it deploys more than 3,500 terrestrial AIS receiving stations that actively relay AIS information from more than 180 countries (as of end- 2018). Figure 1 shows a visualization of these data compiled by MarineTraffic and they are available online in real time.

From AIS Data to Port Call Data

AIS data are vast, generating billions of records on a daily basis. From a large base of AIS messages, MarineTraffic generates a more *structured* but still large dataset called "port calls." Port call data focuses only on vessel activity near a port, particularly on incoming and outgoing vessels from the vantage point of a port.

As our focus for this research is to nowcast trade activity, port call data provide essential information. By focusing on port call data, we can track trade activity where it eventually happens after an international voyage—at the port. By doing so, we can also reduce the size and complexity of the data significantly, without compromising accuracy, as tracking the movement of vessels across their full voyage requires far more data than tracking port events. Port call data are also likely to be more accurate than full voyage information because the coverage of AIS-receiving stations tends to be better near ports. This is so for two reasons: port authorities have an intrinsic incentive to monitor vessel traffic near ports for safety reasons; and tracking vessels is less expensive near ports as it can be done simply by terrestrial receivers, rather than through more expensive satellite receivers, which are necessary to track vessels in open international waters.

Figure 1. A Snapshot of Global Vessel Traffic Based AIS Data



Source: MarineTraffic.
Note: Different types of vessels are shown in different colors.

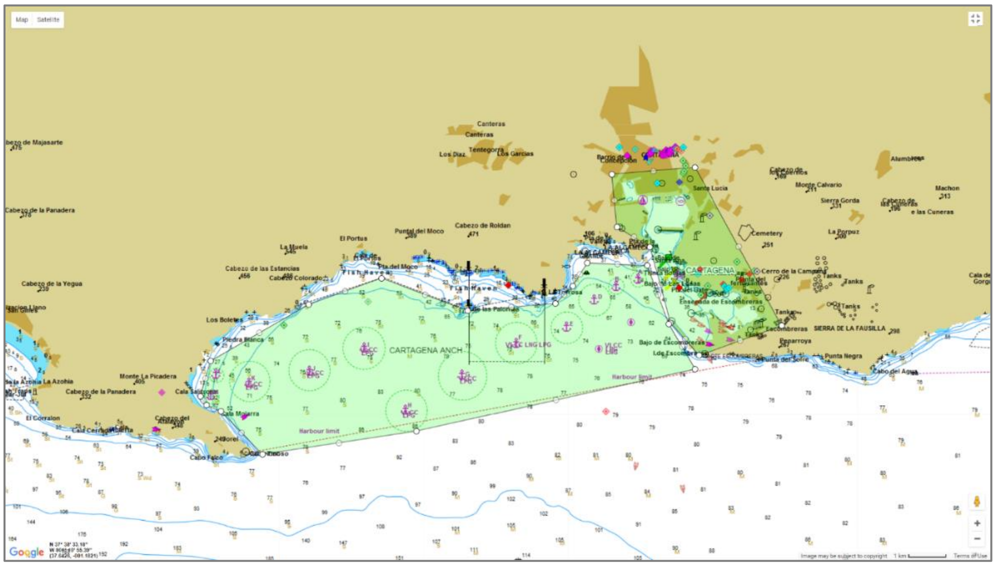
At the same time, defining port and anchorage boundaries requires careful work (Figure 2 provides an example for Port of Cartagena, Spain). Ports a defined as bounding boxes usually covering the harbor and anchorage as well as the surrounding area. Defining ports geospatially is one of the key contributions of AIS data providers, such as MarineTraffic. In the case of MarineTraffic, more than 7,300 ports are being monitored in this way, including all the major ports in the world.

A port call is registered when two positions of a vessel inside and outside of the port's bounding box is registered within a short interval based on AIS data. For a vessel to be recorded in the port call, its speed must be virtually zero (i.e., below 1 knots) inside the port's bounding box. Otherwise, the vessel is categorized as an "in-transit" vessel.

A typical port call data entry would include the following information: port name; vessel identifier (i.e., IMO, MMSI, or SHIP_ID number); gross tonnage, deadweight tonnage, and draught of the vessel; vessel type (e.g., container ship); a timestamp with arrival and departure times; and actual departure time from the last port and estimated arrival time to the next port.

A port call may not get recorded for three reasons: AIS coverage is low around the port area; the vessel visiting the port switches off the AIS transponder;[3] or the port is relatively small and hence not registered in the database. For Malta, none of these limitations appear particularly relevant. There are only two commercial ports in Malta (Valetta and Marsaxlokk), both are covered well by AIS-receiving stations, and both are registered in the MarineTraffic database.

Figure 2. Defining Port and Anchorage Boundaries for Port of Cartagena, Spain



Source: MarineTraffic.

Advantages and Disadvantages of Port Call Data versus Official Trade Statistics

The first advantage of port call data is that it can improve the *timeliness* and *periodicity* of official trade statistics. Port call data are available on a daily basis in real time, while official trade statistics often appear on a monthly basis, with a one-to-three month lag *at best*. In countries with weak statistical capacity, they could even be published on an annual basis, with a lag of one year or more after reference period.

The issue is even more relevant for small island states. Small states account for nearly a quarter of the IMF's membership. Most of these are small islands states, where the bulk of international trade is seaborne. For these countries, port call data would notably improve the timeliness and periodicity of official trade statistics, as these countries also tend to have weaker statistical capacity. (Figures 3 and 4 show the timeliness and periodicity of official merchandise trade data published by small states, based on current reporting lags to the IMF and metadata available through the IMF's data dissemination standards initiatives.) In most

[3] Vessels can sometimes turn off their AIS transponders, but they would normally keep them on for safety reasons during port arrivals or departures given the congestion at ports.

cases, small states produce official trade data on a quarterly basis with a lag of three-five months. In fact, a sizable percentage of these countries publish trade data only on an annual basis and with a lag of 12 months or more. For these countries, port call data could be especially helpful for increasing the timeliness and periodicity of official trade statistics. The second advantage of port call data is that it can improve the *granularity* of official trade data. In many cases, trade data are not broken down by port or vessel type. But such information is available in port call data and can shed more light on what may be driving trade patterns at a given point in time. For example, is congestion in a port reducing trade activity in a given month? How do changes in port infrastructure (e.g., building a new terminal) change trade patterns? Are there interesting changes in trade patterns by vessel type, such as by oil tankers? The additional granularity provided by port call data could help answer such questions.

The third potential advantage of port call data is their potential to improve the *accuracy* of official trade data in some cases, as when there are significant statistical weaknesses in the collection of trade data. For example, if duty-free imports are not required to be recorded at customs, official trade statistics can be distorted.

A final advantage—mainly for small island states—is that trade activity based on port call data may be a useful *proxy* for real consumption, or even real GDP growth. In small island states, imported goods typically constitute most of the consumption basket—in some cases 70-80 percent. In such cases, trade volume based on port call data can also be a proxy for real consumption and GDP growth, and can inform central banks and other government agencies on possible turning points in the business cycle. At the same time, for highly service-oriented small islands states, such as Malta, the indicator may not correlate well with GDP given that it is a measure of trade in goods, not services. In summary, our trade activity indicator based on port call data may provide useful signals on real growth when (i) most trade is in goods, not services; (ii) most trade is seaborne; and (iii) either the import share of domestic consumption/investment is high or the export share of domestic production is high.

But AIS data also have some disadvantages. First, the data are provided by commercial data providers for a fee. Acquiring historical data and subscribing provision of real-time feed can be costly. Second, the data may not be as accurate as official trade data if the coverage of AIS-receiving stations near the port is weak. Third, the data may be noisy (as detailed in the next section) and may thus require specialized domain experience and well-designed filtering techniques.

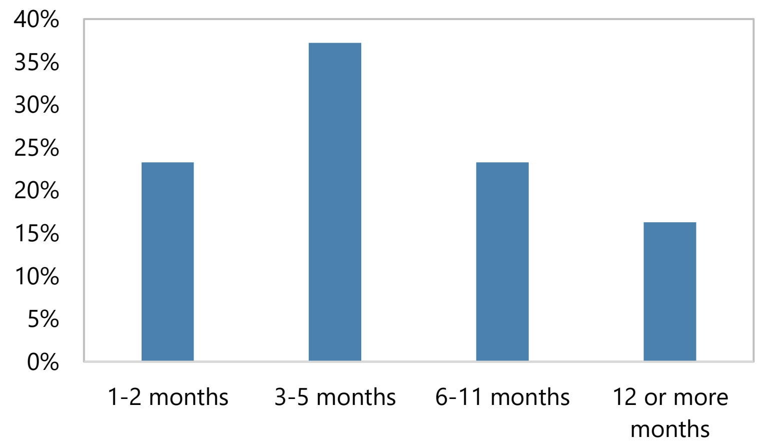
III. Our Proposed Approach

We now describe our proposed approach for deriving indicators of vessel traffic using AIS data. The methodology consists of two steps:

- We first develop a filter to identify cargo ships that are assumed to generate trade activity by unloading and loading goods at the port. We then derive high-frequency indicators on the filtered ships, by aggregating static and voyage-related information contained in the port call data.

Figure 3. Timeliness of Merchandise Trade Data

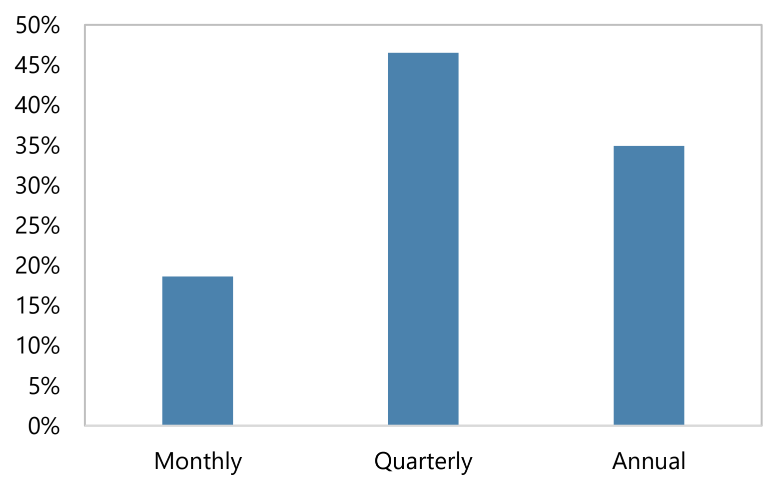
(In percent of all small states)



Source: Based on data and metadata from country authorities. Sample includes 43 Fund members that are small states, defined as countries less than 1.5 million people.

Figure 4. Periodicity of Merchandise

(In percent of all small states)



Source: Based on data and metadata from country authorities. Sample includes 43 Fund members that are small states, defined as countries less than 1.5 million people.

We develop this approach by using AIS data available for Malta. Malta is an excellent test case for demonstrating the validity of our approach to nowcast trade. It is a small and open economy and is highly dependent on external trade (Appendix 3). Malta depends heavily on imports for its industries and consumers. About two-thirds of these imports are carried by ship. As a member of the European Union (EU), Malta complies with EU regulations by providing reliable and comparable port statistics. Such statistics are useful benchmarks to validate the arrival and departure of ships using AIS port calls.

To conduct this study, we use a sample of port call data for Malta provided by MarineTraffic. The data covers all port calls observed in Malta ports between January 2015 and December 2018. The sample starts in 2015 as data availability and reliability improved significantly after 2014 as the coverage of AIS-receiving stations around Malta grew and MarineTraffic's algorithm to generate port call data was enhanced further. We restrict the focus on two main Maltese ports: Marsaxlokk and Valletta. The Port of Marsaxlokk (southeast Malta) consists of a Freeport container terminal, and storage facilities for industrial goods and oil products. In contrast, the Grand Harbor of Valletta (northeast Malta) operates cargo terminals that handle ro-ro containers and conventional cargo ships, and also offers grain terminals, oil tanks, and a range of services to the maritime industry (e.g., ship repairs, offshore).

A. Filtering Port Calls Generating Trade Activity

The AIS-based data contains 52,863 port calls detected in the boundaries of Marsaxlokk and Valletta between January 1, 2015, and December 31, 2018 (Table 1). Two-third of these calls (about 35,000) are reported from Marsaxlokk. As for ship type, tankers account for more than half of port calls in the two ports. Malta imports oil to produce some of its electricity for domestic use.[4] However, a large share of imported oil in Malta is re-exported after basic processing. The port of Marsaxlokk, for example, offers oil storage, blending, and treatments for third-party countries. Re-exports may also account for most of other tankers carrying liquefied natural gas (LNG) or chemicals. Containerships and general cargo ships – which carry manufactured goods – account for nearly 45 percent of port calls.

We use three rules to filter out invalid port calls, eliminating cargo ships that are not expected to generate trade activity at the port. Overall, the three rules together eliminate 12,050 port calls (22.8 percent of the total). About half of the ships filtered out are tankers. The three exclusion rules are explained below:

- **Anchorage and bunkering tankers.** A lot of bunkering and ship-to-ship (STS) transfer activity takes place in the Marsaxlokk anchorage area. As a result, many port calls record short-distance movements between Marsaxlokk and the anchorage location off the eastern port of the island. Some of these movements are related to tankers transporting fuel (see Box 1 on the complexities of vessel movements related to an LNG floating storage unit). Bunkering is the practice of providing fuel to vessels located at seaports. The AIS data show the movement of almost 4,000 vessels (about 8 percent of total port calls) classified as "bunkering tankers." Fuel supplied to

[4] Malta also imports electricity through an interconnector with Sicily and a significant portion of domestically generated energy is now being produced by a new natural gas fired power plant (see Box 1).

foreign vessels should be recorded as exports of the country according to international standards, although it is recognized that data collection may be challenging.[5] Since the inclusion of these tankers introduces considerable volatility to the indices, we omit bunkering tankers from our valid port calls.[6]

Table 1. Malta: Identification of Valid Port Calls by Type of Cargo Ships
(Port calls in Marsaxlokk and Valletta. Period: 2015-2018)

	Total Port Calls (1)	*Rule 1. Anchorage and Bunkering Services*	*Rule 2. Ships Arrived, but not Departed*	*Rule 3. Stay in Harbor Outside Range (5h-60h)*	**Invalid Port Calls**	**Valid Port Calls (2)**	*% total (2)/(1)*
All cargo ships	**52,863**	*3,861*	*418*	*7,771*	*12,050*	**40,813**	**77.2**
Container ships	15,974	0	104	509	*613*	15,361	96.2
Bulk carriers	405	0	23	160	*183*	222	54.8
Oil tankers	18,852	0	97	3,001	*3,098*	15,754	83.6
Gas tankers	177	0	3	40	*43*	134	75.7
Other tankers	9,199	3,861	66	2,034	*5,961*	3,238	35.2
General cargo	7,238	0	98	1,561	*1,659*	5,579	77.1
Other types	1,018	0	27	466	*493*	525	51.6

Source: Authors' estimates based on MarineTraffic data.

- **Ships arrived but not departed.** Port calls are expected to record arrival and departure of the same ship in a port. The data specifies for each port call the type of vessel movement through a binary variable ("0" for arrival, "1" for departure). For each arrival of a ship, we look for a matching departure. If we do not find a departure, we eliminate the unmatched port call. We find 418 unmatched port calls (less than 1 percent of the sample), which are noted for all types of ships.

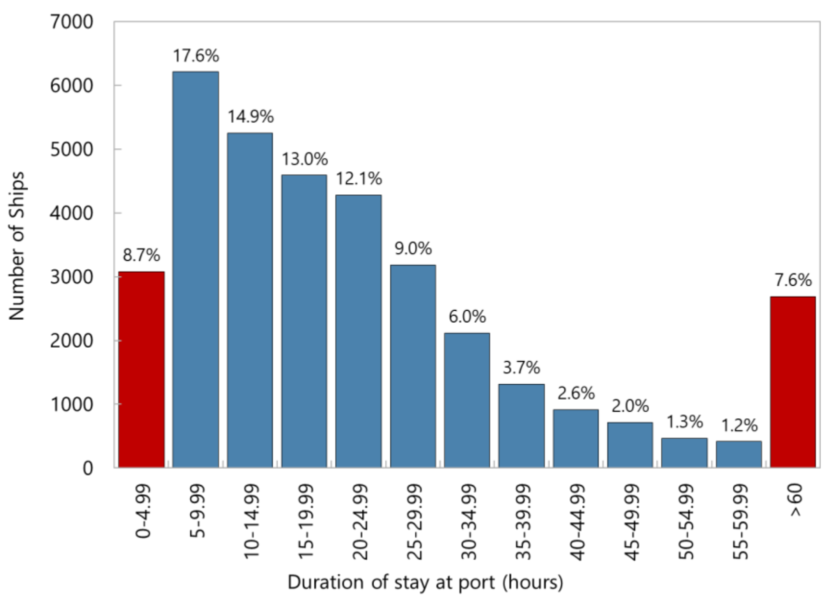
- **Stay in the harbor outside reasonable range for trade activity.** The third rule eliminates calls of ships that remained in the port boundaries for only a short time (less than five hours) or for too long (more than 60 hours).[7] Available port statistics

[5] See paragraph 1.32 of the *International Merchandise Trade Statistics 2010* (United Nations, 2010).
[6] Bunkering activity between non-resident entities is not part of trade statistics. As noted in footnote 8 of Malta's NSO News Release 098/2019: "Adjustments for exports and imports of goods are made for Balance of Payments (BOP) and National Accounts purposes, since merchandise trade data include imports and exports of oil made by non-resident companies having a Maltese VAT number. These are not considered as BOP transactions. Consequently, such imports and exports are being subtracted from the totals."
[7] The chosen thresholds were chosen through a sensitivity analysis. They were calibrated against maritime statistics used as benchmark for our indicators. Going forward, we plan to use other methods, such as

for Malta indicate that almost 80 percent of cargo vessels stay less than one day, and very few exceed three days (Table 2.12 of National Statistics Office of Malta, 2016). Ships that stay for a few hours are unlikely to have enough time to load or unload goods in the port.[8] Longer stays may be associated with ships visiting the port for repairs or maintenance services. Almost 8,000 ships are eliminated with this rule (about 16 percent of the matched port calls), most of which are tankers. Figure 5 shows the frequency distribution of the ships with matched port calls by duration of stay in harbor, and it highlights how this filter eliminates the tails of the distribution.

Figure 5. Filtering Out Cargo Ships with Short and Long Stays in Port

(Number of Ships by Duration of Stay in Marsaxlokk and Valletta. Period: 2015-18)



Note: The bars in red indicate the port calls that are dropped as a result of the third filtering rule.

Source: Authors' estimates based on MarineTraffic data.

minimizing Root Mean Squared Forecast Errors (RMSE) ala Stock and Watson (2003), which could be used to set thresholds on a country-by-country basis. Machine learning techniques, such as Long-Short-Term Memory (LSTM) networks, may also be particularly useful for the purposes of this paper.

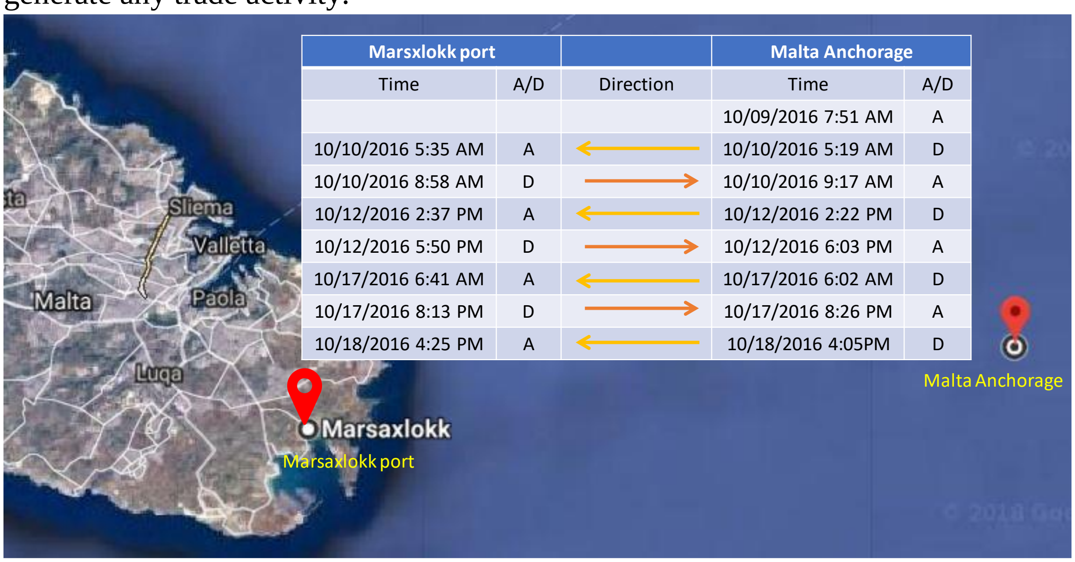
[8] An exception could be the fast ferry services to-from Sicily, which carry a significant proportion of daily perishables for Maltese supermarket chains, which tend to spend less than five hours in Maltese ports. Another exception could be aquaculture exports, as these may require processing longer than 60 hours.

Box 1. Tracking the Arrival of a Liquefied Natural Gas Tanker in Malta[1]

On October 9, 2016, the AIS data detects the arrival of Armada Mediterrana in Malta waters. Armada Mediterrana was a liquefied natural gas (LNG) tanker built in 1985, and then was transformed into a floating storage unit (FSU) through a 17-month conversion process in Singapore. The arrival of this LNG tanker in Malta received wide coverage in local news (Malta Independent, 2016). The unit is currently providing storage facility and supplying gas to an on-shore electricity power station on a continuous basis. This operation is part of the Malta government's energy policy to reduce the country's reliance on oil products for electricity production.

Using the AIS data, we were able to track the movements of Armada Mediterrana at the time of arrival (see map below). The vessel arrived at a Malta anchorage location (from the Suez Canal) on October 9, 2016 at 7:51am (GMT time). The next day, it departed for Marsaxlokk port at 5:19am, arriving a few minutes later. Local media reported the news from a press conference after the arrival of the tanker, with representatives from the Maltese government. Three hours later, the vessel moved back to anchorage. In the following days, the AIS data captured several movements between Marsaxlokk and the anchorage due to drifting events and recalibration of anchorage boundaries at the time of measurement (experts at MarineTraffic provided such explanations) In January 2017, the tanker/storage unit was permanently moored at a terminal jetty in Marsaxlokk.

This example highlights the necessity to filter out cargo movements that are not involved in merchandise trade activity. First, Armada Mediterrana was an empty tanker when it first arrived in Malta. Offshore storage vessels like this should be (and are) excluded from our valid sample of port call data to generate genuine trade activity. Second, the back-and-forth movements between anchorage and Marsaxlokk are irrelevant to our purposes, as they did not generate any trade activity.



Marsxlokk port			Malta Anchorage	
Time	A/D	Direction	Time	A/D
			10/09/2016 7:51 AM	A
10/10/2016 5:35 AM	A	←	10/10/2016 5:19 AM	D
10/10/2016 8:58 AM	D	→	10/10/2016 9:17 AM	A
10/12/2016 2:37 PM	A	←	10/12/2016 2:22 PM	D
10/12/2016 5:50 PM	D	→	10/12/2016 6:03 PM	A
10/17/2016 6:41 AM	A	←	10/17/2016 6:02 AM	D
10/17/2016 8:13 PM	D	→	10/17/2016 8:26 PM	A
10/18/2016 4:25 PM	A	←	10/18/2016 4:05PM	D

1/ This box was prepared with inputs by Jung Eun Yoon.

B. Deriving High-Frequency Indicators of Vessel Traffic

We derive weekly indicators of trade activity thanks to the availability of the date and time of port events in the data. The weekly aggregation is a key advantage of our indicators compared with official statistics on trade, which are based on customs records that are only available monthly (in some countries quarterly, or even yearly).

With these considerations in mind, we calculate two indicators of vessel traffic from the filtered container and cargo ships (Table 1):

- **Cargo number indicator**. The *cargo number indicator* counts the number of incoming ships. This indicator is presented in Figure 6a. The chart shows the number of cargo ships arriving and departing from Malta ports from the first week of 2015 to the last week of 2018 (211 weeks). The indicator moves around an average level of about 100 ships a week. A seasonal trough is noted at the beginning of the year, while seasonal peaks look concentrated around weeks 24-25 (the second half of June). As expected, the indicator shows a substantial noise component owing to the weekly frequency of the data. A five-term (centered) moving average is used in the chart to smooth the noise. This indicator does not carry any information about the size of the ship,[9] or about its cargo load (i.e., all ships are equal).

- **Cargo load indicator.** The *cargo load indicator* (Figure 6b) is derived by combining information on the ship's deadweight tonnage and the draught reported in AIS messages. Deadweight tonnage is a measure of the maximum weight a ship can carry (including cargo, fuel, passengers, and other loads). The draught measures the vertical distance between the waterline and the bottom of the hull. The draught can be used to approximate the cargo load.

  Let $DWT_{i,t}$ be the deadweight tonnage of ship *i* arrived in port on a given week *t*. Let $d_{i,t}^{A}$ be the reported draught of the same ship upon arrival, and $d_{i,t}^{D}$ the reported draught upon departure (assuming, for simplicity, that arrival and departure happens in the same week *t*). We calculate the cargo load indicator as follows:

$$CWI_t = \sum_i DWT_{i,t} \frac{\left| d_{i,t}^{D} - d_{i,t}^{A} \right|}{\max(d_i)}, \qquad (1)$$

  where $\max(d_i)$ is the maximum draught reported by the ship in the sample data. For each ship, $DWT_{i,t}$ is adjusted with a *capacity utilization ratio*. The numerator of the ratio calculates the *absolute change* in draught. The difference is expected to correlate

[9] We also developed an indicator based on gross tonnage, a conventional measure for ship size (Appendix 1). The gross tonnage indicator may be useful for ports hosting ships of different size. For Malta, this indicator showed similar movements of the cargo number indicator and is not shown in this paper.

with the volume of cargo loaded or unloaded in the port. We take the absolute value because we want to measure total trade activity in the country (imports plus exports). Furthermore, by taking the absolute value we eliminate the occurrence of negative changes when the departure draught ($d_{i,t}^{D}$) is lower than the arrival draught ($d_{i,t}^{A}$). We divide the reported change in draught by the maximum draught of the ship. The resulting ratio – which is less than, or equal, to 1 by definition – can be interpreted as the capacity utilization rate of the ship. High values of this ratio, for example, may signal that the ship is loaded to capacity, and vice versa. The adjusted $DWT_{i,t}^{\prime}$ is aggregated across all ships for each week.

Formula (1) has two potential shortcomings. First, the value $\max(d_i)$ is a local maximum drawn from port calls and not the maximum draught designed for the ship (which was not available in our sample). The formula may underestimate the cargo load when the local maximum is far from the maximum draught. To remedy this, the formula should use the maximum draught available from vessel registers (e.g., Lloyds' Register). Second, the formula assumes no trade activity when there is no change in draught. This may not be the case when the weight of goods unloaded upon arrival equals the weight of goods loaded on departure. However, the number of cases with no change in draught were limited in the case of Malta (less than 5 percent of filtered ships). We should also consider that the draught information is a field manually entered by the crew and subject to inaccuracy and delay. The draught is sometimes updated before approaching the next destination, and not when a ship departs from a port. Whereas these instances were not significant in number in Malta's case, these could represent a higher share in another country. In any event, given that the draught data is entered by crew and hence may be subject to measurement errors, it is important to work with large samples to minimize this measurement error.[10] Refinements to address these shortcomings are left for future research.

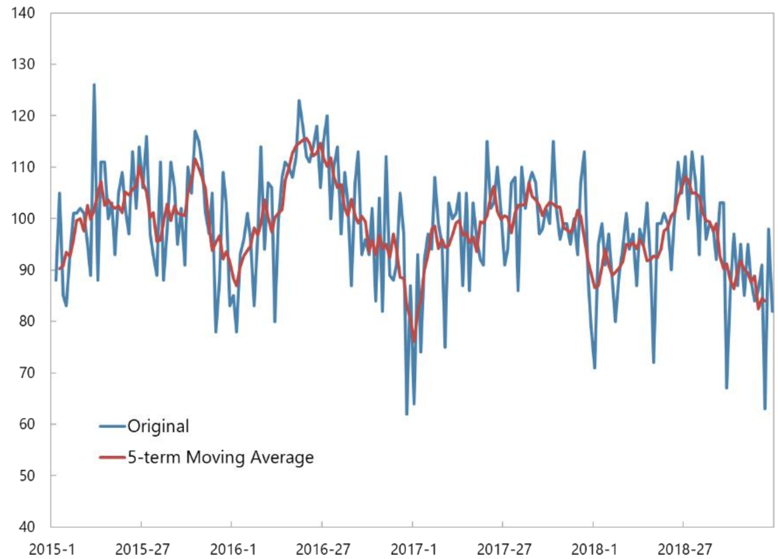
The cargo load indicator shows an evident peak of activity between the last week of May and the second week of August 2016. This peak is then followed by a steep fall in subsequent weeks, until the indicator returns to the 2015 level at the start of 2017 and begins a moderate upward trend through the end of 2018. In the next section, we will see that this pattern is also visible in the official trade statistics.

[10] Jia and others (2015) investigate the reliability of the draught parameter reported over AIS for the capsize dry bulk sector of the freight market. They validate the AIS-reported draught data with information on the cargo type and cargo size from port agents' lineup reports and fixtures data. Their results suggest that that, although the draught parameter may not be reliable on a *per-ship* basis, a sufficiently populated *sample* appears to provide useful information about average payload and utilization within a given ship type and size category.

Figure 6. Malta: Weekly Indicators of Vessel Traffic based on AIS Data

(a) Malta: Cargo Number Indicator

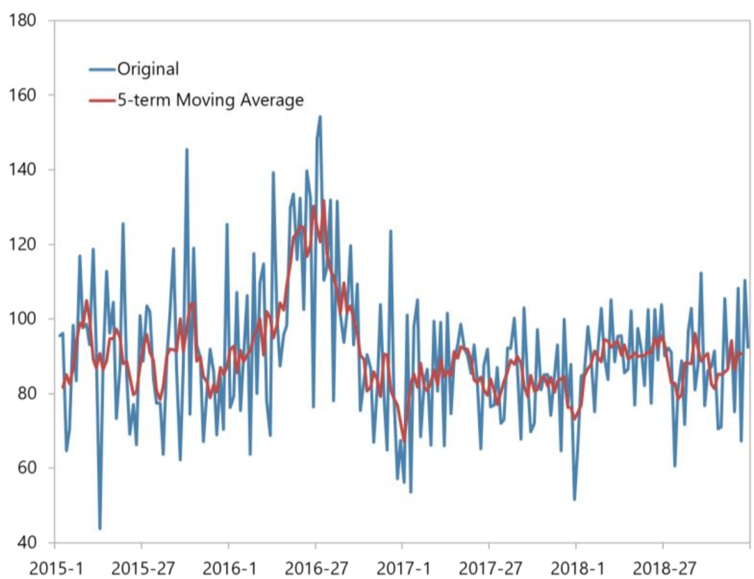
Number of ships arrived based on port calls, weekly. Period: 2015-18.



Source: Authors' estimates based on MarineTraffic data.

(b) Malta: Cargo Load Indicator

Deadweight tonnage adjusted for draught based on port calls, weekly. Period: 2015-18.



Source: Authors' estimates based on MarineTraffic data.

IV. Quality Assurance of AIS-Based Indicators

To verify the quality of our indicators, we compare them with the official Maltese statistics. First, we show how our cargo number indicator compares with the corresponding figures available from maritime statistics. Second, we verify the ability of our cargo load indicator to track Malta's official trade statistics.

A. Maritime Statistics

Maritime transport statistics contain, among others, the number of vessels and gross tonnage arrived in ports. The data are collected by the national authorities using a variety of data sources, such as port administration systems, national maritime databases, customs databases, or questionnaires results from ports or shipping agents.

The data are collected at the port level. A port is defined as a "a place having facilities for merchant ships to moor and to load and/or unload cargo or to disembark and/or embark passengers to or from vessels, usually directly to a pier." A main port is a port with annual movement of no less than 200,000 passengers or recording more than one million tons of cargo. For main ports, detailed data on type of cargo and other variables are provided; for other ports, only summary data are provided. The type of cargo classification is set according to the United Nations Economic Commission for Europe (UNECE).[11]

Maritime statistics of Malta are compiled by the National Statistics Office (NSO). They are readily accessible from the *Transport* database of the Eurostat portal. We focus our comparison on Malta's two international ports: Marsaxlokk and Valletta. (Figure 7 compares the number of ships arrived at these two ports using AIS-based port call data (red line) and the official numbers (blue line) between the first quarter of 2015 and the first quarter of 2018.)[12] The number of ships based on AIS port calls consistently exceeds official numbers (by about 20-30 percent). We interpret this as a sign of exhaustive coverage of cargo and tanker ships using port calls based on AIS. Although AIS data may record multiple visits of the same ship, or ships that may only be transiting, we cannot be sure that port statistics are complete.

In a 2016 report, UNCTAD indicates that it is difficult to ascertain the quality of port statistics, as data available from the maritime industry are often "selective, and their coverage is patchy" (UNCTAD, 2016). But even though the levels of the series differ, it is reassuring that their dynamics look very similar. The correlation coefficient between the two series is very high (0.75 for the whole sample).

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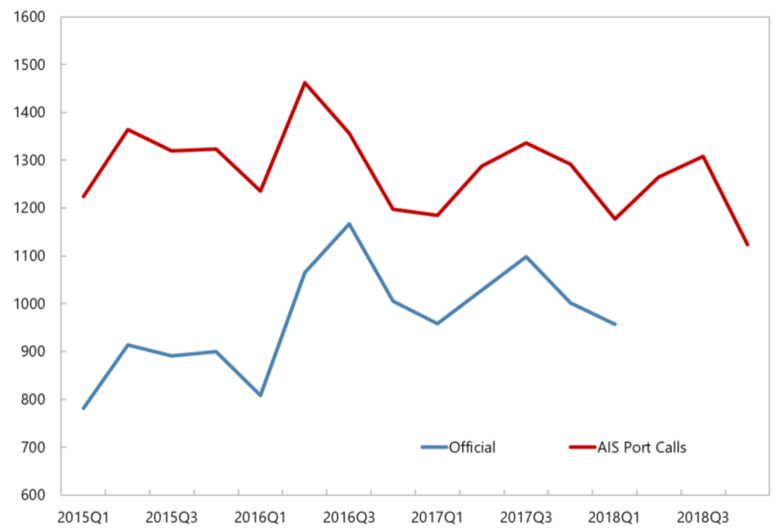
[11] See UNECE - Codes for types of cargo, packages and packaging materials, Recommendation 21, Geneva, March 1986.

[12] At the time of writing, official port statistics for Malta were available up to the first quarter of 2018. Instead, port call data provided by MarineTraffic were available through December 2018.

Figure 7. Malta: Cargo Number Indicator Good Proxy of Official Port Statistics

(Cargo Number Indicator vs. Official number of ships in Marsaxlokk and Valletta, quarterly. Period: 2015-18)



Source: Eurostat and authors' estimates based on MarineTraffic data. Official data available up to 2018q1.

It bears highlighting that port call data from AIS messages are available almost in real time and can be used to forecast the vessel traffic in the two ports for up to two-three quarters.

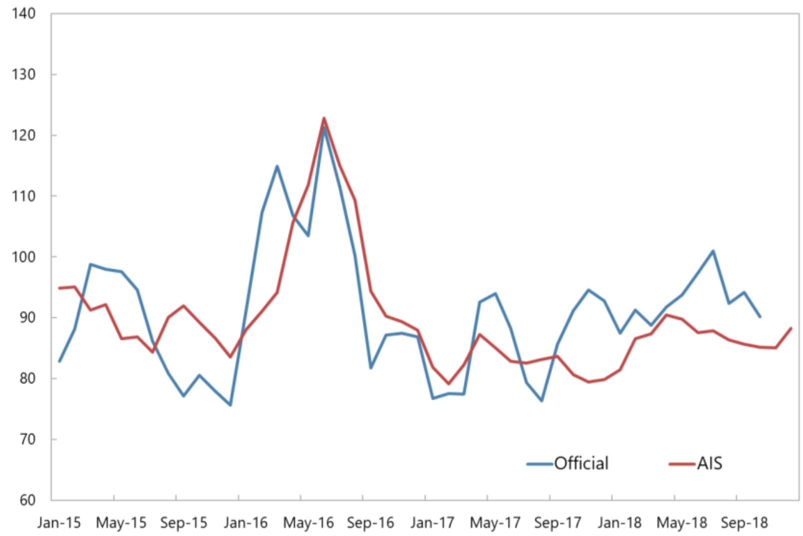
B. Trade Statistics

Volume Trade

Overall, our indicator appears to follow closely Malta's trade volume (sum of imports and exports). In particular, the June 2016 peak in trade activity and the subsequent deceleration is perfectly detected by the cargo load indicator. Figure 8 compares our cargo load indicator with the official estimate of trade in volume terms available from the NSO of Malta. The official trade index appears to present higher short-term volatility than our indicator. Such differences can be justified by the different coverage and methodology adopted in the two indicators. For example, the official trade index also includes goods that are imported and exported by air. But the high correlation between the two series (0.65) is promising evidence that our indicator can potentially be used as a predictor of Malta's real imports.

Figure 8. Malta: Cargo Load Indicator Broadly Follows Trade Volumes

(Cargo Load Indicator versus Official Trade in Volume, quarterly index, three-month moving average, 2016=100. Period: 2015-18)



Source: Eurostat and authors' estimates based on MarineTraffic data. Official data available up to October 2018.

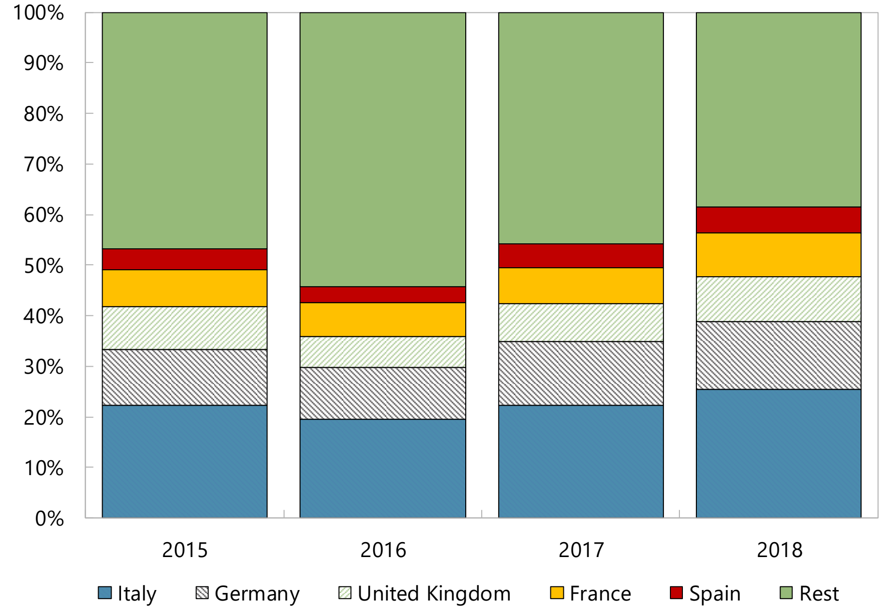
Trade by Partner Countries

Finally, we look at the geographic distribution of our cargo load indicator in comparison with the trade-by-partner data available in the IMF's *Direction of Trade Statistics* (*DOTS*). The trade shares of the top five exporting countries to Malta during 2015-18 were: Italy, Germany, United Kingdom, France, and Spain (Figures 9-10). In this period, these countries accounted for about 55-60 percent of total nominal trade in goods of Malta.

As expected, the trade distribution based on "country of last port" from AIS data is somewhat different from the *DOTS*. Italy and France remain in the top five. But the other main "partners" based on AIS data are Spain, Turkey, and Egypt. In *DOTS*, these countries take a very small share of Malta's trade. Other main partners from *DOTS* are Germany and the United Kingdom, which are not recorded as trading partners in the port call data (i.e., no ships arrive in Malta directly from either country). Most ships arriving in Malta transit through the ports of Egypt, France, Italy, Spain, and Turkey because of their geographic proximity to Malta. AIS data record the last known port of ships before arriving in Malta, not the port of origin where the goods were first loaded to destination. Furthermore, container ships include goods coming from landlocked exporting countries, which cannot be recorded in port call data.

Figure 9. Malta: Trade by Country of Origin (Customs Data)

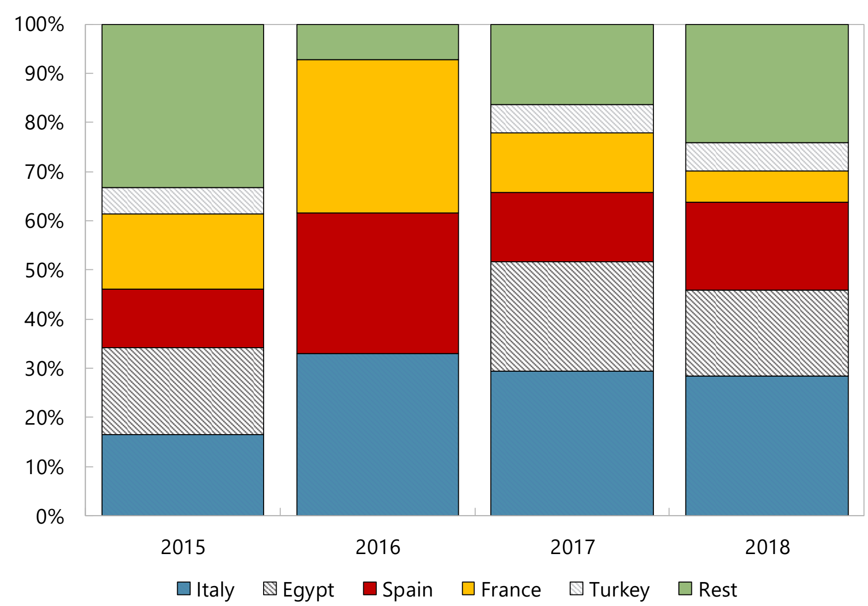
(Share by partner country based on Direction of Trade Statistics, 2015-18)



Source: IMF, Direction of Trade Statistics.

Figure 10. Malta: Trade by Country of Last Port (AIS)

(Share by partner country based on cargo load indicator, 2015-18)



Source: Authors' estimates based on MarineTraffic data.

Trade shares based on AIS data can also be affected by temporary changes in sea routes in the maritime industry. In 2016, AIS data show that Malta did not receive any cargo or tanker ship from Egypt and Turkey, while in other years the two countries take more than 20 percent of Malta's overall trade, according to the cargo load indicator.

More generally, cargo ships on a multi-stop schedule do not necessarily imply a direct connection between countries of origin and countries of destination. In that sense, cargo ships are more like "buses" in the ocean, which make tracking the country origin of goods very difficult. On the other hand, tankers, general cargo, and bulkers tend to behave more like "taxis" with a specific origin and destination (Brancaccio and others, 2017).

At the same time, it is important to acknowledge the existence of geographical choke points. In Malta's specific case, a ship would need to pass from one of three choke points—Gibraltar/Algeciras/Tangiers, Suez/Port-Said, and Istanbul/Dardanelles. Together these three choke points force ships to pass from UK Overseas Territory/Spain/Morocco, Egypt and Turkey, respectively. This will naturally distort the geographical distribution of trade.

Finally, it is not always easy to monitor the trade flows between country pairs for oil tankers—oil may be sold while still on the high seas, economic ownership transferred, deposited in storage facilities onshore, re-sold a number of times, and then re-exported. This is an important feature of oil trade, which is also relevant for Malta.

V. Conclusions and Policy Implications

In this paper, we show that real-time vessel data can be used to nowcast trade flows. Using Malta as a benchmark, we develop a methodology to extract indicators of vessel traffic and trade activity from AIS-based port call data.

The quality of the indicators we extract is verified by comparison with official trade and maritime statistics. The results of this comparison indicate that:

- The *cargo number* indicator (e.g., number of ships arrived to and departed from Malta) shows a larger number of ships compared with data from official port statistics. We interpret this finding as a sign of exhaustive coverage of commercial vessels using port calls based on AIS.

- The *cargo load* indicator appears to be a good proxy of Malta's trade volumes. In particular, the indicator detects effectively the large peak of trade activity in mid-2016, and the subsequent deceleration in the following months. Using the availability of AIS data in real time, the cargo load indicator can offer suitable information to nowcast Malta's trade flows.

We believe that these findings have important implications for policymaking. International trade is an important share of GDP in many countries, particularly small states with an open economy. Tracking a country's trade in real-time may offer prompt and valuable insights into the health of an economy. The methodology applied for Malta can easily be extended to other countries, particularly those with a significant share of trade carried by ships. On a global scale, AIS data offer great potential for monitoring world trade flows on a real-time basis, which would be an invaluable input for monitoring global trade patterns.

Our results are also of interest for member countries seeking to improve the quality of their trade data. Countries usually produce official trade statistics based on customs records, which are available with some delay, and sometimes only on a quarterly or annual basis. Port calls may be used as an additional source to yield an early estimate of official trade statistics (as well as maritime statistics). Furthermore, our AIS indicators may be used to validate official volume indicators of trade. Trade volume indicators are based on unit value indices, which are generally not good measures of export and import prices for non-homogeneous items (Silver, 2010). This validation work may be particularly useful for national accounts compilers as they sometimes face mismatches between volume estimates of domestic demand components (final consumption and capital formation) and net exports.

It could be added that the benefits of using this approach grow exponentially if we aggregate information for all countries. In other words, the approach could be extended to generate a real-time worldwide indicator of trade statistics with comparability across countries. At the same time, it should be noted that this would be an indicator of trade in goods, not services. Also, the indicator would not provide information on the detailed types of traded goods, except for some general categories such as oil and gas.

Our proposed approach is a first attempt to extract indicators of trade based on AIS data. The proposed methodology can be extended in several ways, which are left for future research:

- The robustness of our indicators should be tested further with longer spans of data and additional countries.
- The quality of the cargo load indicator may be improved by exploiting the statistical relationship between actual cargo size and AIS-reported draught (Jia and others, 2015).
- Dynamic data available through AIS on speed and course over ground may be useful for isolating ships moving around the port's boundaries, not actually entering the port for loading/unloading cargo operations.

Notwithstanding these limitations, the approach put forward in the paper could be valuable for a number of reasons. It could improve the early detection of macroeconomic risks at a country/global level and help assess the effects of trade protectionism on global trade. The approach would also seem particularly suitable for small island states that are heavily dependent on maritime trade. The approach could be used by statisticians in advanced economies to complement other official statistics. One could imagine, for example, a leading indicator of trade in Europe, being compiled on the basis of aggregate, high-frequency port call data for Europe's top maritime hubs.

In concluding, we emphasize that this research does not question the accuracy of official trade statistics. We strongly believe that customs data (the main source used by statistical agencies) provide the most accurate and comprehensive measurement of trade flows. However, we are confident that AIS data (as well as other big data sources) can bring value added to complement the picture on trade, such as by filling data gaps, improving timeliness, increasing granularity, and offering an innovative way to look at trade patterns around the globe. In this light, we are hopeful that our research will encourage statistics agencies and researchers working on trade measurement to conduct further work in this area.

Appendix 1. Glossary of Maritime Terms

Gross tonnage (GT) is a measure of a ship's volume.

Deadweight tonnage (DWT) is a measure of how much weight (in tons) a ship can carry.

Draught (or draft) is the depth to which a vessel is immersed in water. It is the vertical distance (in meters) between the waterline and the bottom of the vessel's hull.

Maximum draught (or draft) is a special marking on the hull of a ship, also known as the international load line or Plimsoll line, that indicates the legal limit to which a ship may be loaded to safely maintain buoyancy.

IMO number is unique seven-digit reference number assigned to each ship when constructed. It follows the ship identification system introduced by the International Maritime Organization (IMO) in 1987 to improve maritime safety and to prevent maritime fraud. The IMO number is permanently associated with the hull of a ship and would not change regardless of a change in the ships name, owner, or flag. The IMO number is part of the static AIS information provided by the vessels crew and can be transmitted additionally, but not all vessels have an IMO number.

Maritime Mobile Service Identity (MMSI) number is used as an alternate to the IMO number. It is a nine-digit number programmed into AIS systems on board of the vessel. While every vessel has an MMSI, it may change over time as it is not permanent like the IMO number. In particular, a ship could have a different MMSI number when its owner or flag changes.[13] The AIS system requires transmission of the MMSI but not the IMO number.

Ship_Id is a proprietary vessel identifier introduced by MarineTraffic in 2014 to provide a more reliable and unique identifier for each vessel, in addition to IMO or MMSI numbers. Using the Ship_Id, MarineTraffic further ensures that AIS information is attributed to the correct vessel regardless of whether the vessel has an IMO number or if the MMSI number changes with a sale and purchase.

Port call is a discrete event representing a vessel arriving at or departing from a port. It is triggered when two positions of a vessel inside and outside of the port's defined boundaries are recorded within a short interval.

[13] The first three digits of the MMSI are called MID (Maritime Identification Digits). These digits are assigned by the International Telecommunications Union (ITU) to denote the country of registration of a vessel. Hence, the MMSI number of a vessel could change when it is sold or reflagged.

Appendix 2. Primer on the AIS

The Automatic Identification System (AIS) is an automated, autonomous tracking system that is extensively used in the maritime world for the exchange of navigational informational between AIS-equipped terminals (e.g., other vessels or coastal authorities). The International Maritime Organization (IMO) requires all international voyaging vessels with above 300 gross tonnage and all passenger vessels to be equipped with an AIS transponder.[14]

An AIS transponder has a GPS (Global Positioning System) receiver that collects the vessel's position and movement details. Along with other static information provided by the vessel's crew, this information is automatically broadcast at regular intervals via a built-in VHF transmitter. AIS messages include the following information:

- **Dynamic information** that is automatically transmitted every 2-10 seconds depending on the vessel's speed and course, and every 6 minutes while anchored. These include the Maritime Mobile Service Identity number (MMSI)—a unique identification number from which a vessel's flag can also be deducted—speed, course, rate of turn, and position coordinates of the vessel.

- **Static information** that is provided by the vessel's crew and is transmitted every 6 minutes regardless of the vessel's movement status. These include the IMO number — this number remains the same upon transfer of the subject vessel's registration to another country (flag)—name, type, and dimensions of the vessel.

- **Voyage-related information** that is also provided by the vessel's crew and is transmitted every 6 minutes regardless of the vessel's movement status. These include the vessel's draught, destination, and estimated time of arrival.

These messages can be captured by terrestrial land-based antennas (T-AIS) or low earth orbit satellites (S-AIS). In principle, the messages can offer real-time information on the location of all ocean-going vessels, their past routings, and expected future port call. With the use of special software, geo-positions in AIS messages can be processed and depicted on chart plotters (e.g., on MarineTraffic's Live Map).

The availability of the AIS information to the public quickly led to a drastic change regarding the initial perception of its use. AIS was originally developed by IMO as a standard that would help vessels avoid collisions while assisting port authorities control marine traffic more efficiently. But the fact that its capabilities could become applicable to a wider spectrum of maritime-related business fields soon became clear. Nowadays, AIS information

[14] This decision was the result of the 2002 SOLAS (Safety of Life at Sea) international agreement to improve maritime safety.

is used for various purposes and facilitates the work of people in various fields. Combined with other data sources containing information on the type and size of cargo onboard, the data could also enable the generation of more timely and perhaps equally accurate trade data (Adland and others, 2017).

AIS-based data can potentially present a rich picture of international trade by providing information on real-time positions of vessels that can be aggregated to high-frequency (even daily) trade data. However, they do not provide direct information on the cargo of the vessel. This information can be gathered indirectly from the following sources:

- **Type of ship**. This could indicate whether the cargo is commodities (general cargo), manufactured goods (containers), or oil and oil-related products (tankers).

- **Gross tonnage of ship**. This could provide information on the size of the ship.

- **Draught of ship**. This could be used to infer the potential weight of the cargo being transported. In particular, the *change* in the draught (before and after a port visit) may correlate with the net volume of cargo being loaded or unloaded in ports (which is the idea used in our paper to calculate the cargo load indicator).

Use of AIS Data by National Statistics Offices and Other Users

With the increasing availability and completeness of AIS data, it is not surprising that the data are increasingly being used to track trade activity by national statistical offices.

National statistics offices in the Netherlands, Singapore, and the United Kingdom have begun to explore the use of AIS data to complement official maritime statistics. The European Statistical System (ESS) has explored the use of AIS data to improve the quality and comparability of existing statistics and for new possible statistical products (de Wit and others, 2017). The findings of the ESS exercise, a collaboration between the national statistics offices of Denmark, Greece, the Netherlands, Norway, and Poland, suggest that AIS data can be a promising source for nowcasting trade.

Another use of AIS data has been to track global trade activity and global growth. Similar to the Baltic Dry Index, which measures global freight rates for container shipping, vessel traffic data have been used as a barometer of global growth, including by market participants.

Other potential uses of AIS data have been for marine safety, including traffic anomaly detection, route estimation, collision prediction and path planning (Tu and others, 2017). Spiliopoulos and others (2017) have examined computational methods to process AIS data, including data mining and machine learning approaches. Others have examined how AIS data could help improve reduce carbon emission by vessels and congestion times at ports (de Wit and others, 2017). Another potential use case for AIS data, which is not exploited in this paper, is to support the enforcement and collection of a carbon tax on maritime fuels. Such a tax was proposed by Parry and others (2018) and discussed further in IMF (2019).

At the same time, to our knowledge, only a few papers have used AIS data to nowcast trade flows. A notable exception is Adland and others (2017), which examine the reliability of AIS-based trade volume estimates in for crude oil exports. The authors find that the data show remarkably good alignment with official export numbers, although they note temporal and country-specific differences owing to the use of pipelines and transshipment in parts of the supply chain. A related paper is Brancaccio and others (2017), which use vessel data to build a model of shipping patterns, search frictions, and endogenous trade costs.

Appendix 3. Malta: A Small Open Economy

Malta is an advanced small island state with a GDP per capita of about $31,000 in 2018 and a population of about half a million people. The Maltese economy is very open to international trade, with both imports and exports consistently above the level of its GDP (Appendix Table 3.1.) Similar to other small island states, Malta depends heavily on imports for industrial and consumption needs. The import content of total final sales was about 61 percent in 2015 (Briguglio, 2016). In 2018, Malta had a positive trade balance owing to its relatively diversified exports of services (tourism, transportation, financial services, remote gaming, and information and communications technology). Most of Malta's trade in services occurs with the European Union (EU).

Appendix Table 3.1. Malta: National Accounts
(billion euros unless indicated otherwise, 2018)

National Accounts Component	**2018**
Gross domestic product at market prices	12.3
Final consumption expenditure	7.4
Gross capital formation	2.3
Exports of goods and services	17.8
Exports of goods (percent of total)	*17.5%*
Exports of services (percent of total)	*82.5%*
Imports of goods and services	15.2
Imports of goods (percent of total)	*29.8%*
Imports of services (percent of total)	*70.2%*

Source: National Statistical Office of Malta.

Since early 2000, however, the merchandise trade balance has been in deficit because a large proportion of Malta's imports are of industrial supplies for the manufacturing sector, capital goods, and consumer goods (Appendix Table 3.2.) Malta also imports a large amount of oil for re-export. Malta's trade statistics include the imports of large reserves of oil stocks bunkered offshore in oil tankers, which are then re-exported.

Appendix Table 3.2. Malta: Merchandise Trade Statistics
(2018)

Malta's Trade in Goods (billion euros)	*2018*	*Percent Share in 2018*
Imports of Goods	**6.1**	**100.0**
Industrial Supplies	*1.4*	*22.4*
Capital Goods	*1.2*	*19.5*
Consumer Goods	*1.4*	*22.0*
Fuels and Lubricants	*1.8*	*29.7*
Exports of Goods	**3.3**	**100.0**
Fuels and Lubricants	*0.8*	*24.2*

Source: National Statistical Office of Malta.

With regard to the volume of goods handled in ports, Malta could be considered mainly an importing country. According to Eurostat, Malta imported 3.8 million tons of goods in 2016, while exporting only 0.4 million tons (Appendix Table 3.3.) This suggests that a volume indicator of trade activity in Malta ports would be a particularly good proxy for the volume of imported goods.

Appendix Table 3.3. EU-28: Gross Weight of Seaborne Goods Handled in Ports
(Million tons, 2006-16)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016			Growth rate 2015-2016 (%)	Growth rate 2006-2016 (%)
	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Inwards	Outwards	Total		
EU-28	**3 860.4**	**3 965.6**	**3 945.7**	**3 466.8**	**3 671.0**	**3 786.1**	**3 742.7**	**3 719.2**	**3 790.4**	**3 840.5**	**2 290.3**	**1 570.5**	**3 860.8**	**+0.5**	**+0.0**
Belgium	218.9	236.3	243.8	203.4	228.2	232.8	224.0	228.1	237.9	241.5	137.8	114.9	**252.7**	**+4.6**	**+15.4**
Bulgaria	27.5	24.9	26.6	21.9	22.9	25.2	26.0	28.8	27.2	27.2	13.1	15.6	**28.7**	**+5.6**	**+4.3**
Denmark	107.7	109.7	106.1	90.6	87.1	92.6	87.8	88.4	92.2	95.1	56.5	39.4	**95.9**	**+0.8**	**-10.9**
Germany	302.8	315.1	320.6	262.9	276.0	296.0	298.8	297.3	303.7	295.9	175.2	121.9	**297.1**	**+0.4**	**-1.9**
Estonia	50.0	45.0	36.2	38.5	46.0	48.5	43.5	42.9	43.6	35.0	11.1	22.5	**33.6**	**-3.9**	**-32.8**
Ireland	53.3	54.1	51.1	41.8	45.1	45.1	47.6	46.7	47.5	50.7	33.7	17.0	**50.8**	**+0.2**	**-4.8**
Greece	159.4	164.3	152.5	135.4	129.1	135.3	153.3	161.0	168.5	167.0	95.0	80.1	**175.1**	**+4.8**	**+9.8**
Spain	414.4	426.6	416.1	363.5	377.1	403.8	419.9	397.5	427.7	447.0	253.8	197.5	**451.3**	**+0.9**	**+8.9**
France (¹)	350.3	346.8	352.0	315.6	316.1	322.3	303.3	303.0	298.2	297.9	196.3	95.9	**292.2**	**-1.9**	**-16.6**
Croatia	26.3	30.1	29.2	23.4	24.3	21.9	19.0	19.4	18.6	18.9	12.7	5.8	**18.6**	**-2.0**	**-29.5**
Italy	520.2	537.3	526.2	469.9	494.1	499.9	476.8	457.1	443.1	458.0	296.0	165.9	**462.0**	**+0.9**	**-11.2**
Cyprus	7.7	7.5	8.0	6.8	7.0	6.6	6.2	7.2	7.2	10.3	6.6	3.7	**10.3**	**-0.1**	**+33.7**
Latvia	56.9	61.1	61.4	60.1	58.7	67.0	72.7	67.1	71.8	67.8	6.4	54.6	**61.0**	**-10.1**	**+7.2**
Lithuania	27.2	29.3	36.4	34.3	37.9	42.7	41.0	39.8	41.1	43.1	16.7	29.5	**46.2**	**+7.2**	**+69.8**
Malta	3.6	3.2	3.4	3.4	3.8	3.3	3.3	3.1	3.5	3.7	3.4	0.4	**3.8**	**+2.2**	**+5.9**
Netherlands	477.2	507.5	530.4	483.1	538.7	550.7	557.3	558.5	571.6	594.3	398.3	190.5	**588.8**	**-0.9**	**+23.4**
Poland	53.1	52.4	48.8	45.1	59.5	57.7	58.8	64.3	68.7	69.5	41.0	32.0	**72.9**	**+4.9**	**+37.3**
Portugal	66.9	68.2	65.3	61.7	66.0	67.5	67.9	78.2	80.2	86.8	53.8	37.5	**91.3**	**+5.3**	**+36.6**
Romania	46.7	48.9	50.5	36.1	38.1	38.9	39.5	43.6	43.8	44.5	20.6	25.7	**46.3**	**+4.0**	**-0.9**
Slovenia	15.5	15.9	16.6	13.4	14.6	16.2	16.9	17.2	18.0	19.9	14.1	7.1	**21.2**	**+6.2**	**+36.7**
Finland	110.5	114.8	114.7	93.2	109.3	115.5	105.1	105.1	105.5	100.0	52.0	53.9	**105.9**	**+5.9**	**-4.2**
Sweden	180.5	185.1	187.8	161.8	179.6	177.1	173.0	161.6	167.5	169.7	93.1	78.2	**171.3**	**+1.0**	**-5.1**
United Kingdom	583.7	581.5	562.2	500.9	511.9	519.5	500.9	503.3	503.2	496.7	303.1	180.9	**484.0**	**-2.5**	**-17.1**
Iceland	5.9	6.1	6.6	6.2	6.0	6.1	6.4	6.8	6.7	7.1	5.3	2.1	**7.4**	**+4.3**	**+25.8**
Norway	196.8	198.5	193.4	182.6	195.1	199.0	206.0	207.1	200.8	193.6	59.3	140.8	**200.1**	**+3.4**	**+1.7**
Montenegro	:	:	:	:	:	:	1.2	1.3	1.2	1.5	0.8	0.8	**1.6**	**+8.7**	**:**
Turkey	:	:	305.3	293.9	338.1	359.1	374.7	379.4	378.7	411.8	244.9	180.9	**425.9**	**+3.4**	**:**

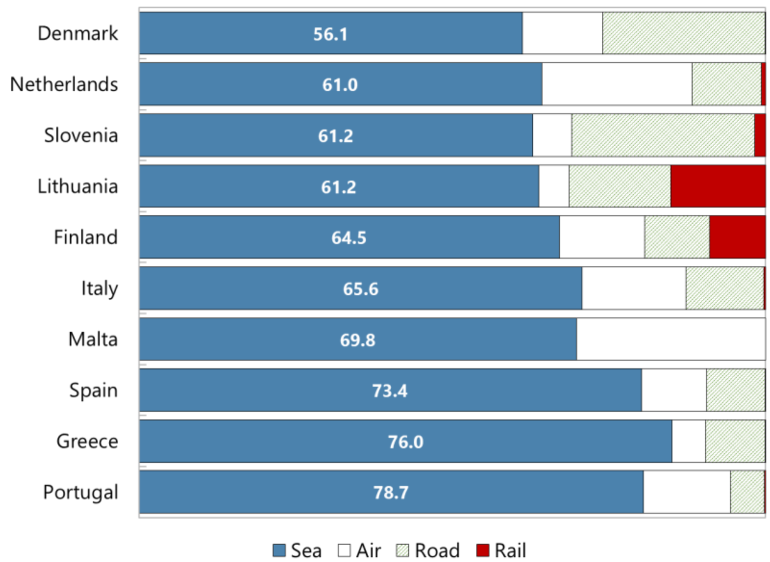
Note: (:) not available.
(¹) 2009-2014: partially estimated by Eurostat.

Source: Eurostat

Finally, seaborne trade consists of about 70 percent of Malta's imports from non-EU countries, the fourth largest share in the EU behind Portugal, Greece, and Spain (Appendix Figure 3.1). Tracking the volume of trade in ports would detect most commodities and manufactures imported from abroad. Air transport – the other transport mode of trade in Malta – is used to import high-value goods, such as electronics and pharmaceuticals, or time-sensitive items, such as perishable foodstuff.

Figure Appendix 3.1. Countries with Largest Shares of Seaborne Imports in the EU

(Extra-EU imports by mode of transport, percent of total, 2016)



Source: Eurostat.

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