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I. MOTIVATION

Maritime trade has formed the backbone of economic prosperity from ancient times to the current globalized century (Spiliopoulos and others 2017). Until recently, it was nearly impossible to accurately track the plethora of shipping routes. But new technologies now allow us to do so and thus derive real-time data on 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 internationally traded goods were loaded at the world’s ports (UNCTAD 2018).

Most international trade is carried by cargo vessels and it is now relatively easy to track these vessel voyages in real time. Modern technology allows us to monitor the global movements of cargo 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. It requires all major commercial ships (over 300 gross tons) to install a device that emits a radio signal about the ships’ course by indicating the ships’ identification number, position, speed, and other safety-related information. 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 Overarching Strategy on Data and Statistics 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, big data can benefit policymaking in several ways. It can complement the timeliness, granularity, and, in some cases, 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 benefit for countries relying 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. This may require close collaboration among several institutions, including with the private sector. Specific statistical techniques may be needed to extract signals from big data sources that are unstructured for policy analysis. In this context, and particularly relevant for high-frequency big data sources, statistics derived from real-time data could risk erroneously picking up erratic responses that could—building on noisy short-term developments—lead to suboptimal 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 include 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 reliable signals for trade monitoring; we also emphasize the advantages and limitations of this approach. In particular, we note that vessel data can be used to measure trade in goods (not services); trade volume (not value); gross trade (not re-exports); and trade by broad groups; rather than specific goods (beyond such homogeneous goods as oil or natural gas). Moreover, we highlight that vessel data could be a good proxy of trade volume in goods when the share of seaborne trade in total merchandise trade is high (in volume terms) and when 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 the coverage of AIS-receiving stations (terrestrial or satellite) is poor near the country’s ports or in the case of trade sanctions that may cause vessels to switch off their AIS transponders during trade activity with sanctioned countries.

In doing so, we propose a two-step approach to nowcast trade flows in real time:

- developing a filter to identify cargo ships involved in trade activity in port calls data,
- producing two indicators based on the filtered ships: a “cargo number” indicator that counts the number of ships visiting ports, and a “cargo load” indicator that 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.

Malta is an excellent benchmark 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 and 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 for validating 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—based on actual movements of ships detected through technology—offer better coverage of vessel traffic in ports than traditional maritime data based on partial surveys and administrative data collected by port authorities.
Our cargo load indicator tracks well Malta’s official trade volume statistics. The strong correlation between official and AIS-based estimates is encouraging. It 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 to be expected given that the country origin of goods transported by 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 can 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 may reveal emerging patterns in international trade, including those associated with global trade tensions.

• The data could close data gaps, especially for countries whose international trade is mostly seaborne and whose 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 whose 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 can thus benefit from this alternative data.

The rest of the paper is organized as follows. Section II describes the characteristics of the vessel data as an innovative source for trade. In Section III, we advance 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
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 data set 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 require careful work (Figure 2 provides an example for Port of Cartagena, Spain). Ports are 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 knot) 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;
- 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 island states, where the bulk of international trade is seaborne. For these countries, port call data would notably improve 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.

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In small states, official trade data on a quarterly basis with a lag of three to 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, 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.

A final disadvantage is that port call data may be noisy (as detailed in the next section) and thus require specialized domain experience and well-designed filtering techniques. The AIS data also have some disadvantages. First, the data are provided by commercial data providers for a fee. Acquiring historical data and subscribing to real-time feeds 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 thus require specialized domain experience and well-designed filtering techniques.
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 because 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-thirds 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. 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.

- 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).
(about 8 percent of total port calls) classified as “bunkering tankers.” Fuel supplied to foreign vessels should be recorded as exports of the country according to international standards, although it is recognized that data collection may be challenging.

Since the inclusion of these tankers introduces considerable volatility to the indices, we omit bunkering tankers from our valid port calls.

### Table 1. Malta: Identification of Valid Port Calls by Type of Cargo Ships

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

Source: Authors’ estimates based on MarineTraffic data.

- **Ships arrived but not departed.**

- **Stay in the harbor outside reasonable range for trade activity.**
Available port statistics 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. Longer stays may be associated with ships visiting the port for repair 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

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 minimizing Root Mean Squared Forecast Errors (RMSE) a la 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.

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

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 Inde, 2016). The unit is currently providing storage facility and supplying gas to an onshore 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.

The vessel moved back to anchorage a few hours later. 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.
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, 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 measure is the vertical distance between the waterline and the bottom of the hull. The draught can be used to approximate the cargo load.

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

$$\text{CWI}_{it} = \sum_{i} DWT_{it}^{A} \left| \frac{d_{it}^{D} - d_{it}^{A}}{d_{it}^{A}} \right|,$$

where $\text{max}()$ is the maximum draught reported by the ship in the sample data.

For each ship, $DWT_{it}^{A}$ is adjusted with a capacity utilization ratio. The numerator of the ratio calculates the absolute change in draught. The difference is expected to correlate.
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 is lower than the arrival draught. 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 is aggregated across all ships for each week.

Formula (1) has two potential shortcomings. First, the value max(id) 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. 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. 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.

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. The results suggest 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: 2015-2018.
Source: Authors' estimates based on MarineTraffic data.

(b) Malta: Cargo Load Indicator
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

The data are collected at the port level. A port is defined as a “a place having facilities for passengers to or from vessels, usually directly to a pier.” 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 from ports or shipping agents.

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).

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.)

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 the dynamics look very similar. The correlation coefficient between the two series is very high (0.75 for the whole sample).

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13 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.
B. Trade Statistics

Volume Trade

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). During 2015-18, the trade shares of the top five exporting countries to Malta 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. DOTS, on the other hand, shows a very small share of Malta’s trade with these countries. DOTS also does not capture trade with 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, 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.
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, resold 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 for extracting indicators of vessel traffic and trade activity from AIS-based port call data. The quality of the indicators we extract is verified by comparing official trade with maritime statistics. The results indicate that:

• The cargo number indicator (e.g., number of ships arrived to and departed from Malta) shows a larger number of ships relative to data from official port statistics. We interpret this finding as signifying the 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. The indicator detects effectively the large peak of trade activity in mid-2016 and the 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 open economies. Tracking a country’s trade in real-time may yield 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 ship. On a global scale, AIS data offer great potential for monitoring world trade flows in real time, an invaluable input for monitoring global trade patterns. Our results are also relevant 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.

The benefits of using this approach could 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. However, 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 such general categories 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 we leave for future research:

• Testing the robustness of our indicators further with longer spans of data and additional countries.
• Exploiting the statistical relationship between actual cargo size and AIS-reported draught (Jia and others 2015) can improve the quality of the cargo load indicator.
• Gathering 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 or unloading cargo).

Notwithstanding these limitations, the approach advanced in this paper offers a number of advantages. It could improve the early detection of macroeconomic risks at the country or global level and help assess the effects of trade protectionism on global trade. The approach would also be particularly relevant for small island states that depend heavily on maritime trade. And 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 largest maritime hubs.