ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/315918103

Are AIS-based trade volume estimates reliable? The case of crude oil exports

Article *in* Maritime Policy & Management · March 2017

DOI: 10.1080/03088839.2017.1309470

CITATIONS
22

READS
644

3 authors, including:

Haiying Jia
NHH Norwegian School of Economics

25 PUBLICATIONS **257** CITATIONS

SEE PROFILE

Siri Pettersen Strandenes

37 PUBLICATIONS **408** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Real energy efficiency at the seaway View project

Project SmartDigital View project

All content following this page was uploaded by Haiying Jia on 27 November 2017.

The user has requested enhancement of the downloaded file.

Maritime Policy & Management

The flagship journal of international shipping and port research

ISSN: 0308-8839 (Print) 1464-5254 (Online) Journal homepage: http://www.tandfonline.com/loi/tmpm20

Are AIS-based trade volume estimates reliable? The case of crude oil exports

Roar Adland, Haiying Jia & Siri P. Strandenes

To cite this article: Roar Adland, Haiying Jia & Siri P. Strandenes (2017): Are AIS-based trade volume estimates reliable? The case of crude oil exports, Maritime Policy & Management

To link to this article: http://dx.doi.org/10.1080/03088839.2017.1309470

Published online: 28 Mar 2017.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
http://www.tandfonline.com/action/journalInformation?journalCode=tmpm20

Download by: [51.174.28.44] **Date:** 28 March 2017, At: 09:29

MARITIME POLICY & MANAGEMENT, 2017
http://dx.doi.org/10.1080/03088839.2017.1309470

Are AIS-based trade volume estimates reliable? The case of crude oil exports

Roar Adland [a], Haiying Jia [b] and Siri P. Strandenes [a]

[a]Department of Economics, Norwegian School of Economics (NHH), Bergen, Norway; [b]Center for Applied Research (SNF), The Norwegian School of Economics, Bergen, Norway

ABSTRACT

Most global trade statistics in the public domain refer to official customs data, which are not generally available on a micro (individual cargo) level. With the increasing availability and completeness of ship positioning data from the global Automated Identification System (AIS), it is possible to derive more timely and detailed trade statistics for homogeneous commodity groups. The objective of this article is twofold: (1) to compare the accuracy of AIS-derived trade statistics to official customs data in the crude oil market and (2) to add a breakdown of trade by vessel size over time. We find that while AIS-derived data for seaborne crude exports show good alignment with official export numbers in aggregate, there are substantial temporal and geographical differences across countries and time due to the use of pipelines and transshipment in parts of the supply chain. We highlight the challenges in properly structuring and aggregating micro-level cargo data. Our findings are important for the proper derivation of shipping demand from trade data.

KEYWORDS

AIS; oil exports; tankers; maritime big data; trade statistics; trade flows

1 Introduction

Most global trade statistics in the public domain refer to official customs data. Such trade data is widely available, for instance, through the UN Comtrade database or government statistics agencies of individual countries. The data are well standardized according to international conventions (e.g. HS codes) and accessible as country-to-country flows or complete trade matrices for the selected good or commodity. These customs statistics form the basis for most historical analysis and empirical modelling of international trade.

An alternative to customs trade data, long present in the shipping industry, is the aggregation of inter-regional seaborne trade flows by tracking vessel movements over time. Starting in the 1960s, Oslo-based ship broking firm Fearnleys published annual reviews of the world bulk trades by following ship movements and cargo flows in major bulk trades such as crude oil, oil products, iron ore, coal, grain, phosphates, and some minor bulks. Fearnleys' publication was mostly based on shipbrokers' knowledge and network, specific vessel cargo assignments, and export/import statistics as explained in Nossum (1996). The laborious nature of structuring such vessel movement data, despite a considerably smaller global fleet size, naturally meant that higher-frequency or up-to-date observations were difficult if not impossible to construct. We also note that this data were not entirely independent from export/import statistics (Nossum 1996).

CONTACT Roar Adland roar.adland@nhh.no Department of Economics, Norwegian School of Economics (NHH), Helleveien 30, 5045 Bergen, Norway

This article is a revised and expanded version of a paper entitled "Are AIS-based trade volume estimates reliable? The case of crude oil exports" presented at the annual IAME conference, Hamburg, 23–26 August 2016.

© 2017 Informa UK Limited, trading as Taylor & Francis Group

The advent of the global Automated Identification System (AIS) for the reporting of vessel positions offers a degree of automation in data processing and aggregation that was not previously possible. AIS is a very-high-frequency-radio-wave-based system that enables vessels to send out signals identifying themselves to other vessels or coastal authorities. The International Maritime Organization requires all international voyaging vessels with above 300 Gross Tonnage and all passenger vessels to be equipped with an AIS transmitter. AIS messages include information regarding vessels identity (IMO, MMSI, name, and vessel type), physical appearance (Length Overall, beam), voyage-related information (draught, destination, Estimated Time of Arrival, etc.), and dynamic data (speed, course, rate of turn, etc.). These signals can be captured by terrestrial land-based antennas (T-AIS) and Low Earth Orbit satellites (S-AIS). In theory, such AIS reports offer real-time information on the whereabouts of all ocean-going vessels, their past routings, and expected future port of call. Combined with expert knowledge or other data sources containing information on the type and size of cargo onboard, this should enable the generation of more timely and perhaps equally accurate trade data.

The two approaches to aggregating trade flows are in fact very different. Customs statistics generally only report imports or exports by aggregate value and volume/weight and is disaggregated by commodity or the type of good.[1] Neither transport mode (sea, road, rail, or pipeline) nor the loading or discharge port is generally provided as part of a country's customs statistics. Such official data is also only provided at the monthly frequency and usually with a time lag of several weeks. Alternatively, AIS-based trade data can potentially present a very rich picture of international trade by providing information on (1) real-time cargo positions and loading/discharging activity that can be aggregated to high-frequency (even daily) trade data, (2) the identity and technical specifications of the vessels used, and (3) the loading and discharge ports used. However, AIS-based estimates of trade volumes also have limitations. Firstly, the approach is only applicable to commodities where the cargo type is observable and homogeneous, and not for containerized cargoes where the 'box content' is generally unknown. Thus, commodities such as crude oil, coal, and iron ore, which are typically loaded from single-use terminals and where one parcel occupies the entire capacity of a vessel, are suitable candidates. Secondly, AIS-based trade flow estimates, by definition, cover only *seaborne* trade and may therefore differ substantially from official customs data for countries and commodities where other transport modes are significant. Thirdly, the AIS system is known to have challenges with time-varying coverage and quality.

In principle, the tracking of vessels (cargoes) enables maritime economic researchers and commercial shipping analysts to estimate shipping demand (tonne miles) with substantially greater accuracy. This is because such data provides information on the true sailing distance between port pairs, better estimates of individual cargo sizes (see, e.g., Adland, Jia, and Strandenes 2016; Jia, Prakash, and Smith 2015), and the ability to aggregate by vessel type or size group (e.g. VLCC, Suezmax tankers). Conversely, basing such estimates of tonne mile demand on customs data can only give a rough approximation, both because distances must be approximated (country-to-country[2]) and because the share of the different transport modes is generally not known. It follows that a comparison of the two data sources is crucial in order to establish a better understanding of their limitations, strengths, and weaknesses, particularly as it relates to shipping market analysis. To our knowledge, no such comparisons currently exist in published research. Accordingly, the objective of this paper is twofold: (1) to compare the accuracy of AIS-generated trade statistics to official customs data and (2) to add a breakdown of trade by vessel size over time.

The remainder of our article is structured as follows: Section 2 reviews the relevant literature, Section 3 describes our data and empirical results, and Section 4 contains concluding remarks.

2 Literature review

The current literature on trade flows are generally concerned with either theoretical models of international trade at the macro level or ship routing at the micro level.

Traditionally, the estimation of international trade flows has focused on the application of gravity equations, which was pioneered by Tinbergen (1962) and developed by Anderson (1979) and many others.[3] Only a few papers focus specifically on the modelling and determinants of seaborne commodity trade. Mayr and Tamvakis (1999) investigate the relationship between financial markets and physical oil trade, and find that financial spreads on refinery margins Granger-cause US seaborne crude oil imports. In a study of seaborne coal transportation, Ubøe et al. (2009) compare the performance of cost-minimizing models with the gravity model approach. Their main finding is that cost-minimizing models provide relative poor fits to observed behaviour compared to a simple one-parameter gravity model. Babri, Jörnsten, and Viertel (2015) argue that only a small part of the market need be subject to choice due to the presence of long-term contracts or simply trading habits and, accordingly, propose an extended gravity model formulation with a fixed component where only residuals are subject to discrete choice. Taken together, these studies suggest that observed trade volumes are a result of a complex system of long-term contractual obligations, trading habits, opportunistic (spatial) price arbitrage demand from commodity traders, and the classical choice-based demand from other economic agents.

At the micro level, Kaluza et al. (2010) present the first comprehensive study of ship movements based on arrival and departure records for each vessel, derived from AIS data. The focus here is on complex network topology (e.g. port connectivity, centrality, clusters). Similar 'complex network' descriptions of container shipping can be found in Ducruet and Notteboom (2012) and Montes, Seoane, and Laxe (2012) and of tramp shipping in Moon, Qiu, and Wang (2015). Rigot-Müller et al. (2012) investigate the mapping of maritime freight flows in and out of the UK, considering all commodities and ship types. We note that most of the research on container networks cannot be readily transferred to the modelling of trade flows of bulk commodities, as these are dominated by vessels operating in a tramp shipping market.

The relevant literature on the application of AIS data focus on operational issues such as vessel speeds (Assmann, Andersson, and Eskeland 2015, Adland and Jia 2016a, 2016b), capacity utilization (Adland, Jia, and Strandenes 2016), and onboard cargo sizes (Jia, Prakash, and Smith 2015). Jia, Prakash, and Smith (2015) point out that the cargo size and cargo type onboard a vessel cannot be observed directly from AIS data and propose different models for the estimation of the cargo size based primarily on the draught of a vessel. Using a large sample of drybulk cargoes from port agent reports, they find that draught models can predict cargo sizes with a standard deviation of 7–9%. In our context of trade volume estimation, these studies point to the possibility of merging AIS data with other data sources (e.g. port agent reports), in order to obtain data on the actual onboard cargo size for each voyage. This is also the approach behind our data set. In related work on the visualization of trade flows, Jia et al (2015) propose an automatic algorithm going from raw AIS data through filters highlighting vessel types, cargo or regions, to the visualization of abstracted discrete transport patterns, describing the geographical, directional, and total volume of transport. The resulting user interface is useful for the visualization of aggregate trade flows at different spatial zoom levels, but does not consider the reliability of the resulting volumes.

We note that because of the lack of accessible disaggregate data for ship demand on a tonne-mile basis, researchers must often take a simplified view of demand dynamics. For instance, Yin, Luo, and Fan (2016) use the volume of coal and iron ore from trade data as a demand proxy for regional freight rates in the Capesize drybulk market. In general, any research that deals with market fundamentals, such as the study by Kagkarakis, Merikas, and Merika (2016) on demolition market dynamics, could benefit from AIS-derived tonne-mile demand data (see Shi and Li 2016 for a comprehensive review of the recent maritime transport literature).

The above review highlights the gap in the literature between the theoretical macro-models of international trade and the empirical micro-level studies that focus on ship routing and network analysis. There is a clear need to employ bottom-up analysis in studies of international seaborne trade. In this regard, our study contributes to the literature as the first comparison of aggregate

AIS-derived trade volumes with official export statistics based on customs data. Additionally, we show how using AIS data allows for the construction of a richer data set on seaborne trade, crucial in the estimation of shipping demand, where the distribution of vessel sizes by load country and across time can be properly accounted for.

3 Data and empirical results

Our empirical work is based on a detailed database of crude oil shipments obtained from Clipper Data Ltd. The sample contains shipments where loading commenced during the period 1 January 2013 through mid-March 2016. The raw data contains information on the vessel identity (IMO number), shipment size, load terminal/port, load date, and several other variables related to discharge place and crude oil quality. As in Jia, Prakash, and Smith (2015), the data results from the combination of AIS-tracking of individual vessel voyages with cargo information from the line-up reports of port agents, in this case Inchcape Shipping Services. We note that each observation in our data set pertains to a shipment from a single loading terminal to a single discharge terminal. Accordingly, if the tanker in question visits more than one load port and/or more than one discharge port – which is surprisingly common – then this will result in multiple shipments on the same vessel by our definition. The true number of international voyages will therefore be lower than the number of shipments. While this nuance is inconsequential for the aggregation of shipments into exports by country, it explains why the average shipment size will appear to be substantially below the average capacity of a tanker of a certain size category (see Table 1).

We exclude shipments transported by barges, articulated barges (ATBs), coastal tankers, unknown vessels, and non-tankers, leaving those performed by crude tankers of Aframax size or larger. Additionally, our final sample includes some shipments using vessels ordinarily classified as product tankers (Medium Range and Long Range type 1). Such vessels have coated cargo tanks and can shift between the product and crude oil trades depending on market conditions. We also exclude fully domestic voyages – typically related to lightering, part discharge of offshore storage vessels, or simply moving oil between storage tanks (e.g. within Singapore) – though acknowledge that for some countries, particularly on the West African coast, this may remove some observations that relate to the offshore loading of a larger vessel for exports.

Our preferred measure of trade volume is barrels of oil (bbls) as opposed to metric tonnes, as the latter would require a mapping of the transported crude oil quality to its appropriate density. We also note that capacity utilization for tankers generally is constrained by volume in the sense that each cargo tank must be filled to its capacity to avoid sloshing and stability-reducing free surface effects. This still allows for the part loading of a vessel if cargo tanks are left empty, with ballast water added. This implies that vessel draught need not be a perfect indication of the cargo size onboard.

Table 1 shows the aggregate number of shipments and transported volumes by year and vessel type. While these numbers are not necessarily indicative of shifts in tanker demand, as they do not

Table 1. Aggregate shipments and volumes by vessel type.

	2013		2014		2015		2016[a]	
	mbbls	# shipments	mbbls	# shipments	mbbls	# shipments	mbbls	# shipments
VLCC	6074	7190	6308	7588	6655	7974	1451	2260
Aframax	3846	8072	3750	8265	3818	8375	807	1961
Suezmax	2752	4513	3066	4880	3313	5240	718	1413
LR1	369	1470	345	1393	363	1450	72	330
MR	33	181	34	196	26	150	4	23
ULCC	2	1	1	4				
Total	13,077	21427	13,504	22326	14,175	23189	3,053	5987

[a]Year-to-mid-March only.

account for sailing distances, they do suggest that the overall demand growth in the oil market has been catered for primarily by Very Large Crude Carriers (VLCCs) and Suezmax tankers, with Aframax tanker volumes declining between 2013 and 2015. We can observe a similar pattern on the supply side, with fleet growth in the VLCC and Suezmax sectors and a stagnating Aframax fleet size (Clarkson Research 2016). Shipments of crude oil by product tankers have also declined, and Ultra Large Crude Carriers (ULCCs) have disappeared from the active fleet altogether.

Table 2 shows the aggregate export volumes for the top 20 seaborne oil exporters in our data set, compared with official oil export data from the Joint Organizations Data Initiative Oil World Database (JODI 2016). JODI is a joint initiative for cooperation on energy market statistics by Eurostat, OPEC, IEA, and other key organizations.

We note that there are very large differences in the relative accuracy of the AIS-derived trade data across countries and, to a lesser extent, across time. The reasons for this can be broadly categorized as follows:

- Countries with major crude oil storage or transshipment activity appear as major exporters of crude oil, even with no domestic production (Netherlands Antilles).
- Countries that host pipeline terminals (Turkey, Egypt) appear as major seaborne exporters even if there is no or low domestic oil production.
- Countries that have some domestic production but also receive crude oil by pipeline for re-export appear with seaborne exports substantially higher than reported exports (e.g. UK, Qatar). As an example, Norway is using Teeside, UK, as a receiving port for some of its North Sea oil production.
- Countries that export a certain share of their crude oil by pipeline (e.g. Norway, Russia, Iraq) appear to be underestimating exports. This merely highlights the difference between total and seaborne exports when there are competing transportation modes. However, most exports initially shipped by pipeline eventually become seaborne at the receiving terminal and so this is only a temporal and spatial shift of apparent export volumes.
- Countries that are major crude oil exporters but mainly or only export by pipeline do not appear in the table at all (e.g. Canada, Azerbaijan).

Table 2. Comparison of AIS-derived seaborne exports and official total exports.

Volumes in mbbls	2013			2014			2015		
	AIS	JODI	%diff	AIS	JODI	%diff	AIS	JODI	%diff
Saudi Arabia	2486	2753	−9.7	2326	2592	−10.2	2352	2698	−12.8
Russia	1360	1565	−13.1	1282	1640	−21.8	1393	1787	−22.0
UAE	835	945	−11.7	937	934	0.4	941	468	101.1
Iraq	688	867	−20.7	868	920	−5.7	980	1097	−10.6
Venezuela	667	468	42.8	698	539	29.5	713	530	34.6
Nigeria	584	755	−22.6	729	765	−4.6	709	777	−8.8
Kuwait	663	751	−11.8	672	730	−7.9	681	661	3.0
Angola	591	595	−0.8	572	577	−0.9	598	607	−1.6
Iran	352	606	−42.0	422	506	−16.6	439	496	−11.6
Mexico	417	464	−10.2	410	445	−7.9	413	455	−9.3
Qatar	436	218	99.5	401	217	84.7	406	179	126.5
Norway	206	437	−52.9	373	439	−15.0	339	451	−24.8
Turkey	292	–		249	–		368	–	
Oman	271	306	−11.4	280	294	−4.6	307	287	7.0
Egypt	266	35	657.7	253	43	492.4	281	57	396.7
Colombia	245	257	−4.6	267	264	1.2	263	156	68.8
UK	224	224	0.3	234	208	12.6	237	217	9.2
Brazil	133	133	−0.4	189	189	−0.1	228	269	−15.0
Algeria	190	229	−17.0	170	206	−17.5	165	193	−14.7
Neth. Antilles	142	–		161	–		189	–	
Total top 20	11,047	11,610	−4.8%	11,493	11,506	−0.1	12,002	11,384	5.4

Top 20 seaborne crude exporters ranked by AIS-derived data.

Looking at aggregate volumes from the top 20 seaborne exporters, this shows substantially better alignment with official export data. Indeed, the deviation in overall volumes for 2014 is a mere 0.1%, with 2013 and 2015 coming in within approximately ±5%. This supports the notion that the impact of pipelines as a transportation mode for crude oil is only temporary in most cases, but will still cause a spatial shift if we base the definition of the exporting country only on AIS-derived cargo movements.

If deviations were stable over time at the country level, AIS-derived data could still play a role in benchmarking or forecasting, but this is generally not the case. The most promising candidate is Saudi Arabian exports, and to investigate the relationship closer, Figure 1 shows a comparison of monthly AIS-derived seaborne exports and total exports.

We note that there is a fairly constant vertical shift in the AIS-derived data, indicating that pipeline exports represent a steady share of total exports. However, the correlation between the two time series is a modest 52%, indicating that we are not dealing with a simple linear transformation. We also cannot be sure how much of the difference can be explained by measurement error in the AIS-based data, particularly as regards the true shipment size.

In general, we would also expect that there is a slight delay between AIS-based and customs-based trade data. This could be due to differences in when a cargo is deemed as exported (which may not be directly tied to the loading or physical movement of the ship), possible delays in customs processing, and the use of pre-loading or transshipment storage facilities in free trade zones.

Another key difficulty in creating and structuring such micro-level oil shipment data is the prevalence of ship-to-ship (STS) offshore transfers of crude oil cargoes. This is usually done close to shore and related to logistical or physical port constraints, such as the loading of a larger vessel by smaller vessels or barges, the discharge of a large tanker by smaller vessels (lightering), or the use of a larger vessel as a temporary floating storage facility. However, such STS transfers may also be done mid-ocean, even at speed, in order to obscure ownership or the sourcing of the crude oil. Such activity can be difficult to accurately track and will be a source of measurement error in the data. In general, any transshipment or temporary storage of oil creates difficulties in keeping track of and identifying the original source of the shipment, and in case of blending of different shipments for quality reasons, such information is lost altogether.

As a special case on the temporary impact of pipelines, it is worth mentioning the common situation where VLCCs en route to the Atlantic part-discharge cargoes at Ain Sukhna to go through the Sumed pipeline to Sidi Kerir, reloading at the Mediterranean terminal. This enables

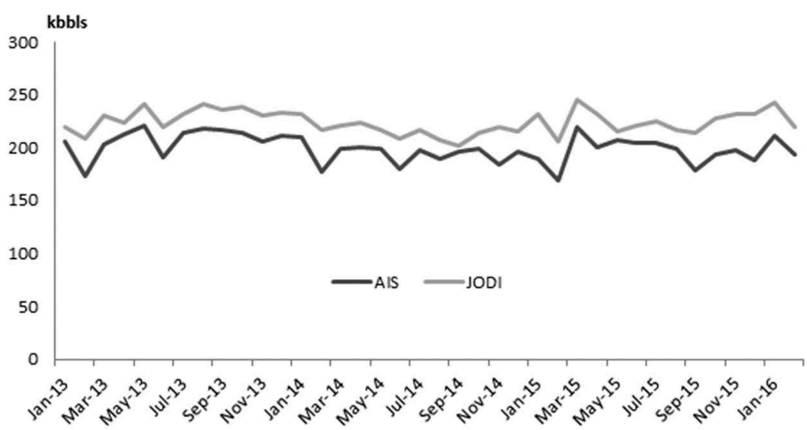

Figure 1. Comparison of AIS-derived and official Saudi Arabian crude exports.

Table 3. Seaborne export share by vessel size for selected countries.

Saudi Arabia	2013	2014	2015	2016[a]
VLCC	87.6%	87.8%	88.1%	87.2%
Suezmax	8.0%	8.2%	8.0%	8.5%
Aframax	4.0%	3.5%	3.5%	3.6%
LR1	0.4%	0.4%	0.3%	0.7%
ULCC	0.0%	0.1%	0.0%	0.0%
MR	0.0%	0.0%	0.0%	0.0%
Angola				
VLCC	65.2%	61.8%	58.3%	64.7%
Suezmax	34.5%	37.7%	41.5%	35.3%
Aframax	0.1%	0.2%	0.2%	0.0%
LR1	0.1%	0.2%	0.0%	0.0%
MR	0.0%	0.0%	0.0%	0.0%
Norway				
Suezmax	41.1%	49.4%	55.6%	58.7%
Aframax	57.4%	50.4%	44.2%	41.3%
LR1	1.2%	0.2%	0.0%	0.0%
MR	0.4%	0.0%	0.2%	0.0%
Russia				
Aframax	79.3%	77.6%	78.3%	77.1%
Suezmax	19.3%	19.6%	17.4%	17.8%
LR1	0.9%	2.3%	4.0%	4.5%
MR	0.5%	0.4%	0.4%	0.6%
Venezuela				
Aframax	43.7%	47.8%	46.4%	42.1%
VLCC	34.6%	30.6%	34.9%	39.5%
Suezmax	15.5%	16.8%	15.2%	14.9%
LR1	6.1%	4.7%	3.5%	3.4%
MR	0.0%	0.0%	0.0%	0.0%

[a]Year-to-mid-March only.

even such large vessels to transit the Suez Canal in a part laden condition. The large apparent seaborne export volume of Egypt suggests that this is not always properly accounted for.

Finally, to illustrate the use of AIS-derived data to generate richer data sets for maritime trade, Table 3 illustrates the breakdown by vessel size for the seaborne exports of selected countries.

As expected, countries with substantial long-haul exports such as Angola and Saudi Arabia transport a larger share of their exports on large tankers (VLCCs and Suezmax), while countries with a more regional focus such as Norway and Russia use small and mid-size vessels only. The mix of short- and long-haul destinations of Venezuelan exports is also reflected in the diverse vessel mix. We note that the above analysis can fairly easily be extended to account for hauling distances and the estimation of tanker demand by vessel size, but we leave this for future research.

4 Concluding remarks

We have in this article shown that AIS-derived data for seaborne crude exports show good alignment with official customs-based export numbers in aggregate. However, at the country level, estimated seaborne exports can exhibit large and unstable deviations from official crude oil export volumes. We attribute this to the role of several countries as key storage and transshipment hubs and the use of pipelines in parts of the supply chain. We have further highlighted the difficulties in generating and structuring high-quality micro-level shipment data such as offshore loading/discharge, deep-sea ship-to-ship transfers, and floating or onshore temporary storage and blending. Most of these issues can be solved through careful quality assurance and intelligent use of computer science.

We acknowledge that current methods of estimating cargo sizes, either indirectly based on a ship's draught or based on third-party information from port agents as in our data source, are likely to be inaccurate. Unfortunately, there are no regulations that punish the signalling of delayed or fraudulent information through the AIS system (specifically, on draught and destination which are input manually). Furthermore, advance knowledge of trade developments requires access to private contractual data at the time of the sale of the cargo, which will tend to be some time prior to the contracting of transport and, certainly, the loading event. Trade volumes derived from AIS data are only observable once vessels are laden and sailing to an importing port that is known with reasonable certainty.

Further improvements in the bottom-up estimation of seaborne trade volumes based on ship movements appear to depend on policy action. Specifically, transparency of Bill of Lading data would be required, particularly with regard to cargo size and re-export events. Similarly, international standards securing the standardization and quality of AIS-reported data, with penalties for the dissemination of fraudulent information, would be welcomed.

Further research in this area should consider the analysis of quality and sustainability in the maritime supply chain, for instance whether certain oil importers consistently operate old, substandard tonnage or make 'green' choices in their chartering strategies.

Notes

1. The only exception with readily available micro-level data on individual shipments is the United States, where information contained in the Bill of Lading is provided to third-party 'publishers' that disseminate this into the public domain.
2. Consider the extreme example of Russian crude exports to Asia which may originate in the Baltic or Far East ports, a difference of thousands of nautical miles.
3. Blonigen and Wilson (2013) provide a useful review of the evolution of trade modelling.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Research Council of Norway as part of the project 'CARGOMAP: Mapping vessel behaviour and cargo flows' [grant number 239104].

ORCID

Roar Adland http://orcid.org/0000-0002-0345-2446
Haiying Jia http://orcid.org/0000-0002-7935-3700
Siri P. Strandenes http://orcid.org/0000-0003-1542-2663

References

Adland, R., and H. Jia. 2016a. "Dynamic Speed Choice in Bulk Shipping." *Maritime Economics & Logistics*. Advanced online publication. doi:10.1057/s41278-016-0002-3.

Adland, R., and H. Jia. 2016b. "Vessel Speed Analytics Using Satellite-Based Ship Position Data." *IEEE Xplore*. doi:10.1109/IEEM.2016.7798088.

Adland, R., H. Jia, and S. P. Strandenes. 2016. "The Determinants of Vessel Capacity Utilization: The Case of Brazilian Iron Ore Exports." *Transportation Research Part A: Policy and Practice*. Advanced online publication. doi:10.1016/j.tra.2016.11.023.

Anderson, J. E. 1979. "A Theoretical Foundation for the Gravity Equation." *American Economic Review* 69 (1): 106–116.

Assmann, L., J. Andersson, and G. S. Eskeland. 2015. "Missing in Action? Speed Optimization and Slow Steaming in Maritime Shipping". Discussion Paper 2015/13. Department of Business and Management Science, Norwegian School of Economics.

Babri, S., K. Jörnsten, and M. Viertel. 2015. "Application of Gravity Models with a Fixed Component in the International Trade Flows of Coal, Iron Ore and Crude Oil." *Maritime Economics & Logistics*. Advanced online publication. doi:10.1057/mel.2015.27.

Blonigen, B. A., and W. W. Wilson. 2013. "The Growth and Patterns of International Trade." *Maritime Policy & Management* 40 (7): 618–635. doi:10.1080/03088839.2013.851454.

Clarkson Research. 2016. "Shipping Intelligence Network Database." Accessed 2 August 2016. http://www.clarksons.net

Ducruet, C., and T. Notteboom. 2012. "The Worldwide Maritime Network of Container Shipping: Spatial Structure and Regional Dynamics." *Global Networks* 12 (3): 395–423. doi:10.1111/glob.2012.12.issue-3.

Jia, H., O. D. Lampe, V. Soltezova, and S. P. Strandenes. 2015. "An Automatic Algorithm for Generating Seaborne Transport Pattern Maps Based on AIS." Paper presented at the IAME annual conference, Kuala Lumpur, August 24–26.

Jia, H., V. Prakash, and T. Smith. 2015. "Estimating Vessel Utilization in the Drybulk Freight Market: The Reliability of Draught Reports in AIS Data Feeds". Paper presented at the ECONSHIP conference, Chios, June 24–27.

JODI. 2016. "Joint Oil Data Initiative database." Accessed 31 July 2016. http://www.jodidb.org/TableViewer/tableView.aspx

Kagkarakis, N. D., A. G. Merikas, and A. Merika. 2016. "Modelling and Forecasting the Demolition Market in Shipping." *Maritime Policy & Management* 43 (8): 1021–1035. doi:10.1080/03088839.2016.1185181.

Kaluza, P., A. Kolzsch, M. T. Gastner, and B. Blasius. 2010. "The Complex Network of Global Cargo Ship Movements." *Journal of the Royal Society - Interface* 7 (48): 1093–1103. doi:10.1098/rsif.2009.0495.

Mayr, T. P., and M. N. Tamvakis. 1999. "The Dynamic Relationships between Paper Petroleum Refining and Physical Trade of Crude Oil into the United States." *Maritime Policy & Management* 26 (2): 127–136. doi:10.1080/030888399286952.

Montes, C. P., M. Seoane, and F. Laxe. 2012. "General Cargo and Container Emergent Routes: A Complex Network Description." *Transport Policy* 24: 126–140. doi:10.1016/j.tranpol.2012.06.022.

Moon, I. K., Z. B. Qiu, and J. H. Wang. 2015. "A Combined Tramp Ship Routing, Fleet Deployment, and Network Design Problem." *Maritime Policy & Management* 42 (1): 68–91. doi:10.1080/03088839.2013.865847.

Nossum, B. 1996. "The evolution of dry bulk shipping, 1945-1990". Self-published. Oslo.

Rigot-Müller, P., J. Mangan, C. Lalwani, and J. Dinwoodie. 2012. "Mapping UK International Seaborne Trade and Traffic". Paper presented at the Low Carbon Shipping conference, Newcastle, September 11–12.

Shi, W., and K. X. Li. 2016. "Themes and Tools of Maritime Transport Research during 2000 – 2014." *Maritime Policy and Management* 44 (2): 151–169. doi:10.1080/03088839.2016.1274833.

Tinbergen, J. 1962. "Shaping the World Economy". The Twentieth Century Fund. New York.

Ubøe, J., J. Andersson, K. Jörnsten, and S. P. Strandenes. 2009. "Modeling Freight Markets for Coal." *Maritime Economics & Logistics* 11 (3): 289–301. doi:10.1057/mel.2009.10.

Yin, J., M. Luo, and L. Fan. 2016. "Dynamics and Interactions between Spot and Forward Freights in the Dry Bulk Shipping Market." *Maritime Policy and Management* 44: 271–288. doi:10.1080/03088839.2016.1253884.

View publication stats