van den Bos and Wiegmans *Journal of Shipping and Trade* (2018) 3:6
https://doi.org/10.1186/s41072-018-0032-3

Journal of Shipping and Trade

ORIGINAL ARTICLE Open Access

Short sea shipping: a statistical analysis of influencing factors on SSS in European countries

Gertjan van den Bos[1] and Bart Wiegmans[1,2*]

* Correspondence:
b.wiegmans@tudelft.nl
[1]TU Delft, Civil Engineering and Geosciences, Department of Transport & Planning, Stevinweg 1, 2628 CN Delft, P.O. 5048, 2600 Delft, GA, the Netherlands
[2]Associate Transport Institute, Asper School of Business, University of Manitoba, Winnipeg, Canada

Abstract

Short sea shipping (SSS) is the maritime transport of goods over relatively short distances, as opposed to the intercontinental cross-ocean deep sea shipping. The goal of the current paper is to identify SSS growth potential and the univariate regression analysis indicates that the following variables influence total SSS volume in European countries: land area, coastline, total number of SSS ports, number of small SSS ports, number of large SSS ports, number of inhabitants, Gross Domestic Product (GDP), GDP per head, road length and rail length. An additional multivariate regression analysis indicates that more than 78% of the variance in the total SSS volume per country can be explained by variations in the number of large SSS ports and the GDP per head. Finally, future prospects for SSS indicate that most countries show (theoretical) potential to further increase their SSS volume calling for tailor-made policies to utilize this potential.

Keywords: Short sea shipping, Regression analysis, Data envelopment analysis, Future prospects

Introduction

In European history, maritime transport (both deep sea and short sea) has always been a major catalyst of economic development and prosperity. Almost 75% of the EU external freight trade volume (or about 51% in value) is seaborne. Short Sea Shipping (SSS) represents approximately 33% of intra-EU exchanges in terms of ton kilometers (European Union 2017). An important part of European SSS policy is laid down in: 'the concept of Marco Polo program', in which subsidies for SSS are driven by the desire to move trucks from congested roads to SSS, and address sustainability issues at the same time. Overall, SSS is an important transport mode in Europe, and policymakers expect it to facilitate more freight transport in order to relieve congestion on European roads and to increase sustainability (European Union 2011).

However, SSS is already transporting approximately 33% of intra-EU ton kilometers which makes it an important transport mode and this might indicate limited further growth potential. Furthermore, if policymakers address the claimed potential of SSS, often a clear goal such as a certain increase in the market share of SSS is lacking. In addition, SSS consists of many sub markets (e.g. bulk, containers, feeders, frozen products, etc.) and each sub market requires a dedicated approach in order to realize potential improvements. It appears to be clear that SSS is able to deliver solutions to the congestion and sustainability problems in Europe. The interesting issue is, however, how large the solution potential of SSS is and also for which SSS sub markets this solution potential holds. The above sketched problems and challenges for SSS lead to a need to analyze the SSS market in much more detail in order to indicate its growth potential through a statistical analysis of influencing factors on SSS in European countries.

Given this background on the SSS transport market and its challenges and problems, the central research question in this article is: 'Which factors influence SSS in European countries?' The starting point for a study of SSS is to gain insight into markets, followed by an analysis of the 'drivers' of successful short sea transport services. First, the article will give a short introduction into SSS, it describes the main definitions for SSS and analyses its respective important sub-market segment. Also the future prospects of SSS are discussed. Secondly, our dataset needs are described and the characteristics of the resulting actual dataset are given. Thirdly, a regression analysis is performed on the country level to analyze the SSS growth potential in the respective European countries. Several different regression analyses are performed, and also different segments are analyzed. In order to check the results, a DEA analysis is performed to see which countries are efficient in SSS and which countries are less efficient. Last of all, several hypothesis are tested. The paper closes with several conclusions.

Short sea shipping in Europe

Defining SSS: In several scientific papers, SSS is positioned as a solution to congestion problems and sustainability issues (Perakis and Denisis 2008; Medda and Trujillo 2010; Brooks and Frost 2004; Sambracos and Maniati 2012; Lopez-Navarro et al. 2011). There are a number of different definitions of SSS, and there is no single definition that is universally agreed upon. In-depth discussions on the definition of SSS can be found in Paixão-Casaca and Marlow (2007) and in Medda and Trujillo (2010). In particular, Paixão-Casaca and Marlow investigate a large number of different SSS definitions in great detail. Often used classification criteria for SSS are based on: 1) geography, 2) type of loads, 3) type of traffic, and 4) legal (port of origin and destination). But there is no consensus among scientists on the SSS definition, due to the broad and diverse SSS market (Douet and Cappuchilli 2011). In our paper, the definition of Eurostat is used as most data come from Eurostat, which in turn is derived from the Communication of the Commission COM (1999) 317 on the development of Short Sea Shipping in Europe: "'Short sea shipping' means the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports and ports situated in non-European countries having a coastline on the enclosed seas bordering Europe" (European Commission 1999). The importance of SSS in Europe: In Europe, after road transport, SSS is the main transport mode in terms of ton kilometers in intra-EU transport. Never the less, since 1995, while the share of road transport has risen by 4 percentage points, the market share of SSS has remained relatively stable (see Fig. 1).

It is regularly claimed that SSS has more potential to transport freight. When the data are analyzed (e.g. in terms of ton kilometers) it is found that SSS already has a market share of 33%. In order to understand the influencing factors on SSS in European countries also the SSS market segments are important. The SSS sector and market segments; The short sea market is diverse and complicated and can be divided into

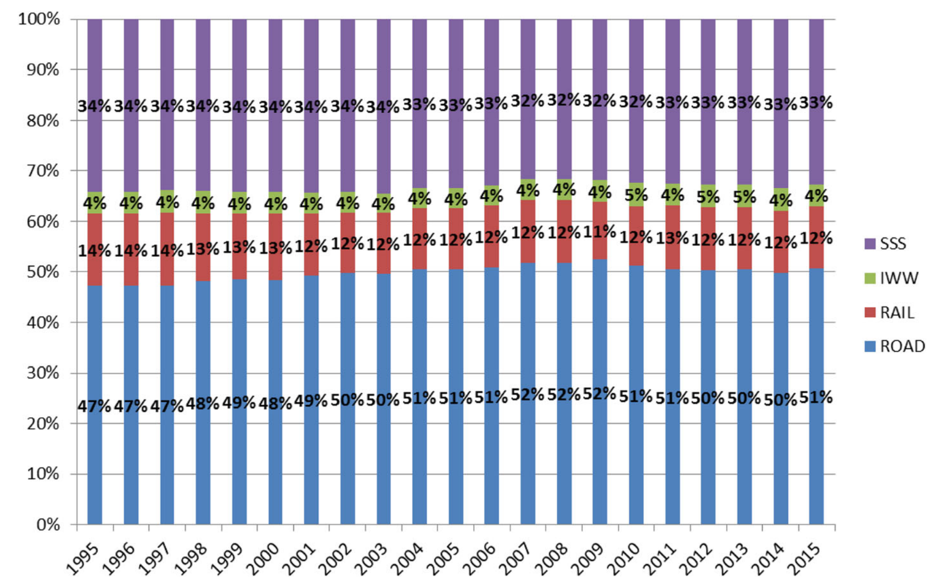

Fig. 1 Split of freight transport in the EU-27 in ton-kilometers (European Union 2017). *Note: SSS = short sea shipping, IWW = inland waterways*

several different classifications of market segments. Basically, there are six ways to distinguish market segments (adapted from European Commission 2015): 1. Type of products, 2. Volumes according to geography, 3. Vessels, 4. Type of contracts, 5. Transport distance, and 6. SSS suppliers. Precise data (e.g. origin-destination) about type of products being transported in Europe by SSS are lacking but it would be interesting to analyze data about dry bulk, liquid bulk, containers, neo-bulk, and ferries in much more detail. Secondly, the SSS sector can be viewed according to volumes transported with a geographical focus. Data about volumes could be distinguished according to sea regions or country (which is the basis for the data analysis that we perform on the influencing factors of SSS in countries in Section 4). Thirdly, transport means could be used to distinguish different market segments: the size of the SSS vessels, or roll-on-roll-off (RO-RO) versus load-on-load-off (LO-LO). The SSS market could also be distinguished according to contract type: voyage versus period charters. Fifthly, different market segments according to transport distance could be of interest for data analysis. According to Brooks and Trifts (2008), mode choice for distances under 700 kms is dominated by truck, and distances over 1400 kms by intermodal transport. Finally, the focus could be on the number and type of SSS companies. These different ways of distinguishing the different market segments in SSS serve to indicate the quite fragmented and complicated character of the SSS market (see also Medda and Trujillo 2010, p. 286). Paixão-Casaca and Marlow (2005) made a first analysis of the strengths and weaknesses of SSS. Medda and Trujillo (2010) analyzed the advantages, disadvantages, and goals of SSS. In this paper, we have extended these strengths and weaknesses (See Appendix). The main conclusions that arise are: 1) the SSS strengths are mainly positive external effects, important to policy makers, and 2) the SSS weaknesses are mainly challenges in the price/quality ratio, important to companies. Therefore, the main challenge for SSS is to define options to improve its quality, reliability, speed, and price, in order to make it more attractive to customers.

Short sea shipping data requirements and availability

In SSS, there are no publicly available commodity data, vessel data, and transport cost data to name all but a few. This limits the possibilities to build models that predict future freight flows and that optimize freight flows between multiple origins and destinations. In our research, we performed an extensive search in order to build a large SSS dataset. The data we have been able to find is concentrated on the country level and this thus leads us to this level of analysis for our paper. This necessarily means that a lot of the statistical analyses are related to the infrastructure and geography fields. It is important to stress here that there are more, and possibly more important, factors involved (such as commodity type, sales, vessels, etc.). However, publicly available data on SSS is limited. In the end, we were able to find data in the form of country-based SSS data for the main ports in 25 countries in Europe and this is the market segment division that we use for our quantitative analysis (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_sg_am_cwk&lang=en). Because the data concerns total transport volumes (both inward and outward), there is a potential issue with "double counting" related to this data (http://ec.europa.eu/eurostat/cache/metadata/en/mar_esms.htm). For an overview of the country-based SSS data see Table 1.

Data that have been used in the analysis of the influencing factors of SSS in European countries are: land area of the EU countries (https://www.cia.gov/library/publications/the-world-factbook/fields/2147.html), the length of the coastline (https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html), the coastline to area ratio, the total number of SSS ports per EU country (ports handling more than 1 million tons per year) (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database?_piref458_1209540_458_211810_211810.node_code=mar_go_am), the number of small SSS ports per EU country (ports handling 1 to 10 million tons per year), the number of large SSS ports per EU country (ports handling more than 10 million tons per year), the number of inhabitants per country (http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00001), the GDP per country (http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tec00001&language=en), the GDP per head, the length of the road network (motorways and main or national roads) (http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf), the length of the rail network (http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf), and the length of the inland waterway (IWW) network (http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf). These data have been used in order to determine the relationship between these variables and the SSS volume per country. The variables have been selected based on their public availability and their expected correlation with the SSS volume of each country. For an overview of the data see Table 2.

Based on the literature and this data we have been able to find, we have formulated four hypotheses about SSS: 1) a longer coastline leads to more SSS, 2) a higher GDP leads to more SSS, 3) more ports lead to more SSS, and 4) a large rail infrastructure leads to less SSS. A longer coastline would also most likely mean more ports and thus more possibilities for the usage of SSS. Also islands tend to have a longer coastline and by nature are more involved in SSS. In general, a higher GDP means more freight flows and more freight flows might also indicate more possibilities for SSS. If more ports are available and offering SSS services this might also result in more SSS for a country.

Table 1 SSS volume per European country and per segment in 2012 (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_sg_am_cwk&lang=en)

Country	Total SSS volume	Liquid bulk SSS volume	Dry bulk SSS volume	RO-RO units SSS volume	Containers SSS volume	Other SSS volume
	Million tonnes in 2012					
Belgium	123,9	35,5	22,3	17,7	41,3	7,2
Bulgaria	22,1	10,6	7,4	0,2	1,8	2,1
Croatia	12,1	6,1	3,1	0,8	0,8	1,4
Cyprus	5,7	2,3	1,2	0,1	1,8	0,2
Denmark	66,1	19,4	18,2	20,2	4,4	4,0
Estonia	25,5	13,5	3,3	3,8	1,6	3,2
Finland	88,0	29,1	21,8	16,4	10,0	10,7
France	171,0	95,2	33,6	22,2	9,1	10,9
Germany	170,4	43,7	37,3	31,8	47,9	9,6
Greece	90,0	39,9	13,8	12,3	20,1	4,0
Iceland	2,2	0,3	0,1	0,0	0,3	1,4
Ireland	37,0	10,3	8,2	11,6	6,5	0,4
Italy	285,5	141,9	32,2	53,0	37,3	21,1
Latvia	61,0	19,1	30,6	2,7	3,7	4,9
Lithuania	32,4	17,5	6,7	2,9	3,6	1,7
Malta	3,0	1,5	0,5	0,5	0,6	0,1
Netherlands	253,5	155,3	41,0	11,5	26,1	19,6
Norway	147,4	70,0	53,5	5,9	5,0	12,9
Poland	48,7	13,4	17,9	6,2	8,4	2,8
Portugal	34,7	14,5	7,8	0,2	8,7	3,5
Romania	23,9	8,1	10,0	0,4	1,8	3,6
Slovenia	8,8	2,5	2,2	0,5	2,7	0,9
Spain	191,4	82,1	37,6	12,2	42,8	16,8
Sweden	142,1	54,0	21,2	42,2	11,3	13,3
Turkey	254,6	84,1	89,6	8,4	55,8	16,6
United Kingdom	311,0	129,9	61,7	82,9	22,7	13,8

Data from main ports only (ports handling more than 1 million tons per year)

Finally, the interaction between freight transport networks, such as SSS and rail could be interesting to analyze. SSS and rail might compete on certain routes and if rail options are available this might harm SSS.

Statistical analysis of influencing factors on SSS

SSS in European countries: Univariate linear regression analysis

Most scientific studies on predictions of volumes have been mainly based on long-term forecasting (Peng and Chu 2009). One of the most widely-used methods in forecasting is the regression analysis that identifies causal relationships between variables. In addition to the regression analysis performed in this study, also four hypothesis are tested: 1) a longer coastline leads to more SSS, 2) a higher GDP leads to more SSS, 3) more ports lead to more SSS, and 4) a large rail infrastructure leads to less SSS. The initial univariate linear regression analysis started with six aspects of SSS volume: 1) total SSS, 2) liquid bulk SSS, 3)

Table 2 Variables used as potential influencing factors of SSS in European countries (https://www.cia.gov/library/publications/the-world-factbook/fields/2147.html, https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database?_piref458_1209540_458_211810_211810.node_code=mar_go_am, http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00001, http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tec00001&language=en, http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf)

Country	Land area	Coastline	Coast/ Area rtio	Total number of SSS ports in 2012	Number of small SSS ports in 2012	Number of Large SSS Ports in 2012	Number of Inhabitants in 2012	GDP in 2012	GDP per Head in 2012	Length of road network in 2010	Length of rail network in 2011	Length of inland waterway network in 2010
	km^2	*km*	*m/km^2*	*Port*	*port*	*Port*	*Inhabitant*	*Million euro*	Euro/Inhabitant	*km*	km	*km*
Belgium	30.278	67	2,2	4	1	3	11.094.850	375.881	33.879	14.992	3.558	1.516
Bulgaria	108.489	354	3,3	2	0	2	7.327.224	39.668	5.414	3.407	3.947	470
Croatia	55.974	6.268	112,0	5	5	0	4.275.984	43.682	10.216	8.055	2.722	805
Cyprus	9.241	648	70,1	2	2	0	862.011	17.887	20.750	2.443	0	0
Denmark	42.434	7.314	172,4	23	22	1	5.580.516	245.252	43.948	3.835	2.629	0
Estonia	42.388	3.794	89,5	5	4	1	1.333.788	17.415	13.057	4.118	792	335
Finland	303.815	1.250	4,1	19	16	3	5.401.267	192.350	35.612	13.329	5.944	8.006
France	640.427	4.853	7,6	18	12	6	65.327.724	2.032.297	31.109	21.146	30.884	5.110
Germany	348.672	2.389	6,9	16	10	6	80.327.900	2.666.400	33.194	52.529	33.576	7.728
Greece	130.647	13.676	104,7	22	18	4	11.123.034	193.749	17.419	10.490	2.554	0
Iceland	100.250	4.970	49,6	0	0	0	319.575	10.567	33.066	4.941	0	0
Ireland	68.883	1.448	21,0	6	4	2	4.582.707	163.938	35.773	5.680	1.919	0
Italy	294.140	7.600	25,8	45	28	17	59.394.207	1.567.010	26.383	27.524	17.045	1.562
Latvia	62.249	498	8,0	3	1	2	2.044.813	22.257	10.885	1.653	1.865	0
Lithuania	62.680	90	1,4	2	1	1	3.003.641	32.940	10.967	6.675	1.767	448
Malta	316	253	800,0	2	2	0	417.546	6.851	16.407	184	0	0
Netherlands	33.893	451	13,3	9	4	5	16.730.348	599.338	35.823	5.121	3.016	6.104
Norway	304.282	25.148	82,6	23	19	4	4.985.870	389.149	78.050	10.877	4.154	0
Poland	304.255	440	1,4	5	2	3	38.538.447	381.204	9.892	18.608	19.725	3.659

Table 2 Variables used as potential influencing factors of SSS in European countries (https://www.cia.gov/library/publications/the-world-factbook/fields/2147.html, https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database?_piref458_1209540_458_211810_211810.node_code=mar_go_am, http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00001, http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tec00001&language=en, http://ec.europa.eu/transport/facts-fundings/statistics/doc/2013/pocketbook2013.pdf) *(Continued)*

Country	Land area	Coastline	Coast/ Area rtio	Total number of SSS ports in 2012	Number of small SSS ports in 2012	Number of Large SSS Ports in 2012	Number of Inhabitants in 2012	GDP in 2012	GDP per Head in 2012	Length of road network in 2010	Length of rail network in 2011	Length of inland waterway network in 2010
	km^2	*km*	*m/km^2*	*Port*	*port*	*Port*	*Inhabitant*	*Million euro*	Euro/Inhabitant	*km*	km	*km*
Portugal	91.470	1.793	19,6	7	4	3	10.542.398	165.108	15.661	8.703	2.793	0
Romania	229.891	225	1,0	3	2	1	20.095.996	131.579	6.548	16.552	10.777	1.779
Slovenia	20.151	47	2,3	1	0	1	2.055.496	35.319	17.183	1.588	1.209	0
Spain	498.980	4.964	9,9	27	14	13	46.818.219	1.029.002	21.979	29.365	15.932	0
Sweden	410.335	3.218	7,8	27	25	2	9.482.855	407.820	43.006	15.434	11.213	0
Turkey	769.632	7.200	9,4	22	14	8	74.724.269	611.967	8.190	33.475	9.642	0
United Kingdom	241.930	12.429	51,4	41	25	16	63.495.303	1.932.702	30.439	52.697	16.134	1.050

dry bulk SSS, 4) RO-RO SSS, 5) container SSS, and 6) other SSS (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_sg_am_cwk&lang=en). 'Other SSS' is not taken into account in the final results because in the analysis the category 'other SSS' shows results which are mainly consistent with the total SSS volume, its relatively small volume, and the largely unknown composition of 'other SSS'. The results of the initial univariate regression analysis are presented in Table 3. The univariate regression analysis is executed to be able to select the variables that show a sufficiently strong relationship with the SSS volume. The software that has been used for the regression analysis is the open source programming language R, using the generic lm() function from the stats package (R Core Team 2017).

The results indicate that the following variables correlate (at least to some extent) with total SSS volume: land area, coastline, total number of SSS ports (ports handling more than 1 million tons per year), number of small SSS ports (ports handling 1 to 10 million tons per year), number of large SSS ports (ports handling more than 10 million tons per year), number of inhabitants, GDP, GDP per head, road length and rail length. The coast/area ratio and the inland waterway (IWW) length show only limited correlation with total SSS volume. The coast and area variables are still included in the analysis when the coast/area ratio is disregarded. For the IWW length this might be simply because only a limited number of countries have sufficient IWW infrastructure leading to a low correlation. A comparison of the different SSS freight-type sectors shows that both liquid and dry bulk have similar results compared with the total SSS volume, which is no surprise because the total SSS volume is largely made up of liquid bulk (42.1%) and dry bulk (22.3%). The results of the SSS RO-RO units sector are also largely in accordance with the overall results for the total SSS volume, except for a lower relevance of both land area and coastline. However, the SSS container sector has some different results, with overall lower correlations and explanatory power (R^{40}) for the different variables. The lower explanatory power of both the total number of SSS ports and the number of small SSS ports is most notable, but may be explained by the high level of concentration of container flows around only a couple of main ports (e.g. Antwerp, Hamburg, and Rotterdam).

SSS in European countries: Multivariate linear regression analysis

The number of variables considered in the multivariate linear regression analysis has been reduced by removing both the coast/area ratio and the waterway length, due to their limited correlation with the total SSS volume as well as with each of the four SSS segments considered in the analysis. Therefore, the variables that are used for the multivariate linear regression analysis are: land area, coastline, total number of SSS ports (SSS ports), number of small SSS ports (sSSS ports), number of large SSS ports (lSSS ports), number of inhabitants, GDP, GDP per head, road length and rail length. As several of these (independent) variables are expected to explain the same part of the variance in the total SSS volume between countries (dependent variable), a stepwise model estimation procedure has been used. The stepwise model estimation procedure is chosen because the total number of potential models is computationally prohibitive. The procedure starts with an empty model, to which variables are added in order of their statistical significance (using a significance boundary of $\alpha = 0.05$). The resulting model is then 'pruned' by removing any variables that are no longer statistically significant after the inclusion of other variables (using a significance boundary of $\alpha = 0.05$). In

Table 3 SSS univariate regression analyses and correlations

Dependent variables↓		*Independent variables*											
		Land area	Coastline	Coast/Area ratio	Total number of SSS ports	Number of small SSS ports	Number of large SSS ports	Number of inhabitants	GDP	GDP per head	Length of road network	Length of rail network	Length of inland waterway network
Total SSS Volume	R^2	0.346	0.166	0.065	0.645	0.444	0.748	0.554	0.552	0.128	0.529	0.274	0.081
	Corr. Coeff.	0.588	0.407	−0.254	0.803	0.666	0.865	0.744	0.722	0.357	0.727	0.523	0.285
	Corr. Sig.	0.002	0.044	0.220	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.007	0.167
Liquid Bulk SSS Volume	R^2	0.220	0.148	0.048	0.537	0.355	0.661	0.379	0.410	0.127	0.295	0.186	0.084
	Corr. Coeff.	0.469	0.385	−0.219	0.733	0.596	0.813	0.616	0.640	0.357	0.543	0.432	0.290
	Corr. Sig.	0.018	0.057	0.294	0.000	0.002	0.000	0.001	0.001	0.080	0.005	0.031	0.159
Dry Bulk SSS Volume	R^2	0.499	0.240	0.061	0.377	0.264	0.426	0.486	0.292	0.101	0.445	0.176	0.030
	Corr. Coeff.	0.706	0.490	−0.247	0.614	0.514	0.652	0.697	0.540	0.317	0.667	0.419	0.174
	Corr. Sig.	0.000	0.013	0.233	0.001	0.009	0.000	0.000	0.005	0.122	0.000	0.037	0.405
RO-RO Units SSS Volume	R^2	0.090	0.095	0.020	0.666	0.561	0.546	0.317	0.493	0.117	0.508	0.255	0.034
	Corr. Coeff.	0.301	0.308	−0.141	0.816	0.749	0.739	0.563	0.702	0.341	0.713	0.505	0.184
	Corr. Sig.	0.144	0.135	0.500	0.000	0.000	0.000	0.003	0.000	0.095	0.000	0.010	0.379
Containers SSS Volume	R^2	0.294	0.014	0.060	0.251	0.122	0.445	0.536	0.355	0.007	0.509	0.225	0.064
	Corr. Coeff.	0.543	0.118	−0.246	0.501	0.349	0.667	0.732	0.595	0.081	0.713	0.474	0.253
	Corr. Sig.	0.005	0.573	0.236	0.011	0.087	0.000	0.000	0.002	0.700	0.000	0.017	0.222

The R^2 rows show the values for the univariate regression lines with the independent variable as the single predictor of the dependent variable addition, collinearity statistics are employed to check for the presence of multicollinearity due to correlation between two or more of the independent variables included in the model. First, 'land area' correlates with road length and rail length, where road length and rail length appear to have a more direct relationship with the total SSS volume. Secondly, 'inhabitants' correlates with GDP, where GDP appears to have a more direct relationship with total SSS volume. Thirdly, 'GDP' has a stronger correlation with SSS volume than GDP per head with SSS volume. Therefore, the variables that are used for the multivariate regression analysis are: number of ports; GDP; road length; and rail length. When these four variables are combined into one linear regression model for the total SSS volume, the road length is no longer a significant determining variable, because the importance of road length as an explanatory variable of the total SSS volume is relatively limited compared with the other three factors. This might be because each country has a substantial road infrastructure that is up to European standards, and the road length is therefore not a distinctive variable. The sign and magnitude of the variable rail length appears not to be as expected and is therefore disregarded. Finally, this procedure results in a linear regression model for the total SSS volume with only two variables, as shown in Table 4.

The adjusted R^2 (adjusted to the number of variables included in the model) has a value of 0.788 ($F = 45.5$, $p = 0.000$), which indicates that 78.8% of the variance in the total SSS volume per country can be explained by variations in the number of large SSS ports and GDP per head (Fig. 2). It should be noted however that due to the relatively small number of observations ($n = 25$ countries) used in the model estimation, the reliability of the adjusted R^2 value is somewhat limited and it should be interpreted as a rough estimate only of the model fit of each of the multivariate linear regression models presented in this section. The low Variance Inflation Factor (VIF) in the last column in Table 4 indicates the virtual absence of multicollinearity in the model. The sign and magnitude of the two independent variables included in the model, as shown in Table 4, appear to be as expected. The total SSS volume is larger for countries with a higher number of large SSS ports (lSSS ports) and/or a higher GDP per head, which might be expected.

For explaining the SSS volume in the liquid bulk sector, the two variables as shown in Table 5 are important. These are the same two variables as in the multivariate linear regression model for the total SSS volume.

Both factors show the same effects as for the total SSS volume, with lower values for the coefficients due to the smaller size of this single sector as compared with the total SSS sector. Again, the fact that lSSS ports is included in the model, instead of either SSS ports or sSSS ports, indicates that especially the number of large SSS ports is relevant for determining the liquid bulk SSS volume of a country. This may be explained

Table 4 Total SSS model

Total SSS volume Adjusted $R^2 = 0.788$, $F = 45.5$, $p = 0.000$				
Variables	Coefficient	T-value	Sig.	VIF
Constant	−0.532	−0.031	0.976	
Number of Large SSS Ports [port]	16.877	8.755	0.000	1.020
GDP per Head [1000 euro]	1.419	2.544	0.018	1.020

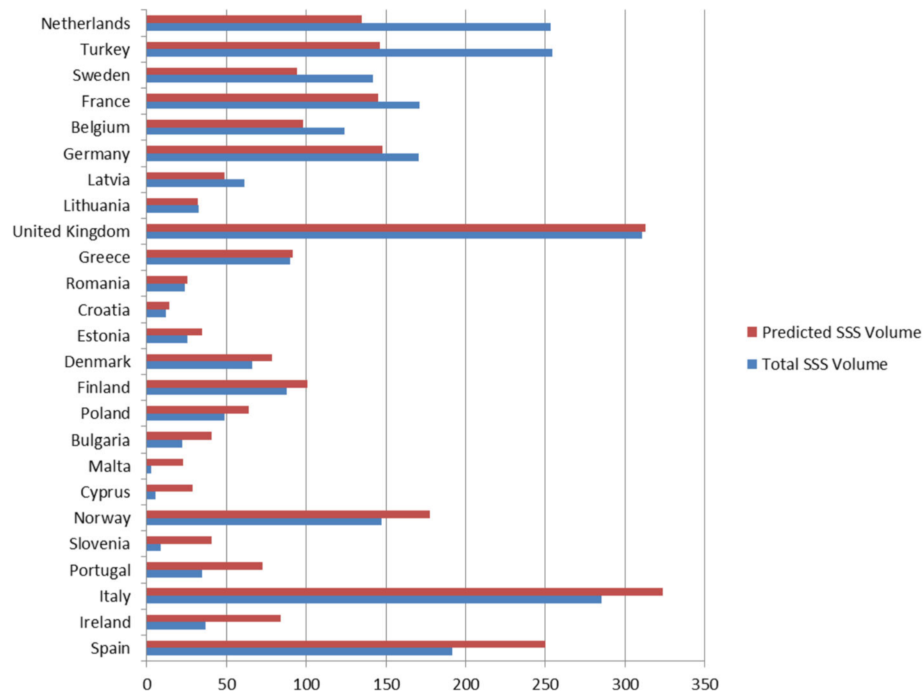

Fig. 2 Predicted and actual SSS volumes per country

by the high level of concentration of liquid bulk flows around only a couple of main ports with major oil refineries (e.g. Antwerp, Hamburg, and Rotterdam).

Three factors are important for explaining the SSS volume in the dry bulk sector, as shown in Table 6. The inclusion of both the GDP per head and the number of inhabitants indicates that not only the standard of living is important in determining the dry bulk SSS volume, but also the size of a country in terms of its number of inhabitants.

The positive coefficients for these two factors indicate that countries with a higher standard of living and more inhabitants relate to a larger dry bulk SSS volume, which might be expected. More interestingly, the third factor included in the model indicates that the dry bulk SSS volume decreases for countries with a larger length of railway. This could be explained by the fact that rail transportation might be able to act as a substitute for dry bulk SSS, but only if sufficient rail infrastructure is available. The fact that all of the three factors regarding the number of SSS ports are excluded from the model indicates that these factors are less relevant in determining the dry bulk SSS volume of a country. Last of all, the values in the VIF column in Table 6 indicate that there is some concern for multicollinearity in the multivariate linear regression model for the dry bulk SSS volume, due to correlation between railway length and number of

Table 5 Liquid bulk SSS model

Liquid bulk SSS volume
Adjusted $R^2 = 0.696$, $F = 28.5$, $p = 0.000$

Variables	Coefficient	T-value	Sig.	VIF
Constant	−4.997	−0.501	0.621	
Number of Large SSS Ports [port]	7.627	6.850	0.000	1.020
GDP per Head [1000 euro]	0.705	2.188	0.040	1.020

Table 6 Dry bulk SSS model

Dry bulk SSS volume Adjusted $R^2 = 0.761$, F = 26.5, $p = 0.000$				
Variables	Coefficient	T-value	Sig.	VIF
Constant	−0.284	−0.066	0.948	
GDP per Head [1000 euro]	0.572	4.191	0.000	1.052
Inhabitants (million persons)	1.217	7.362	0.000	4.077
Railway length [1000 km]	−2.107	− 4.462	0.000	4.117

inhabitants. However, the VIF values are still well below a commonly used threshold value of 5 (above which multicollinearity can be considered high).

Table 7 shows that three factors are important in explaining the SSS volume in the RO-RO sector.

The first factor, SSS ports, indicates that for the SSS volume in the RO-RO sector in each country the total number of SSS ports is more relevant than the size of these SSS ports. The second factor included in the model indicates that the RO-RO SSS sector requires sufficient road infrastructure to be able to achieve a significant volume, which might be expected. The third and last factor indicates that large countries in terms of land area correspond to smaller RO-RO SSS volumes. This might be explained by the relative cost advantage of both rail and barge over truck on long distance inland transport, which can also influence the RO-RO SSS volume. For explaining the SSS volume in the container sector, two factors are important as shown in Table 8.

First of all, countries with more inhabitants relate to a larger container SSS volume. The second factor indicates that the container SSS volume decreases for countries with a greater length of railway. As in the dry bulk SSS sector, this could be explained by the fact that rail transportation might be able to act as a substitute for container SSS, but only if sufficient rail infrastructure is available. This is an interesting conclusion as it indicates a relationship between different types of freight transport networks (in this case SSS and rail). This is important as governments generally try to encourage rail freight transport and SSS transport instead of road freight transport. In this respect, not very often the policy impacts of SSS policies on rail freight transport are taken into account. The fact that all of the three factors regarding the number of SSS ports are excluded from the model indicates that these factors are less relevant in determining the container SSS volume of a country. The values in the VIF column in Table 8 indicate that there is again some concern for multicollinearity in this last multivariate linear regression model, due to correlation between railway length and the number of inhabitants. However, the VIF values are again well below the previously mentioned

Table 7 RO-RO units SSS model

RO-RO units SSS volume Adjusted $R^2 = 0.796$, F = 32.2, p = 0.000				
Variables	Coefficient	T-value	Sig.	VIF
Constant	−2.679	−0.952	0.352	
Total Number of SSS Ports [port]	1.095	5.688	0.000	1.788
Road Length [1000 km]	0.707	3.884	0.001	2.123
Land Area [1000 km^2]	−0.039	−3.337	0.003	1.760

Table 8 Containers SSS model

Containers SSS volume Adjusted $R^2 = 0.600$, $F = 19.0$, $p = 0.000$				
Variables	Coefficient	T-value	Sig.	VIF
Constant	6.391	2.210	0.038	
Inhabitants [million persons]	0.809	4.950	0.000	3.914
Railway Length [1000 km]	−1.123	−2.416	0.024	3.914

threshold value. Last of all, the relatively medium adjusted R^2 value (as compared to the other presented multivariate linear regression models) of 0.600 indicates that the model is not so successful in explaining the variance in the SSS volume of containers per country.

Future prospects of SSS: Multivariate linear regression model and DEA

Future prospects of SSS based on the multivariate linear regression model.

The multivariate linear regression model estimated for the total SSS volume per country has also been used to determine in which countries the total SSS volume is smaller than would be expected based on the influencing factors included in the estimated model. These countries can be considered to have a potential to grow in total SSS volume. A note of caution is required here, as the potential to grow in terms of total SSS volume as discussed below is only based on geographical indicators that might not reflect the size of the actual market of goods that can be transferred to SSS. It should therefore be considered solely as a theoretical potential to grow, based on geographical indicators.

The first multivariate regression model (Table 4) represents the mean relationship for European countries between the total SSS volume and both the number of large SSS ports and the GDP per head. For each country, the total SSS volume has been estimated using the corresponding model. The estimated total SSS volume is compared with the observed total SSS volume to indicate whether a further increase of its total SSS volume is (theoretically) possible for that particular country, based on its number of large SSS ports and GDP per head (Fig. 2). As an example, this analysis of the residuals is demonstrated for Norway in Table 9. The constant is considered to be zero, as its *p*-value (0.976) shown in Table 4 indicates that it is not significantly different from zero.

Several countries do have a smaller SSS volume than would be expected based on their number of large SSS ports and GDP per head (Fig. 2). The group of countries with

Table 9 Analysis of residual for Norway

Total SSS volume			
Variables	Value	Coefficient	ΔSSS volume
Constant		−0.532	0
Number of Large SSS Ports [port]	4	16.877	67.5
GDP per Head [1000 euro]	78.050	1.419	110.8
Estimated total SSS volume [million ton]			178.3
Observed total SSS volume [million ton]			147.4
Residual/SSS Potential [million ton]			30.9

SSS volume over 50 million tons and potential to further increase their SSS volume consists of Spain, Italy, Norway, Finland and Denmark. Poland, Ireland, Portugal and Estonia each now has a SSS volume of over 25 million tons, and also shows potential to further increase their SSS volume. Slovenia, Bulgaria, Cyprus and Malta now possess small volumes of SSS and are predicted to be able to grow significantly, but, given their size and GDP, this might be questionable. The smaller observed than estimated total SSS volume in for example Spain and Italy might be explained by the current relatively low utilization of the high number of large SSS ports located in these countries (13 in Spain, 17 in Italy, compared to 4.2 on average for the 25 countries considered), which indicates a possible further increase in SSS volume in case these ports are utilized to their full potential.

Some countries have a larger SSS volume than would be expected based on their number of large SSS ports and GDP per head (Fig. 2). This group of countries is made up of the Netherlands, Turkey, Sweden and Belgium. For the Netherlands and Belgium the explanation might be that they are centrally located towards the core economic regions of Europe, and are used by these regions (Germany, France, Austria, and Switzerland) as SSS gateways. In this respect, Belgium and The Netherlands are countries with a small population but very well developed hinterland connections into Europe that the countries´ ports serve.

Future prospects of SSS based on data envelopment analysis

The use of Data Envelopment Analysis (DEA) for the analysis of the efficiency of countries in SSS encompasses several discussion issues: DEA is meant for companies and to a lesser extent for countries; the number of countries is relatively limited; the number of inputs and outputs is also quite limited; it is difficult to obtain data, and the inputs (number of large SSS ports and GDP per head (Fig. 2)) do have a quite fixed character. When interpreting the results of the DEA, these issues should be kept in mind. In the scientific literature, deep-sea container port and container terminal performance have been studied thoroughly by using DEA. Wang and Cullinane (2006) conclude from their analysis of 104 European container terminals that terminals in the British Isles and in Western Europe are the most efficient. Turner et al. (2004) found that scale economies exist at the container terminal level in container ports. Cullinane and Wang (2010) implemented panel data in order to be able to implement medium- and long term efficiency analysis. They found that efficiency levels of container ports vary over time. More recent literature on DEA analyzes ports in developing regions such as Almawsheki and Shah (2015) who measured the technical efficiency of 19 container terminals in the Middle-East region. The results show that the Jebel Ali, Beirut and Salalah terminals are the most efficient terminals in the region. Nguyen et al. (2016) applied a DEA model to a sample of 43 Vietnamese ports. The results learn that the average mean of efficiency scores for Vietnamese ports is quite low and offers considerable possibilities for improvement.

The measurement of efficiency received fast growing attention in recent decades. In DEA, the most important methodological contribution has been made by Charnes et al. (1981), who developed DEA, a performance measurement technique which can be used to evaluate the relative efficiency of companies. DEA is an extreme point method that compares each producer with only the ‘best’ producers. A fundamental assumption is that, if a given country is capable of producing X (output) with Y (inputs), then other countries should be able to produce exactly the same. However, for the countries in this analysis, the difference in inputs (ports and GDP) is quite fixed and thus important. DEA assumes that outputs can be fully explained from the inputs (i.e., as well as the potential inefficiency and there are no random fluctuations in the output). Any deviation from the efficiency frontier is stated as inefficient. DEA's distinguishing factor is the absence of assumptions regarding the underlying functional form relating the (in) dependent variables (Charnes et al. 1994). For a full methodological explanation of DEA we refer to Cullinane et al. (2006).

In order to verify the results of the analysis of the residuals, a DEA was performed for the group of 25 European SSS countries and the DEA model was built in Excel. The same two variables (number of large SSS ports and GDP per head (Fig. 2)) were used as inputs for the DEA, while the output in the DEA is made up of the total SSS volume. The outcomes of the analysis should be treated with caution and in relation to the analyses above as discussed before (the limited number of inputs and outputs and the possible correlation between number of ports and SSS volume). The DEA generates an efficiency value for each of the SSS countries, with a low value for countries that have a smaller total SSS volume than might be expected based on their number of large SSS ports and GDP per head (Fig. 2), and vice versa. The DEA efficiency for all countries are presented in Table 10.

The countries with low efficiency values are mostly the same countries as those that were indicated in the analysis of residuals to have smaller than expected SSS volumes, but which do have significant SSS volumes, e.g. Spain, Italy, Norway, Finland, Poland, Ireland, Portugal and Estonia. The only exception is Denmark, which is shown to already be quite efficient in the DEA even though the analysis of the residuals indicated it as a country with a smaller observed than estimated SSS volume. This last difference in results might be because Denmark has quite a significant SSS volume but only one large SSS port (Fredericia) and a relatively high GDP per head, which are accounted for somewhat differently in the DEA as compared with the regression analysis. Countries for which the estimated SSS volume was similar to the observed SSS volume in the analysis of the residuals, but that are shown to be somewhat inefficient in the DEA include Greece, Romania and to some extend the United Kingdom. In the end, DEA provides a way to "assess" the effects of "scale economies" in the performance and volumes going beyond the strictly linear relationship obtained through the multivariate analysis.

Hypotheses testing based on the multivariate linear regression model

Based on the literature and the data we have been able to find, we have formulated four hypotheses about SSS: 1) a longer coastline leads to more SSS, 2) a higher GDP leads to more SSS, 3) more ports lead to more SSS, and 4) a large rail infrastructure leads to less SSS. First, a longer coastline does not necessarily imply a larger SSS volume. Although the coastline was shown in Table 2 to correlate significantly with total SSS volume, coastline was not included as a factor in any of the multivariate linear regression models. The reason for this is that the explanatory power of coastline is limited and other (related) factors, such as the total number of SSS ports or the number of large SSS ports show a much stronger relationship with the total SSS volume.

Table 10 DEA results

Country	Efficiency value
Belgium	0.730
Bulgaria	0.299
Croatia	1.000
Cyprus	0.232
Denmark	0.677
Estonia	0.432
Finland	0.511
France	0.639
Germany	0.622
Greece	0.535
Ireland	0.281
Italy	0.502
Latvia	0.672
Lithuania	0.578
Malta	0.154
Netherlands	1.000
Norway	0.540
Poland	0.418
Portugal	0.259
Romania	0.490
Slovenia	0.136
Spain	0.435
Sweden	1.000
Turkey	1.000
United Kingdom	0.563

Second, even though GDP was shown to correlate strongly with total SSS volume, it is not included in any of the multivariate linear regression models. However, the GDP per head is included as a factor in the multivariate linear regression model for total SSS volume, liquid bulk SSS volume and dry bulk SSS volume. This indicates that it is not so much a high absolute value of the GDP of a country that leads to more SSS, but especially a high value of the GDP relative to the number of inhabitants (GDP per head), which relates to a larger SSS volume. Third, the number of SSS ports (in total as well as only small or large SSS ports) was shown to correlate strongly with total SSS volume. Especially the number of large SSS ports displayed a very high correlation with total SSS volume and was also included in the multivariate linear regression model for total SSS volume and liquid bulk SSS. This indicates that it is not so much a higher total number of SSS ports that leads to a larger SSS volume, but more specifically a higher number of large SSS ports which each handle more than 10 million tons per year. For the RO-RO SSS volume on the other hand, the total number of SSS ports is more relevant as indicated by its inclusion in the multivariate linear regression model for RO-RO SSS volume. Either case confirms the third hypotheses that, in general: a higher number of ports relates to a larger SSS volume. The final hypothesis states that a large rail infrastructure relates to a smaller SSS volume. The factor rail length was shown to correlate strongly with SSS volume, but was not included in the multivariate linear regression model for the total SSS volume. However, it was included in the multivariate linear regression models for dry bulk SSS volume and container SSS volume. In both of these models the coefficient of rail length was negative, which confirms the hypothesis that a higher rail length relates to a smaller SSS volume, but only for these two SSS segments. This indicates that countries with a large rail network in general have a smaller dry bulk and container SSS volume.

Conclusions

In this paper, the focus has been on the position of the SSS sector in Europe. The central research question in this article was: 'Which factors influence SSS in European countries?'

The univariate regression analysis indicates that the following variables influence total SSS volume in European countries: land area, coastline, total number of SSS ports, number of small SSS ports, number of large SSS ports, number of inhabitants, GDP, GDP per head, road length and rail length. The multivariate regression analysis indicates that more than 78% of the variance in the total SSS volume per country can be explained by variations in the number of large SSS ports and the GDP per head. This should, however, be treated with care as this concerns only two variables and much more detailed variables on terminal level could be added to the analysis if data were available. Analysis of liquid bulk SSS leads to comparable conclusions as for the overall SSS sector. For dry bulk SSS it is interesting to note that in general the volume decreases for countries with a greater length of railway, which could be explained by the fact that rail transportation might be able to act as a substitute for dry bulk SSS, but only if sufficient rail infrastructure is available. In RO-RO SSS, it can be observed that large countries in terms of land area correspond to smaller RO-RO SSS volumes. This is interesting for countries such as France and Germany and might be explained by the competition of both rail and barge transport with truck transport on longer inland distances. These relations between different transport networks is also an interesting issue that could be explored in further research. For container SSS, it can be observed that the results are mixed and the reliability and performance of the estimated model (R^2 of 0.60) is not very high. Future prospects for SSS indicate that based on the influencing factors found in the respective analysis, most countries show (theoretical) potential to further increase their SSS volume. Four countries – the Netherlands, Turkey, Sweden and Belgium – have a larger SSS volume than might be expected based on their number of large SSS ports and GDP per head (Fig. 2).

Four hypotheses were tested in order to further analyze the influencing factors on SSS. First, a longer coastline does not necessarily imply a larger SSS volume. Second, it is not so much a large absolute value of the GDP of a country that leads to more SSS, but especially a large value of the GDP relative to the number of inhabitants (GDP per head), which relates to a larger SSS volume. Third, the number of SSS ports (in total as well as only small or large SSS ports) was shown to correlate strongly with total SSS volume. Especially the number of large SSS ports displayed a very high correlation with total SSS volume and was also included in the multivariate linear regression model for total SSS volume and liquid bulk SSS. This indicates that it is not so much a higher total number of SSS ports that leads to a larger SSS volume, but more specifically a higher number of large SSS ports which each handle more than 10 million tons per year. The final hypothesis states that a large rail infrastructure relates to a smaller SSS volume. The results indicate that countries with a large rail network in general have a smaller dry bulk and container SSS volume.

Due to the relatively small number of observations ($n = 25$ countries) used in our model estimations, the outcomes should be interpreted as a rough estimate. It is important to stress here that there are more, and possibly more important, factors involved besides the (geographical) influencing factors employed in this article. In further research, also relative values to for example inhabitants could be analyzed in greater detail. Further research could also incorporate variables such as overall maritime traffic per country, peripherality of the country, and proximity to major sea routes. Detailed data search could be done into other "physical" characteristics to describe the port (yard area, berth lengths with a given draught, equipment), (capacity) of the terminals for each kind of SSS traffic. In addition, also the current research methodologies (DEA especially) could benefit from more extensive data leading to the availability of panel data.

Appendix

Table 11 Strengths and weaknesses of SSS

Strengths	Weaknesses
- SSS can solve congestion problems - SSS can play a significant role in curbing transport growth, rebalancing the modal split, and bypassing land bottlenecks - SSS is more energy-efficient (than road transport) - SSS is safer (than road transport) - SSS is environmentally-friendly SSS removes dangerous goods from the roads - SSS is green for bulk shipping (not for RO-RO). - The sea has an unlimited capacity (i.e. it does not require a huge land-take) - Port investments and port maintenance are low - SSS can offer services at lower freight rates due to inherent economies of scale and distance - It has no time restrictions, and has the ability to use the oceans 7 days per week, 52 weeks per year - Shippers perceptions of SSS are favorable (on the East coast of North America) - SSS is flexible: increase in volume does not require infrastructure improvement	- Depending on load factors of the vessel and the trailers, the effective load factor may vary between 25% and 40% making RO-RO much less efficient and green than is claimed - Regulatory safety and security frameworks are required that contribute to increasing industry costs - Costs associated with improving or increasing the port infrastructure (SSS terminals) are considerable - SSS is a capital-intensive industry (both vessels and terminals) - Capacity-filling due to high fixed costs is necessary - There is a lack of port capacity - SSS can hardly offer a door-to-door transport service: part of a broken chain - SSS has old/traditional organizational cultures - SSS has low vessel speed - There is a lack of information technology/ information systems compatibility - SSS port operations are at low speed - There are low levels of port reliability - SSS has a poor image - There is port congestion at the land-side of large container ports - SSS has additional handling costs - The door-to-door price by sea would have to be 35% less if door-to-door transport were to switch to SSS - Market suffers from overcapacity, and is obliged to lower rates to be competitive - There is a lack of service differentiation - There is a higher risk of damage to goods

Sources: based on Perakis and Denisis 2008; Paixão-Casaca and Marlow 2005; Brooks and Trifts 2008; Medda and Trujillo 2010; Hjelle 2010; Paixão-Casaca and Marlow 2007; Paixão-Casaca and Marlow 2009; Garcia-Menendez and Feo-Valero 2009; Gouvernal et al. 2010; Bendall and Brooks 2011; Morales-Fusco et al. 2013; Baindur and Viegas 2011; Martell et al. 2013

Abbreviations
DEA: Data envelopment analysis; GDP: Gross domestic product; lSSS ports: Large SSS ports; SSS: Short sea shipping; sSSS ports: Small SSS ports; VIF: Variance inflation factor

Acknowledgements
The authors would like to acknowledge the worthwhile and constructive comments and suggestions of the anonymous reviewers.

Availability of data and materials
Are presented in the main paper.

Authors' contributions
Both authors contributed equally to the paper. Both authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 24 August 2017 Accepted: 1 May 2018
Published online: 14 May 2018

References
Almawsheki ES, Shah MZ (2015) Technical efficiency analysis of container terminals in the middle eastern region. Asian J Shipping Logistics 31(4):477–486
Baindur D, Viegas J (2011) Challenges to implementing motorways of the sea concept—lessons from the past: Marit Policy Manag 38(7):673-690. https://doi.org/10.1080/03088839.2011.625990
Bendall HB, Brooks MR (2011) Short sea shipping: lessons for or from Australia. Int J Shipping Transport Logistics 3(4):384–405
Brooks MR, Frost JD (2004) Short sea shipping: a Canadian perspective. Marit Policy Manag 31(4):393–407
Brooks MR, Trifts V (2008) Short sea shipping in North America: understanding the requirements of Atlantic Canadian shippers. Marit Policy Manag 35(2):145–158
Charnes A, Cooper WW, Rhodes E (1981) Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through. Manag Sci 27:668–697
Charnes A, Cooper WW, Rhodes E (1994) Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through. Manag Sci 27:668–697
Cullinane K, Wang T (2010) The efficiency analysis of container port production using DEA panel data approaches. OR Spectr 32(3):717–738
Cullinane K, Wang T-F, Song D-W, Ji P (2006) The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis. Transp Res A 40(4):354–374
Douet M, Cappuchilli JF (2011) A review of short sea shipping policy in the European Union. J Transp Geogr 19:968–976
European Commission (1999) The development of Short Sea shipping in Europe: a dynamic alternative in a sustainable transport chain – second two-yearly progress report. European Commission, Brussels
European Commission (2015) Analysis of recent trends in EU shipping and analysis and policy support to improve the competitiveness of short sea shipping in the EU
European Union (2011) WHITE PAPER roadmap to a single European transport area – towards a competitive and resource efficient transport system, Brussels
European Union (2017) EU transport in figures, Statistical pocketbook 2017. Publications Office of the European Union Luxembourg
Garcia-Menendez L, Feo-Valero M (2009) European common transport policy: empirical evidence based on modal choice models. Transp Rev 29(2):239–259
Gouvernal E, Slack B, Franc P (2010) Short sea and deep sea shipping markets in France. J Transp Geogr 18:97–103
Hjelle HM (2010) Short sea shipping's green label at risk. Transp Rev 30(5):617–640
Lopez-Navarro MA, Moliner MA, Rodriguez RM, Sanchez J (2011) Accompanied versus unaccompanied transport in short sea shipping between Spain and Italy: an analysis from transport road firms perspective. Transp Rev 31(4):425–444
Martell H, Martínez M, Martínez de Oses X (2013) Speeds & capacities necessity of boats for improve the competitiveness of the short-sea-shipping in West Europe respecting the marine environment. J Marit Res 10(2):65–76
Medda F, Trujillo L (2010) Short sea shipping: an analysis of its determinants. Marit Policy Manag 37(3):285–303
Morales-Fusco P, Saurí S, De Melo G (2013) Short Sea shipping in supply chains. A strategic assessment. Transp Rev 33(4):476–496
Nguyen H-O, Nguyen H-V, Chang Y-T, Chin ATH, Tongzon J (2016) Measuring port efficiency using bootstrapped DEA: the case of Vietnamese ports. Marit Policy Manag 43(5):644–659
Paixão-Casaca AC, Marlow PB (2005) The competitiveness of short sea shipping in multimodal logistics supply chains: service attributes. Marit Policy Manag 32(4):363–382. https://doi.org/10.1080/03088830500301469
Paixão-Casaca AC, Marlow PB (2007) The impact of the trans-European transport networks on the development of short sea shipping. Marit Econ Logistics 9:302–323

Paixão-Casaca AC, Marlow PB (2009) Logistics strategies for short sea shipping operating as part of multimodal transport chains: Marit Policy Manag 36(Edition 1):1–19
Peng W-Y, Chu C-W (2009) A comparison of univariate methods for forecasting container throughput volumes. Math Comput Model 50:1045–1057
Perakis AN, Denisis A (2008) A survey of short sea shipping and its prospects in the USA. Marit Policy Manag 35(6):591–614
R Core Team (2017) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. https://www.R-project.org/
Sambracos E, Maniati M (2012) Competitiveness between short sea shipping and road freight transport in mainland port connections; case of two Greek ports. Marit Policy Manag 39(3):321–337
Turner H, Windle R, Dresner M (2004) North American containerport productivity: 1984-1997. Transp Res E 40(4):339–356
Wang TF, Cullinane K (2006) The efficiency of European container terminals and implications for supply chain management. Marit Econ Logistics 8(1):82–99