A GEOGRAPHICAL ANALYSIS OF THE RELATIONSHIP BETWEEN INLAND ACCESSIBILITY AND MARITIME TRANSPORT SUPPLY

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Abstract - *This paper measures the contribution of inland accessibility to the spatial concentration of general cargo and container shipping services in European NUTS 3 regions. We found that the variation in inland accessibility (measured by a potential access to population) accounts for 43% of variation of the general cargo transport supply. This seems to indicate that maritime transport supply remains strongly linked with the economic potential of regions, even if container services are slightly less linked to the latter (36%) because they depend more on the structure of hub & spokes networks. Through a segmentation of sea services by world regions, we show that the contribution of inland accessibility to maritime connectivity varies depending on the overseas markets.*

Key-words - PORT, HINTERLAND, ACCESSIBILITY, GENERAL CARGO, CONTAINER

JEL Classification - A1

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1. INTRODUCTION

The heterogeneity of maritime services in regions can be understood as the visible manifestation of two complementary dynamics. On the one hand, there are hinterland-related factors of regional attractiveness, such as size and activities. On the other hand, there are a series of dynamics resulting from strategies pursued by maritime companies.

Several studies analyze the linkage between port activity and various characteristics of the hinterland. In this context the question of direction of causalities is inevitably raised. Most authors have chosen to analyze the impact of maritime transport on economic activity or certain types of employment (see, for example, Bottasso et al., 2013). Research intended to demonstrate the opposite causal relationship is less common (Ducruet and Itoh, 2014). Certainly we cannot deny that maritime transport can have a multiplier effect on the territory served. However, conversely, it is evident that maritime services will not be provided just anywhere.

Although the relationship between accessibility and maritime throughput is well known (Coto-Millan et al., 2010), only few works deliver systematic geographical analysis of this link (Chapelon, 2006, Vanoutrive, 2012). However, seaport throughput (in tons or TEUs) is an aggregation of flows from very different forelands, and that could be unequally linked with the inland regions served.

The purpose of this paper is to help to fill this void by a systematic analysis of the contribution of inland accessibility to the concentration of sea services in Europe. While we show that inland accessibility well reflects the concentration of maritime services, we also identify the deviations to this general trend in order to highlight the territorial specificities of container and general cargo markets. Indeed, we attempt to understand why in some regions the maritime transport supply seems to be less linked that we might expect from its inland market potential. The segmentation of maritime transport supply by overseas regions could deliver some explanation about these deviations.

The paper is structured as follows. Section 2 presents data and methods, which are applied in Section 3 to describe and understand the relationship between maritime services and inland accessibility. We conclude in section 4.

2. LINKING INLAND MARKET ACCESSIBILITY TO MARITIME SERVICES: HYPOTHESIS, DATA AND METHODS

Empirical evidence on actual hinterlands is only available through enquiries that do not exist on comprehensive, Europe-wide basis. For these reasons we have decided to work on the basis of accessibility indicators, knowing that they are an imperfect proxy of the actual hinterlands of ports. We use homogeneous data on regional economy and maritime connectivity that make international comparisons possible. As in most of the existing literature, a classical linear regression model was drawn up in order to measure the intensity of the link between inland accessibility and maritime transport supply.

2.1. Methodology: database on maritime transport supply

This research was carried out using a set of Automatic Information System (AIS) positions. The implementation of this new tracer technology in the ship's bridge begins with the IMO A.917 (22) resolution (Harati-Mokhtari et al., 2007) and it is currently compulsory for all vessels over 300 GT's, which report call, departure and vessel data to the port authorities by mean of this devices. This database has been used by many authors to describe maritime transport trade networks for several different classes of vessel (Kaluza and Kölzsch, 2010; Ducruet et al., 2010a, 2010b).

A sample of vessel paths was built with the following criteria: (a) not to consider containerships with less than 1000 TEUs or general cargo vessels with less than 6000 DWT to eliminate short range navigation activity noise; (b) consider vessels built before 2007, in order to obtain an equilibrated amount of AIS positions stored per ship; (c) eliminate anchorage, strait or canal positions; and (d) prioritize for the final sample vessels that perform inter-continental activity. This selection procedure guarantees, as a corollary, that at least the most important ports (AIS call – berthing – positions) will be taken into account.

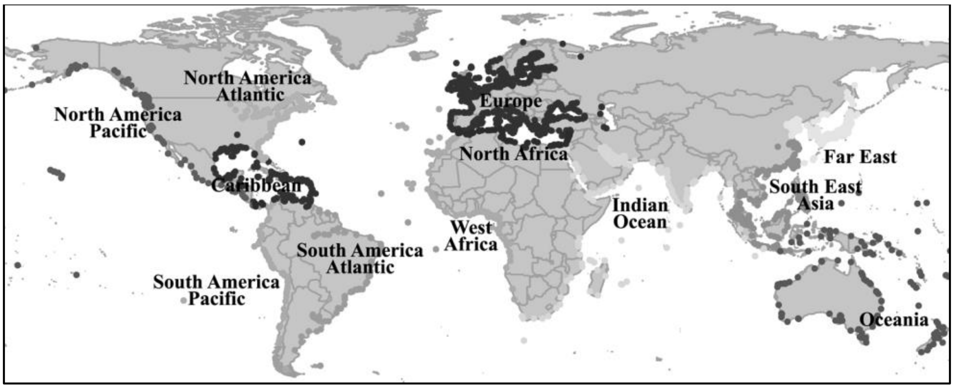
The analysis was conducted by splitting each vessel class sample into two time periods: 2009 and 2010 AIS positions. So for each year, the sequence of vessel calls defines subsequently another sequence of port of departure-port of arrival pairs. Hence, it can be built, using a programming language with vector calculus features (postgreSQL), a structure of nodes and edges that will allow to perform calculus of complex network parameters over this general cargo and containership AIS sets.

An additional layer of meaning was added to the entire set of worldwide call positions, in order to differentiate world trade areas. The division considered can be seen in figure 1, and is based in a very common trade regions partition. The final sample composition and its main network features can be seen in Table 1.

According to total world fleet supply estimated by UNCTAD, database used covers approximately a 25% of total general cargo, and more than a 80% of containership existing fleet. It can be seen a growth in vessels analyzed from 2009 to 2010, with the correspondent increases in total AIS positions.

A very important difference can be seen in the number of different ports considered for general cargo vessels and containerships. While the number of ports of call increases for break-bulk classes (from 1,325 in 2009 to 1,356 in 2010), the number of ports of call decreases for containership sample (from 749 in 2009 to 527 in 2010). There are some quantitative approximations, made using complex networks measuring methodologies (González-Laxe et al., 2012) explaining part of this behaviour as an outcome of the demand crisis happened in 2008, which caused a severe impact in main containerized lines, having effects in the mean connectivity of world gateways, and causing a conjunctural concentration during 2009-2010 of all the remaining active supply lines in less containerized terminals. The average degree [1] increases for both transport modes, but maximum decreases for containerships, showing another aspect of this port activity concentration process.

Figure 1. World AIS movements partition



Source: own elaboration.

The average Betweenness Centrality[2] increases both for general cargo and containerized modes (Pais-Montes et al., 2012), showing that ports have strengthened their mean regional importance, and have been successful accomplishing catching new traffic tasks.

But, again, another important difference emerges for containership sample regarding average Betweenness Centrality: it grows for break-bulk, but decreases for containerized terminals, showing again difficulties for some new modern containerized terminals to play intermediary roles (*Ibid.*).

2.2. Methodology: NUTS-3 aggregation of maritime data

Starting from the 2010 version of NUTS 3 available at Eurostat, identification between administrative coastal units and ports has been performed in order to proceed to the analysis.

Figure 2 is illustrative of how it was made the first step of this attempt to identify ports with those geographical units. Using GIS software it can be seen the superposition between ports and regions along the English Channel. For example in FR232 we can see port complex of Le Havre (633), Antifer (589)

[1] Degree, or degree centrality, is the number of connections that one node establishes with another ones.

[2] Betweenness Centrality is a measure of the regional influence of a node, expressing the number of times that a node appears in a random route connecting any pair of nodes (Brandes, 2001).

and Dieppe (5061). This fact suggest the following identification criteria: the port with maximum throughput in the considered period is the representative of its native NUTS 3, in case of NUTS 3, FR232 region, called Seine-Maritime, will be identified with all network parameters of Le Havre. The size of NUTS 3 appears to be adequate to perform the identification between hinterland parameters and port connectivity as it will be shown in this paper.

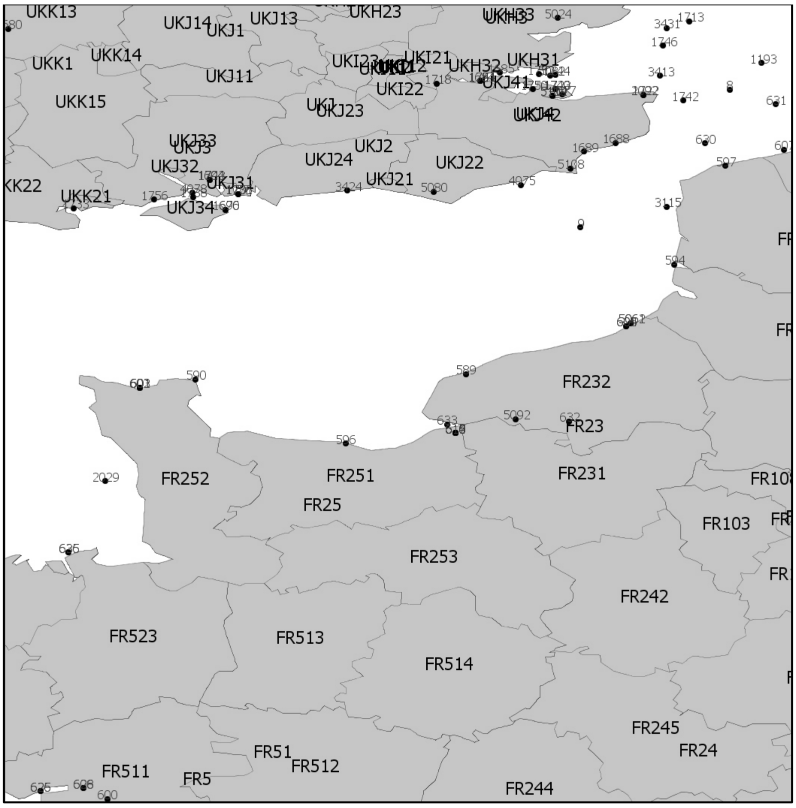
Thus, by this method, each NUTS 3 coastal region is associated with an unique value of throughput, degree and centrality for each time period. In a second stage of postgreSQL programming tasks, total throughput for each geographical unit will be divided according to the share of DWTs or TEUs moved towards (or coming from) each world partition. This last algorithm will allow obtaining an index of trade importance of each world region with each NUTS 3 unit.

Table 1. Sample composition

		General cargo (supply in DWTs)		Containerships (supply in TEUs)	
	Time scope sample	**2009**	**2010**	**2009**	**2010**
Number of vessels analyzed		1,864	1,943	2,032	2,144
Number of AIS positions analyzed		64,975	79,011	126,920	145,736
Vessel supply	**Maximum**	49,370	51,624	15,550	15,550
	Minimum	1,510	1,510	450	1,057
	Average	13,764	14,074	4,533	4,730
Total fleet supply present in sample		25,657,183	27,347,038	9,211,236	10,142,327
Total world fleet supply estimated*		105,492,000	108,881,000	10,760,173	12,142,444
Number of different ports of call (World sample)		1,325	1,356	749	527
Number of different ports of call (Europe)		422	433	162	124
Degree	**Maximum**	324	332	202	180
	Average	21	23	15	19
Normalized Closeness Centrality	**Maximum**	0.5352	0.5375	0.5500	0.5800
	Average	0.3612	0.3593	0.3642	0.3781
Normalized Betweenness Centrality	**Maximum**	0.1058	0.1341	0.0022	0.1400
	Average	0.0014	0.0013	0.1100	0.0031

Method: UNCTAD (2013). Source: own elaboration.

Figure 2. NUTS 3 and ports identification



Source: own elaboration.

2.3. Methodology: road accessibility to population

When studying the links between maritime activity and accessibility to inland markets, the question of the delineation of the hinterlands of the ports is a difficult issue. Even when taking in account large spatial units (i.e. countries, Nuts-2 regions) some large seaports obviously serve much wider territories. Unfortunately, many different parameters can influence the size and shape of hinterlands. Reviewing the recent literature Guerrero (2014) and Notteboom (2010) show that the size of hinterlands varies a lot from one port to another. Unfortunately, empirical evidence on the actual hinterlands is only available through enquiries that do not exist on comprehensive, Europe-wide basis. For these reasons we have decided to use an indicator of accessibility to population, knowing that it is an imperfect proxy of the actual hinterlands.

Practically, we will use a measure of accessibility implemented by S&W for the European Spatial Planning Observatory Network (Spiekermann and Schurmann, 2007, Espon, 2009). This indicator is based on two elements: (1) population in NUTS 3 regions and (2) the effort in time to reach them by road, which is the largely dominant mode of pre and post maritime carriage. The accessibility model measures the minimum time between all NUTS 3 regions by road. The potential accessibility of a NUTS 3 region is calculated by summing up the population in all other European regions, weighted by the transport time to reach them. Compared to the mere consideration of the potential of the region where the port is located, this method allows to take in account the potential of every region, in particular those that are close to the port. Although accessibility database is rather old (2006), it still can be used since road infrastructure and population has changed little in the NUTS 3 regions of Western Europe between 2006 and 2010.

3. RESULTS

3.1. Measuring the link between inland market accessibility and maritime services

To explain the geography of European supply of container transport, we simply assessed the correlation between transport supply and road accessibility to population at the NUTS 3 level (table 2). In 2010, correlation is rather significant (R^2=.36), which means that 36% of container supply differences between NUTS 3 regions are described by the road accessibility to population. This is partly due to the importance of the container supply of Northern Range ports that are close to the economic core of Europe, where most of population and wealth is concentrated. However, several other factors, like the strategies of shipping lines (hub & spokes networks) and the proximity of certain European regions to main container routes also explain this geography.

Table 2. Linear correlation between maritime transport supply and accessibility

		R^2	n
TEUs	2009	0.33	76
	2010	0.36	83
General cargo	2009	0.43	189
	2010	0.43	211

Source: own calculations from AIS data (2010) and Espon (2006).

In the case of general cargo services, the link between maritime transport supply with inland accessibility is even stronger (R^2=.43) than for TEUs. This could be due to a less selective scheme of general cargo maritime networks that are less limited to large ports than containers.

According to the model, the volume inland accessibility thus explain to a large extent the spatial variation in European shipping services[3]. This type of analysis naturally raises, however, the question of the deviations from the predictions.

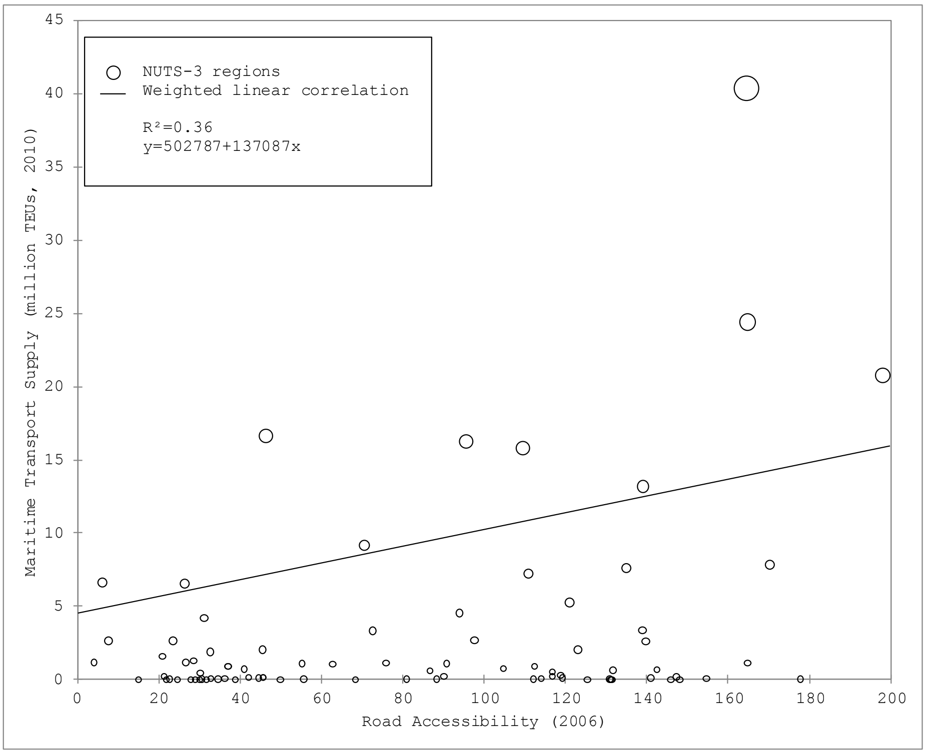
[3] In both cases (containers and general cargo), the probability corresponding to the F value is lower than 0.0001 indicating that the model is statistically significant.

3.2. Interpreting the deviations from the model

Many regions deviate from the general trend, some having better maritime supply and other having worse maritime supply that estimated by the model. Figures 3 and 4 represent the regions deviating to the general trend according to their maritime supply.

In the case of TEUs (figure 3), the model underestimate the maritime transport supply of main seaport regions (the size of the circles is proportional to their maritime transport supply) and overestimates it in the secondary regions (small circles).

Figure 3. TEUs supply vs Road Accessibility by NUTS 3

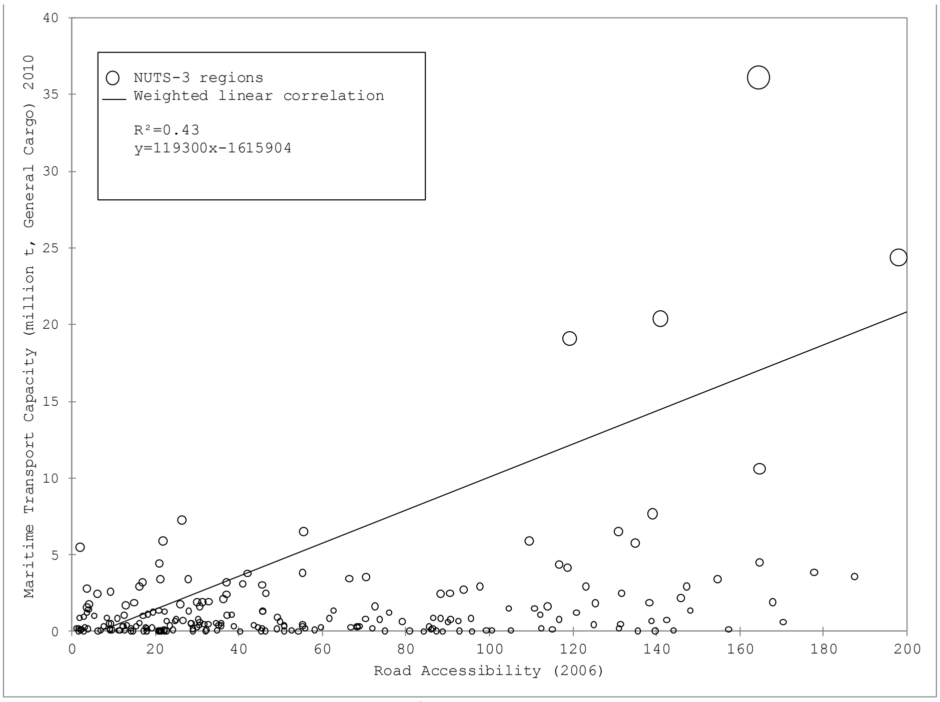


Source: own calculations from AIS data (2010) and Espon (2006).

In the case of general cargo (figure 4), the model also underestimate the values of main seaport regions, but less than for TEUs. Moreover, the maritime supply of small seaport regions (small circles) is better predicted and less overestimated than for TEUs.

Figures 5 and 6 show the ratio between the observed and the expected (as of the model) volumes of maritime transport supply. Dark circles thus show regions with better maritime transport supply than expected, light circles with thick outline those with lower supply than expected.

Figure 4. General cargo supply vs Road Accessibility by NUTS 3



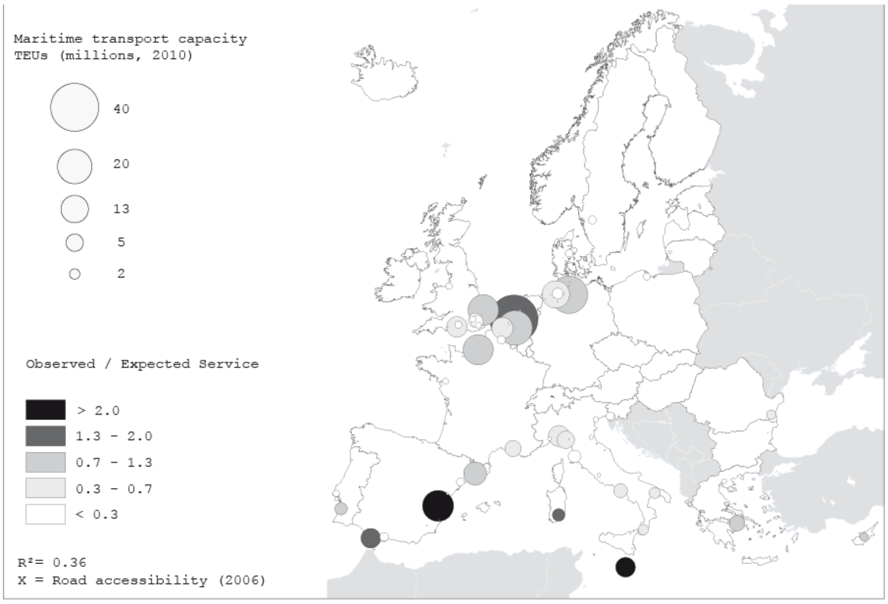
Source: own calculations from AIS data (2010) and Espon (2006).

On the map of container supply (figure 4) the main 'oversupplies' can be founded in largest port regions of Southern Mediterranean. We also see, in a lesser extent, excess supply outside the Mediterranean, in the region of Rijnmond (Rotterdam). The regions of Bremerhaven, Zeebrugge and most of secondary port regions, located inside the economic core of Europe, are in the opposite situation, with less maritime transport supply by expected by the model.

The map of deviations for general cargo supply (figure 5) show a more complex pattern. The main oversupplies are not limited to one region, but are rather spread over Europe (Northern Range, Baltic region, Southern Ireland, Eastern Europe) and marginally present in the Mediterranean (i.e. Algeciras). Undersupplies are also very spread, and mostly concern small port regions.

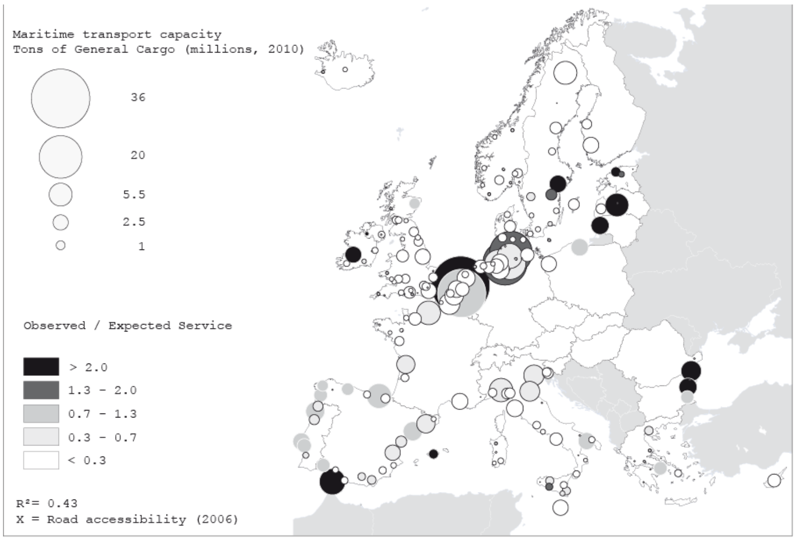
The picture that emerges for TEUs and general cargo suggests that the 'oversupply' of certain regions is linked with their specific position vis-à-vis shipping routes. In order to test this hypothesis, we implemented a detailed approach of maritime transport supply considering the variety of overseas markets.

Figure 5. Observed vs expected maritime transport supply (TEUs)



Source: own calculations from AIS data (2010) and ESPON (2006).

Figure 6. Observed vs expected maritime transport supply (General cargo)



Source: own calculations from AIS data (2010) and ESPON (2006).

3.3. Analysing inland market accessibility for different forelands

For 2010, the relationship is particularly strong with both shores of South America and Caribbean (0.4-0.6), meaning that these regions are rather served by metropolitan ports located near large urban areas or heartland Europe. The relationship with regions of North America Atlantic and Far East, that are the main container markets for Europe are, is close to the global value. In 2010 the world region less linked to population access was West Africa. This could be due to niche markets (i.e. counter-season fruits, timber) where peripheral ports far from heart are also important.

Table 3. Linear correlation between maritime transport supply by world regions and accessibility

			Total throughput	Europe	North America Atlantic	North America Pacific	Caribbean	South America Atlantic	South America Pacific	North Africa	West Africa	Indian Ocean	Far East	South-East Asia	Oceania
TEUs	2009	R^2	0.33	0.33	0.34	0.22	0.36	0.47	0.39	0.32	0.27	0.31	0.32	0.33	0.31
		n	76	87	62	52	64	50	46	79	55	69	63	65	50
	2010	R^2	0.36	0.37	0.26	0.25	0.46	0.4	0.61	0.36	0.17	0.3	0.35	0.37	0.27
		n	83	78	61	56	67	51	52	66	61	63	61	64	38
General cargo	2009	R^2	0.43	0.46	0.48	0.52	0.5	0.44	0.49	0.45	0.42	0.53	0.53	0.55	0.48
		n	189	187	152	98	164	154	113	183	176	148	147	145	114
	2010	R^2	0.43	0.44	0.45	0.53	0.45	0.41	0.46	0.41	0.41	0.5	0.5	0.49	0.42
		n	211	202	170	105	172	157	105	196	187	155	137	147	118

Source: own calculations from AIS data (2010) and Espon (2006).

For general cargo transport supply, the relationship with accessibility to population is slightly the same for 2009 and 2010. The link is considerably strong for Asian markets (Indian Ocean, Far East, South-East Asia) and the Atlantic coast of North America meaning that the maritime transport supply to these regions is higher in metropolitan regions or near the economic heart of Europe. In the same way as containers, the connections with West and North Africa are less limited to metropolitan regions and involve all kinds of regions, even peripheral ones.

4. CONCLUSIONS

This paper attempts to measure the linkage between maritime transport supply and inland accessibility in Europe, both for container and general cargo services. The results of this paper support the expectation that maritime transport supply is strongly dependent on the demographic size and economic potential of hinterlands. More specifically, the findings here suggest that inland accessibility to population explain 36% of the geographic variations maritime transport supply for containers and 43% for general cargo. Beyond these global figures it should be noted that the relationship between accessibility and maritime transport supply varies considerably depending on the overseas market served. In the case of container shipping South American markets seem to be more linked to inland accessibility that the other forelands. In the case of general cargo shipping, Asian and North American overseas market are more linked with inland accessibility that the other forelands.

The work explain an accurate GIS methodology to put in relation port activity with hinterland flows, and opens a wide field of study which might be completed, in further research, adding port specialization, foreland specific features and another hinterland parameters.

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ANNEX 1.
List of NUTS-3 regions used for general cargo

Antwerpen, Zeeuwsch-Vlaanderen, Stade, Kiel, Kreisfreie Stadt, Hamburg, Bremerhaven, Kreisfreie Stadt, Neumünster, Kreisfreie Stadt, Vizcaya, Riga, Genova, Norrbottens Lan, IJmond, Nord FR, Constanta, Bremen, Kreisfreie Stadt, Tarragona, Grande Porto, Gent, Barcelona, Charente-Maritime, Varna, Klaipedos apskritis, Satakunta, Sodermanlands lan, Grande Lisboa, Taranto, Cuxhaven, Mid-West, Overig Zeeland, Bouches-du-Rhône, Valencia/València, Szczecinski, Malta, North and North East Lincolnshire, Trojmiejski, Wesermarsch, Península de Setúbal, Groot-Amsterdam, Pontevedra, West-Noord-Brabant, Huelva, Overig Groningen, Rostock, Kreisfreie Stadt, Burgas, Kypros, Calvados, Napoli, Southampton, Østjylland, Leer, Mallorca, Aberdeen City and Aberdeenshire, Castellón/Castelló, Ostergotlands Lan, Gotlands Lan, La Spezia, Obalno-kraska, Põhja-Eesti, Baixo Vouga, Kurzeme, Cádiz, Pohjanmaa, Vosterbottens Lan, A Coruña, Northumberland, Loire-Atlantique, Gloucestershire, Gui-púzcoa, , Kent CC, Hartlepool and Stockton-on-Tees, Sydjylland, Outer London - East and North East, Vastra Gotalands Lan, Palermo, Siracusa, Monmouthshire and Newport, Thurrock, Inverclyde, East Renfrewshire and Renfrewshire, Gironde, Brugge, Granada, Vasternorrlands Lan, Murcia, Agrigento, Cantabria, Málaga, Catania, Glasgow City, Reggio di Calabria, Belfast, Alkmaar en Omgeving, Delfzijl en omgeving, Asturias, Brindisi, South-West IE, Dublin, Sevilla, Alentejo Litoral, Vest-og Sydsjalland, Kesk-Eesti, Dorset CC, Alicante/Alacant, Cagliari, Byen K?benhavn, Fyn, Manche, Suffolk, Skane Lan, Sunderland, Tulcea, Ragusa, Girona, , Blekinge lan, Cardiff and Vale of Glamorgan, South-East IE, Savona, Seine-Maritime, Almería, Friesland DE, Hampshire CC, West Cumbria, Bridgend and Neath Port Talbot, Border, Carbonia-Iglesias, Morbihan, Crotone, Pas-de-Calais, Hallands Lan, Ille-et-Vilaine, Edinburgh, South West Wales, Cornwall and Isles of Scilly, Sassari, Bornholm, Lochaber, Skye & Lochalsh, Arran & Cumbrae and Argyll & Bute, Portsmouth, Lübeck, Kreisfreie Stadt, Finistère, Laane-Eesti, Oristano, Ostvorpommern, Gavleborgs lan, Flensburg, Kreisfreie Stadt, Nordjylland, Outer Belfast, Østsjalland, Wismar, Kreisfreie Stadt, Medway, Norfolk, East Ayrshire and North Ayrshire mainland, Mid-East, Rügen, Nordfriesland, Dobrich, Pieriga, Stockholms lan, Lugo, Eilean Siar Western Isles, Plymouth, Cosenza, Bournemouth and Poole, West Sussex, Nordsjaelland, Alpes-Maritimes, Trapani, Kirde-Eesti.

ANNEX 2.
List of NUTS-3 regions used for containers

Hamburg, Antwerpen, Valencia, Suffolk, Seine-Maritime, Bremerhaven, Kreisfreie Stadt, Zeeuwsch-Vlaanderen, Barcelona, Brugge, Genova, Southampton, Malta, Cádiz, La Spezia, Thurrock, Napoli, Cagliari, Alentejo Litoral, Medway, Taranto, Cuxhaven, Reggio di Calabria, Constanta, Málaga, Kypros, Nord FR, Obalno-kraska, Tarragona, Østjylland, Hampshire CC, Trojmiejski, Grande Lisboa, Outer London - East and North East, Kent CC, Loire-Atlantique, Savona, Klaipedos apskritis, Bouches-du-Rhône, IJmond, Castellón/Castelló, Grande Porto, Kiel, Kreisfreie Stadt, Stade, Skane lan, Groot-Amsterdam, Península de Setúbal, Overig Zeeland, Calvados, Pontevedra, Vizcaya, Neumünster, Kreisfreie Stadt, Siracusa, Dublin, Gloucestershire, Murcia, Bremen, Kreisfreie Stadt, Belfast, Leer, Dorset CC, Messina, Riga, Palermo, Alkmaar en omgeving, Varna, Inverclyde, East Renfrewshire and Renfrewshire, Wesermarsch, Friesland DE, Alicante/Alacant, Rostock, Kreisfreie Stadt, Crotone.

ANALYSE GÉOGRAPHIQUE DE LA RELATION ENTRE ACCESSIBILITÉ TERRESTRE ET OFFRE DE TRANSPORT MARITIME

Résumé - *Le but de ce travail est d'évaluer le rôle de l'accessibilité terrestre dans la concentration des services maritimes dans les ports. Nos résultats, à partir de l'étude des régions NUTS 3 européennes (les départements en France), montrent que l'accessibilité terrestre explique à elle seule 43% de l'offre de transport maritime dans le domaine des navires vraquiers. Ainsi, l'offre de transport maritime demeure étroitement liée au potentiel démographique et économique des régions situées à proximité du port. Dans le cas des conteneurs, où le transbordement est plus développé, la relation entre offre de transport maritime et accessibilité terrestre reste forte (36%) mais moins que dans le cas des vraquiers. Des résultats détaillés par régions du monde montrent que la contribution de l'accessibilité terrestre varie en fonction des* forelands *considérés.*

Mots-clé - PORT, HINTERLAND, DIVERS CONTENEUR, ACCESSIBILITÉ