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Spatial competition and complementarity in European port regions

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ABSTRACT

The purpose of this study is to investigate whether inter-port relationships in European container shipping are characterized primarily by competition or complementarity, and to what extent this differs between major port regions. Utilizing a set of spatial dependence model specifications and quarterly container throughput data for 92 European ports in five regions between 2000 and 2014, it is found that the nature of inter-port relationships tend to differ between major port regions. While the Hamburg-Le Havre region is characterized mostly by competition, ports in the Mediterranean region are found to be complementary with regard to demand.

1. Introduction

Competition between ports is nested in broader concepts of competition. A decision maker's choice of calling at a particular port from a set of feasible alternatives is conditioned on the higher order choice of maritime over alternative modes of transportation. Not only other ports, but also other modes of traffic, other routes, and combinations of the two, are relevant substitutes. Choice of port is also subject to certain restrictions such as port capacity, availability, location, cargo handling specialization and accommodation of certain vessel sizes. Such restrictions, along with high entry barriers in the port market, dampen the intensity of competition between maritime ports. However, the development of intermodal logistics chains has tended to add flexibility to some of these restrictions.

Inter-port relationships are likely to be complex, and may not always be characterized only by competition. One reason for lacking or low degrees of competition is that ports are generally considered to possess a significant degree of natural market power (Goss, 1999; Verhoeff, 1981). The tendency for ports to exploit market power in pricing practices has led to strong arguments for creating competition within ports (De Langen and Pallis, 2006). Another reason for lacking competition is that ports may rather be incentivized by co-operation than by competition. In terms of demand analysis, one might characterize a set of ports as either substitutory (in a situation where inter-port relationships are characterized by competition), or as complementary (in the case of co-operation).[2]

To illustrate the two types of relationship features in a simple example, consider a scenario where two ports X and Y are able to separately serve the same hinterlands. Standard economic reasoning says that a decrease in the generalized cost of using port X (be this the effect of an efficiency improvement, a reduced charge or something else) is likely to lead to an increase in demand for port X and a decrease in demand for port Y. A counteracting effect would be one of complementarity; a lower generalized user cost for port X results in a lower total cost for a vessel calling at both ports X and Y, increasing demand for both X and Y. This can be termed a spillover effect or a positive externality. Naturally, the example can be generalized to a large network of ports. A change in user cost for one port will affect other parts of the transportation network, and the size of this effect is related to the intensity of the relationship between the ports.[3]

There is a rather wide body of research concerning the changing role of inter-port competition in the face of increased supply chain integration (Juhel, 2001; Notteboom, 2008; Song and Panayides, 2008). Previous research has approached the analysis of competition in the port sector from a variety of methodological approaches, including microeconomic indifference analysis (Yap and Lam, 2004), measures of industry concentration (Figueiredo et al., 2015; Hoyle and Charlier, 1995), revealed preferences of port-calling patterns (Notteboom, 2009a) and various qualitative indicators of competition (Fleming and Baird, 1999). The incentives for ports to engage in competitive or cooperative behavior has also been analyzed using game-theoretical approaches (Anderson et al., 2008; Ishii et al., 2013; Wang et al., 2012). Following a large volume on literature on estimates and determinants of operational efficiency in ports, several contributions have also studied the relationship between port efficiency, performance and competition (Figueiredo et al., 2015; Simões and Marques, 2010; Yuen et al., 2013). The spatial characteristics and

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[2] The characterization of substitutability and complementarity as indicators of competition is found in a number of other studies (Notteboom, 2009a; Song, 2002; Yap and Lam, 2004).
[3] User cost should be understood in the general sense. This general meaning applies to efficiency, accessibility or monetary charges incurred on the user.

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development of port systems has been recognized as vital to the understanding of port regions (Ng and Gujar, 2009; Notteboom and Rodrigue, 2005). There has however been no attempt to model port competition using spatial dependence models, a field that has garnered an increasing amount of attention in applied economics (Anselin, 2001).

Spatial analytical tools are well suited for studying port competition for a few key reasons. Ports represent fixed areas of interconnected infrastructure interfacing seaborne and land-based modes of transportation. The market structure facing ports is widely taken to resemble monopolistic competition, though this is subject to political and economic factors. The tendency for a set of container ports to be regarded by a shipper as substitutory within a supply chain is likely determined (or rather approximated) by the distance that separates them. In other words, distance can be used as a measure for characterizing the intensity of the relationship between any set of ports. For a large set of ports, spatial econometric tools provide a variety of convenient methods for modeling relationships based on geographical data. In addition, the governance structures of European ports tend to be classifiable by region (Verhoeven, 2011).

This study estimates spatial dependence in inter-port relationships as a measure of competition within five major container port regions. It provides a theoretical contribution to the port economics literature by extending the much-researched topic of inter-port competition to a spatial econometric framework, as well as an empirical contribution by applying this methodology to well-defined segments of the European container market. As this paper is the first to treat port competition as a case of spatial dependence, it represents a novel contribution to the literature. The European port system comprises the highest concentration of ports in the world (Chlomoudis and Pallis, 2002), and the historical lack of a pan-European policy for governance of ports in the single market of the European Union poses the interesting question of how various national and regional policies governed by different interests affect the maritime transportation system. In light of recent and previous proposed frameworks for a harmonized European Union ports policy (Chlomoudis and Pallis, 2005; European Commission, 2013), it is vital to understand differences in the European port system in order to establish a desirable way to move forward.

The structure is as follows: Section 2 reviews previous research on port competition and port governance in various regions of Europe. Section 3 introduces the methodological framework, the data and the empirical model applied. Section 4 presents and interprets the results of the study, while Section 5 is dedicated to a discussion regarding the results and some limitations of the method. Finally, Section 6 summarizes the conclusions of the study.

2. Inter-port competition: theoretical concepts and institutional enablers

The term port competition is by itself very imprecise, as it may refer to a wide number of things. Verhoeff (1981) was perhaps the first to identify the complex structure of the market in which ports and terminal businesses compete, recognizing that there is competition between ports in a confined area, between ports within a larger region, and between entire regions of ports.[4] Competition among ports within regions is, according to Verhoeff, especially complex because public authorities tend to support and seek to strengthen national ports through subsidization. If a port region is then stretched over several countries, such policies may have a catalyzing impact on competition.

The literature that followed Verhoeff and other early works in port economics has tended to focus on two subtopics, inter-port competition and intra-port competition. Previous research in the former is briefly reviewed in the next section, followed by a look at country-specific governance and regulations in Europe.

2.1. Inter-port competition

Competition between individual ports has been a subject of discussion since the early works in port economics. Verhoeff (1981) observes that ports tend to operate in a market structure that is monopolistic. Jansson and Schneerson (1982) note that demand for the services of an individual port cannot be taken as inelastic with regard to queuing times and port charges, since some shippers will call at other ports when these costs increase. For a system of ports, Jansson and Schneerson regard total demand as inelastic, which can only be the case if there is no competition from other modes of traffic (perhaps a reasonable assumption for ocean haulage, but less so for short-sea shipping). In a study of shippers' criteria for port selection in the North Atlantic, Slack (1985) finds that port infrastructure and service characteristics do not play a large role in routing decisions. Fleming and Baird (1999) note that port competition is often used as an undefined term by researchers to characterize any rivalry between ports. The authors find that competition is not necessarily an accurate characterization of inter-port relationships; some heavily invested ports may rather be interested in cooperation. In line with this, Song (2003) conceptualizes a mixed strategy of competition and cooperation (termed “co-opetition”) and argues that finding a balance between these elements is crucial for ports. Hinterland contestability, structure and access are considered important factors in assessing inter-port competition (Notteboom, 2008; Notteboom and Rodrigue, 2005). In evaluating structural changes in hinterland access, Homosombat et al. (2016) show that structural changes in the location of hinterland producers are likely to have significant impact on the competitive balance between regional ports. Notteboom (2002) finds that European container ports, despite high barriers to entry, do face competitive pressures from structural changes in logistics chains, which prevent the extraction of monopolistic profits. A potential concern for policy makers with regard to port competition is that competitive incentives may lead to excessive infrastructure investments, yielding overcapacity in a port system. Treating strategic investment decisions in ports as a game theoretical problem and applying this approach to large East Asian ports, Anderson et al. (2008) find that large observed levels of investment may not be consistent with strategic evaluation. Game theoretical applications in previous research have also focused on pricing competition (Ishii et al., 2013), and it has been suggested that cooperation strategies between ports serving overlapping hinterlands may be in conflict with institutional and political factors of port governance (Wang et al., 2012). While most of the above cited research is concerned with the strategies and incentives which induce competitive behavior of ports through pricing and investment, a significant amount of related research has also focused on identifying, describing or quantifying sources of port competitiveness (Fleming and Baird, 1999; Lee and Lam, 2015).

In a theoretical examination of inter-port relationships, Yap and Lam (2004) apply indifference analysis to show that a pair of ports may be complementary or substitutory in terms of demand. To illustrate the principle of indifference analysis, it might be useful to revisit the example stated in the introductory section of this paper. For a decreased cost of calling at Port X, there will be an effect on demand for calling at Port X and the neighboring port Y. This is illustrated using a simple framework in Fig. 1, where the decrease in cost causes a change in the slope of the budget line. The effect on demand for X can be grouped into the substitution effect (SE), which is (always) negatively related to the change in the cost of X, and is shown by the increase in demand $X_0 \rightarrow X_1$. The income effect (IE), which is shown by an increase in demand $X_1 \rightarrow X_2$, is positive under the assumption that port services are not inferior “goods”. The subsequent total effect on demand for Y (shown by $Y_0 \rightarrow Y_1$ and $Y_1 \rightarrow Y_2$), is positive in the case of complementarity (as shown in Fig. 1), but negative in the case of competition. In general terms, the substitutability of X for Y and vice versa will depend on the slope of the indifference curve, which is the marginal rate of substitution.

Yap and Lam exemplify the concept of complementarity in port

[4] The terms ‘range’, ‘region’ and sometimes ‘cluster’ are to a certain extent used interchangeably in the literature to describe a geographical area comprising a system of ports providing access to adjacent or overlapping hinterlands. For consistency, the term ‘region’ is used throughout this paper.

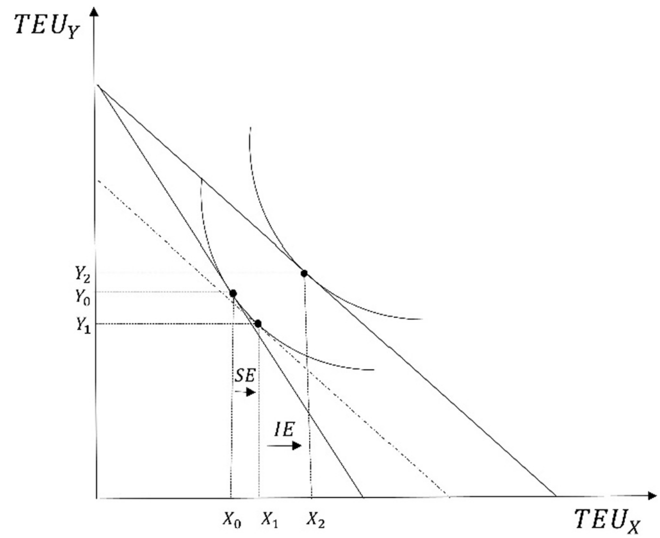

Fig. 1. Complementarity in port demand.Note: The impact on throughput demand in twenty-foot equivalent unit containers (TEUs) for complementary ports X and Y following a decrease in the generalized cost of using port X.

demand by using the case of Port Klang and its neighboring Port of Singapore in the late 1990s. The effect of a reduced cost of calling at Port Klang resulted in a positive effect (in terms of demand) for both Port Klang and Singapore, illustrating an instance where the total effect of reduced user costs on demand for a neighboring port was positive (as in Fig. 1). In an analysis of container port complementarity in the gateway region of the Rhine-Scheldt Delta, Notteboom (2009a) finds that the port-calling patterns of vessels indicate significant elements of substitution between large ports such as Rotterdam and Antwerp.

2.2. Differences in governance and public sector role

There is commonly a substantial degree of public financing involved in port investment in Europe, though the degree of public sector involvement (and the tier of government involved) differs between countries. In a study of public financing of infrastructure in major seaports of northern Europe, Baird (2004) finds that subsidization schemes of Germany, Belgium and the Netherlands are relatively homogenous, with significant public sector involvement at the municipal level. The French port sector has undergone recent reform toward devolution, i.e. decentralization of governance, and liberalization of port operations with the public sector taking responsibility mainly for 'landlord' duties (Debrie et al., 2007; Lacoste and Douet, 2013). The active role of public sector in capacity planning and financing is often seen as justified from a public goods perspective (Baird, 2004). Port infrastructure may be regarded as a public good in the sense that it facilitates trade growth and economic development, and that if left up to market forces, capacity could suffer from underinvestment. However, as Baird goes on to argue, the public financing of port infrastructure seldom has a system-based view of maritime transport. Rather, subsidies typically stem from local authorities' interest in national or regional benefits, despite that many major ports mostly handle transshipments, which do not have any direct effect on own-country growth or development.[5] The UK, however, stands out as an example of a markedly different approach to the rest of northern Europe, as the port sector has undergone major privatization processes (Baird, 2004; Baird and Valentine, 2006). In the UK, government (whether at the local or national level) is only primarily involved in approval of planned investment, and funding is largely left to the market.

In Mediterranean countries, organizational reform has been a common theme. The Italian port sector, having being governed by centralized policy, underwent deregulation in the 1990s, which triggered reform in organization (Valleri et al., 2006). The Spanish port sector saw a similar reform toward decentralization during the 1990s, which has been argued to have benefited the growth of port traffic (Castillo-Manzano et al., 2008). The last decade has also seen a process of privatization of major ports in Greece, motivated by inefficiencies and lack of sufficient facilities (Pallis and Syriopoulos, 2007).

In a comprehensive fact finding survey for the European Sea Ports Organization (ESPO), Verhoeven (2011) finds that differences in port governance in Europe can be understood through the Hanse, Latin and Anglo-Saxon typology framework. The Hanse group, comprising Belgium, Netherlands, Germany and the Scandinavian countries, is distinguished by municipal management. The Latin group, comprising southern European countries, is characterized by more centralized government control and less regional autonomy. The Anglo-Saxon style of management is instead based on more independence and financial autonomy, where the main governing economic objective is profit maximization. It is important to note that these regional distinctions are somewhat crude and should not be overly simplified. Ports within regions are not fully homogenous with regard to institutional factors influencing governance. There is however a general north-south dichotomy in Europe when it comes to port autonomy and decentralization (Verhoeven, 2011). Faced with regional differences in port governance, there have been attempts and expressed intentions by the European Union to harmonize institutional factors under a common policy (Chlomoudis and Pallis, 2005, 2002; European Commission, 2013).

What are the likely implications of subsidies motivated by national and/or local interests? In regions where ports located in different countries provide access to overlapping hinterlands, and the interests of local authorities do not align with the efficiency of the transport system as a whole, the lack of a centralized (transnational) public policy may lead to catalytic impacts on competition. That is, it is reasonable to expect a greater degree of competition in areas where local interests, rather than centralized planning, are involved in determining the degree of port investment. This is because efforts to increase the competitiveness of the local port may trigger competition among regional alternatives, which was a point made by Verhoeff (1981). By similar reasoning, it can be expected that public sector involvement aimed at promoting national interests induces a higher level of competition in multi-country port regions than would a system based solely on private funding.

3. Methodology

Spatial dependence implies not only that there is heterogeneity in a cross-section of observed units, but that the variability in these units is also some function of space. The inclusion of spatial parameters in economic models may be justified for a variety of reasons (LeSage, 2008). Consider for instance the case of transport infrastructure investment. The effects of improved accessibility to urban transport on real estate value are likely to be positive in the area where the improvement is made. It is also likely that there will be a ripple effect on nearby areas, illustrating an externality that is spatial by nature. Another situation where spatial parameters are appropriate is where there are unobservable effects that cannot be directly included in the model but can be approximated by geographical data. This is the main justification for using spatial models in this paper: the degree to which demand for throughput in a set of ports is interdependent is assumed possible to approximate by distance. That is, alternative ports within closer regions are assumed better able to serve the targeted hinterlands than ports that are more remote. In addition, a change in the generalized cost of using a port (e.g. a reduction of user costs through a capacity expansion or an increase in costs through high level of congestion) is assumed to have demand spillover effects that are spatial by nature.

In this paper, the term competition is operationalized as spatial spillovers of throughput demand. The level of competition is defined as

[5] There may however be significant impacts on regional employment and level of business activity of maintaining a competitive position in the port market.

the strength of a negative spatial dependency of throughput between a port and its neighbors. While this operationalization differs from a classic interpretation of competition relating to market shares or industry concentration, the underlying assumption is that spatial spillovers captures the extent to which ports are deemed to be substitutory. Complementarity is defined as the inverse of competition, a situation in which ports are positively co-dependent in terms of demand.

For the purposes of spatial analysis, a weight matrix W_{ij}, is constructed, where each value is a representation of the geographical features of the relationship between units i and j. In the analysis of regional units such as states or counties, this value may be set to 1 if i and j are neighboring units and 0 otherwise. Since ports are more similar to points on a map than contiguous spatial areas, distance between ports is used to represent the geographical features of the data. The weight matrix is therefore constructed using the inverse distance between any ports i and j, with zero diagonal values. The weight matrix is standardized so that the sum of each row equals 1. The weight matrix is constructed based on Euclidean (i.e. simple straight-line) distances.

$$W_{ij} = \begin{bmatrix} 0 & d_{ij}^{-1} & d_{ij}^{-1} \\ d_{ij}^{-1} & 0 & d_{ij}^{-1} \\ d_{ij}^{-1} & d_{ij}^{-1} & 0 \end{bmatrix} \tag{1}$$

Two standard ways of modeling spatial dependence in regression analysis are the spatial lag model and the spatial error model (Anselin, 2001). The former is generally used in cases where the spatial coefficient is a parameter of interest, while the latter is applicable when spatial dependence is a nuisance parameter potentially biasing model estimation. The panel spatial autoregressive (SAR) model (a case of the spatial lag model), where unobserved effects are specified as fixed, can be described (Millo and Piras, 2012) in matrix form as:

$$\mathrm{Y} = \lambda(I_T \otimes W_N)\mathrm{Y} + (\iota_T \otimes I_N)\alpha + \mathrm{X}\beta + \varepsilon \tag{2}$$

where Y is a stacked NT*1 matrix of the endogenous variable and X is an NT*k matrix of the exogenous regressor variables. The factor λ is the spatial autoregressive parameter corresponding to the N-by-N spatial weights matrix W_{ij} and the identity matrix I_T. The term ι_T is a column vector of length T with all elements set to 1, and α is a vector of fixed effects. The noise term ε is normally distributed with zero mean. Spatially lagged dependent variables are, unlike serial lags, by definition correlated with the error term (Anselin, 2001). This is because neighbor-relationships are two-directional. This introduces an element of endogeneity, rendering OLS biased and inconsistent. Suggested estimation approaches (Anselin et al., 2008) are based on maximum likelihood (ML) and generalized method of moments (GMM). This study utilizes a two-step ML-based estimation procedure that estimates a transformed version of Eq. 2.[6] This transformation is achieved by eliminating the fixed effects through subtracting the average value over time for each cross sectional unit. This transformed model is represented as:

$$Y^* = \lambda(I_T \otimes W_N)Y^* + X^*\beta + \varepsilon^* \tag{3}$$

where Y^*, X^* and ε^* are the demeaned variable representations. It should be noted that the fixed effects model suffers from the 'incidental parameters problem', which renders the fixed effects coefficients α inconsistent when T is fixed and N → ∞ (Elhorst, 2003). When the SAR model is estimated in demeaned form as stated in Eq. (3), the estimator is not a function of the unobserved effects and the inconsistency of α does not transfer to the slope coefficients.

Positive spatial dependence (a positive value of λ) implies clustering of similar values, while negative spatial dependence would imply that a variable is negatively related to the values of its neighbors. In some empirical applications of geo-analysis, negative spatial dependence

[6] See Millo and Piras (2012) for details on the estimation procedure.

Table 1
Summary statistics for five container port regions.
Note: Throughput data from 2014 (Eurostat, 2016a).

Port region	N.o. ports included	TEU share of total	Avg. distance (km)
Atl	10	2,9%	577
H-LH	17	48,9%	377
Med	27	33,0%	1125
S/B	23	3,8%	748
UK	15	11,3%	364

Port region abbreviations, Atl: Atlantic, H-LH: Hamburg–Le Havre, Med: Mediterranean, S/B: Scandinavia/Baltic.

does not have a meaningful interpretation. This is because the nature of the phenomena that are analyzed tend toward clusters in space, rather than portraying a "checkerboard"-pattern, which is implied by negative spatial dependence. An area where negative spatial dependence is relevant is regional competition. There are a number of studies that do find meaningful interpretations of negative spatial dependence, such as in welfare competition between states (Saavedra, 2000), competition in activity between research institutes (Elhorst and Zigova, 2014) and in competition between states for federal grants (Boarnet and Glazer, 2002). Negative spatial dependence can be assumed prevalent when competition among regions is greater than effects of complementarity or co-operation (Kao and Bera, 2013).

3.1. Data and port regions

This study estimates the spatial dependence in demand for port services, approximated as the quarterly tonnage flow of containerized goods, in 92 European ports during the years 2000–2014. All throughput data is retrieved from the Eurostat official statistics database (Eurostat, 2016a). Very small ports (with average quarterly throughput < 100 TEU) are not assumed to significantly affect larger ports and are therefore excluded from analysis. The total number of observations for the full model where all ports are included simultaneously is 5520. For the analysis of competition within 5 major container port regions, the data size ranges from 600 to 1620 per estimation.

Based on the available data for the period of study, ports are segmented into five port regions: Hamburg–Le Havre, Scandinavia/Baltic, Atlantic, Mediterranean and the UK.[7] Table 1 presents summary statistics for the five port regions. It is clear from the market share figures for 2014 that Hamburg–Le Havre and the Mediterranean are the two major segments for container throughput. These are considered significant gateway regions to the European continent, but also as major hubs for transshipment. The average distance between ports is calculated based on every pair of ports within the region (i.e. the average non-zero values of the distance matrices). This gives a measure of dispersion, or stretch of distance within the regions. Table 2 presents summary statistics at the country level, where average TEU throughput indicates the relative sizes of the national ports.

3.2. Empirical model and demand factors

In analyzing demand relationships between ports, it must be kept in mind that services such as transportation or goods handling are not valued in themselves; rather they are inputs to the production of other things. The demand for port services, just as the demand for transportation, is derived from the demand for trade (see for instance McCarthy (2001)). It is therefore relevant to distinguish between demand in the nominal sense (which is increasing with the demand for trade for all modes and almost all ports), and inter-port (as well as inter-modal)

[7] The definition of what constitutes a region in the European container port market is adapted from Notteboom (2009b, 1997).

Table 2
Country-level summary statistics for 92 included ports.
Note: Throughput data from 2014 (Eurostat, 2016a).

Country	N.o. ports included	Port region (s)	Avg. quarterly throughput (TEU)
Belgium	3	H-LH	604,700
Denmark	5	S/B	32,600
Finland	5	S/B	23,200
France	6	H-LH, Atl	150,400
Germany	9	H-LH, S/B	345,700
Greece	4	Med	123,100
Italy	15	Med	133,000
Netherlands	5	H-LH	478,200
Portugal	3	Atl	81,449
Spain	12	Med, Atl	182,700
Sweden	10	S/B	28,500
UK	15	UK	126,200

Table 3
Descriptive statistics of model dependent and explanatory variables.
Note: Throughput, trade and population data collected from Eurostat (2016a, 2016b, 2016c). Petroleum price series is from UNCTAD (2016).

Variable	Mean	Median	Min	Max	Std. dev
TEU_{it}	171,472	29,579	0	3,015,551	406,024
TR_{it}	90,379	86,045	7269	314,821	66,378
$TR_{EU,t}$	1,180,329	1,204,430	846,769	1,482,992	202,050
Pop_{it}	2,480,427	1,842,176	371,866	8,573,471	1,872,535
$PetPrice_t$	65,31	64,9	19,19	132,5	32,1

Trade is expressed in million euro.

demand for a given level of trade. In order to account for correlation in throughput volumes among ports that is due to increases in trade, variables corresponding to the volume of own-country trade (imports plus exports) and total EU28 trade are included as control variables. For almost all ports, there is a strong linear relationship between throughput and trade volumes. If trade growth were unaccounted for, all ports would appear complementary. In addition, the demand for port services is likely linked to the shipping cost level. In order to account for this, a variable corresponding to the price of crude petroleum is included in the estimated function as an approximation for shipping cost. The reason for using such a variable as a proxy is that fuel is the primary operating cost item incurred on a ship operator (Stopford, 2009) and should influence the rates for all relevant liner services. Petroleum price is also a variable that is readily observable during the entire period of study. It can be hypothesized that the flow of cargo allocated to any particular port in a region is related to the size of the hinterland market. This is accounted for in the model by using regional population figures as a proxy for hinterland market size. Besides these variables, seasonal and dynamic variation in the series is accounted for by employing quarterly dummy variables and a (serially) lagged dependent variable. The serial lag is introduced to account for shocks that have a lingering effect on demand in more than one period. Such shocks may range from the positive effect on demand of a port attracting a large volume of traffic through entering a new contract with a liner company, to the negative effect of a lingering labor strike, causing customers to call elsewhere. Combining the framework outlined in Section 3 with the variables described above, the empirical model is formalized as:

$$\ln TEU_{i,t} = \lambda \sum_{j=1}^{N} w_{i,j} \ln TEU_{j,t} + \rho \ln TEU_{i,t-1} + \alpha_i + \beta_0 + \beta_1 \ln TR_{i,t} + \beta_2 \ln TR_{EU,t} + \beta_3 \ln Pop_{i,t} + \beta_4 \ln PetPrice_t + \beta_5 Q1 + \beta_6 Q2 + \beta_7 Q3 + \varepsilon_{i,t} \quad (4)$$

where TEU_{it} is the throughput volume of port i at time t, TR_{it} is the volume of trade in the country of port i at time t, $TR_{EU,t}$ is the total volume of trade in the EU28-countries at time t, Pop_{it} is the number of inhabitants in the region where the port is located,[8] and finally $PetPrice_t$ is a weighted barrel price of crude petroleum. The expression $\lambda \Sigma_{j=1}{}^{N} w_{ij} \ln TEU_{j,t}$ is the spatial lag of the dependent variable, which can be interpreted as a 'proximity-weighted' value of the throughput in neighboring ports to port i at time t where the parameter λ is the estimated coefficient of spatial dependence. The term w_{ij} indicates the i:th, j:th element of the spatial weights matrix, the N-by-N standardized inverse distance matrix, where each value corresponds to the relative proximity of two ports. The explanatory variables are all gathered from the Eurostat database (Eurostat, 2016a, 2016b, 2016c), with the exception of PetPrice, which is gathered from the United Nations Conference on Trade and Development statistics database (UNCTAD, 2016). Q1–Q3 are sets of seasonal dummy variables. The model is estimated in a general way, allowing for both serial and spatial autocorrelation. The serial lag coefficient ρ is not in itself of interest in the analysis, but if there is serial dependence, leaving such an effect out of the model could lead to inefficient coefficient estimates and biased standard errors (Baltagi and Liu, 2008). The model is estimated in two different ways: for all countries in a complete model, and for each port region in separate models. In the complete model, w is set to 0 for any port pair that has a distance over a specified cut-off value. The reason for employing a cut-off value is that demand levels for ports separated by very large distances are unlikely to be inter-dependent. The estimated cut-off values for spatial dependence are 500 km, 750 km, and 1000 km. Multicollinearity is expected to affect the parameter estimates β_1 and β_2, since the trade variables are strongly correlated. This does however not bias the estimate of spatial dependence, λ, which is the parameter of interest. Descriptive statistics of the variables entering the model are presented in Table 3.[9]

Table 4
Hypotheses for parameter estimates of inter-port relationships.

Hypothesis	Parameter values
H0: neighboring ports are not distinctively competitive or complementary	$\lambda = 0$
H1: neighboring ports distinguished by competition	$\lambda < 0$
H2: neighboring ports distinguished by complementarity	$\lambda > 0$

For the purposes of this analysis, a set of hypotheses can be considered. These are summarized in Table 4.

4. Results

Table 5 presents the autoregressive coefficients derived from estimating a complete spatial fixed effects model for all 92 ports, with three different cut-off values for the spatial weights matrix. The estimates of λ reveal in all cases that there is no significant positive or negative spatial dependence of demand in the European container port sector when the country data are aggregated. The LM tests for spatial dependence do however imply rejection of the null hypothesis of no spatial dependence (Baltagi et al., 2003).[10] The different cut-off values of 500 km, 750 km or 1000 km do not affect the results or the model fit. Under all the specifications, neither complementarity nor competition is a distinguishing characterization of inter-port relationships. The parameter estimates for population size and petroleum price exhibit the expected positive and negative signs, but are not signifi-

[8] Regional population data is segregated at the NUTS-2 level. Since these data are annual, quarterly data are estimated by linear interpolation.

[9] For the TEU series, there were 19 (out of 5520) observations equal to zero. In order to be able to take logs, these observations were set to 1.

[10] This test is specified to detect residual spatial dependence in the data when the model is estimated without a spatial dependence parameter. Rejection of the null implies that the residuals from the model estimated without a spatial dependence parameter are spatially correlated.

Table 5
Spatial regression results for full data model with varying cut-off values for *W*.

	$W < 500$	$W < 750$	$W < 1000$
λ	0,01	0,02	0,03
	(0,02)	(0,02)	(0,02)
ρ	0,75***	0,75***	0,75***
	(0,01)	(0,01)	(0,01)
$\ln TR_i$	− 0,12	− 0,13	− 0,13
	(0,10)	(0,10)	(0,10)
$\ln TR_{EU}$	0,33*	0,33*	0,32*
	(0,18)	(0,18)	(0,18)
ln*Pop*	0,43	0,43	0,41
	(0,32)	(0,32)	(0,32)
ln*PetPrice*	− 0,03	− 0,03	− 0,03
	(0,05)	(0,05)	(0,05)
Q1	− 0,01	− 0,01	− 0,01
	(0,02)	(0,02)	(0,02)
Q2	0,08***	0,08***	0,08***
	(0,02)	(0,02)	(0,02)
Q3	0,02	0,02	0,02
	(0,02)	(0,02)	(0,02)
LogLik	− 19,565,1	− 19,564,9	− 19,564,7
LM-sp	7,76***	7,88***	7,70***
N.o. obs	5428	5428	5428

Note: Maximum likelihood estimates. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively. Standard errors in parentheses.

Table 6
Spatial regression results per port region.

	Atl	H-LH	Med	S/B	UK
λ	− 0,03	− 0,14**	0,09**	− 0,02	0,06
	(0,04)	(0,06)	(0,04)	(0,04)	(0,06)
ρ	0,81***	0,70***	0,80***	0,79***	0,49***
	(0,02)	(0,02)	(0,01)	(0,02)	(0,03)
$\ln TR_i$	− 0,62*	− 1,51***	− 0,06	0,05	− 0,01
	(0,37)	(0,57)	(0,16)	(0,17)	(0,16)
$\ln TR_{EU}$	0,76*	0,67	0,06	0,36	0,96***
	(0,44)	(0,79)	(0,26)	(0,29)	(0,36)
ln*Pop*	− 1,12*	3,58	0,55	− 0,27	− 1,47*
	(0,63)	(2,23)	(0,37)	(0,46)	(0,80)
ln*PetPrice*	− 0,02	− 0,11	− 0,01	− 0,01	− 0,17*
	(0,10)	(0,19)	(0,07)	(0,07)	(0,10)
Q1	− 0,15**	− 0,03	− 0,10***	− 0,01	− 0,08**
	(0,04)	(0,08)	(0,03)	(0,03)	(0,04)
Q2	0,03	0,06	0,11***	0,05*	0,09**
	(0,04)	(0,08)	(0,04)	(0,03)	(0,04)
Q3	− 0,11***	0,01	0,03	− 0,02	0,10**
	(0,05)	(0,09)	(0,03)	(0,03)	(0,04)
LM-sp	4,07***	6,21***	2,73***	1,87*	2,52**
N.o. obs	590	1003	1593	1357	885

Note: Maximum likelihood estimates. ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively. Standard errors in parentheses.

cantly different from zero. The significance of the serial lag parameter ρ indicates that there is indeed a high degree of serial dependence in the data. Omission of such a factor would lead to misspecification.

It should be kept in mind that the aggregated model is useful in the sense that it is liberal in its specification of relevant competitors: spatial weights are given to any port within the specified cut-off distance. It does however lead to a lack of precision in that it for instance considers some British ports to be possible substitutes to some French or Dutch ports, which is obviously quite unlikely and may lead to a lack of precision in estimating the spatial parameter. For this reason, this paper focuses mostly on the analysis of within-region competition, addressed in the following section.

4.1. Competition within port regions

Table 6 presents the results of the same model specification when the data are segmented by port region, as defined in Section 3. As a first point, it can be concluded that the specification tests of spatial dependence imply that the null hypothesis of no spatial dependence can be firmly rejected at the 1% level in the Atlantic, Hamburg-Le Havre and Mediterranean regions. In the Scandinavia/Baltic and UK regions, the test values imply rejection only at the 10% and 5% level respectively. The lambda coefficient of spatial dependence is significantly different from zero for the Hamburg-Le Havre and the Mediterranean regions. The estimated coefficients however interestingly indicate that there are substantial differences between these regions. In the Hamburg–Le Havre region, significantly negative spatial dependence is found. The Mediterranean region, however, exhibits positive spatial dependence. The significance and sign of other variable parameters vary between the port regions.[11]

The estimated spatial dependence parameters show that there appears to be a difference in inter-port relationship characteristics between the two largest regions. The only distinctive instance of competition between ports is found in Hamburg–Le Havre, and the only distinctive instance of complementarity is found among Mediterranean ports. There may be several explanations for such a finding. One explanation could be that ports in the Hamburg-Le Havre region, which are to a greater extent governed by lower-tier governmental bodies, engage to a greater extent in competitive behavior with regard to pricing and investment. Another explanation could be related to the quality of connecting infrastructure. In order for freight planners to be able to choose a different port than that which is most aptly located, sufficient communications for inter-modal transport must be in place. However, since this analysis does not explicitly control for factors of governance or quality of infrastructure, such explanations are not possible to infer.

One might expect that within-regional competition could be to some extent explained by port concentration in the area. However, as presented in Table 1, low (high) average inter-port distances do not necessarily correspond to high (low) coefficients of spatial dependence (Table 6). The region that appears the most competitive, Hamburg–Le Havre, is actually slightly less concentrated than the UK. The most widely dispersed area, the Mediterranean, is characterized by mostly complementarity.

4.2. Potential shortcomings and further extensions

In the analysis of time series data, it is important to safeguard against spurious results arising from random correlated patterns in non-stationary variables. In order to affirm that the results of the previous section are not spurious findings, the panel data sets (TEU throughput series) are tested for non-stationarity using the Levin-Lin-Chu test for panel unit roots (Levin et al., 2002). Under the null hypothesis of the test, all series contain a unit root, while the alternative hypothesis states that all series are stationary. The test was run both at the aggregate level and for each port region. Testing at the aggregate level led to rejection of the null hypothesis of joint non-stationarity, and the same result was found for all individual regions with the exception of the Scandinavia/Baltic port region. Though the issue of non-stationarity is not as serious for panel estimators (with large N and T) as for pure time series analysis (Kao, 1999; Phillips and Moon, 2000), the estimated coefficients for Scandinavia/Baltic can be interpreted with caution.

While the methodology applied to the analysis of inter-port competition and complementarity in this paper makes it possible to detect distinguishing differences between regions, it does not guide inference in what factors influence the intensity of competition. There are likely structural differences in the studied regions, for instance with

[11] While the estimations of spatial autoregressive coefficients are based on fixed effects estimation, the specification of fixed/random effects does not affect the sign or significance of any lambda estimates.

regard to the locality of ports and the quality of connecting hinterland infrastructure. For future developments in quantitative assessment of inter-port competition, such factors could be explicitly addressed.

5. Discussion

A recurring criticism of spatial econometrics is that issues of identification render much applied methods appropriate for describing data but limited for explaining causality (Gibbons and Overman, 2012). It should therefore be reiterated that the purpose of this paper is not to explain the drivers of demand for port services, to assess the impact of governance on competition, nor to explicitly determine the relationship between the cost and demand for adjacent ports. Instead, the utilization of spatial dependence models serves the purpose of identifying substitutory/complementary demand relationships between ports. This is an important distinction.

A point that has been discussed in previous research is that ports may be considered to be in competition not only for throughput, but also for terminal companies (Mclaughlin and Fearon, 2013). Given that terminal operating companies are dominant actors in the supply chain, and are free to relocate, there is competitive pressure on ports to provide better infrastructure and offer other advantages to terminal operators. Thus, it is important to note that inter-port rivalries may manifest in other forms than simply competition for services provided (as is modeled in this paper).

During the last two decades, various port governance decentralization reforms have taken place in southern Europe (see Section 2.2). Though the objectives of the reforms appear to be harmonizing with the decentralized governance systems in other parts of Europe, there is still a marked difference in governance between southern and northern Europe. In light of the regional differences in port governance described in Section 2.2, the finding that inter-port competition differs between the Hamburg-Le Havre and the Mediterranean regions motivates further research of the potential impact of governance on competition.

6. Conclusions

This study investigates whether inter-port relationships are characterized primarily by complementarity or competition. The results show that the nature of inter-port relationships differs significantly between the major European port regions. The two largest port regions in Europe, Hamburg–Le Havre and the Mediterranean exhibit opposite characteristics. While Hamburg–Le Havre appears to be primarily distinguished by competition, the Mediterranean ports appear mostly complementary. Based on the findings of this study it appears motivated to further research the impact of port governance on capacity and competition in maritime ports. If European Union policy makers wish to harmonize the laws and policies governing the financial and functional autonomy of port authorities, the indication of this paper is that close attention should be paid to effects on port competition, and conversely, on the ability and incentives for ports to co-operate.

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