

Vanoutrive, Thomas

**Conference Paper**

## Explaining Port Size: Accessibility, Hinterland Competition and a Semi-Endogenously Determined W.

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Vanoutrive, Thomas (2012) : Explaining Port Size: Accessibility, Hinterland Competition and a Semi-Endogenously Determined W., 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/120647>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# **Explaining Port Size: Accessibility, Hinterland Competition and a Semi-Endogenously Determined $W$ .**

Thomas Vanoutrive

University of Antwerp  
Faculty of Applied Economics  
Department of Transport and Regional Economics

## **abstract**

There is an ongoing debate on the concentration of container throughput in the European container port system. This paper explains the size of ports as a function of hinterland accessibility and competition. The concept of port competition is operationalised via the measurement of hinterland overlap, which is incorporated in the model using a spatial weights matrix  $W$ . The distance decay parameter underlying the accessibility and competition variables is determined semi-endogenously.

## 1. Introduction

One of the most remarkable features of the European port system is the concentration of activities in the Hamburg-Le Havre range (Notteboom, 2010). This concentration in the European core region conflicts with policy goals in the field of regional policy. Indeed, the aim of regional policy is to solve the regional problem, i.e. the existence of significant, long-term disparities in economic performance between (European) regions (Armstrong and Taylor, 2000). This view influenced among others the European White Paper on transport (European Commission, 2011, p.7) which states that,

*‘On the coasts, more and efficient entry points into European markets are needed, avoiding unnecessary traffic crossing Europe. Seaports have a major role as logistics centres and require efficient hinterland connections. Their development is vital to handle increased volumes of freight both by short sea shipping within the EU and with the rest of the world.’*

In this quote, ‘more entry points’ can thus be interpreted as ‘more ports’, or less concentration in the port system. A second relevant element is ‘unnecessary traffic’, i.e. due to the high degree of concentration in the European port system, many unnecessary trips are supposed to be made to inland destinations. These trips use capacity on the European transport networks and are a source of pollution. Capelli and Libardo (2011) argue that a shift in port traffic from northern to Mediterranean ports would be beneficial for the environment since ships that sail via the Suez canal do not make a detour around the Iberian peninsula. In their view, an internalisation of the external costs of shipping would induce a shift from the Hamburg-Le Havre range to ports in the north of Italy. In this North-South debate, port authorities of Northern ports try to convince, among others, the European Commission that the current pattern is based on economic reality (Antwerp, Hamburg and Rotterdam) while their southern counterparts argue that a shift to the south will occur and is beneficial for an ecological and economical perspective (e.g. Barcelona).

The main reason for the concentration of port activities is found in the distribution of population and economic activity in the hinterland. Scholars refer to the link between (population) density and port activities already for decades (see e.g. Figure 1, 1961 data (Bird, 1967)). Figures 2 and 3

show (respectively) the distribution of population and GDP in Europe in 2007. These maps show the ‘blue banana’, the concentration of people and economic activity in the region ranging from London over the Low Countries, south-western Germany, Switzerland, to the north of Italy. However, a visual inspection of the maps does not reveal why ports in the north of the banana attract much more maritime traffic than those in the south. Note that most existing conceptual (Notteboom and Rodrigue, 2005) and empirical work (Notteboom, 1997; 2010) mainly refer to port throughput data, but less to real figures on the distribution of population and economic activity in the hinterland, in contrast with the present paper.

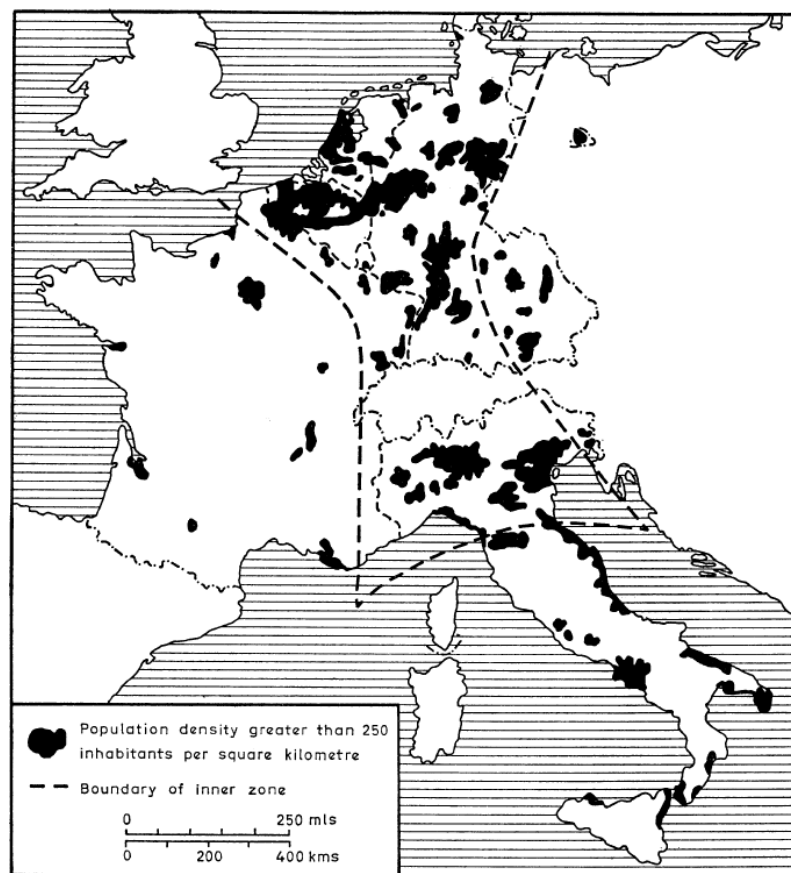


Figure 1: Despichts ‘Inner Zone’ of the European Economic Community as depicted by Bird (1967).

A wide variety of models exists that analyse port throughput. Given the strong linkages between ports and their hinterlands, port throughput is often modelled as a function of the economic

situation in the hinterland using GDP or trade figures (Janssens et al. 2003; Meersman and Van de Voorde, 2008; Meersman, 2010). In most cases, these approaches focus on the dynamics using time series. As an alternative, Chapelon (2007) measures the hinterland accessibility of ports with much detail and observes that these figures might explain the size of European ports. Even when leaving freight corridors aside and just taking into account road transport, the Rhine-Scheldt Delta ports (notably Antwerp and Rotterdam) can access in the same time span more people and wealth than other European ports (Chapelon, 2007). However, this study does not incorporate port throughput figures and accessibility indicators in one model. Therefore, we here aim at getting a more comprehensive view on the port-hinterland relationship by building a model with port throughput as dependent variable and accessibility as independent variable. This paper starts from that the idea that if hinterland accessibility is the main determinant of port throughput, we should be able to measure it.

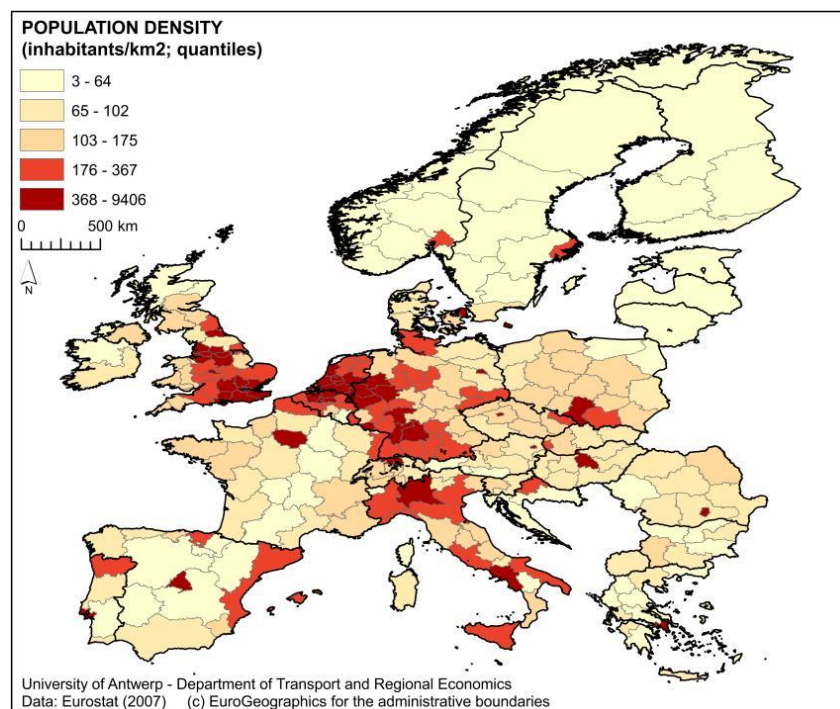


Figure 2: Spatial distribution of population density in Europe

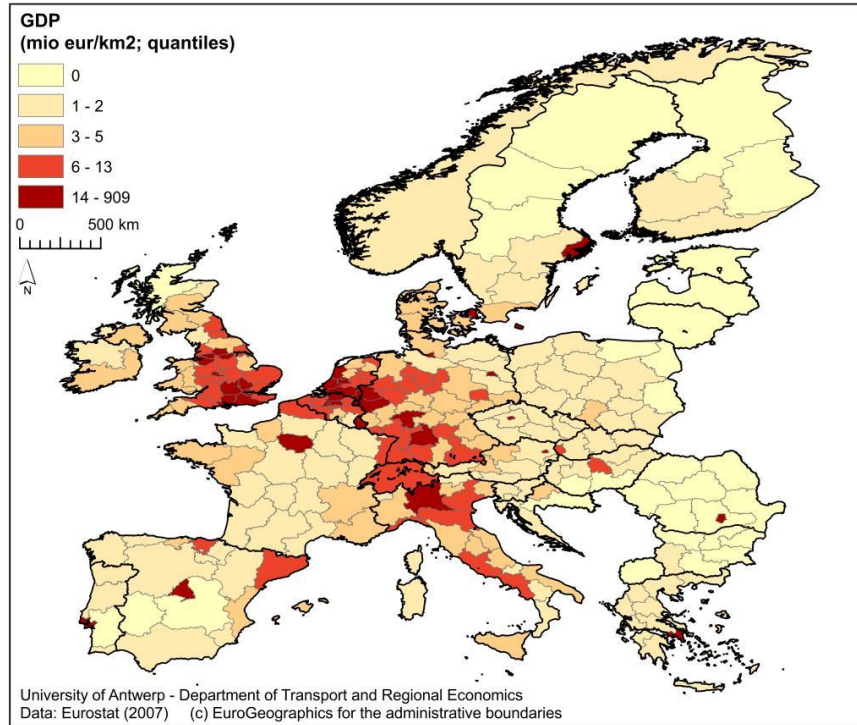


Figure 3: GDP per km<sup>2</sup> in Europe

## 2. Data and method

### 2.1 Data

The hinterland in our model consists of 306 European regions, mainly NUTS 2 regions but also Russia and some other CIS-countries were included. For most regions, GDP figures (2008) were found in Eurostat databases but for some countries we relied on World Bank data. Furthermore, data at the subnational level was lacking for several countries and where regional population figures were available we distributed GDP over the country weighted by population (Switzerland, Norway, Turkey). Note that we ignored density and, as a consequence, also the fact that more dense regions tend to have higher GDP/capita figures.

Container throughput figures are also provided by Eurostat. The files contain records for more than 250 ports. Container throughput is measured in Twenty-foot Equivalent Units (TEU) which is the standard measurement unit for containerised transport. We deleted ports outside Europe (e.g. Réunion and Guadeloupe) and inland ports (e.g. Duisburg). The remaining 257 port handled 83 252 472 TEU in 2008. More than three quarters of these containers are shipped via the 20

largest ports and 99% via the 110 largest ones. We further omitted ports located on islands (e.g. Ireland, Malta and the Azores), but we kept British ports since the Chunnel and regular ferry services connect Great Britain with mainland Europe. For example, some distribution centres serve Britain from mainland Europe (e.g. via the port of Zeebrugge (Belgium)). Some ports were merged for reasons of data availability (e.g. Copenhagen and Malmo and some British ports) and we only kept ports that handled at least 150 000 TEU. Our final dataset consist of 54 ports which have a total container throughput of 74 850 669 TEU in 2008.

The distance between the ports and the hinterland regions is measured over the road network (including the Calais-Dover link between the UK and France). If the distance is lower than 150km, the distance was set at 150km since it is common that transport rates have a fixed rate for local transport and a kilometre-based tariff if larger distances need to be covered. A side-effect is that this reduces measurement problems since region centroids often do not correspond with the real economic centres in a region. For regions near ports these biased measurements can influence distance-based accessibility measures.

## 2.2 Model

The aim of the present study is to explain how the market share of a port can be determined by its accessibility (equation 1).

$$\text{throughput}_{\text{port } i} = f(\text{accessibility}_{\text{port } i}) \quad (1)$$

### 2.2.1 Competition

Ports compete for the same hinterland and we need to correct the model for hinterland overlap. If several ports are located in the same region, throughput figures will be lower since competing ports handle part of the cargo. A simple way to take into account competition is (1) computing the market share of each port  $i$  in region  $k$  using an accessibility measure and (2) dividing the GDP of the region over all ports proportionate to this accessibility. However, this standardisation method assumes that €1 of GDP generates  $x$  TEU. In contrast, in what follows we assume that the further inland a region is located the less maritime traffic it generates. For similar reasons we cannot apply accessibility measures with competition as discussed by van Wee et al. (2001) since

in that approach the amount of jobs in a region is fixed while we allow that the amount of containers generated by a region depends on its accessibility. Therefore, instead of standardising the accessibility measure, a correction factor is added in equation 2.

$$\text{throughput} \times e^{\rho \text{ hinterlandoverlap}} = f(\text{accessibility}) \quad (2)$$

After taking logarithms this results in following model:

$$\log(\text{throughput}) = \beta_0 + \beta_1 \log(\text{accessibility}) - \rho \text{ hinterlandoverlap} \quad (3)$$

The hinterland overlap variable can be operationalised using a spatial weights matrix  $W$ . For each port pair  $ij$  the hinterland overlap is measured, resulting in a  $n \times n$  matrix  $W$  with  $n$  = the number of ports. The competition effect is then computed by multiplying  $W$  with the size of the other ports,  $y$ . The higher the level of hinterland overlap, the more TEUs a neighbouring port will ‘steal’ from the port under consideration, and the larger a neighbouring port is, the more TEUs it will take away. This type of model is better known as the spatial lag model (equation 4) (Anselin, 1988).

$$y = \beta_0 + \beta_1 x_1 + \rho W y \quad (4)$$

Our dependent variable  $y$  is the logarithm of container throughput in a port in 2008. As a next step we need to measure hinterland accessibility ( $x_1$  in equation 4) and to specify hinterland overlap in  $W$ . Spatial econometric models and their counterparts in network analysis are often criticised for the arbitrary nature of  $W$  (Leenders, 2002; Corrado and Fingleton, 2012). Section 2.2.3 discusses how the  $W$  is based on the concept of hinterland overlap. Furthermore, we will endogenously determine the exact specification of the hinterland overlap and the accessibility functions (Anselin, 2010; Corrado and Fingleton, 2012). The aim is that the model determines how ports compete for a shared hinterland.

### 2.2.2. Accessibility

There exists a wide range of accessibility measures and these are employed in a variety of studies (Geurs and van Wee, 2004; Song, 1996). We took only accessibility measures into account that include the size of the hinterland (measured in GDP) and distance. One of the most popular classes of accessibility indicators are gravity-based measures. Examples can be found in the work of Thill and Lim (Thill and Lim, 2010; Lim and Thill, 2008) who measure the accessibility of regions in the US taking into account intermodal freight transport networks and ports. In contrast with these studies, we focus on ports instead of regions. Applied to our case, the gravity function can be formalised as follows:

$$\text{accessibility}_i = \sum (\text{GDP}_k / \text{distance}_{i,k}^\lambda) \quad (i = \text{port}, k = \text{region}) \quad (5)$$

The GDP of a region divided by the distance to the port (to the power  $\lambda$ ) is a measure for the amount of cargo region  $k$  generates and receives for and from port  $i$ . In line with Newton's law of gravitation, the distance decay parameter  $\lambda$  is often set at 2. However, we will check whether other values of  $\lambda$  could improve the model fit of the model in equation 3. Besides the gravity model, Song (1996) tested several alternative accessibility functions and we test one other measure employed in this study that include hinterland size and distance (equation 6).

$$\text{accessibility}_i = \sum (\text{GDP}_k / e^{\lambda \text{distance}_{i,k}}) \quad (6)$$

### 2.2.3 Weights matrix

Section 2.2.1 described how the factor  $\rho W y$  is used as a control for competition. The weights matrix  $W$  gives values of hinterland overlap for each pair of ports. Note that on the diagonal  $\text{hinterlandoverlap}_{ii} = 0$ . Hinterland overlap is defined as the extent to which ports rely on the same regions for generating and attracting cargo. As a simple measure we take the correlation between the contributions of the regions to the accessibility of the ports.

$$\text{hinterlandoverlap}_{ij} = \text{correlation}((\text{GDP}_k / \text{distance}_{i,k}^\lambda), (\text{GDP}_k / \text{distance}_{j,k}^\lambda)) \quad (7)$$

(i, j = ports, k = region)

Further research can give near regions a higher weight in the measurement of the correlation, but the most remarkable fact is that the hinterland overlap measure is based on the accessibility measure. This is logic since the same thing lies at the basis of these two processes. The amount of cargo generated and attracted by regions depends on the level accessibility which at the same time determines to what extent ports compete for this cargo in the same hinterland. Since two independent variables are based on the same thing, we will check whether multicollinearity is present or not.

#### 2.2.4 Model strategy

The final model is equivalent to equations 3 and 4 and a dummy variable is added for three Mediterranean ports whose relative high throughput figures are determined by their seaside accessibility. These ports (Algeciras, Gao Tauro and Valencia) act as transshipment hubs and their size is not determined by their nearby hinterland.

$$\log(\text{throughput}_i) = \beta_0 + \beta_1 \log(\text{accessibility}_i) - \rho \text{ hinterlandoverlap}_i + \beta_2 \text{HubDummy} \quad (8)$$

with:

$$\text{accessibility}_i = \sum (\text{GDP}_k / \text{distance}_{i,k}^{\lambda}) \quad (9)$$

$$\text{or} \quad \text{accessibility}_i = \sum (\text{GDP}_k / e^{\lambda \text{distance}_{i,k}}) \quad (10)$$

In order to estimate the model, we need to determine  $\lambda$ . Here, the same strategy as applied by Song (1996) is followed. A grid search is used to search for the  $\lambda$  which maximises the loglikelihood of the final model.

### 3. Results

Table 1 shows the results of three regression models. The first two models use a gravity-based accessibility measure while the third model employs the accessibility indicator given in equation 10. In Model 2,  $W$  is not row standardised and we could not estimate a model with a non row standardised  $W$  for the second accessibility measure using the standard default values for the `sarlm` function in the R package `spdep` (Bivand et al. 2008; R Development Core Team, 2012; Bivand, 2012).

Table 1: Results of three regression models

	Model 1	Model 2	Model 3
Row standardised W	yes	no	yes
Accessibility measure	eq. 9	eq. 9	eq. 10
$\lambda$	4.2	3.9	0.011
$\rho$ (hinterland overlap)	-1.54 (p 0.35)	-0.0022 (p 0.73)	-12.54 (p 0.043)
$\beta_0$ (intercept)	38.05 (21.21)	18.27 (4.38)	176.71 (92.68)
$\beta_1$ (accessibility)	0.49 (0.15)	0.50 (0.17)	0.34 (0.11)
$\beta_2$ (hub dummy)	2.47 (0.63)	2.54 (0.66)	1.81 (0.58)
loglikelihood	-76.81	-77.17	-75.15
Breusch-Pagan	9.98 (p 0.0068)	10.35 (p 0.0057)	9.61 (p 0.0082)
Correlation (accessibility, hinterland overlap)	0.47	0.11	-0.15

*Notes:* dependent variable: log(TEU2008); n = 54; values between brackets are standard errors or p-values (indicated with a 'p'). Software: R, package spdep (Bivand et al. ,2008; Bivand, 2012; R Development Core Team, 2012)

The values for  $\lambda$  were obtained after a grid search. Figures 4 to 6 show how this parameter changes the loglikelihood of the regression models. The (local) maxima were used to compute the accessibility variable and  $W$ .

The estimates have the expected signs, the higher the level of accessibility ( $\beta_1$ ) the more container throughput in a port. The presence of nearby (especially) large ports reduces the amount of containers shipped via the port ( $\rho$ ), and the transshipment hubs in the Mediterranean have higher levels of throughput than can be explained by their hinterland accessibility ( $\beta_2$ ). Multicollinearity is not an issue given the relative low correlation coefficients between the accessibility and hinterland overlap variables which are much below the 0.8 threshold of serious multicollinearity problems (Gujarati, 2004, p.359).

The main problem seems to be heteroskedasticity given the results for the Breusch-Pagan test. Concretely, the model systematically overestimates the throughput of large ports and underestimates the size of smaller ones as can be seen in Figure 7. This effect is not removed by adding e.g. a dummy variable for the four largest ports, removing variables or employing alternatives for the logarithmic transformation of the dependent variable. A spatial Durbin model

seems to solve the heteroskedasticity problem (Table 2). However, from a content point of view this might be hard to interpret. Future research will explore whether the scaling of variables and other adaptations can solve the problem. Note that the sample size is relatively small ( $n = 54$ ). Overall, the results of the model are promising as can be seen in Figure 8. The resulting ranking of ports corresponds well with the real-life situation.

Table 2: Results of the Spatial Durbin Model

Row standardised W	yes
Accessibility measure	eq. 10
$\lambda$	0.011
$\rho$ (hinterland overlap)	-16.26 (p 0.027)
$\beta_0$ (intercept)	-578.02 (387.79)
$\beta_1$ (accessibility)	1.41 (0.50)
$\beta_2$ (hub dummy)	0.46 (4.34)
lag (accessibility)	72.64 (30.85)
lag (hub dummy)	-53.80 (230.11)
loglikelihood	-72.12
Breusch-Pagan	6.19 (p 0.19)

*Notes:* dependent variable:  $\log(\text{TEU2008})$ ;  $n = 54$ ; values between brackets are standard errors or p-values (indicated with a 'p'). Software: R, package spdep (Bivand et al. ,2008; Bivand, 2012; R Development Core Team, 2012)

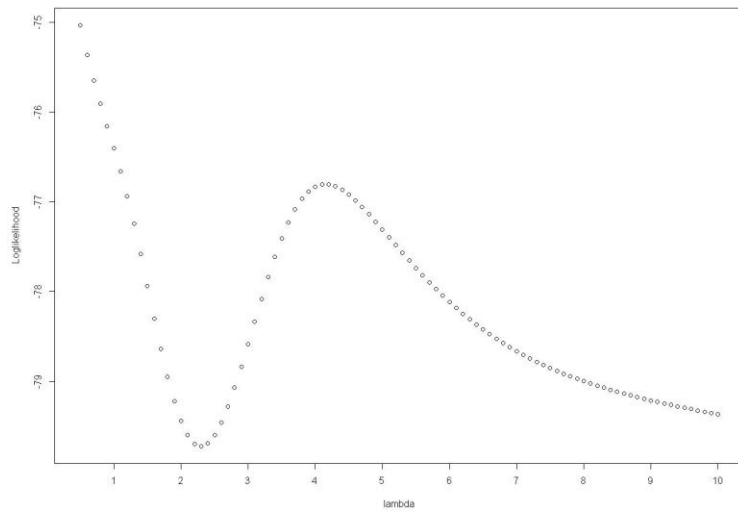


Figure 4:  
loglikelihood with  
varying values of  
lambda, accessibility  
measure: eq. 9, row  
standardised

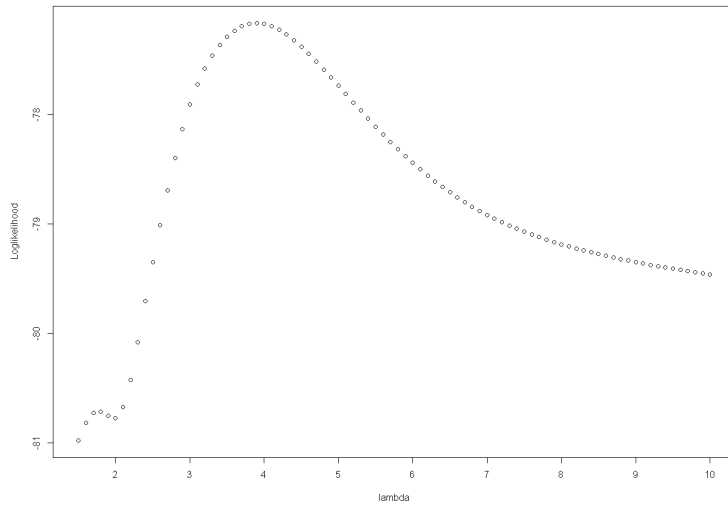


Figure 5:  
loglikelihood with  
varying values of  
lambda, accessibility  
measure: eq. 9, non  
row standardised

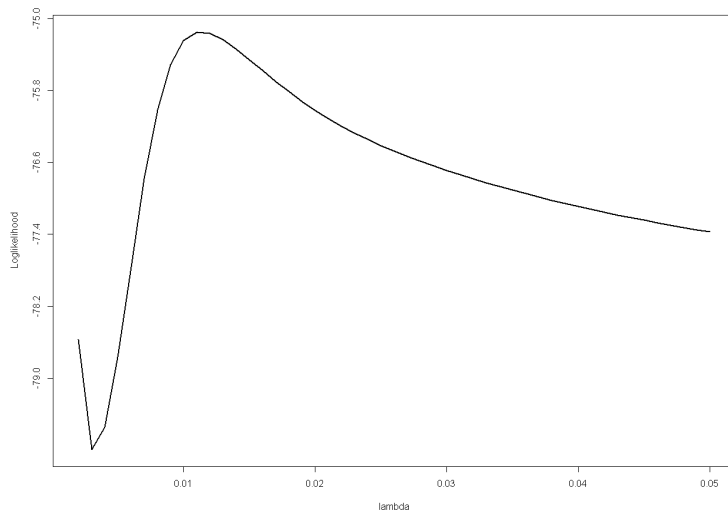


Figure 6:  
loglikelihood with  
varying values of  
lambda, accessibility  
measure: eq. 10, row  
standardised

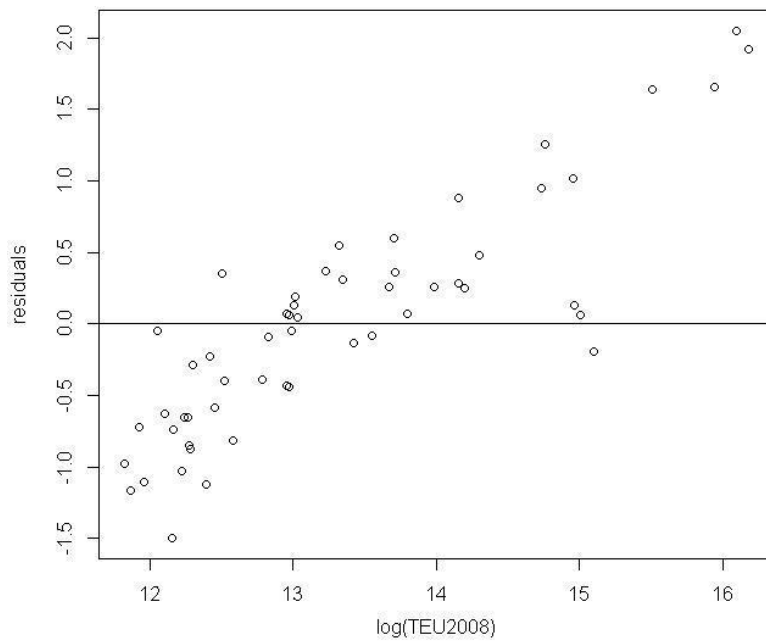


Figure 7: plot of Model 3 residuals versus dependent variable showing heteroskedasticity.

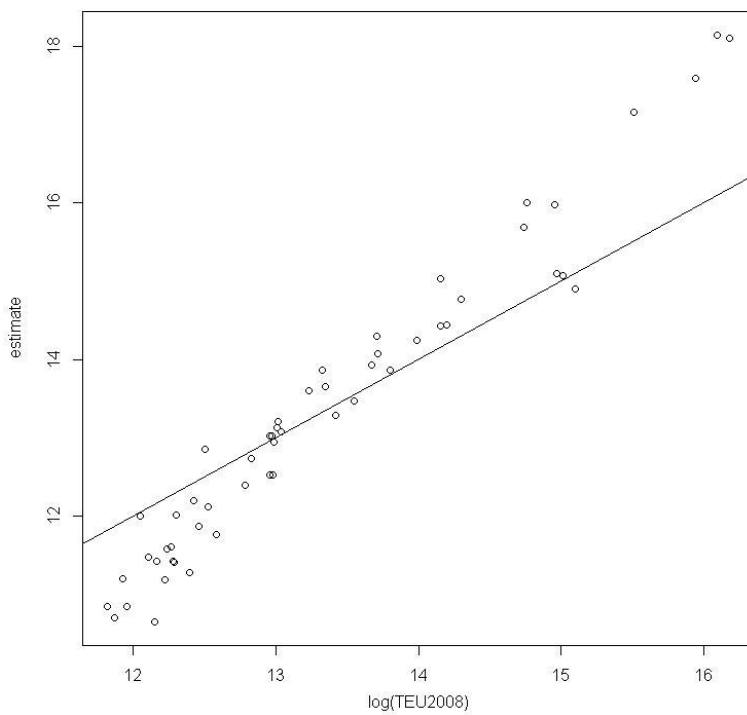


Figure 8: plot of dependent variable and values estimated by Model 3 (with 45° line)

#### 4. Discussion

The present study attempts to measure the relationship between port size and hinterland accessibility. This relationship is often mentioned, but seldom measured. In our model, we controlled for competition between ports with overlapping hinterlands. Accordingly, the analysis allows to operationalise the concept of hinterland overlap. In this way, the paper can contribute to the debate on port competition (Meersman et al. 2010; Notteboom, 2009; Heaver et al. 2001).

Figures 9 and 10 show the hinterland overlap between adjacent ports and for a selected number of non-adjacent but nearby ports like Venice and Genova. These maps are based on the  $W$  matrix employed in Model 3, the non row standardised and row standardised  $W$  variant, respectively. Unsurprisingly, high levels of port competition can be found in northern Italy, the Low Countries, the UK, the Baltic states and the south of Finland. Note that measures for Dunkirk are less reliable since we detected irregularities with the distance measurements which we plan to solve in the future.

Although the model explains port size using a model with a limited number of variables, several issues deserves further attention.

- The heteroskedasticity problem remains an issue. Applying alternative estimators, suitable for small sample sizes ( $n = 54$ ), is one direction. However, the addition or reformulation of variables might have an impact too.

- The logarithmic transformation of our dependent and accessibility variable can influence the results since large ports weight relative less than small ports. In the trade literature, taking the logarithm of gravity-based functions is criticised (Silva and Tenreyro, 2006; Burger et al. 2009). Accordingly, alternative models can be explored.

- The sea-side of maritime transport is largely ignored. We added a dummy variable for three ports that act as transshipment hubs due to their maritime accessibility, but more precise measurements of maritime accessibility and transshipment can be included.

-We only included hinterland transport via the road network. However, barge and rail transport are important too (Rodrigue and Notteboom, 2010; Rodrigue et al. 2010; Roso, 2007; Roso et al. 2009). For instance, the river Rhine makes that ports in the Rhine Scheldt Delta have higher levels of accessibility. Moreover, regions with a connection to the Rhine (or other major rivers) will generate more maritime traffic than expected.

-There is a two-way causality between accessibility to ports, port size and the size of a regional economy. In the present paper, the analysis is static with port size as dependent variable and hinterland accessibility (which is a function of region size) as independent variable. However, the size of regions is partly determined by the connections with ports. Furthermore, port-rich regions might benefit from agglomeration economies, resulting in higher levels of throughput.

-Large ports are different things than small ports since they have larger catchment areas. As a result, it might be interesting to take into account port size when determining the distance decay parameter.

## **5. Conclusion**

Port competition and concentration in the container port system are well-studied topics. The role of hinterland accessibility is often mentioned, but seldom measured. This paper presents a model which explains the size of large European ports as a function of hinterland accessibility and hinterland overlap (competition). The results are promising but some issues need to be resolved.

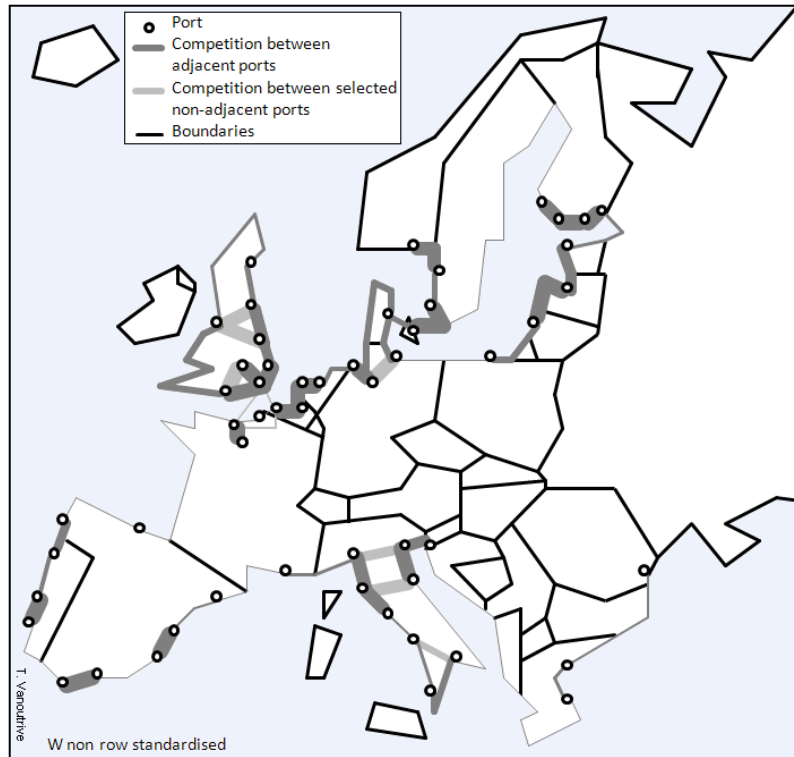


Figure 9: Map illustrating hinterland overlap between European ports (non row standardised W)

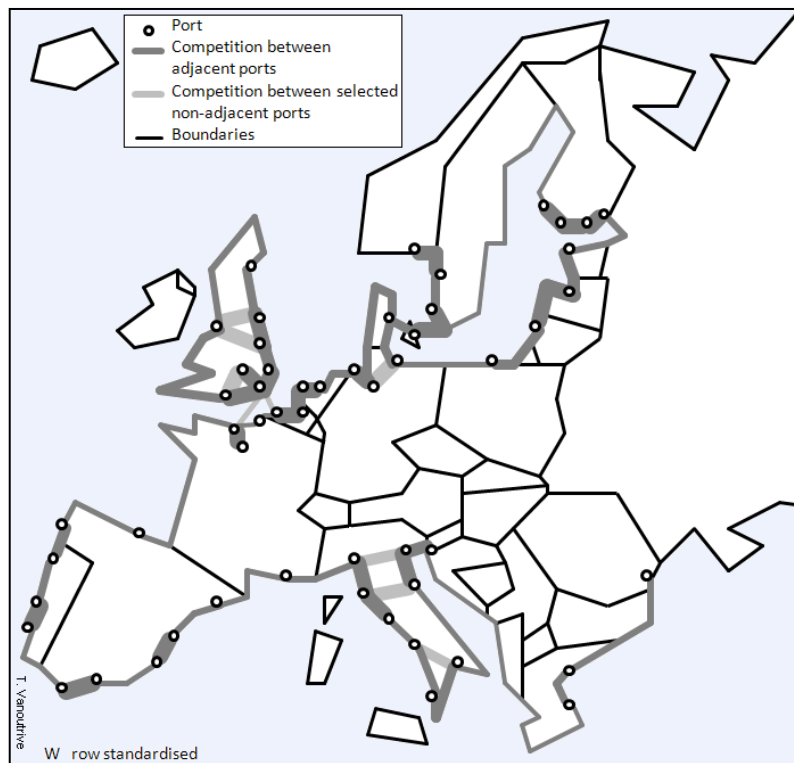


Figure 10: Map illustrating hinterland overlap between European ports (row standardised W)

## Acknowledgements

Part of this research was funded by the Antwerp Port Authority in the framework of a general agreement between the Antwerp Port Authority and the University of Antwerp. We are indebted to Jeroen Cant for his assistance with the distance measurements.

## References

- Anselin, L., 1988. Spatial econometrics: Methods and models Kluwer Academic Publishers, Dordrecht.
- Anselin, L., 2010. Thirty years of spatial econometrics. *Papers in Regional Science* 89, 3-25.
- Armstrong, H. and Taylor, J., 2000. Regional Economics and Policy Blackwell Publishers, Oxford.
- Bird, J., 1967. Seaports and the European Economic Community. *The Geographical Journal* 133, 302-322.
- Bivand, R., 2012. spdep: Spatial dependence: weighting schemes, statistics and models. R package version 0.5-46.
- Bivand, R.S., Pebesma, E.J., and Gómez-Rubio, V., 2008. Applied Spatial Data Analysis with R. Springer, New York.
- Burger, M., van Oort, F., and Linders, G.J., 2009. On the Specification of the Gravity Model of Trade: Zeros, Excess Zeros and Zero-inflated Estimation. *Spatial Economic Analysis* 4, 167-190.
- Capelli, A. and Libardo, A., 2011. Greening ports and logistics. *Proceedings of the Greenports Conference 2011 Venice*
- Chapelon, L., 2007. L'accessibilité, marqueur des inégalités de rayonnement des villes portuaires en Europe. *Cybergeographie : European Journal of Geography, Systèmes, Modélisation, Géostatistiques* article 345.
- Corrado, L. and Fingleton, B., 2012. Where is the Economics in Spatial Econometrics? *Journal of Regional Science* 52, 210-239.
- European Commission, 2011. WHITE PAPER Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system COM(2011) 144 final. Brussels.
- Geurs, K.T. and van Wee, B., 2004. Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography* 12, 127-140.
- Gujarati, D.N., 2004. Basic Econometrics 4 ed. McGraw-Hill, New York.
- Heaver, T., Meersman, H., and Van de Voorde, E., 2001. Co-operation and competition in international container transport: strategies for ports. *Maritime Policy & Management* 28, 293-305.
- Janssens, S., Meersman, H., and Van De Voorde, E., 2003. Port throughput and international trade: have port authorities any degrees of freedom left? in: Loyen, R., Buyst, E., and Devos, G. (Eds.), *Struggling for Leadership: Antwerp-Rotterdam Port Competition between 1870-2000* Physica-Verlag, Heidelberg, pp. 91-113.
- Leenders, R.T.A.J., 2002. Modeling social influence through network autocorrelation: constructing the weight matrix. *Social Networks* 24, 21-47.

- Lim, H.W. and Thill, J.C., 2008. Intermodal freight transportation and regional accessibility in the United States. *Environment and Planning A* 40, 2006-2025.
- Meersman, H., 2010. Applications of forecasting methods in the port and maritime sector. in: Van De Voorde, E. and Vanelander, T. (Eds.), *Applied Transport Economics - a management and policy perspective de boeck*, Antwerp, pp. 496-520.
- Meersman, H. and Van De Voorde, E., 2008. The Relationship between Economic Activity and Freight Transport. in: Ben-Akiva, M., Meersman, H., and Van De Voorde, E. (Eds.), *Recent Developments in Transport Modelling- Lessons for the Freight Sector Emerald*, Bingley, UK, pp. 69-92.
- Meersman, H., Van De Voorde, E., and Vanelander, T., 2010. Port competition revisited. *Review of business and economics* 55, 210-232.
- Notteboom, T., 1997. Concentration and load centre development in the European container port system. *Journal of Transport Geography* 5, 99-115.
- Notteboom, T.E., 2009. Complementarity and substitutability among adjacent gateway ports. *Environment and Planning A* 41, 743-762.
- Notteboom, T.E., 2010. Concentration and the formation of multi-port gateway regions in the European container port system: an update. *Journal of Transport Geography* 18, 567-583.
- Notteboom, T.E. and Rodrigue, J.P., 2005. Port regionalization: towards a new phase in port development. *Maritime Policy & Management* 32, 297-313.
- R Development Core Team, 2012. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria
- Rodrigue, J.P., Debie, J., Fremont, A., and Gouvernal, E., 2010. Functions and actors of inland ports: European and North American dynamics. *Journal of Transport Geography* 18, 519-529.
- Rodrigue, J.P. and Notteboom, T., 2010. Comparative North American and European gateway logistics: the regionalism of freight distribution. *Journal of Transport Geography* 18, 497-507.
- Roso, V., 2007. Evaluation of the dry port concept from an environmental perspective: A note. *Transportation Research Part D-Transport and Environment* 12, 523-527.
- Roso, V., Woxenius, J., and Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. *Journal of Transport Geography* 17, 338-345.
- Silva, J.M.C.S. and Tenreiro, S., 2006. The log of gravity. *Review of Economics and Statistics* 88, 641-658.
- Song, S., 1996. Some Tests of Alternative Accessibility Measures: A Population Density Approach. *Land Economics* 72, 474-482.
- Thill, J.C. and Lim, H., 2010. Intermodal containerized shipping in foreign trade and regional accessibility advantages. *Journal of Transport Geography* 18, 530-547.
- van Wee, B., Hagoort, M., and Annema, J.A., 2001. Accessibility measures with competition. *Journal of Transport Geography* 9, 199-208.