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NORTH-SOUTH CONTAINER PORT COMPETITION IN EUROPE: THE EFFECT OF CHANGING ENVIRONMENTAL POLICY

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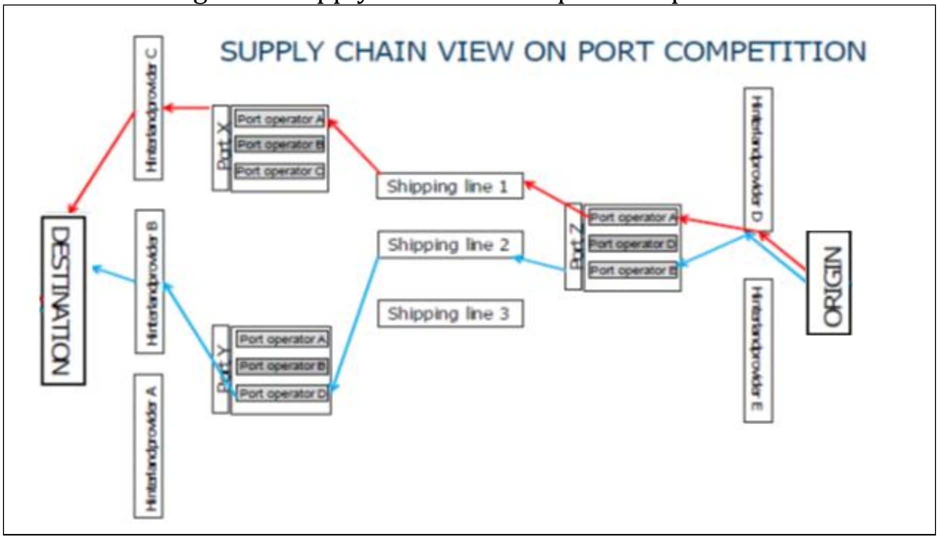
ABSTRACT: This article examines environmental policy impacts on competition between the European container ports in the Hamburg – Le Havre range on the one hand and the Mediterranean ports on the other. More in particular, two scenarios are considered: the internalisation of external cost on the European hinterland and the establishment of an Sulphur Emission Control Area (SECA) in the North Sea region. Geographically, applications are made for container loops from both Asia and South America to Europe. A total chain model is applied that incorporates the maritime, port and hinterland legs of the supply chain. The calculations show that the effects of either policy option would not significantly impact on the theoretical captive hinterland of respectively the Hamburg – Le Havre range and the ports of the Mediterranean, as the effects measured are smaller than the error margin of the model applied. Additionally, it is found that the impacts of the two policy options on competition between ports in the Hamburg – Le Havre range and the Mediterranean ports would differ for the two containers loops considered.

Keywords: external costs, internalisation, (S)ECA zone, port competitiveness, chain cost

1 RATIONALE AND SETTING

The underlying assumption in port competition analysis used to be that ports essentially vie among each other. More recently, however, port competition has come to be seen as unfolding between logistics chains, in which ports are merely links. These chains have an origin in a hinterland region, from where goods are moved to a port by a hinterland transport company. Next, a shipping line carries the cargo to another port. And in the final leg of the journey, the freight is again transported to its final destination by a hinterland operator (Meersman et al, 2010). These consecutive movements are illustrated schematically in Figure 1, where the chain with the lowest generalised cost will emerge as the most successful chain.

Figure 1. Supply chain view on port competition



Source: Meersman and Van de Voorde (2012)

This means that several chains can serve the same hinterland destination. For instance, a chain originating in Asia and with a European hinterland destination could include an Asian port, say Hong Kong, and a European port in either the Hamburg - Le Havre range or in the Mediterranean.

The main advantage of the Northern European ports is their strong historical position, which has allowed them to build a solid reputation and attract substantial cargo flows. Also, these ports were quicker to accommodate the largest vessels (more than 19,000 TEU in 2015). In the Mediterranean ports, draught restrictions have only recently been removed. Today, some Mediterranean ports can also accommodate these largest container vessels.

Table 1 gives an overview of the number of services of container shipping line CMA-CGM on the Asia - Europe and Southern America – Europe trade lanes. There is no complete set of data available for Maersk and MSC. Hence, the calculations are based on CMA-CGM data only.

Table 1: Overview of number of loops serving Europe from Asia and South America in 2015

		Number of loops	Number of ships	Average ship size (TEU)
Asia - EU	via Hamburg - Le Havre	8	75	14,500
	via Mediterranean ports	6	70	7,600
Southern America - EU	via Hamburg - Le Havre	3	21	6,000
	via Mediterranean ports	1	8	5,600

Source: Based on data from CMA-CGM (2015)

This overview also shows the average ship size that is deployed on those loops. On the basis of Table 1, one may conclude that the trade lane between Asia and Europe is characterised by strongly varying ship size depending on whether the loops incorporate Northern or Southern European ports. The larger ships tend to call at ports in the Hamburg – Le Havre range, the smaller ones at ports in the Mediterranean. It is also apparent that larger vessels are deployed on the routes from Asia to Europe than on the trade lane connecting Southern America and Europe.

To reach Europe from Asia via the Mediterranean ports, one option is to operate smaller container ships (7,600 TEU on average) calling directly at the port concerned. The fact that vessels deployed in the Mediterranean region tend to be smaller is in part due to draft restrictions at some of these ports. However, some of the Spanish (Valencia, Barcelona and Algeciras), French (Marseille FOS) and Italian (Genoa) ports are able to accommodate large container vessels. Here, the deployment of smaller vessel sizes reflects a strategic choice on the part of the container shipping companies (due to smaller transport volumes). An alternative option is to sail 17,000 TEU vessels via the Hamburg – Le Havre range and to tranship containers via Marsaxlokk (Malta) onto 2,200 TEU feeder vessel serving the ports of Southern Europe. On the loops from Southern America to Europe via the Hamburg – Le Havre range, ships of 6,000 TEU are typically deployed. Similar ship sizes are used on loops from Southern America to Europe via the Mediterranean.

This paper examines the impact of two policy scenarios on the competitiveness of container ports in the Hamburg - Le Havre range and the ports of Southern Europe:

- The internalisation of external costs in the hinterland.
- The introduction of an Sulphur Emission Control Area (SECA) in the North Sea.

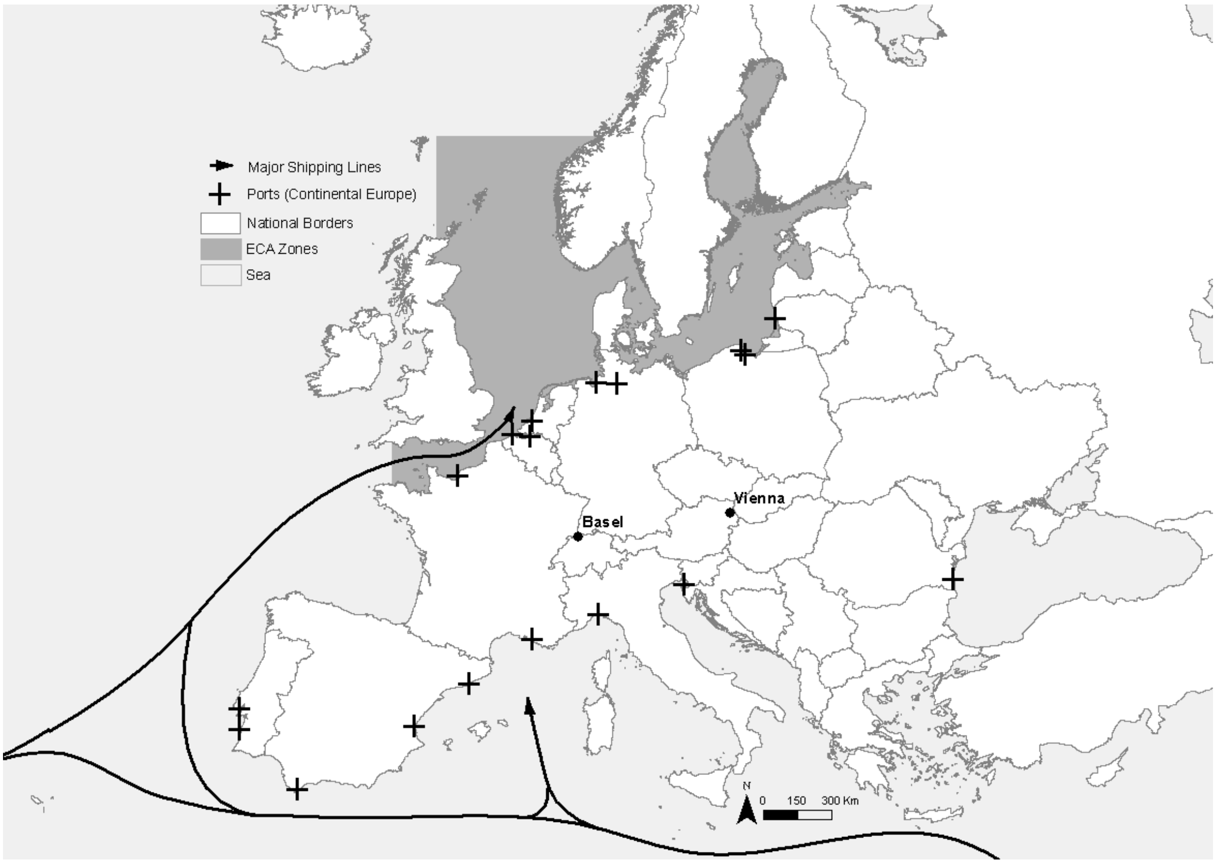
The analysis takes into account the maritime aspects of ship size and shipping distances, port characteristics such as physical dimensions, port dues, pilotage, handling cost etc., as well as road, inland waterway and rail connections between port and hinterland. Different total logistics chain analyses are performed whereby we calculate how the relative competitive positions of the ports in the Hamburg – Le Havre range and in the Mediterranean changes and which ports are affected most strongly by the aforementioned scenarios.

Competition between the ports in the two regions is considered for two existing container loops:

- From Asia to Europe via the ports in the Hamburg – Le Havre range (with a 17,500 TEU ship) on the one hand and via the Mediterranean ports (with a 9,600 TEU ship) on the other.
- From Southern America to Europe via the ports in the Hamburg – Le Havre range (with a 6,000 TEU ship) on the one hand and via the Mediterranean ports (with a 6,000 TEU ship) on the other.

Figure 2 represents the European leg of the two container loops analysed for both alternatives. It also highlights two origins/ destinations, Basel and Vienna, which are used in the detailed generalised chain cost calculations in the next sections. These cities were selected for the analysis because of their location in a key hinterland area, where most North-European port authorities indicate there is a strong competition between the ports in the Hamburg – Le Havre range and the Mediterranean ports.

Figure 2: Overview of the two container loops and scenarios considered



Source: own composition

In order to quantify the cost-competitiveness of the different chains that run via the ports in the Hamburg – Le Havre range or via the Mediterranean ports, a model is applied that allows one to calculate the total generalised chain costs for different container loops. This model, which was first developed in van Hassel et al. (2015a), incorporates the entire supply chain, including maritime transport, the port process and hinterland transport. To account for the uncertainty in respect of the impact of some of the input parameters on the model outcome, we also perform sensitivity analyses.

This paper is structured as follows. First, section 2 presents a literature review. Section 3 elaborates on the updated chain model, which allows one to calculate the generalised cost of several chains, and on its extensions. In section 4, the model is applied to two container loops (Asia- Europe and Southern America - Europe). In section 5, sensitivity analysis is performed in order to assess the impact of some of the main input parameters of the model applied. Finally, in section 6, conclusions are drawn and contributions to scholarly knowledge and managerial practice identified.

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And an entry	1	2
And another entry	3	4
And another entry	5	6

2 LITERATURE REVIEW

Much research has been conducted on the question of port competition. Aronietis et al. (2011) presented an extensive literature review in which they identify the port choice decision-makers as the shippers, forwarders, shipping companies and terminal operators. The authors found that shippers, forwarders and shipping companies are instrumental in determining which port is used for the movement of goods in the short and medium terms. Terminal operators, on the other hand, tend to approach choice of port as a long-term decision, considering the associated level of investment in superstructure (e.g. offices, warehouses, workshops) and terminal equipment (e.g. cranes, conveyor belts).

According to Arionietis et al. (2011), the most commonly cited criteria among shippers (in descending order of citation frequency) are cost, port operations quality/reputation and port location. Others include shipping services, speed/time, efficiency, port facilities/infrastructure, port information system, intermodal/hinterland connections, port congestion, port services and flexibility (for special cargo). The crucial criteria according to forwarders are efficiency and port operation quality/reputation. Less-cited factors are cost, frequency, location, speed/time, port information systems and intermodal/hinterland connections. For shipping companies, the key criteria are cost, location, port facilities/infrastructure and port operations quality/reputation. Secondary criteria include speed/time, efficiency, congestion in port, frequency of shipping service, intermodal/hinterland links, port information systems, information availability, port administration, port services and flexibility for special cargo. (Aronietis et al., 2011)

NEA (2011) looked into the observation that the ports of Northern Europe achieve around four times the container throughput of the top eleven ports competing along Europe's Southern coastline. In their study, they focus on the trade from Asia to Europe, as it accounts for 43% of the total container transport to Europe (NEA, 2011). In addition, NEA studied the effect on that specific loop of internalising external costs. It was found that the impact on the container distribution between the ports in Northern and Southern Europe is rather small. In the present research, we also look at the impact of introducing an SECA in the North Sea and we consider an alternative loop (Southern America to Europe), as a benchmark for the results obtained for the Asia-Europe loop.

One of the most commonly heard arguments for shifting traffic from the ports in the Hamburg - Le Havre range to ports in the Mediterranean is that such shift would be beneficial to the environment, since ships that sail via the Suez Canal do not need to make a detour around the Iberian peninsula (Capelli and Libardo, 2011). In this North-South debate, the port authorities of Northern European ports have tried to convince the European Commission and others that the current pattern is induced by economic reality (higher concentration of GDP and population densities in the regions near the Northern European ports of Antwerp, Hamburg and Rotterdam), while their Southern European counterparts maintain that a shift to Southern Europe is inevitable, as it would be beneficial from an ecological and economic perspective (e.g. Barcelona with its strategic location and connections). (Vanoutrive, 2011)

Francesetti (2005) compared the competitive position of ports in Italy with that of ports in the Hamburg – Le Havre range. This study considered ships of 4,000 and 6,500 TEU, and, in terms of hinterland transport modes, it was restricted to road haulage and rail transport. It found that the Italian ports are able to serve a large part of the European hinterland thanks to their competitive geographic location.

The Mediterranean ports have tried to use their crucial position on the Asia - Europe trades to attract larger throughput. Some have not been particularly successful in attaining this goal, for various reasons. The Port of Barcelona, for example, has met with setbacks in certain infrastructure projects, while the port of Marseille has been paralysed by industrial action on more than one occasion. The INTERMED initiative, involving the ports of Barcelona, Marseille and Genoa and aimed at boosting the participating ports' market shares through capacity increases and logistics developments, has not moved as quickly as planned. The project intends to counter the rail connectivity problems between France and Spain and the exclusion of Marseille's connectivity from the latest TEN-T schemes - which might also face liquidity problems and delay in the wake of the ongoing financial crisis. This delay might change in the future, as improved rail connectivity (e.g. BarceLyon Express) and the development of new transport chains at the operational level are high on the agenda. The role of the selected Southern European ports in achieving sustainable and more efficient logistics may be fourfold: (1) reduction in navigation days and CO_2 and NO_x emissions (e.g. an emissions reduction of up to about 15% on the Far East - Europe route), (2) reduction in congestion in Northern European infrastructures, (3) taking advantage of the Mediterranean and North African economic potential, and (4) a reduction in logistics costs (Ruá, 2012; Sys et al., 2015)

The first scenario in our analysis concerns the policy option of internalising the external costs of European hinterland transport. Quite an extensive body of literature is available on this topic too. In what follows, we briefly consider the contributions on which we relied on the most in the present research.

According to Blauwens et al. (2012), the main cost components of the external costs are: congestion, infrastructure, environmental (air quality, climate and noise) and accidents.

For the monetary values of the external costs for land modes, we rely on research by Maibach et al. (2008). This study provides an overview of the monetary values for the relevant external cost items for road, rail and inland waterway transport.

The second policy scenario to be analysed in the present study is the introduction of an SECA in the North Sea. The purpose of SECAs is to contribute to the reduction of sulphur emissions in coastal areas (Sys et al., 2015). Shipowners operating in an SECA face increased operating costs due to the stringent regulation in ports, and they must also familiarise themselves with available options for complying with regulation (Acciaro, 2014). Obviously such an increase in North Sea operating costs may impact the competitiveness of the ports in the Hamburg – Le Havre range as compared to their counterparts in the Mediterranean.

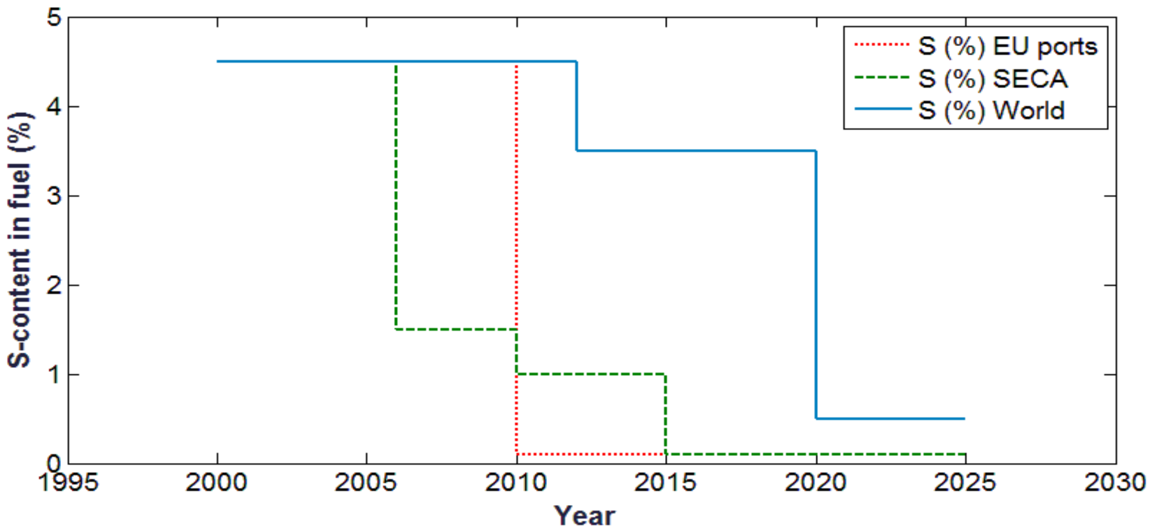
The International Maritime Organisation (IMO) and national governments[1] have accelerated their environmental efforts in international shipping by developing an extensive legislative playing field. The strong correlation between sulphur emissions in maritime exhausts and acid rain on the one hand and public health on the other is undoubtedly one of the driving forces behind this strategy. In 2008, the IMO directed the first revision of the International Convention for the Prevention of Pollution From Ships (MARPOL Annex VI), which put in place a substantial policy package towards a stepwise worldwide reduction in SO_x and NO_x emissions (IMO,2008). After the revision of MARPOL annex VI, the focus moved to the long-standing issue of CO_2 reduction and the optimisation of shipping efficiency (see for instance Aronietis et al., 2014; Stevens et al., 2014). The requirements of a reduction in SO_x and NO_x also triggered the development of other guidelines, such as the code for gas-fuelled ships, the International Code

[1] European Commission (2013) for instance states that "The Commission's 2011 White Paper on transport suggests that the EU's CO2 emissions from maritime transport should be cut by at least 40% off 2005 levels by 2050, and if feasible by 50%. However, international shipping is not covered by the EU's current emissions reduction target".

for Ships Using Gases or Other Low-Flashpoint Fuels or IGF code and guidelines for scrubbers. The package as a whole compels the shipping industry to search for new business models and aims at providing environmental benefit and health gains. (Sys et al., 2015)

By the introduction of the North Sea SECA, the maximum permitted amount of sulphur content will be reduced to 0.1%. The timescale for this reduction is given in Figure 3.

Figure 3 – Timing of sulphur regulation



Source: Clean North Sea Shipping, 2009

Figure 3 shows that sulphur content will be reduced to 0.1% by 2015 in the Sulphur Emission control Area (SECA) in the North Sea, and that, globally, sulphur content will be reduced to 0.5% by 2020, though an extension of this timeline to 2025 is likely.

At the North Sea, no additional NO_x limit is set other than the requirement for the Tier II diesel engines installed on ships built from 2011 onwards. The further requirement for Tier III diesel engines will, at this stage, only apply to diesel engines installed at ships built from 2016 onwards and for those ships that are operating in an ECA (IMO, 2016). At this stage the only NO_x control area is in the coastal waters of the United States and Canada.

There are several available strategies to overcome the impacts of the introduction of an ECA, such as installing LNG propulsion, scrubbers or using low-sulphur fuel (Stevens et al., 2014). Aronietis et al. (2014) have demonstrated that shipowners are willing to invest in such technologies for improved economic and/or energetic performance. Speed reduction and using low-sulphur fuel have been shown to substantially outperform all other tested technologies. In Yang et al. (2012), it was also concluded that the most cost-effective way of reducing the SO_x (and PM10) emissions is to use the bi-fuel option. Lindstad et al. (2015) find that there is no unanimous answer to the question of what is the best abatement option from an operational cost perspective, but rather that the best option depends on engine size, annual fuel consumption in the ECA and anticipated future fuel prices. Jiang et al. (2014) show that both sulphur scrubbers and marine gas oil are two promising alternatives for shipowners. However, their economic comparisons are primarily based on a private perspective, whereas the socio-economic outcome depends strongly on fuel prices. Brynolf et al. (2014) make an analysis from an emission performance point of view, and find that none of the three alternatives considered will significantly reduce the lifecycle impact on climate change compared to heavy fuel oil (HFO). In Acciaro (2014), an analysis is made with respect to the implementation of LNG propulsion. The author concludes that, due to the great uncertainty involved, the best option is to delay investment in LNG propulsion.

In Yang et al (2012), selective catalytic reduction and the humid air motor are considered the most powerful techniques in reduction of the NOx emission, while continuous water injection is identified as the best option at this moment when cost-related concerns are taken into account. In the present analysis, in order to deal with the establishment of an SECA in the North Sea, ships are assumed to use Marine diesel oil (MDO) when operating inside the SECA and HFO when operating outside it. The effect of using Tier II diesel engines is not taken in to account because this requirement is needed for all ships regardless of the sailing area.

In section 3, an overview is given of the model applied to test both scenarios.

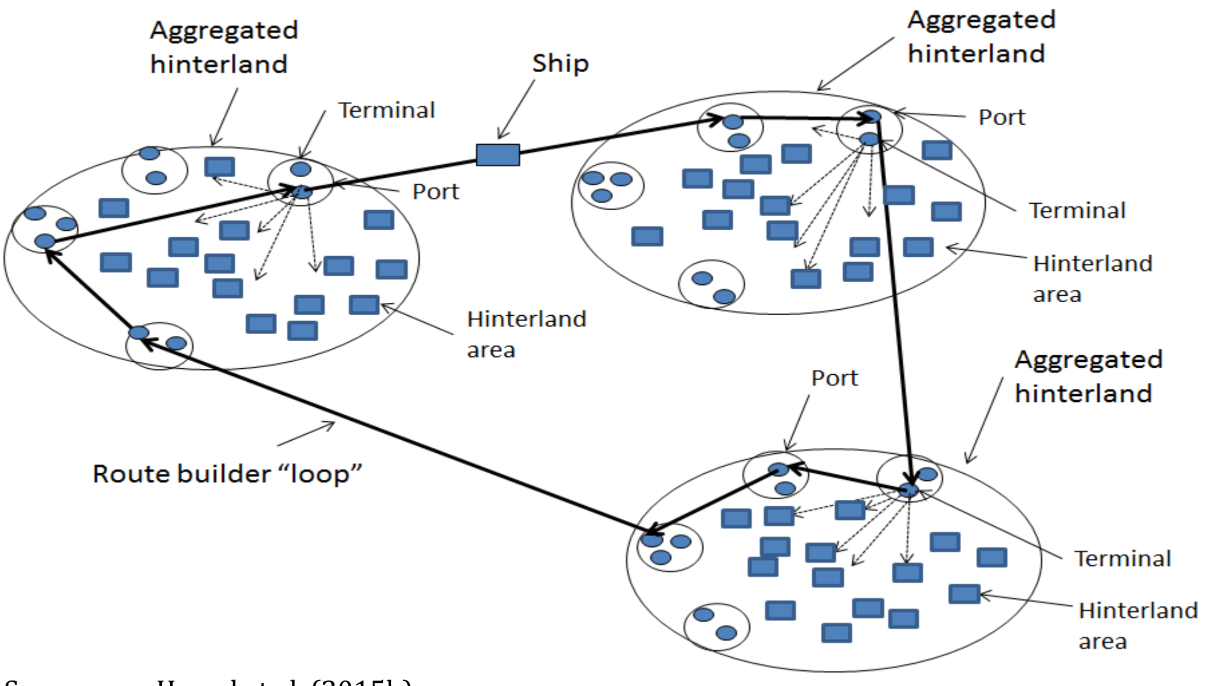
3 METHODOLOGY AND MODELLING APPROACH

This section elaborates on the original model proposed in van Hassel et al (2015b) and how it was adapted and updated in order to deal with the specific research questions addressed in the present paper. First, we provide a brief overview of the model and the desired input parameters. Subsequently, we look at some of the adaptations.

3.1 *Overview of the basic methodology*

In this section, a brief overview is provided of the main model components (see also van Hassel et al., 2015a and b for a more detailed description). The purpose of the proposed model[2] was to allow calculation of the generalised chain cost from a selected point of origin, via a predefined container loop, to a destination point. In order to calculate the chain cost, first a container loop has to be specified. A loop is defined as a circular ship route between ports (hence it has neither a beginning nor an end). Such a loop encompasses the maritime leg of the supply chain. Figure 4 provides a general overview of the model developed (van Hassel et al 2015b).

Figure 4. Structure of the chain model



Source: van Hassel et al. (2015b)

[2] The model was coded in C# and uses Microsoft Excel (data) and JMP11 (maps) as output formats.

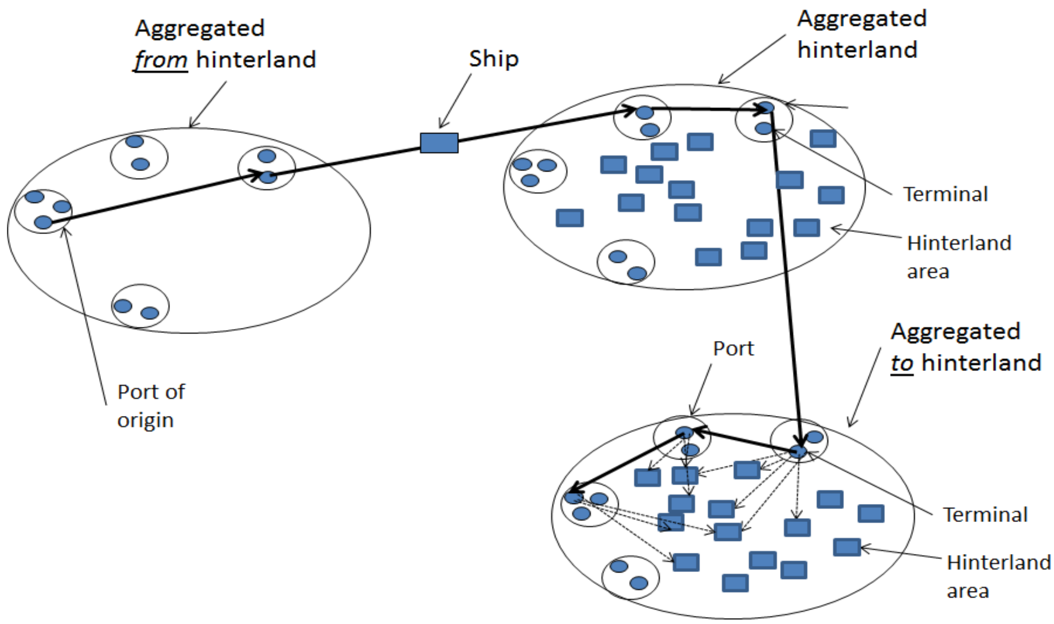
A choice was made to use the generalised cost approach in order to determine the captive hinterland of a port in a container loop. The calculated captive hinterland of a port is therefore a first theoretical approximation. The shipper's choice or preferences are influenced by many more parameters than just the generalised cost. These include aspects such as reliability, service, flexibility and port information system quality (see section 2), which are harder to quantify. However with the proposed model, the most important decision criteria for shippers, forwarders and shipping companies are incorporated into the research. These are: cost (maritime, port and hinterland), port infrastructure (container cranes allowable drafts, quay wall length) and port location. Therefore, the first approximation of the hinterland distribution can be calculated using this model. The proposed methodology provides a first insight into the likely policy impact on the theoretical division of the European hinterland between the ports of the North and those of the South.

In the model, different aggregated hinterlands are connected via a route along ports (bold lines). The aggregated hinterlands are defined as a summation of different smaller geographical areas, which in Europe correspond to NUTS-2 areas (NUTS-2 areas have usually the size of a province in one of the European Member States). Each aggregated hinterland is served by at least one and usually several ports. Each port is comprised of a set of terminals, all of which have their own set of characteristics. From each port terminal, the hinterland distances via road, rail and inland waterways (if applicable) are incorporated into the model. (van Hassel et al 2015b)

A chain is defined as a route from a hinterland area in a specific aggregated hinterland to another hinterland area in another aggregated hinterland. A chain therefore has a beginning and an end. In order to calculate the chain cost from a point a origin to a destination point, the model must not only calculate the total cost of the ship, but it must also incorporate the cost of transporting a container from a hinterland area to a port at both ends of the chain, the cost of a container in the port phase (port dues, pilotage, container handling, etc.) on both chain sides, and the cost of transporting by sea the container from the port of loading to a port of unloading. (van Hassel et al 2015b)

Figure 5 provides an overview of a chain calculation according to the model. At this stage, the aggregated hinterlands are not fully developed yet.

Figure 5. Definition of a chain in the model



Source: van Hassel et al. (2015b)

In the example of Figure 5, the aggregated hinterland on the left has no hinterland areas. Therefore, it is not possible to select a point of origin in the hinterland. In order to overcome this problem, a port, in that specific aggregated hinterland, can be chosen as a point of origin. The aggregated hinterland in which the origin of the chain is situated is called the aggregated *from*-hinterland, whereas the hinterland where the end of the chain is located is referred to as the aggregated *to*-hinterland. If an aggregated hinterland is part of the selected loop but is not selected to be an aggregated *from*- or *to*- hinterland, then only the maritime costs of sailing to the different ports in that aggregated hinterland are taken into account. (van Hassel 2015b)

3.2 *Input parameters*

The input for the chain model consists in three main elements. The first input concerns the selection of an existing container loop. An actual loop can be built in the model based on data obtained from the websites of the container lines concerned. Second, a specific vessel needs to be selected to sail the selected loop. The main standard input parameters related to the ship are a sailing speed of 22 knots and an occupation rate of 80%. The handling rate of the container cranes is set at 30 moves an hour for the Hamburg – Le Havre range and at 25 moves an hour for the Mediterranean ports. The occupation rate of inland vessels and trains is assumed to be 80%. In the sensitivity analysis, the impact of the parameters is further examined. All the other input parameters are taken from port and terminal websites (number of container cranes and port entering cost for example) and other sources such as Drewry (2005) for the terminal throughputs.

3.3 *Adjustments to the base model*

The focus of this paper is on the competition between the ports in the Hamburg – Le Havre range on the one hand and the Mediterranean ports on the other. Two Mediterranean ports were already part of the original model proposed in van Hassel et al. (2015 a and b):

- Koper
- Marseille

In order for us to be able to analyse the existing container loops of CMA-CGM, the following main container ports were added:

- Algeciras
- Valencia
- Barcelona
- Genoa

These ports are now also fully incorporated into the model. Hence, for each port, the maritime access draught and all available container terminals have been incorporated. For each terminal, the following data was collected:

- The terminal infrastructure data (length quay wall, draft terminal, etc.)
- Terminal throughput (number of TEUs handled at the terminal)
- Terminal equipment (number of container cranes, handling rate of the container cranes)
- Port entering cost parameters (port dues, pilotage, tug boats, (un)mooring and shifting and container handling cost)
- Hinterland data (distance data, for each available hinterland transport mode, from each terminal to all the NUTS-2 region on the mainland of the EU)

The inland waterway distances are based on Euro Global Map Data (EuroGlobalMapData, 2015), while for rail distances, Eurostat data is used (EUROSTAT, 2015). The distances data from each port terminal to an inland rail and inland waterway terminal are determined using a shortest path algorithm over the rail and inland waterway networks. The distances via road transport, from port terminals and the distance from an inland terminal to the centroid of a NUTS-2 region are determined by means of the Google Maps algorithm.

After incorporation of this data for the four additional Mediterranean ports, it was possible to build a complete Mediterranean loop from Asia as well as Southern America to Europe.

Another adjustment to the model as compared to the original model proposed in van Hassel et al. (2015a and b) is that the cost data has been updated from 2012 to 2015 values. This calculation was made for all ports of call, as well as all maritime and hinterland cost (for all hinterland modes).

4 SCENARIO ANALYSIS AND EMPIRICAL RESULTS

Two container routes are analysed: Asia - Europe and Southern America - Europe. First, the generalised chain cost is calculated for an existing loop on both routes, reflecting the 'as is' situation. Subsequently, the two different scenarios outlined in section 1 (hinterland external cost internalisation + introduction of the North Sea SECA) are applied, and the impact on port competitiveness is measured through the impact on the generalised chain cost. Each scenario is compared to the reference scenario, which is the current day split in hinterland between the ports in the Hamburg – Le Havre range and the Southern European ports. A hinterland region is assigned to a port range if the total generalised chain cost with one port range is lower than that with the other port range. If the difference in generalised chain cost between two port ranges is smaller than 5%, the region is assigned to both ports (= battleground).

Sub-section 4.1 analyses the results for the Asia - Europe route, while sub-section 4.2 deals with Southern America – Europe route.

4.1 *Asia – Europe loop*

For the route from Asia to the Hamburg – Le Havre range, an existing loop from CMA-CGM is used (FAL8; CMA-CGM, 2015b). For the route from Asia to Southern Europe, we use the Mediterranean Club Express 2 loop (CMA-CGM, 2015c). For both loops, the port of Shanghai is taken as the origin of the chains, while the mainland of Europe is set as the destination hinterland. For the loop to the Hamburg – Le Havre range, the ports of Hamburg, Rotterdam and Zeebruges are called at with a vessel of 17,000 TEU. For the loop to the Mediterranean, the ports of Genoa, Marseille (Fos) and Valencia are called at, and vessels of 9,700 TEU are deployed.

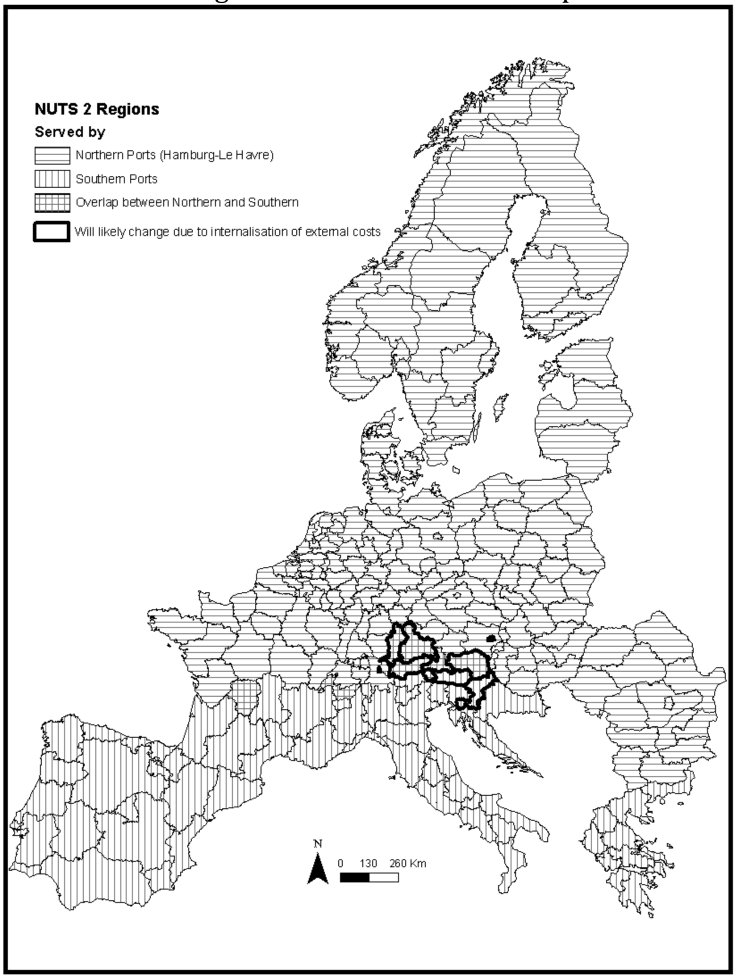
The generalised chain costs of the two container loops are compared to one another. Sub-section 4.1.1 deals with the internalisation scenario, and sub-section 4.1.2 with the ECA scenario.

4.1.1 Impact of internalised external cost

Figure 6 shows the European hinterland split between the ports in the Hamburg – Le Havre range and the Mediterranean ports for the container loops from Asia to Europe. In this figure, the hinterland regions that belong to the Hamburg – Le Havre range are dashed horizontally, while the regions belonging to the Southern European ports are dashed vertically. Regions that are dashed both horizontally and vertically are so-called battleground regions.

The regions with a bold outline are regions that shift from one port region to the other pursuant to the internalisation of the external hinterland cost. All external cost items are taken into account. Also in consequence of internalisation, the modal split from the ports to the hinterland regions changes, as modes offering a lower generalised cost (including the external cost) increase their share.

Figure 6: Impact of internalising external costs on the European hinterland (Asia - EU)[3]



Source: own composition

Figure 6 shows that the regions around the Mediterranean Sea are captive to the ports in Southern Europe, while the regions in Northern Europe (north of the midway of France) belong to the catchment area of the ports in the Hamburg – Le Havre range. The competition between the ports in Northern and Southern Europe is hardly affected by the internalisation of the external costs. Just a few regions in Austria and Slovenia tend towards a shift. For these regions, there was only a small difference in generalised chain cost (battle zone) in the reference scenario, and with internalisation of the external costs, these regions tend towards the Northern European ports, as regions previously served exclusively by the Southern European ports now become battleground regions. These changes are due to the fact that Vienna and the surrounding region can be reached by inland waterway, a very cost-effective mode of transport after internalisation of external costs. None of the other hinterland regions shifts to another port region, mainly because these regions cannot be reached by inland waterway. The most important part of the European hinterland for the Hamburg – Le Havre ports, namely the western part of Germany, the BeNeLux (Belgium, The Netherlands and Luxembourg) and Northern France, covers 73% (18,200,000 TEU) of the total container hinterland distribution of

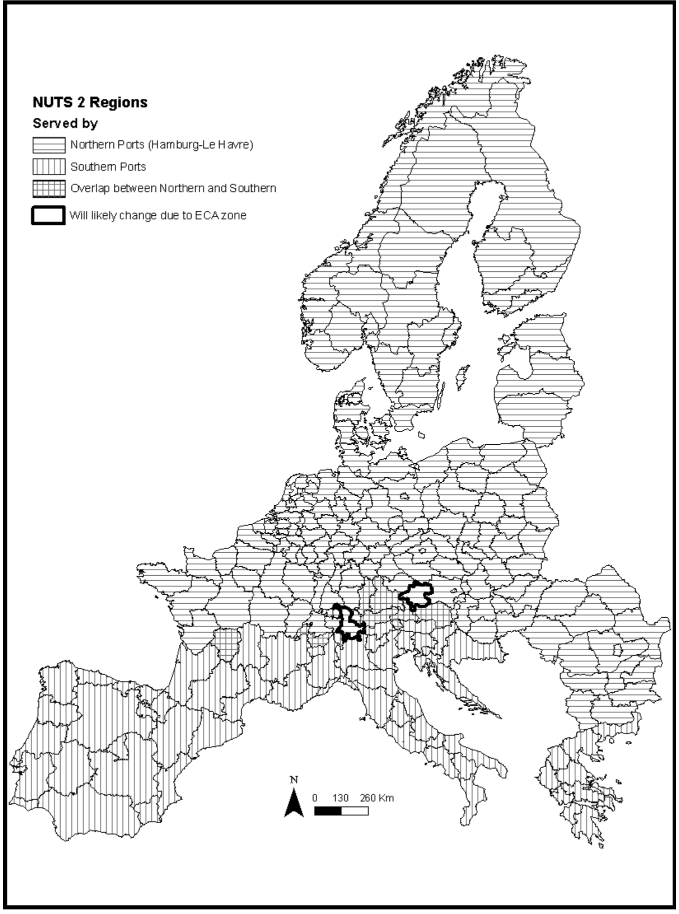
[3] The map shows the EU-27, excluding United Kingdom and Ireland and the islands of the Mediterranean, and including Norway and Switzerland.

the six main Hamburg – Le Havre container ports (Port of Antwerp, 2014). These regions are not affected at all by the internalisation of the external cost.

4.1.2 Impact of SECA

Figure 7 represents the impact on European North-South port competition of introducing the North Sea SECA. The figure uses the same coding as in Figure 6 to indicate to which port range's catchment area a hinterland region belongs.

Figure 7: Impact of introducing the SECA in the North Sea (Asia - EU)



Source: own composition

In order to calculate the impact of introducing the SECA, the data from Table 3 is used, which shows the increase in fuel cost per port associated with a switch from HFO to MDO.

Table 3: Increase in fuel cost on the Asia – EU loop induced by switching to MDO in the ECA

	Sailing distance (nm)	Distance in ECA zone (nm)	Ratio MDO/HFO fuel cost	Increase in fuel cost
Rotterdam	10,747	410	1.56	6%
Hamburg	10,968	670	1.56	10%
Zeebruges	11,248	940	1.56	13%
Rotterdam	11,335	999	1.56	14%

Source: own calculation, distance data based on AXSMarine (2015) and fuel cost on Bunker world (2015)

Figure 7 shows that, with the introduction of the SECA, the shift of hinterland regions from the Hamburg – Le Havre port range to the Southern European port range is again rather limited. The impact of the increase in fuel cost for maritime transport to the ports in the Hamburg – Le Havre range is limited because of the deployment of 17,500 TEU vessels. These large vessels offer economies of scale with respect to power generation: the fuel cost per TEU for a 17,500 TEU ship is 25% lower than for a 9,700 TEU ship. Hence an increase in fuel cost for the largest ships sailing into the SECA will impact only on certain hinterland regions in southern Switzerland and Austria.

4.2 *Southern America – Europe loop*

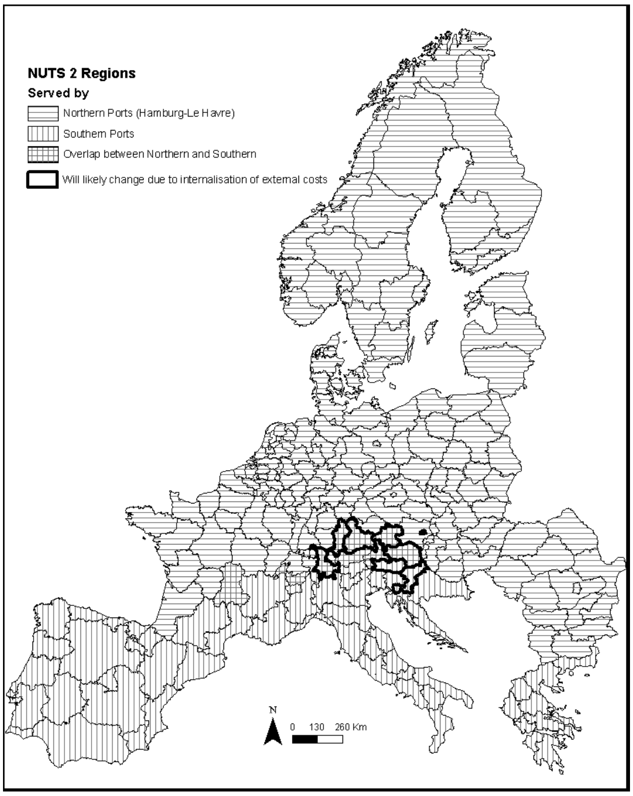
For the route from Southern America to the Hamburg – Le Havre range, the existing SAFRAN1 loop (CMA-CGM, 2015d) is selected. For the connection between Southern America to Southern Europe, we select the Sirius 1 loop (CMA-CGM, 2015e). For both loops, the port of Buenos Aires is taken as the origin of the chains and the mainland of Europe is set as the destination hinterland. For the loop to the Hamburg – Le Havre range, the ports of Hamburg, Rotterdam, Antwerp and Le Havre are called at with a vessel of 6,000 TEU. For the loop to the Mediterranean, the ports of Valencia, Genoa, Marseille (Fos) and Barcelona are called at, likewise by a 6,000 TEU vessel.

The two container loops are now compared to one other. Sub-section 4.2.1 deals with the internalisation scenario, sub-section 4.2.2 with the SECA scenario.

4.2.1 Impact of internalised external cost

Figure 8 represents the European hinterland split between the ports in the Hamburg – Le Havre range and the Mediterranean ports for the container loops from Southern America to Europe.

Figure 8: Impact of internalising external costs on the European hinterland (Southern America – EU)



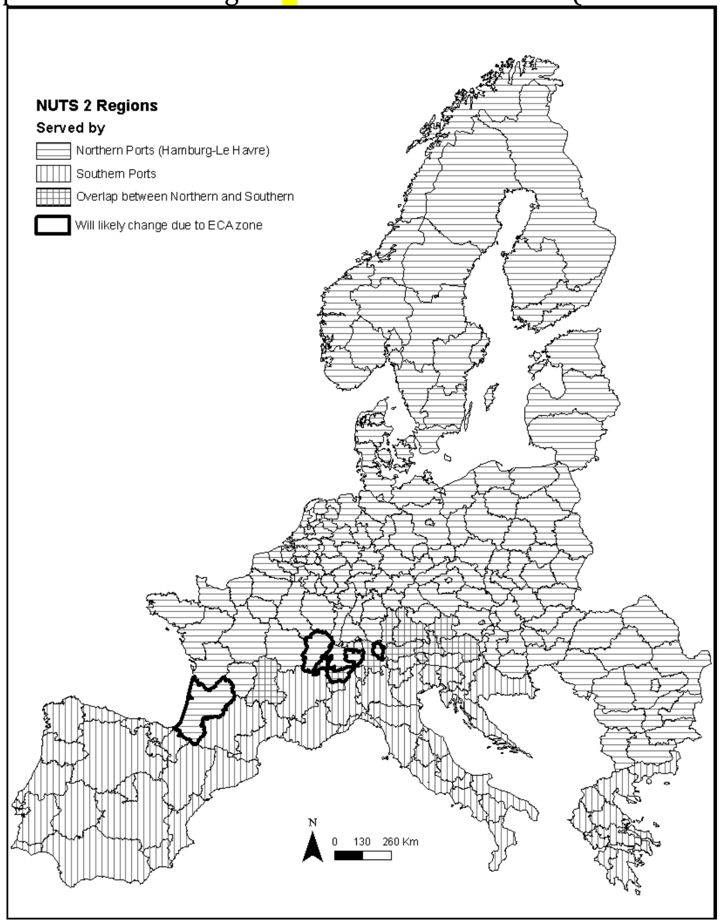
Source: own composition

The figure shows that, in consequence of an internalisation of the external cost, a limited number of hinterland regions will shift to another port region. Most of these regions were battleground regions prior to the policy implementation. After internalisation, the regions concerned tend towards the Hamburg – Le Havre range (especially Antwerp and Rotterdam). The inland waterway connections to Basel and even Vienna are the main reasons for this shift.

4.2.2 Impact of SECA zone

Figure 9 shows the impact of introducing the North Sea SECA on the competition between Northern and Southern European ports insofar as trade lanes with Southern America are concerned. The impact of introducing the SECA is calculated using the data from Table 4. This table provides an overview of the increase in fuel cost per port following a shift from HFO to MDO. The relative increase in fuel cost for this loop is greater than for the loop from Asia to Europe. This is due to the relatively shorter sailing distance from Southern America (Buenos Aires) to Europe compared to that from Asia (Shanghai). Hence, the impact of the establishment of an ECA is greater.

Figure 9: Impact of introducing an SECA on the North Sea (Southern America – EU)



Source: own composition

Figure 9 shows that just five hinterland regions shift from Hamburg - Le Havre range regions to Mediterranean regions. The higher fuel cost in the ECA has a slightly larger impact on this loop than on the loop from Asia to Europe, although the shift between port ranges remains very limited. Note that, on both the loop from Southern America to the Hamburg – Le Havre range and that to the Mediterranean range, a 6,000 TEU vessel is deployed.

Table 4: Increase in fuel cost by using MDO in the SECA on the Southern America – Europe loop

	Sailing distance (nm)	Distance in ECA (nm)	Ratio MDO/HFO fuel cost	Increase in fuel cost
Rotterdam	6,550	405	1.56	9.1%
Bremerhaven	6,767	487	1.56	10.6%
Antwerp	7,026	569	1.56	12.0%
Le Havre	7,205	786	1.56	16.1%

Source: own data based on AXSMarine (2014) and fuel cost on Bunkerworld (2015)

5 SENSITIVITY ANALYSIS

In the preceding analysis, some basic inputs are used that could affect the outcome of the analysis. The main input parameters that are further investigated are:

- Maritime leg of the chain
  - Vessel sailing speed (16 to 24 knots, steps of 2 knots) (for both types of loops)
  - The occupation rate of the vessel (70% to 90%, steps of 10%)
- Port leg of the chain
  - Container handling time at the Mediterranean ports (20 to 35 moves an hour, steps of 10 moves)
- Hinterland leg of the chain
  - The occupation rate of inland vessel and trains (60% to 90%, steps of 10%)

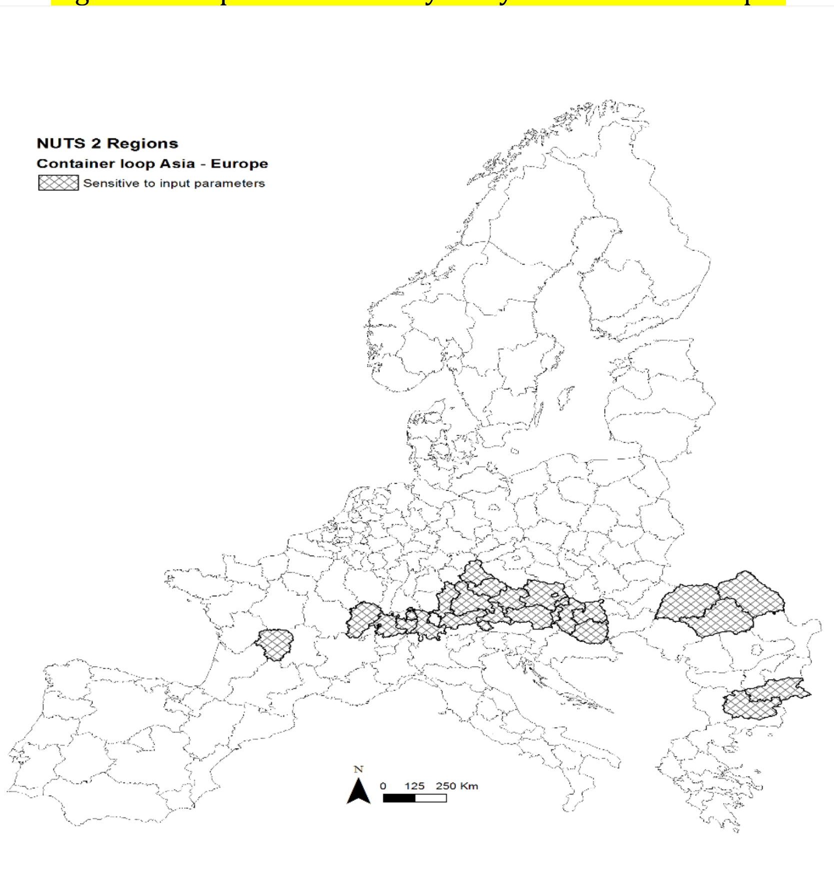
The aim of the sensitivity analysis is to determine how much the calculations are influenced by the main input parameters. More specifically, the impact of variations of the four parameters on the total chain cost is calculated for the trade routes from Asia and Southern America to the European city of Vienna.

5.1 *Asia – Europe via Hamburg Le Havre range*

The calculations ultimately indicate whether hinterland regions are assigned either to the ports in the Hamburg – Le Havre range or to the Mediterranean ports (or both). In order to show the results on a single map, the two extremes are compared. The one extreme is a situation where the Hamburg – Le Havre range ports are in the best possible position (high occupation rate of the vessel, low speed, high occupation rate of the hinterland modes and high handling rate of the container cranes) and the Mediterranean ports are in the worst possible position. The other extreme is the reverse situation, with the Hamburg - Le Havre range worst possibly positioned and the Mediterranean range best possibly positioned. These two extremes impact on the initial split between the two port ranges, as visualised in Figure 10.

The dashed regions are regions affected by the change in input parameters for the two container loops from Asia to Europe. It can be observed that there is an area in between the two port ranges that is basically within the error margin of our model. Looking at the results of the calculations presented in section 4.1, it is apparent that the effects of the two policies (the areas with dark outlines) are also within the error margin of our model. Consequently, we may conclude that either effect is too small to significantly affect competition between the two port ranges for hinterland regions not within the error margin of the model. However, we are unable to identify specifically which regions would switch port ranges in consequence of the implementation of the two policies considered. The city of Vienna is one of the largest cities in a region within the error margin of the model. Therefore, a more detailed analysis is required in order to establish which parameters have the greatest impact on the generalised chain cost (see section 5.3).

Figure 10: Impact of sensitivity analysis on hinterland split



Source: own composition

5.2 *Southern America – Europe via Mediterranean range*

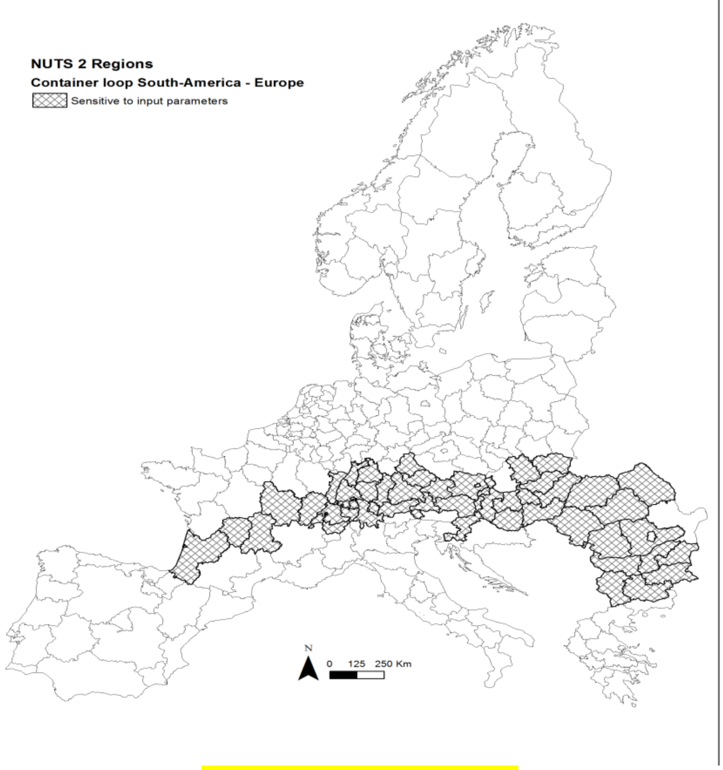
A similar sensitivity analysis is conducted for the two container loops between Southern America and Europe as was made for the container loops between Asia and Europe. The result is shown in Figure 11.

It emerges that the error regions for connections with Southern America are greater than that for the Asia – Europe trade lanes. This is due to the fact that the same ship size was used for the container loops from Southern America to respectively the Northern and the Southern European ports. With identical ship size, the difference in generalised chain cost between the two port ranges is determined more strongly by the difference in hinterland cost. Moreover, it is this cost component that most strongly affects the error margin according to a more detailed sensitivity analysis (see section 5.3).

If one compares Figure 11 to the results presented in section 4.2, the same conclusion may be drawn as in the analysis of the Asia to Europe trade lanes. The changes in hinterland split between the two port ranges, induced by the two policies considered, are again within the error margin of the model. Hence the sensitivity analysis indicates that the impact of the two policies would not significantly affect the hinterland split between the ports in the Hamburg – Le Havre range and the Mediterranean ports.

Again, the city of Vienna lies within the error zone of the model. Consequently, for this container loop, too, a more detailed sensitivity analysis is called for.

Figure 11: Impact of sensitivity analysis on hinterland split



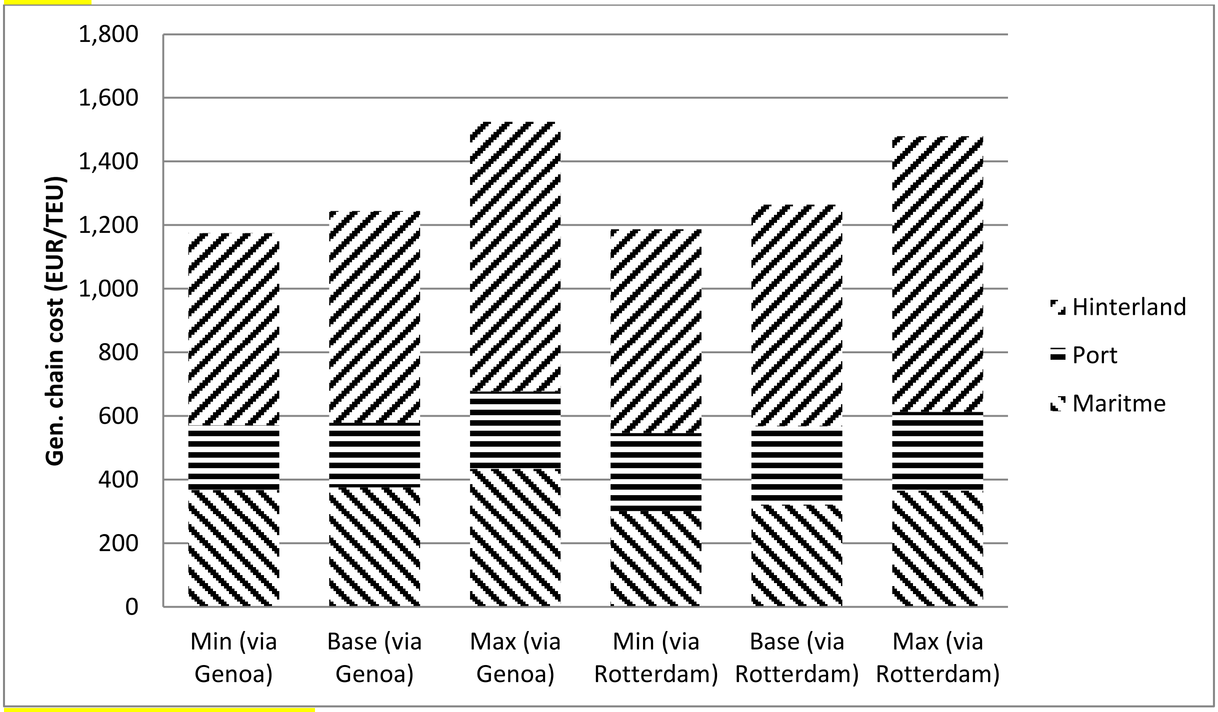
Source: own composition

5.3 *Detailed analysis of the generalised chain cost*

Figure 12 shows the results of the detailed sensitivity analysis of the generalised cost from Shanghai to the city of Vienna. Two different container loops are considered. For each loop, either via the Hamburg - Le Havre Range or via the Mediterranean ports, three different calculations are made for the base case input parameters as well as for the minimum and maximum input parameters. For each calculation, the cost variation related to each phase of the chain (maritime, port and hinterland) is also determined.

From figure 12, it can be concluded that the largest contribution to the variation in generalised chain cost are due to variations in the hinterland cost (-4.4%, +13.4 %), while the variation in the port and maritime phase are relatively small (-1.5% to 3.5%). This means that the results of the calculations are mostly influenced by the occupation rate of the inland vessels and trains. Hence, the generalised chain cost to hinterland regions that are connected to the ports in the Hamburg – Le Havre range and Mediterranean ports via inland waterway and/or rail infrastructure, and that are located far enough from a port to make intermodal transport a viable option, are highly influenced by a variation in the occupation rate of trains and inland waterway vessels. For hinterland regions located closer to the ports, this effect is less outspoken, as such short distances tend to be covered by road transport. In our calculations, we have used a logit type of model to determine the modal split between the three hinterland transport modes. So when the generalised cost via inland waterway or rail increases, so too does the modal share of road transport. (See also van Hassel et al (2015b) for further details on the hinterland modelling approach.)

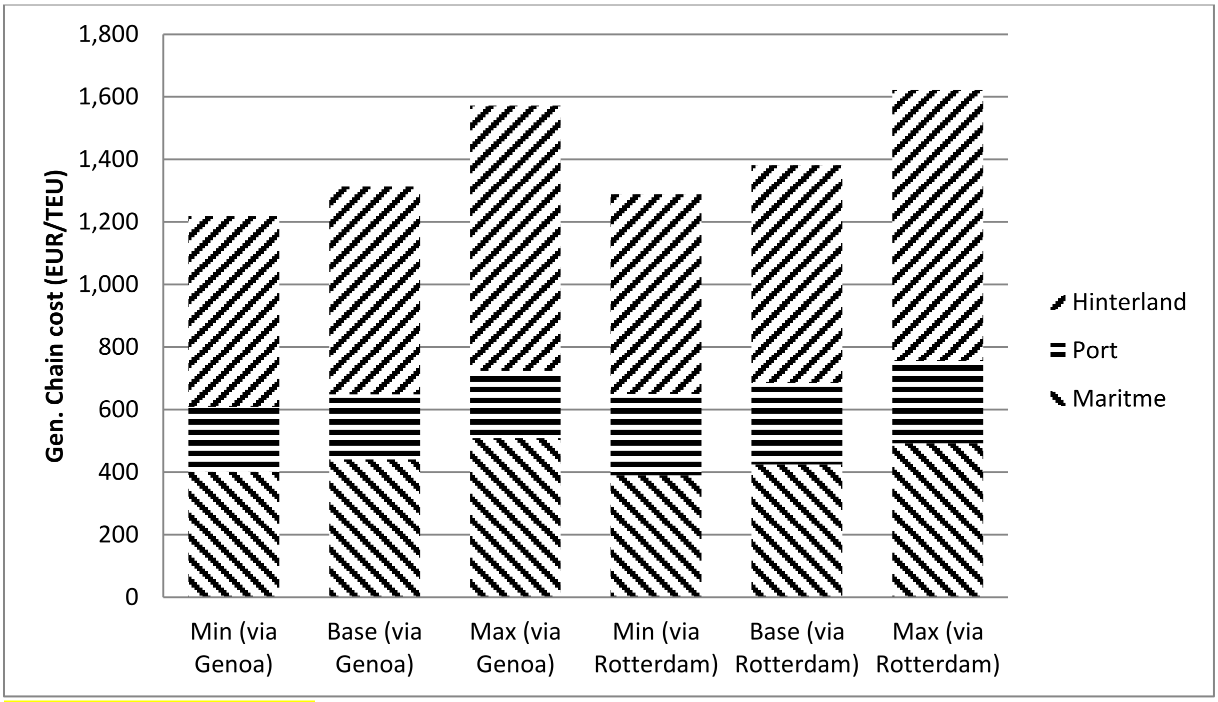
Figure 12: Results of the detailed sensitivity analysis of the generalised cost from Shanghai to Vienna



Source: own calculations

For the container flows from Buenos Aires to Vienna, the same type of variations are considered, as shown in Figure 13. The same observations impose themselves as in the previous analysis, for the Asia – Europe route.

Figure 13: Results of the detailed sensitivity analysis of the generalised cost from Buenos Aires to Vienna



Source: own calculations

6 CONCLUSIONS

This article considers the respective effects of the internalisation of external costs and the implementation of an SECA in the North Sea on the competitiveness of the seaports in the Hamburg – Le Havre range and in the Mediterranean. The hinterland split between the two port regions is based on calculated generalised chain costs.

Implications for managerial practice

The analysis shows that internalising externalities would have a relatively minor effect on the hinterland split between the ports in the Hamburg – Le Havre range and the Mediterranean. Internalising external costs will furthermore affect the same hinterland regions for the Asia - Europe loops as for the Southern America - Europe loops.

With respect to the introduction of an SECA, the two loops impact similarly on the affected hinterland regions. For the loop from Asia to Europe, just two hinterland regions switch catchment areas to the benefit of the Mediterranean ports. On the Southern America - Europe loops, more regions are affected, which is attributable largely to differences in sailing distance within the SECA and to the deployment of different size container ships (17,500 TEU for the Asia – Europe loop as compared to 6,000 TEU for the Southern America - Europe loop). The establishment of a North Sea SECA will not drastically alter the competitive position of the Hamburg – Le Havre ports. However, the SECA does impact differently on the two loops considered.

While both scenarios have a limited effect insofar as competition between the Hamburg - Le Havre range ports and the Mediterranean ports is concerned, an internalisation of externalities does impact more greatly than the establishment of an SECA.

All things considered, we may conclude that the principal hinterland region, where most containers passing through the Hamburg – Le Havre range ports (North-Western-Europe) are destined for, will not be affected by either an internalisation of externalities or the establishment of an SECA. In fact, Northern European ports that are adequately connected to the inland waterway network (i.e. Antwerp and Rotterdam) would benefit from such an internalisation.

These findings have important implications, not only for policymakers who must decide on whether to adopt environmental measures, but also for the businesses concerned, as it provides them with scientifically sound information about whether such measures are detrimental or beneficial to their sector, and about whether welfare is optimised or not. Of course, one must also take into account that both cost internalisation and the establishment of an SECA would make transportation more expensive overall, so that total traffic volumes may as yet be impacted negatively.

Contribution to scholarly knowledge

This study has incorporated all three legs of the supply chain considered (maritime leg, port leg and hinterland leg) in order to correctly assess the impact of specific environmental policy measures. Previous contributions have tended to deal rather with partial chains. Moreover, the model proposed is sufficiently generic, so that it can be applied to any geographical area, any ship type, and any type of container port.

Admittedly, one of the limitations of the current model is that it can only determine the theoretical captive hinterland of the port. Port choice attributes such as reliability and service culture are as yet not incorporated into the model. In order to arrive at a tool for a comprehensive port choice analysis, more attributes will need to be added. Still, on the basis of the current version of the model, and taking due account of the sensitivity analysis, we may conclude that the hinterland split depends mostly on the generalised cost of hinterland transport. Here, the occupation rate of inland vessels and freight trains are a key factor. This suggests that the presence of a rail or an inland waterway connection between the Northern European ports and their hinterland puts these ports at a competitive advantage vis-à-vis their Southern European counterparts so long as transport volumes are sufficiently great, i.e. provided that occupation rates are high enough.

Our calculations show that all changes to the theoretical hinterland split are within the error margin of the model. This means that the effects of either policy is too small to induce a significant shift in the hinterland split. In that respect, the impacts are small. On the other hand, there is some impact on the hinterland split between the Northern and Southern European ports, but with the current version of the model it is impossible to determine how great this impact is.

One of the future research goals must be to investigate further the error margin in the model with a view to gaining closer insight into the effects of the two policy options considered. This will require, among other things, closer study of the frequencies and occupation rates of inland vessels and freight trains.

Additionally, closer insight is required into the cost structures of the maritime, port and hinterland legs of the supply chain. A further division into vessel types, and additional loops, ports and hinterland modes may also be considered. Furthermore, more detailed parameters may be introduced with respect to shippers' choices, including factors such as efficiency, port information system, intermodal/hinterland connections.

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