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Towards a Worldwide Policy Classification and Analysis

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Cold Chain Strategies for Seaports – Towards a Worldwide Policy Classification and Analysis.

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Abstract: *The reefer container market and global cold chains present several opportunities for seaports. This high-value market grows rapidly, but also places demands on ports' logistics processes, infrastructure, and energy provision. The current academic literature lacks a comprehensive understanding of the policy options available to port authorities to address these types of challenges and opportunities. Based on a survey of the world's 50 largest container ports, this study presents a new dataset of policies ports implement in the area of reefer transportation and cold chain logistics. The policies are analyzed in terms of their content, goals and scope. Most commonly, the scope is limited to the port cluster, where ports often (co)-invest in or aim for cluster formation around cold stores within the port. When a port broadens its strategic scope, this is aligned with policy goals formulated at higher levels of governance, such as modal shift goals or the development of domestic post-harvest distribution systems. There is little evidence that port authorities pursue policies in line with an overarching strategy, taking into account the logistics, marketing, technology, and sustainability dimensions of cold chains. The paper outlines the general tenets such a strategy should contain as a consideration for policymakers.*

Keywords: "reefer containers", "cold chain", "ports", "port policy", "container transport".

1. Introduction

The focus of this study is on the policy measures that can be implemented by port authorities to better attract and facilitate transportation of reefer containers. Refrigerated or 'reefer' containers are a fast-growing segment in the container shipping market (Arduino, Carrillo Murillo, & Parola, 2013). Whereas the container shipping market itself is in a phase of maturity, niches such as reefer transportation can still be exploited for further growth (Guerrero & Rodrigue, 2014). Over the past decade, the reefer market has been the only segment showing consistent year-on-year growth in a generally depressed container shipping market (Drewry, 2016). The intermodal compatibility, increased reliability (in terms of delivery and quality control), flexibility, and traceability that these containers and associated technology provide, make it an attractive mode of transportation for temperature-sensitive cargoes. Facilitated by technical developments in the reefer market, the growing global demand for temperature-sensitive products, such as fresh and frozen agrifood products, flowers, chemicals, and pharmaceutical products, drives the further expansion of worldwide reefer trades.

Hence these fast-growing, high-value cargo flows become increasingly relevant for port authorities. Reefer containers, with their built-in technology and sensitive cargo, place more stringent demands on port infrastructure, energy supply, and handling processes than standard

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containers (Behdani, Fan, & Bloemhof, 2018), prompting the question what measures port authorities can take to better facilitate the transportation of reefer containers and improve their competitive position in this market. While the academic literature on port competitiveness has addressed the question how (container) ports can become more attractive to port users, so far containers have generally been considered 'black boxes' – a homogenous commodity without much regard for differentiation in their contents (Rodrigue & Notteboom, 2015). However, ports compete not only for cargo volume, but for cargo added value as well (Martino, Carbone, & Morvillo, 2015). Therefore a more disaggregated perspective on container flows – and how ports can deal with these – is desirable (Castelein, Geerlings, & Van Duin, 2019).

Studies in port governance generally focus on governance models, institutional reform, and their outcomes (Borges Vieira, Kliemann Neto, & Goncalves Amaral, 2014). Most attention has been paid to the predominant port governance model, i.e. the 'landlord' port authority: a privatized entity, often with public ownership, with a role that is limited to infrastructure and real estate management and regulatory functions while balancing public and private interests (World Bank, 2007). This demarcation of port authority roles appears to be in constant flux however, as developments in the global logistics sector may place new demands on ports that forces a reconsideration of port authority roles and functions (Notteboom, De Langen, & Jacobs, 2013; Robinson, 2002). Earlier studies suggested ways in which changing contexts could impel port authorities to broaden their scope to the foreland and hinterland (Dooms, Van der Lugt, & De Langen, 2013; Notteboom & Rodrigue, 2005; L. M. Van der Lugt, Rodrigues, & Van den Berg, 2014) and extend their role beyond that of the landlord to for example being a cluster manager, facilitator, or entrepreneur (Hollen, Bosch, & Volberda, 2015; Verhoeven, 2010). A recent contribution (Parola, Pallis, Risitano, & Ferretti, 2018) provided a novel conceptualization of marketing strategies for ports to engage actively with relevant stakeholders, but remained abstract as to the concrete policy instruments available. At the heart of this literature is the question 'what can a port authority do?', including the issue of how a port authority can insert itself in global supply chains and help create more value for the port cluster (Jacobs & Hall, 2007). So far, the approaches have been predominantly case studies of one or a handful of ports (Dooms, Van der Lugt, et al., 2013; Hollen et al., 2015; Jacobs & Hall, 2007; L. Van der Lugt, Dooms, & Parola, 2013) or more conceptual work (Parola et al., 2018), but a comprehensive *global* perspective on the spectrum of tangible actions a port authority may take in response to threats or opportunities in its changing environment has been missing.

This paper addresses this gap by focusing on port policies specifically tailored for one fast-growing segment of the container market, namely the reefer market, characterized by high-value, sensitive cargoes. Drawing on a newly compiled dataset of reefer and cold chain-related policies implemented by the world's 50 largest container ports, the question how ports can respond to challenges and opportunities in this niche market is addressed. The study surveys the policy measures implemented by the largest container ports in the world to identify the spectrum of measures applied. Drawing on this new database of port policies, the study provides a typology of measures, and discusses these by type, scope, and goal. Furthermore, based on these findings the authors offer considerations on how ports can formulate and implement a coherent and comprehensive strategy for cold chain facilitation.

Section 2 outlines the background to the study, including relevant considerations regarding reefers for ports, and a general discussion of port governance and the policy instruments available to port authorities. Section 3 outlines the process of data collection and coding of the policy instruments found, after which section 4 presents the results. Section 5 discusses and concludes.

2. Background

Research on what ports can do to respond to opportunities and challenges in a developing market – such as cold chains and reefer transportation – has been limited so far. From the existing academic literature two aspects should be highlighted that are relevant to understand ports' policy options in this context. First, the relevance of reefer transportation for ports, and second, insights into how port governance shapes the extent of policy instruments port authorities have at their disposal.

2.1. Cold chain considerations for ports

Three characteristics of reefer container transportation and cold chains make this sector particularly relevant for ports. First is the rapid growth in the market, creating opportunities for ports to attract high-value cargo. Second is the crucial role of ports in reefer chains as locations of (de)-consolidation, multiple transfers of custodianship, and the associated risks. Third, reefer containers account for a considerable share of ports' energy consumption, making them a relevant consideration for ports' energy policy.

Growth in reefer container transport has for long strongly outpaced growth in standard or 'dry' container markets (Drewry, 2016), driven by three factors (Accorsi, Manzini, & Ferrari, 2014; Arduino et al., 2013; Behdani et al., 2018): First, as incomes increase worldwide, people tend to increase their consumption of exotic, non-local food, and demand this regardless of seasonality. Secondly, due to improved preservation techniques and the cost-competitiveness of reefer container transport, there is a modal shift of temperature-sensitive goods away from air and conventional reeferships transport towards reefer containers, with 85% of perishables expected to be transported in reefer containers by 2021 (Drewry, 2017). Third, as reefer containers become more ubiquitous, the range of goods transported is expanded with cargoes that would not have been transported under refrigeration by plane or conventional reefership. These miscellaneous goods range from sensitive electronics to sneakers with temperature-sensitive glue and even live lobsters. Due to these developments, the use of reefer containers worldwide increases, and their range of uses expands.

While ports are only a single nexus in a global cold chain, they are a critical point where reefer containers are disconnected from their power supply, transferred, and re-connected at several points within the port, and possibly stripped or stuffed with new cargo in cold stores. These transfer points, where the container is disconnected from an energy supply while at the same time the custodianship shifts from one chain actor to another, are typically the points where the risk of the cold chain being broken is greatest (Fitzgerald, Howitt, Smith, & Hume, 2011).

Another consideration is the relevance of reefers for port's energy policy. Ports tend to be clusters of energy-intensive activities, energy transport, and power generation ('energy hubs'), while sustainability considerations also place demands on ports to control their emissions and environmental impact. All these demands should be taken into account in port authorities' policymaking (Acciaro, Ghiara, & Cusano, 2014). For cold chains overall, approximately 20% of all energy consumption is used for cargo refrigeration (Fitzgerald et al., 2011). At container terminals, energy consumption of reefer containers is responsible for 30-35% of total energy use, and the prime driver behind energy demand peaks (van Duin, Geerlings, Verbraeck, & Nafde, 2018). Considering recent developments such as the Paris agreement of 2015 stressing the importance of reducing CO_2 emissions, challenges arising from the energy footprint of refrigerated logistics deserve the attention of port authorities.

2.2. Port governance and policy options for port authorities

Recognizing that the reefer sector poses opportunities as well as challenges for port authorities, one should consider the set of instruments available to port authorities to respond to these developments. This entails considerations regarding port governance, strategy-making, and policy options.

There are several generic governance models to which most ports conform, with the 'landlord' port being the most common (World Bank, 2007). There has been considerable discussion in the literature whether this is the best model for port authorities in a period of significant change in the logistics environment. Major external factors include consolidation in the liner and terminal operator sector (Notteboom, 2002; Panayides & Wiedmer, 2011) and the tendency of supply chains becoming more interconnected and footloose (Robinson, 2002). In different contexts and conceptualizations, authors have made arguments for ports to broaden their strategic scope, resulting in roles and concepts such as the 'entrepreneurial port developer,' 'facilitator', 'ambidextrous port', 'cluster manager,' and the 'extended landlord port model.'

Port authorities operate to meet a diverse spectrum of strategic goals, inspired by their hybrid nature with characteristics of a public as well as a private organization (L. Van der Lugt et al., 2013; Verhoeven, 2010). These goals include straightforward financial performance criteria, sustainability goals, and meeting responsibilities to a wide range of stakeholders. The latter include national and local government, the national logistics sector, port users, and regional inhabitants. Drawing on Cochran and Malone's (2014) definition of policy actions as "decisions for implementing programs to achieve […] goals," in the seaport context the port authority can use a range of policy instruments to realize these various strategic goals (Hollen et al., 2015). These options are now discussed for the different roles a port authority can take.

In the traditional 'landlord' model, the port authority manages land concession agreements, has a regulatory role, and is responsible for port infrastructure. Research so far has identified several ways in which port authorities extend their roles, either by using 'traditional' landlord policy instruments in innovative ways, or by engaging in previously unexplored activities (Notteboom et al., 2013). Concession agreements are not only used as a source of income for port authorities, but can also be used to incentivize port user behavior that is desirable from the perspective of the port authority's other goals (e.g. achieving a certain modal split to reduce emissions and congestion) (Langen, Berg, & Willeumier, 2012; Notteboom & Verhoeven, 2010). The role of regulator can also be extended into standard-setting to further the port's societal goals (Lam & Notteboom, 2014) or signal and address market failures. Another dimension of port policy development is a broader conception of what constitutes infrastructure. While physical infrastructure is traditionally within the scope of the landlord port authority, more entrepreneurial port authorities also invest in 'knowledge infrastructure' (Hollen et al., 2015), including information technology (Cepolina & Ghiara, 2013) inter-organizational relations, collaboration, and connectivity (De Martino & Morvillo, 2008; Hollen et al., 2015), and innovation (Martino, Errichiello, Marasco, & Morvillo, 2013). When a port authority extends its role into that of a 'cluster manager' or 'community manager', other considerations play a role as well, such as the mix of activities (co-)located in a port, intra-port inter-organizational relations, and possible co-siting of activities that could benefit from one another's proximity (Hollen et al., 2015).

Ports that are aware of their position in global supply chains will want to undertake actions that help better integrate the port and port actors in these chains. These actions include data-sharing technologies, development of relationships with foreland and hinterland actors, pursuing value-added activities, and improving connectivity (Song & Panayides, 2008). Essentially any national or regional, public or private stakeholder – domestic or abroad – can be within the scope of targeted marketing efforts of port authorities (Parola et al., 2018). Specifically, cooperation between (semi-)public port authorities with private sector

stakeholders (with varying degrees of commitment) are key instruments for port development (Dooms, Verbeke, & Haezendonck, 2013; Panayides, Parola, Siu, & Lam, 2015).
Geographically, an entrepreneurial port also considers areas outside the port cluster (i.e. its hinterland or foreland) to be within its strategic scope. This includes outreach to its own hinterland to improve connectivity – 'regionalization' of the port (Notteboom & Rodrigue, 2005) – or the development of the hinterland region itself (Cahoon, Pateman, & Chen, 2013). Also towards the foreland, research has shown evidence of internationalization of port authority strategies (Dooms, Van der Lugt, et al., 2013).
The question to be addressed with this background in mind is how this port policy 'toolkit' can be used to implement tangible measures – in this case responding to growing opportunities and demands in the reefer segment. The next section outlines the data collection process for the new dataset on which this study will draw.

3. Data and method

3.1. Case selection

To obtain an overview of what is done globally by ports in this niche market, the study draws on information from the world's 50 largest container ports (Lloyd's List, 2017) – as inspired by the 'global review' of hinterland-oriented green port strategies by Gonzalez Aregall et al. (2018). The motivation to opt for the largest container ports globally is twofold. First, they likely have the highest absolute numbers of reefer containers passing through the port, and hence the greatest incentive and possibility to implement (scalable) measures aimed at the reefer segment. Second, the largest ports tend to have the greatest strategic scope, financial means and considerable national and regional political clout that allows them to implement a broad selection of policies that are generally not pursued by smaller ports, particularly towards the port's foreland and hinterland. For each of the 50 ports, the authors collected information on the measures taken to facilitate reefer transportation and cold chain logistics – the units of observation for the purpose of the study.

3.2. Data collection

The starting point of data collection were ports' official (English) web pages, annual reports, and press releases. The authors did not impose a limit on the time period in which the identified measures were implemented or published, since the reefer container market has only fairly recently grown to significance, and the measures found were generally not dating back further than 10-15 years. To omit the limitation of only consulting documents released directly by port authorities, the authors also consulted secondary sources for relevant policies, including academic research, professional publications, and news releases. These secondary sources were searched for through Google (Scholar), using the name of the port and variations of search terms related to reefer- and cold chain transportation (e.g. 'reefer', 'refrigerated', 'cold', 'cool', 'conditioned', 'temperature', 'fresh', 'frozen', and 'perishable'). For each port, these primary and secondary sources were searched until no new information was found, and all reefer-related policies were recorded and compiled.
It should be emphasized that this sampling approach does not guarantee that no relevant action has gone unnoticed. There may be relevant actions that are pursued by port authorities, but for one reason or another not publicized, hence remaining 'unknown unknowns.' For two reasons however, the authors consider this risk to be limited. First, ports that take action to improve their position in cold chains are likely keen to advertise this, either to catch the attention of reefer shippers, or to advertise their efforts towards a broader goal (e.g.

sustainability goals). Secondly, the study focuses on the world's largest ports: large organizations, with large amounts of reefer throughput, hence large-scale reefer-related policy actions, and considerable visibility to national and international industry, media, academia, or other parties that could – in one form or another – make mention of relevant developments. Despite these considerations, the sample may be biased towards including policy measures from those ports with the most accessible English-language information provision. This does not need to be a problem however. Since the goal of this study is to evaluate the full spectrum of policy measures available to ports, one action by one port authority missing – though not preferred – will likely enter the inventory through the use of a comparable action by another port due to benchmarking competition.

3.3. Data recording

All reefer- or cold chain-related actions by port authorities were compiled, each action constituting one observation in the sample dataset. Some actions were not coded as port policies, for example simple requirements to handle reefer containers such as the constructing reefer racks and plugs, performing plugging and unplugging services, and the availability of on-site reefer servicing, including PTIs. Moreover, actions by private sector companies or government agencies in which the port authority itself was not involved (financially or otherwise) were not counted as port policy – even though public-private partnerships with port authority involvement were included. Third, multiple initiatives stemming from the same policy (e.g. subsidizing multiple barge connections as part of the same program) were still counted as one policy.

For every policy identified, as much information as possible was recorded. First the policy instrument itself. Secondly the geographical scope of the policy, distinguishing between actions taken inside the port cluster, towards the hinterland or foreland, or impacting the cold chain in its entirety. Third, if mentioned in the information provided, the goal of the policy. Last – where applicable – the stakeholders with which the port authority partnered in implementing the policy. Aside from these categories, extensive notes were taken on all other information found regarding the policy in question.

3.4 Analytical approach

Even though the data collection process was aimed to be comprehensive, the risk of omissions and (availability) biases in the data precludes findings being proven with statistical significance or statements about causality being made. Also details about the performance of policy measures are generally not available, making quantification of costs and benefits of policies infeasible.

Instead, this study takes an inductive approach to the research question – how can port authorities respond to opportunities in the reefer market? – with the available information from a broad sample of cases. From a classification of the diverse policy measures encountered, we outline the instruments potentially available to port policymakers, while recognizing that institutional arrangements may limit port authorities' access to some of these instruments. Following a case study approach, we aim to identify patterns in the data, and formulate propositions on how port policy instruments, goals, and scope may be related (Yin, 1994).

4. Findings

This section details the findings from the new dataset, starting with some general descriptive information on the ports and policies found.

4.1. Data descriptives

Before discussing substantive findings, the general characteristics of the data deserve attention. Of the 50 ports surveyed, for 35 ports at least one reefer- or cold chain-related measure was recorded, obtaining a sample of 72 individual measures in total. Most individual policy measures (6) were recorded for the Port of Rotterdam (Netherlands). The other ports with the most distinct measures were the Port of Antwerp (Belgium) (5) and the Port of Dalian (China) (4).
Plotting the number of measures identified against the ports' rankings from Lloyd's List (Figure 1) shows that the ports that implement relatively most measures (3 and more) also tend to be the larger ports in terms of container throughput. This skewness suggests that it makes sense to starts with the world's largest ports when compiling such a policy inventory.

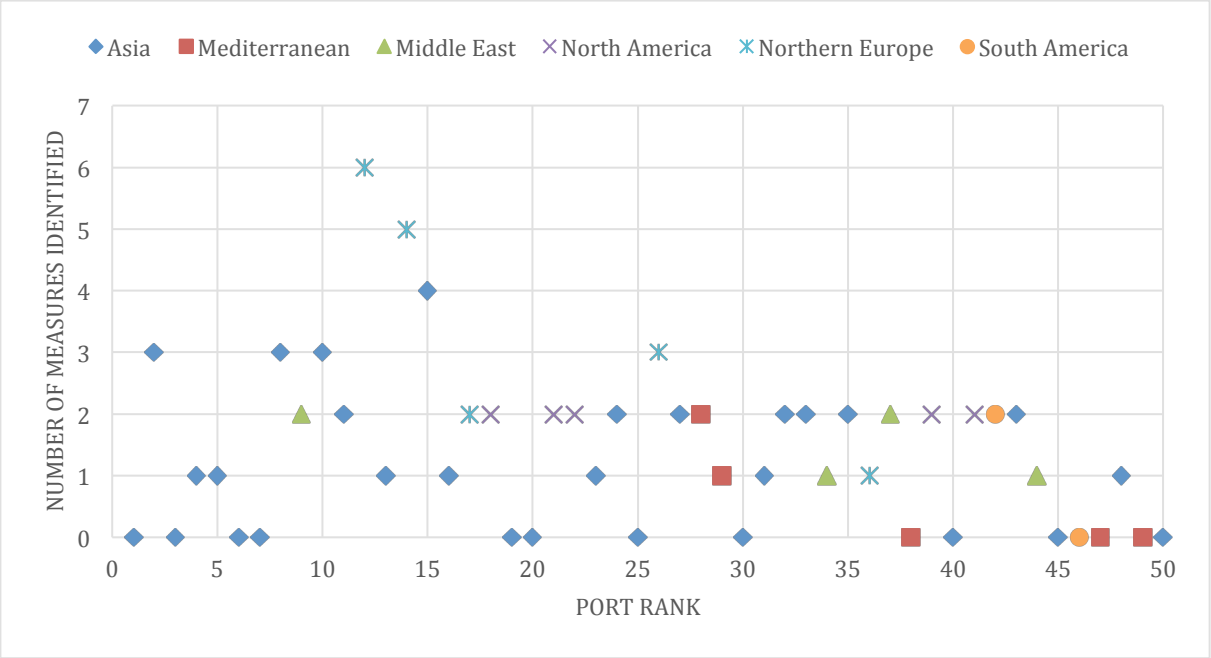

Figure 1. Number of reefer-related measures by port ranking and region (source: own compilation, based on Lloyd's List (2017).

Another important aspect is the geographical distribution of the surveyed ports. Expanding the distinction in Figure 1 between ports in different regions, Table 1 below shows the number of ports per region and the average number of reefer or cold chain-related measures found per port. The regional categorization is adapted from the original source of the ranking (Lloyd's List, 2017), with Europe further divided into North-Western Europe (European Atlantic, North Sea, and Baltic) and the Mediterranean.
Most ports are located in Asia, which may lend a regional bias to the sample. It also deserves attention for which ports no policy measures could be found. This can be either due to their absence, or due to limitations in the port's information provision, in which case this is a blind spot in this investigation. Figure 1 shows that for 4 ports in the top 10, zero measures could be identified. These ports are Shanghai, Shenzhen, Hong Kong, and Guangzhou – all in China, suggesting that there may be a structural reason for lack of information – even though other top-10 Chinese ports, such as Ningbo, Qingdao, and Tianjin provide plenty information. Also

for the Mediterranean ports, 3 out of 5 show zero measures, and an average of 0.6 measures for all ports in the region. This can be expected to be due to the transshipment focus of the larger ports in the region (e.g. Piraeus, Malta), with a smaller market for hinterland-oriented policies or value adding activities. Clearly, for North-Western European ports most distinct measures were identified on average.

Table 1. Regional breakdown of findings.

Region	Number of ports	Number of ports recording zero measures	Average number of measures recorded per port	Minimum	Maximum
Asia	29	11	1,2	0	4
Mediterranean	5	3	0,6	0	1
Middle East	4	0	1,5	1	2
N. America	5	0	2	2	2
NW. Europe	5	0	3,4	1	6
S. America	2	1	2	0	2

Another potential limitation with regard to the data also shows from this breakdown, namely that two major export regions for reefer cargoes (Latin America and Africa) are quite underrepresented.
The three sections below classify and discuss the cases of cold chain policies according to three dimensions: policy goal, scope, and stakeholder involvement.

4.2. Policy goals

The sampled ports shows a broad range of goals behind port policies, beyond commercial goals such as the attainment of market share or cargo added value. Not all measures recorded were accompanied by a statement explaining the goal. Some ports reported a generic or instrumental goal (e.g. 'improve efficiency,' 'serve customers better'), without mentioning the final goal (e.g. sustainability goals, market share, trade facilitation, export development etc.). Where such a concrete goal was reported, this was recorded in the dataset, along with other relevant notes. Roughly, the stated goals can be labeled as relating to sustainability, food safety, trade facilitation, efficiency improvements, and increasing competitiveness. Table 2 below shows these broader goals with a few specific examples (not exhaustive) of port policies implemented with that goal.

Table 2. Possible goals of reefer-related policies and examples of ports reporting a certain goal (not exhaustive).

Goal	Example policies	Example ports
Food quality/safety	- Cooperation with national customs and inspection agencies for quality monitoring and pest control - Aim of establishing a 'halal hub' with quality control and certification	- United States, Indonesia, China. - Port Klang
Sustainability	- Energy use of cold stores: shift to renewable energy - Modal shift away from trucks, stimulate use of barge and rail for reefer transport - Reduce congestion: expedited treatment of trucks with reefers, exemptions from	- Bremerhaven (Ger.) - Antwerp, Rotterdam, Long Beach, Valencia, Dalian - Long Beach, New York/New Jersey, Seattle/Tacoma, Manila

	restrictions, modal shift - Reduce food waste (various monitoring and control initiatives)	- Hamburg, Singapore
Trade facilitation (national) / support domestic perishables-producing sectors	- Cold chain policies as part of nationwide plan to improve post-harvest distribution system - Improve connectivity of exporting regions	- Indonesia, Japan, India, Taiwan, China - Rotterdam, Los Angeles, Santos
More efficient service to customer	- Expedited clearance by customs and inspection agencies; prioritization of trucks picking up reefers at terminal gate - Container tracking within the port or worldwide	- Long Beach, New York/New Jersey, Seattle/Tacoma, Manila, Tanjung Perak - Hamburg, Singapore
Increase competitiveness (market share, value added)	- Marketing: Host trade shows for perishables traders - Marketing: outreach to shippers - Co-invest in cold stores with value added logistics activities	- Hamburg, Algeciras - Multiple - Multiple

The specified goals of some policies can be considered instrumental, rather than final. For example, some port authorities aim to reduce dwell time of reefer containers (specified policy goal), but remain unclear whether this is to reduce energy use, prevent long occupation of scarce reefer plugs, to prevent product spoilage, or several of these (final) goals. A similar example is the reduction of congestion (stated policy goal), which can be aimed for with sustainability or efficiency goals in mind, or to circumvent the need for additional infrastructure investments.

The following general observations can be made based on these goals. First, many ports are aware of the myriad sustainability considerations related to reefer containers, and various ports take multiple measures addressing one or more of these aspects. Second, some goals may conflict, while others may produce attractive synergies. An example of the first is intensified customs and quality controls, which typically entail longer time in transit for larger amounts of cargo – as is the case in Tanjung Perak, Indonesia. Conversely, ports may achieve synergies between policies addressing efficiency and sustainability goals, as smoother handling and shorter time in transit generally reduces overall energy consumption by the reefer container and reduced risk of product waste. Third, a considerable number of ports pursue policies aimed at trade facilitation, and often more specifically export stimulation. Particularly in Asia (India, Malaysia, Taiwan), these port policies are often tied in with a nationwide plan to improve post-harvest distribution systems, addressing both export competitiveness and domestic food security. In Europe and North America ports are also improving connectivity with main agrifood export regions, but in these regions there is less evidence of a nationwide government-led plan, and the focus seems to be predominantly on export competitiveness.

4.3. Categorizing reefer policies by scope

The policy measures can be differentiated by their scope: Some of the most broad-scope measures impact on the cold chain overall, whereas others are limited in scope to the port cluster itself, the port's foreland, or the port's hinterland. A port authority can extend its role beyond the landlord to a greater (e.g. being more entrepreneurial by taking on financial risk)

or lesser degree (e.g. sticking to (knowledge) infrastructure provision, making regulatory provisions). Figure 2 below classifies the reefer-related measures observed by their scope, and lists the (number of) ports that implement the type of measure. Where a similar policy was observed in multiple ports (e.g. (co)-investing in cold store capacity), a generic description of the policy is shown.

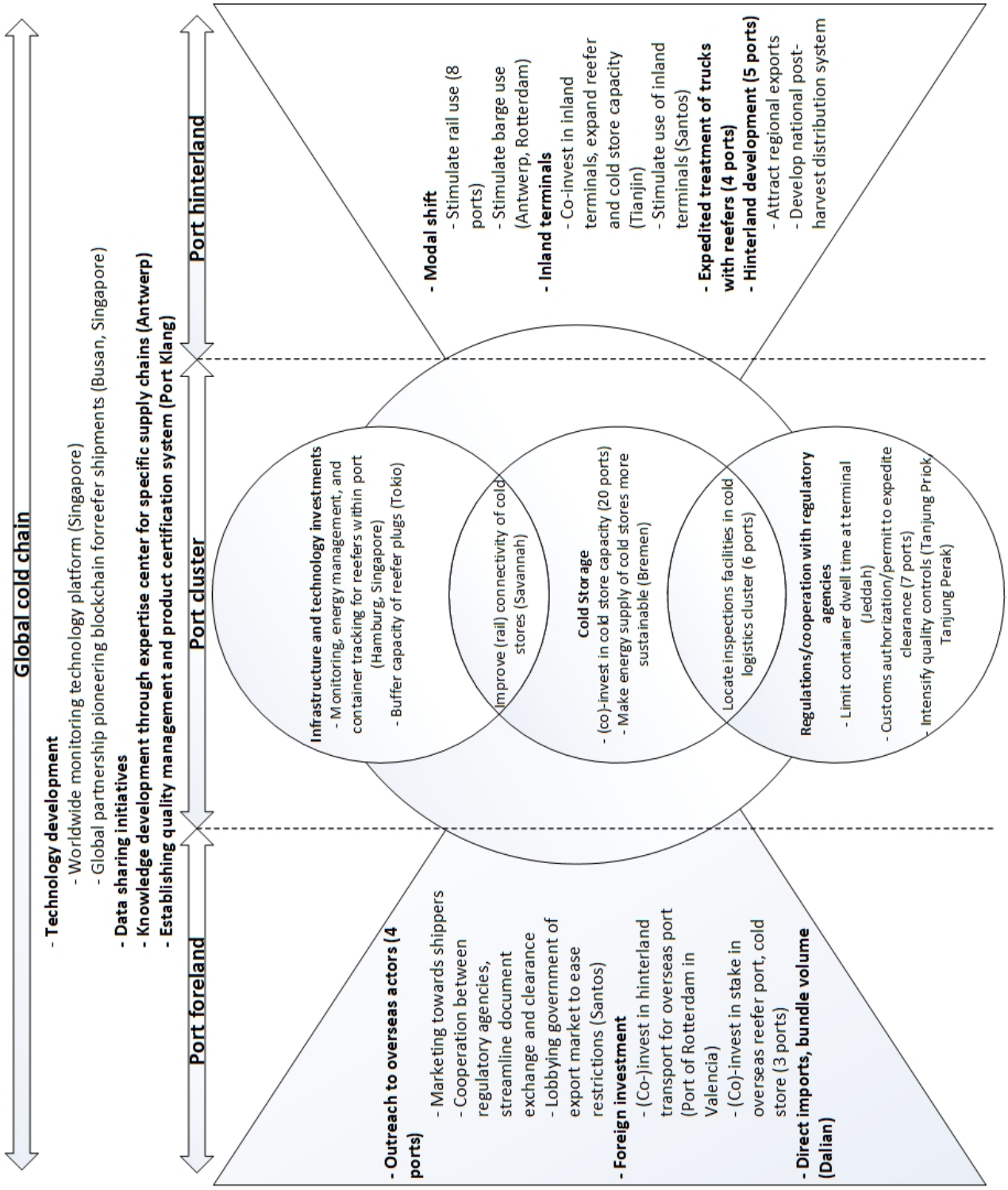

Figure 2. Schematic overview of the full spectrum of port policies for cold chains

4.3.1. Policies for the port cluster

The greatest diversity of observed policy measures is within the port cluster itself – within the scope of the most limited 'landlord' port governance model. The most frequently observed measure is port authority involvement in the construction of cold storage capacity. Although in some cases the port authority plans, constructs and operates the cold store by itself, in most cases this takes the form of public-private partnerships with various degrees and types of port authority involvement. Some port authorities (e.g. Ningbo-Zhoushan, Qingdao, Jeddah) (co-)invest in cold store facilities in a joint venture with one or more private sector counterparties, whereas others participate in these projects by tailoring land concession policies towards a clustering of cold chain activities (e.g. Rotterdam). This type of cluster policy includes customs and inspection facilities and reefer servicing being co-located with cold stores, streamlining cargo clearance and container servicing. Moreover, port authorities can invest in infrastructure to improve the sustainability (e.g. powering cold stores with renewable energy) and connectivity (e.g. constructing rail sidings at cold stores) of the cold stores within the port.

In their regulatory role, port authorities can also impact upon the reefer flows through the port. Some observed measures include the expedition of customs clearance – in cooperation with customs and inspection agencies and select shippers (e.g. Dalian). One port authority (Jeddah) regulates the dwell time of reefer containers at the port's terminals to stimulate quick pick-up. Port authorities can also gear infrastructure policies towards reefer and cold chain facilitation. For example, the Port of Tokyo provides government subsidies to increase the number of reefer plugs within the port, and the Port of Savannah has a strategic plan to always keep the port's reefer plug capacity at 20% above regular demand. More sophisticated infrastructure policies also affect the energy mix with which reefers and cold stores are provided (e.g. cold stores in Bremerhaven being supplied with wind power). Also policies are observed that stimulate reefer-related knowledge infrastructure. For example, the Port of Antwerp has set up an expertise center for cold supply chains through the port, bringing together a network of regional shippers and service providers.

4.3.2. Foreland policies

The simplest policies directed towards the foreland come in the form of outreach or marketing to shippers. More entrepreneurial ports also direct their investment policies towards the foreland parts of their reefer chains. It is observed that some ports invest in other ports with a notable predominance of reefer flows (e.g. the port of Qingdao taking a stake in the Mediterranean reefer hub of Vado). In one case, the Port of Rotterdam participates in a hinterland rail connection from another port (Valencia). Another port – Dalian – takes on the role of shipper itself (through a joint venture) to arrange a container vessel loaded with reefers exclusively destined for Dalian.

Port authorities also engage in policies aimed at trade facilitation, sometimes unilaterally, but in most observed cases in cooperation with higher-level government agencies that also seek to lower barriers to (perishables) trade. National governments as well as port authorities can exert lobbying efforts, or spearhead regulatory agency cooperation to streamline administrative procedures. A good example of the latter is the Port of Antwerp, working with Belgian and Peruvian customs agencies to streamline container clearance with digital certification.

4.3.3 Hinterland policies

In the hinterland dimension of reefer transport, port policies frequently address modal split. 7 policies have been identified that aim to facilitate rail transportation of reefers or temperature-controlled goods, and 2 ports (Rotterdam and Antwerp) have taken steps to increase the modal share of inland waterways transport of reefers. Multiple port authorities stimulate the use of inland terminals, and some even invest in inland terminals or cold storage facilities citing improving hinterland connectivity for reefers as a main goal. Interestingly, the ports that extend their scope the most towards the hinterland, often do so in the pursuit of goals that tie in with policy goals specified at higher levels of governance (e.g. national, regional, or European). In Europe in particular, the aim of a modal shift from road transport to rail or inland waterways was specified in an EU whitepaper, adopted by national governments, and subsequently integrated in port policy (European Commission, 2011). In Asia, more ambitious initiatives extending ports' strategic scope towards their hinterland are often linked with goals formulated by higher-level government pertaining to the improvement of food safety, the development of national or regional postharvest distribution systems, or the ambition to stimulate domestic agricultural exports.

4.3.4. Cold chain policies

At the top of Figure 2, examples are shown of port policies impacting the cold chain in its entirety, which in most cases relates to end-to-end monitoring of reefer containers or conditioned shipments, or data sharing and coordination between stakeholders along the cold chain. Whereas some ports (e.g. Hamburg) invest in container tracking around the port, several more port authorities are involved in initiatives that revolve around new technologies and data exchange – notably experiments with blockchain applications – along the entire reefer chain (e.g. Singapore, Busan, Antwerp). While these technologies will in the future likely have an impact on transportation of standard containers as well, port authorities and their partners in these projects (broad coalitions of shippers, carriers, insurers, government agencies, technology companies, and financial institutions) use the reefer chain to pioneer these technologies. The motivation is probably twofold. First, reefer containers already have the embedded technology that make remote monitoring possible. Second, the perishable and time-sensitive nature of reefer cargoes make that these flows will benefit the most from improved monitoring (allowing real time adjustments) and streamlining of administrative actions. In the long run, one can expect technological advances in the reefer sector to diffuse to the standard container market as well.

4.4. Stakeholder involvement

From the sample, we can distinguish a variety of policy instruments employed by port authorities, including investment, regulation, infrastructure provision, networking, pricing, incentives, subsidies, and marketing. Almost all policy actions identified entail a port authority engaging in a partnership with one or more public and/or private stakeholders and instances where a port authority acts unilaterally are limited.

There is considerable diversity in stakeholder configurations and partnership compositions that port authorities engage in to co-create reefer chain measures. The dataset shows partnerships with shippers, terminals, carriers, other port authorities, logistics and transportation service providers, customs and other government agencies, knowledge institutes, technology companies, and financial institutions - domestic as well as foreign. In particular port policies that aim to impact the cold chain in its entirety are characterized by broad and diverse coalitions of port authorities and other stakeholders. Examples include container tracking, data sharing initiatives and blockchain experiments that typically involve

shippers and port users, as well as technology companies and organizations involved in the administrative dimension of the transport chain. As ports' scopes broaden towards the foreland or hinterland, also the stakeholder coalitions in which policies are implemented become broader. Towards the foreland this may include foreign shippers, carriers, and customs and inspection authorities, whereas in the hinterland port authorities partner (in varying degrees of commitment) with inland terminals and logistics and production clusters.
Some types of partnerships and policies are surprisingly *not* encountered. First, the link between port policy and the processing of reefer cargoes within the port cluster is observed only rarely in the sample – notable exceptions include food processing in Bremerhaven and juice processing in Rotterdam, even though there is no evidence of port policy directed at better facilitating these activities. This is surprising, considering that this is a logical next step in creating opportunities to generate more value added from reefer cargoes shipped through the port. Second, the policies in the sample are rarely related to energy management for reefer and cold chain facilities. One port (Bremerhaven) does mention shifting the energy mix provided to cold stores towards renewable energy sources, but given the relevance of energy strategies for ports, it is striking that these considerations seem to be few and far between.

6. Discussion and conclusions

The study has analyzed the policy options for port authorities to respond to challenges and opportunities arising from the rapidly growing reefer container market and cold chain logistics sector. The sections above discussed the characteristics of 72 individual policy measures sampled from the world's 50 largest container ports, focusing on the policy instruments, goals, scope, and stakeholder involvement. The findings support and further illustrate Robinson's (2002) conjecture that ports indeed position themselves in specific supply chains – in this case a relatively small sub-segment of the container market. It is also in the course of this positioning that port authorities extend their scope beyond the classic 'landlord' model, including actively facilitating, coordinating or even entrepreneurial roles and an extension of their strategic scope towards their hinterland and foreland. To our illustration of these insights, we can add the observation that although public port authorities have been commercialized and privatized, in their most ambitious endeavors (extending the geographical scope of their strategies towards their foreland and hinterland) we still see strong intertwining of the policy goals and efforts of port authorities and higher-level government. Interestingly, this trend varies between regions, with distinctly different underpinnings in Europe and the United States (e.g. modal shift) compared to Asia (agricultural development and food quality). Although in these cases port authorities emphasize public goals this does not preclude an underlying strategic agenda with commercial goals. Interestingly, the most commonly observed policy of cold storage facilitation seems to be the most fundamental type of cold chain policy, since the port authorities that broaden their strategic scope towards their fore- or hinterland do so *in addition* to cold chain policies within the port cluster. The same logic applies to measures that target the cold chain overall (such as data sharing and trade facilitation initiatives), which are generally undertaken by port authorities that already pursue cold chain facilitation policies within the port area.
The limitations of the study should also be addressed. One limitation is the constitution of the sample. By reviewing actions taken by the world's 50 largest ports, the cases of policies entering the sample were highly dependent on the ports' information provision, which may have introduced a bias in the sample. Hence the patterns identified should be seen in the context of this sample. Second, while the authors showed that ports expand their role and focus, and explore new roles and activities beyond only managing infrastructure and land concessions, differences between ports in terms of governance model and operating

environment should be recognized. For example, observations regarding European ports cannot easily be generalized to Chinese ports. In the discussion of the results, we have acknowledged regional variation where appropriate. Third, the cases did not include performance evaluations of the policies studied, either because the information was not publically available or because it concerns relatively recent initiatives of which some are still being developed. Therefore it has unfortunately not been possible to judge the success of the policy measures studied.

The findings present several considerations for academic research and port policy. Most importantly, as the dataset used in this study did not include data on the performance of specific policies, future research should focus on which type of policies achieve the desired outcomes, and which factors impede or enhance the effectiveness of policies. The findings from this study may serve as the starting point for more in-depth research into the performance of specific types of cold chain policies. More generally, similar exercises to the one conducted in this study can be done into the tailoring of port policies for specific (niche) markets – ideally extended with information on policy outcomes in more mature markets. For practice, this study provides a comprehensive overview of what major ports worldwide are doing to facilitate cold chains and reefer transport. The typology of policy actions presented can serve as a palette of possible actions from which policymakers and managers can draw, and adapt generic concepts to their local context. Currently, there is little evidence of ports establishing comprehensive strategies for cold chains. The policy measures identified are generally separate measures, each with their individual goals, with no indication of being part of an overarching strategy. While some port policies in developing regions are connected to national government policies aimed at establishing post-harvest distribution systems, for developed regions (North America, Europe), there is no higher-level governance framework observed addressing cold chain logistics in ports and informing port policy. However, in the light of rapidly growing markets, technological developments, and sustainability concerns, a more thorough and comprehensive approach is desirable. From the findings of this study, at least the most important tenets of such an overarching strategy can be identified. Within the port, port authorities should take an integrated perspective of different cold chain activities, including stripping and stuffing of reefer containers, storage, inspection, processing, and container servicing. A smart port can strive to better connect its cold chain activities with intermodal container networks and co-site relevant activities together to improve handling efficiency with a central role for well-connected cold stores. Considering sustainability concerns, the energy mix of these cold clusters can be made more sustainable, and smarter energy management techniques can be implemented (such as the use of cold stores or reefers as accumulators for energy storage). Towards the hinterland, many ports strive to reduce road congestion while also ensuring fast transit for time-sensitive reefer cargoes. Some do this by prioritizing trucks with reefers, others by stimulating the use of rail and/or barge transport for reefers. To achieve this modal shift, we observed a range of possible measures: infrastructure investments in intermodal connectivity for cold stores, start-up subsidies for barge connections, and investments in inland terminals to improve connectivity. Foreland-oriented policies may consist of marketing and lobbying, but port authorities can also stimulate cooperation between different national customs and inspection agencies to expedite clearance of goods. As also seen for even broader policies that impact on the entire cold chain (e.g. data sharing initiatives, blockchain experiments), smart ports can take a role as networking organizations, forming coalitions with diverse sets of stakeholders, and using the network and expertise of each to address pervasive issues in the reefer chain. This conception of cold chains as complex, multi-stakeholder systems in an uncertain global environment can serve as the rationale behind more comprehensive cold chain strategies for ports and ports' conception

of their own role in these chains. On an even more ambitious note, the same type of integrated policy-making can be extended to port positioning in other supply chains.
The reefer market will likely keep growing in the foreseeable future, and ports would serve themselves well by considering all relevant aspects of this niche market for their own policymaking. In particular two global developments emphasize the relevance of cold chains for ports. First, there is a growing tension between rapidly growing, energy-intensive cold chain markets, and the need to curtail greenhouse gas emissions, as specified in the Paris Agreement. Considering the overall energy-intensity of ports, and their central role as nodes in global cold chains, there is a growing relevance for ports to address the environmental footprint of reefer transport, and perhaps even take a leading role in broader coalitions of stakeholders whose cooperation is required. Secondly, reefer containers are becoming more technology-intensive, allowing for better monitoring and control, and smarter handling – technology that is likely to diffuse to dry containers in the future as well. It is also in this segment in the container that the use of blockchain technology is first being pioneered. Developments such as these suggest that reefer containers are the first sector where new technologies for container transport are tested and implemented. Ports and other service providers that want to have a strong position in the container market when these technologies diffuse are therefore served well by being at the forefront of these new developments in the reefer market. In addition to these trends, considerations regarding sustainability, logistics processes, technology, and competitiveness are top priorities for ports, and the reefer segment poses several challenges in these domains that may require port authorities to develop new activities and capabilities to address. This study serves to help practitioners and researchers get a firmer grip on what ports can do to respond to these challenges and opportunities.

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